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Preliminary GIS-Based Estimation of Soil Bearing Capacity in Talavera, Nueva Ecija Using Soil Type Mapping and Secondary Geotechnical Data

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ABSTRACT: This study utilized a Geographic Information System (GIS)-based approach to estimate soil bearing capacity in Talavera, Nueva Ecija for preliminary geotechnical screening in data-limited settings. Secondary data from Geoportal Philippines and Department of Public Works and Highways (DPWH) reports were integrated with Terzaghi's bearing capacity equation to evaluate representative soil types under standardized dry and groundwater conditions. Computed allowable capacities range from 181–208 kPa under dry conditions and decrease to 98–182 kPa with groundwater influence. Borehole data indicate heterogeneous subsurface profiles composed of interbedded silt, clay, and sand layers, with strength generally increasing with depth. Comparison with field-based values reveals discrepancies due to soil variability, foundation depth differences, groundwater conditions, and data limitations. The results suggest that GIS-based estimation can support preliminary spatial screening; however, site-specific geotechnical investigations remain essential for reliable foundation design.

KEYWORDS: Soil Bearing Capacity, GIS Mapping, Terzaghi's Bearing Capacity Equation, Geotechnical Engineering, Talavera, Nueva Ecija, Secondary Geotechnical Data

I. INTRODUCTION

1.1 Background of the Study

Talavera, Nueva Ecija, in Central Luzon, is experiencing continuous infrastructure and community development, including new housing subdivisions, school buildings, road widening projects, and the conversion of agricultural land for residential and commercial use. Parts of the municipality are also located in low-lying and flood-prone areas, where inappropriate foundation design can increase the risk of differential settlement and structural damage. In this context, understanding local soil conditions is critical for ensuring that new and existing structures are built on stable and safe foundations. However, it must be emphasized that preliminary assessments based on secondary data cannot replace detailed site-specific investigations required for final foundation design.

Soil is a fundamental component in civil engineering because it serves as the foundation that supports buildings, roads, bridges, and other infrastructure. The stability, strength, and long-term performance of these structures are strongly influenced by the physical and mechanical characteristics of the soil on which they are built. Properties such as texture, structure, permeability, compressibility, and shear strength affect the load-bearing capacity of the ground and determine its suitability for different types of construction (Das & Sobhan, 2017). Because of this, accurate soil characterization is essential in minimizing structural risks.

Soil bearing capacity, in particular, defines the ability of soil to safely support structural loads. Accurate estimation of bearing capacity is essential in foundation design to prevent excessive settlement and structural failure, especially for critical facilities such as schools, residential buildings in densely populated barangays, and roads that serve as evacuation routes. Conventional determination of soil bearing capacity requires detailed field investigations and laboratory testing, which may not always be feasible due to cost and time constraints, particularly in rapidly developing municipalities like Talavera. As an alternative, engineers may use generalized soil data, empirical correlations, and recommended values from agencies such as the Department of Public Works and Highways (DPWH) for preliminary assessments only. These approaches are intended for initial screening and must not be used as a substitute for site-specific geotechnical investigation.

In Talavera, commonly occurring soil series such as Maligaya and Bantog are typically classified as clay or clay loam in agricultural soil surveys and are associated with relatively slow permeability (Philippine Rice Research Institute, 2015). These soil series descriptions are based on surface pedological characteristics and are not directly equivalent to engineering soil classifications (e.g., USCS). For the purpose of this study, these soil types are used only as proxies to estimate general engineering behavior. Clay-rich soils may undergo expansion, compression, or reduced stability when subjected to changes in moisture conditions, especially during the wet season or flooding events. Such behavior can affect drainage, increase settlement potential, and influence the performance of shallow foundations.

Given these conditions, mapping the soil bearing capacity in Talavera, Nueva Ecija is important for guiding land development and preliminary engineering decisions. This study aims to identify the prevalent soil types in the municipality and estimate their corresponding minimum allowable soil bearing capacities based on available standards and simplified analytical methods. A consistent assumption is adopted in the analysis, including a uniform foundation depth and a defined groundwater condition (Case 3: groundwater table at or below the base of the foundation), to isolate the effect of soil properties on bearing capacity. The resulting spatial map of minimum allowable soil bearing capacity is intended solely as a preliminary screening tool to support planners, engineers, and local government units in identifying areas that may require detailed geotechnical investigation, and not for direct foundation design or construction purposes.

1.2 Statement of the Problem

This study aims to determine the prevalent soil types in Talavera, Nueva Ecija and estimate their corresponding estimated minimum allowable soil bearing capacities using secondary data sources. The results are intended for preliminary geotechnical screening and not for final design application.

Specifically, this study seeks to answer the following questions:

1. What are the dominant soil types in Talavera, Nueva Ecija based on available Geoportal PH and DPWH data?
2. What are the estimated minimum allowable soil bearing capacities for these soil types using Terzaghi's bearing capacity equation for square footings under consistent assumptions?
3. How does the assumed Case 3 groundwater condition (groundwater table at or below the base of the foundation) influence the computed allowable soil bearing capacity?
4. What are the observed allowable soil bearing capacities in selected areas of Talavera, Nueva Ecija based on available DPWH geotechnical reports?
5. How do the estimated values and observed DPWH-based values compare, considering differences in data source, depth, and soil conditions?
6. How can GIS be used to spatially represent and analyze the distribution of soil types and corresponding allowable bearing capacities to support preliminary engineering planning in Talavera, Nueva Ecija?

1.3 Significance of the Study

This study is beneficial to:

Civil Engineers. This study provides a preliminary reference for conservative foundation assessment using generalized soil data and minimum bearing capacity values, which can guide early-stage decision-making prior to detailed investigation.

Local Government Units (LGUs). This study may assist in land-use planning and zoning by identifying areas that may require further geotechnical evaluation.

Contractors and Developers. This study helps identify locations where detailed subsurface investigation is necessary before construction.

Students and Researchers. This study demonstrates the application of GIS integrated with secondary geotechnical data for preliminary engineering analysis and highlights its limitations in practical design.

1.4 Scope and Limitations

This study presents a preliminary GIS-based estimation of soil bearing capacity in Talavera, Nueva Ecija using secondary data from Geoportal Philippines, Department of Public Works and Highways (DPWH) reports, and standard geotechnical references. Terzaghi's bearing capacity equation was applied under uniform assumptions, including consistent foundation depth, footing dimensions, and groundwater conditions, with results mapped using polygon-based spatial analysis. The study is limited by its reliance on secondary data, the use of agricultural soil classifications as proxies for engineering properties, and the exclusion of settlement analysis. Variability in soil conditions, groundwater levels, and foundation depth further affects comparability with field data. The results are intended solely for preliminary screening and not for final foundation design.

1.5 Conceptual Framework

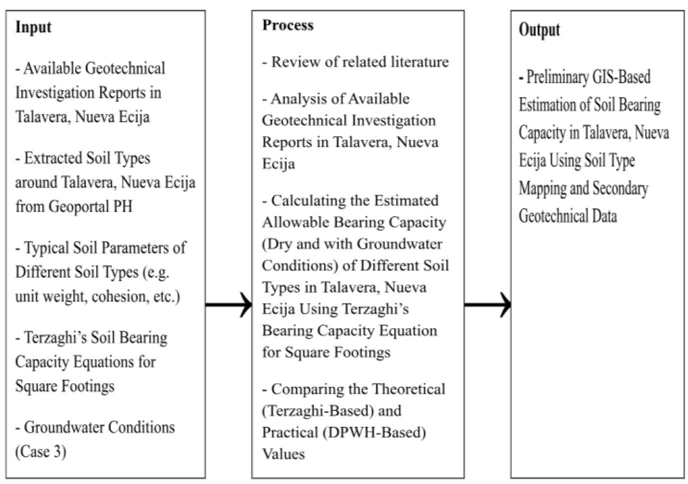

Figure 1. Paradigm of the Study

II. REVIEW OF RELATED LITERATURE

Soil serves as the primary foundation material in civil engineering, directly influencing the stability and performance of infrastructure. In the Philippine context, where rapid urbanization continues to expand, understanding soil properties has become essential for safe and efficient construction. Geotechnical studies emphasize that soil characteristics such as strength, compressibility, and permeability determine the ability of the ground to support structural loads without failure. Variations in soil conditions across different regions further necessitate proper investigation prior to construction, as these differences significantly affect foundation behavior and structural integrity (Dungca et al., 2017).

Soil bearing capacity is a critical parameter in foundation design, representing the maximum load that soil can safely sustain. Empirical studies conducted in Metro Manila and Quezon City demonstrate that bearing capacity varies depending on soil composition and depth, with stronger and more stable layers generally found at greater depths (Dungca et al., 2017; Dungca, 2020). These findings highlight the importance of accurate soil evaluation in preventing excessive settlement and structural failure. Although design codes provide presumptive values for preliminary use, literature consistently emphasizes that these should only serve as conservative estimates, and that detailed site-specific investigations remain necessary for reliable engineering design (Das, 2019).

Theoretical estimation of soil bearing capacity is commonly based on Terzaghi's bearing capacity equation, which remains a fundamental analytical tool in geotechnical engineering (Terzaghi, 1943). However, the model is based on simplifying assumptions, including homogeneous soil conditions and general shear failure mechanisms, which may not accurately represent actual field conditions (Olek, 2019). In practice, soils often exhibit local or punching shear failure, particularly in loose or soft deposits, limiting the direct applicability of the theory (Das, 2019). Consequently, while analytical methods provide a useful framework for preliminary assessment, their results must be interpreted with caution and validated through field investigations.

Advancements in spatial analysis have led to the integration of Geographic Information Systems (GIS) in geotechnical studies, allowing for the visualization and mapping of soil properties over large areas. Research conducted in Butuan City demonstrated that GIS-based mapping can effectively represent spatial variations in soil bearing capacity, supporting infrastructure planning and land-use decision-making (Caingles & Flaviano, 2025). However, the reliability of such maps is affected by the uncertainty inherent in spatial interpolation methods, as soil properties can vary significantly even within short distances. As a result, GIS-based outputs are recommended primarily for regional planning and preliminary screening rather than as substitutes for detailed subsurface investigation (Chen et al., 2022).

The geological and hydrological conditions of Central Luzon, particularly in alluvial environments, further complicate soil behavior and foundation performance. Areas such as Talavera, Nueva Ecija are characterized by unconsolidated alluvial deposits composed of interlayered silts and clays, which are prone to high compressibility and settlement (Villacorte et al., 2018; Shil et al., 2021). In addition, groundwater conditions significantly influence soil strength, as increased saturation reduces effective stress and can lower bearing capacity by up to 50% (Chen et al., 2022). These factors highlight the necessity of adopting a systematic and hierarchical approach to site investigation, progressing from preliminary assessment to detailed analysis. Overall, while theoretical models and GIS-based methods provide valuable preliminary insights, comprehensive geotechnical investigation remains essential to ensure safe and reliable foundation design.

III. METHODOLOGY

3.1 Research Design

The study employed a descriptive, comparative, and GIS-based spatial estimation approach using secondary data sources. The study did not involve field drilling, laboratory testing, or direct geotechnical investigation. Instead, soil bearing capacity was preliminarily estimated using mapped soil types and standardized engineering parameters obtained from literature.

This approach allows the integration of generalized geotechnical properties with spatial data to generate a visual representation of soil bearing capacity distribution within Talavera, Nueva Ecija. The use of GIS in spatial estimation provides an efficient and cost-effective method for analyzing large-scale geotechnical conditions at the municipal level. However, the results are limited to regional screening and may not reflect site-specific subsurface variability.

3.2 Data Sources

The study utilized secondary data obtained from government platforms and engineering references. The primary data sources include:

- Geoportal PH soil map of Talavera
- DPWH geotechnical reports (Bakal I and Mamandil)
- Published geotechnical references for unit weight (γ), cohesion (c), and angle of internal friction (φ)
- Municipal boundary shapefile of Talavera, Nueva Ecija

These datasets were selected to ensure accessibility and consistency in estimating soil bearing capacity without conducting primary field investigations. It is important to note that the Geoportal PH soil data represent agricultural soil series, which were used in this study only as proxies for general engineering behavior. These classifications are not directly equivalent to engineering soil classifications (e.g., USCS), and this limitation is considered in the interpretation of results. Also, the DPWH data used in this study were obtained from actual geotechnical investigation reports available for Brgy. Bakal I and Brgy. Mamandil. These values were derived from field subsurface exploration and engineering assessment for the specific tested locations. Available DPWH geotechnical reports accessible during the study period were limited to Brgy. Bakal I and Brgy. Mamandil; therefore, these records were used as location-specific comparative references.

3.3 Procedure

Soil types identified from Geoportal PH were assigned representative engineering parameters (γ, c, φ) based on published geotechnical references. A single set of consistent parameters was used for each soil type throughout the analysis to ensure comparability between different conditions.

These parameters were then used to estimate the allowable soil bearing capacity using Terzaghi's bearing capacity equation for square footings under standardized assumptions (B = 1 m, Df = 1 m, FS = 3).

3.3.1 Terzaghi's Bearing Capacity Equation for Square Footings

$$q_{ult} = 1.3cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma$$

$$q_{allow} = \frac{q_{ult}}{F.S}$$

Where:

- q_{ult} = ultimate bearing capacity
- q_{allow} = allowable bearing capacity
- c = cohesion (kPa)
- γ = unit weight of soil (kN/m^3)
- D_f = depth of foundation (m)
- B = width of footing (m)
- N_c , N_q , N_γ = Terzaghi's bearing capacity factors (depends on the angle of friction, φ)
- F.S = factor of safety (its value is typically 3) (Coduto, 2001)

The analysis incorporated a consistent groundwater condition defined as Case 3, where the groundwater table is at or below the base of the foundation. Under this condition, the soil unit weight was adjusted to an effective or average unit weight ($\underline{\gamma}$) only where applicable, while keeping all other parameters constant to isolate the influence of groundwater on bearing capacity.

3.3.2 Average Unit Weight of Soil

$$\underline{\gamma} = \gamma' + \left(\frac{d-D_f}{B}\right)(\gamma - \gamma')$$

Where:

- $\gamma' = submerged\ unit\ weight$

$$\gamma' = \gamma_{sat} - \gamma_w$$

Where:

- $\gamma_{sat} = saturated\ soil\ unit\ weight$
- $\gamma_w = unit\ weight\ of\ water$

The application of Terzaghi's bearing capacity equation in this study is limited to simplified and controlled conditions for comparative and spatial analysis. The standardized assumptions applied were intended to maintain uniformity across all soil types. It is recognized that actual bearing capacity values are influenced by several site-specific factors, including footing size and shape, depth of embedment, soil layering, groundwater variability, load conditions, and settlement criteria.

Therefore, the computed allowable bearing capacity values represent generalized estimates (q_{allow}) for preliminary engineering screening only and must not be used for detailed structural design without proper geotechnical investigation.

3.3.3 Adopted Geotechnical Parameters

The representative engineering parameters assigned to each soil type were adopted from established geotechnical references. These values were used as input in the application of Terzaghi's bearing capacity equation for the estimation of allowable soil bearing capacity.

Table 3-1. Adopted Geotechnical Parameters

Soil Type	Unit Weight, γ (kN/m³)	Cohesion, c (kPa)	Friction Angle, φ (°)	Source Basis
Fine Sand	18.0	0	30	Das (2019)
Silt Loam	18.5	20	20	Bowles (1996); NAVFAC (1986)

3.4 GIS Mapping

Polygon-based classification mapping was performed by assigning estimated bearing capacity values to mapped soil units. Each soil type polygon was attributed with its corresponding computed allowable bearing capacity, resulting in a thematic map showing spatial variations in soil strength across the study area. GIS software (e.g., QGIS or ArcGIS) was used to digitize, manage, and visualize the spatial data.

3.5 Comparison of Theoretical (Terzaghi-Based) and Practical (DPWH-Based) Values

Available DPWH borehole-based allowable bearing capacities from selected barangays (Bakal I and Mamandil) were compiled and compared with the estimated values to provide contextual comparison.

This comparison does not serve as full validation of the GIS-based results, but rather as a means of examining the relationship between generalized estimates and site-specific geotechnical data. Differences between estimated and observed values were interpreted considering several factors, including variation in foundation depth, groundwater conditions, soil layering, in-situ test results (e.g., SPT N-values), and the use of agricultural soil maps as proxies for engineering properties.

Additionally, it is recognized that DPWH recommended values may be based on different footing conditions and depths (e.g., ≥1.5 m), while the estimated values in this study assume a uniform depth of 1.0 m. This difference is acknowledged as a limitation in direct comparison.

The comparison is therefore used to highlight trends, identify potential discrepancies, and emphasize the importance of site-specific geotechnical investigation for accurate foundation design.

IV. RESULTS AND DISCUSSION

4.1 Different Soil Types in Talavera, Nueva Ecija

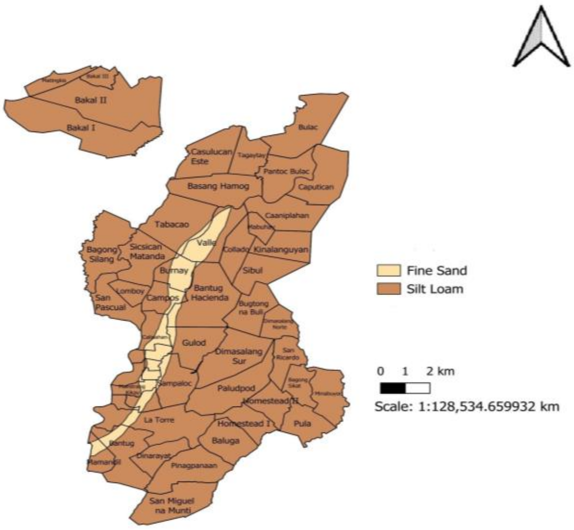

Figure 2. Map of Soil Types in Talavera, Nueva Ecija from Geoportal PH

Based on the Geoportal PH soil data and DPWH geotechnical reports, the dominant soil types identified in Talavera include:

- Clay / Clay loam (e.g., Maligaya and Bantog series)
- Silt loam

The DPWH borehole data confirm that subsurface conditions are generally composed of cohesive soils (clay and silt) with occasional granular layers such as fine sand. These findings are consistent with regional soil studies indicating that Central Luzon is predominantly composed of alluvial deposits with varying clay and silt content, which influence compressibility and strength characteristics (Philippine Rice Research Institute, 2015).

4.1.1 Geotechnical Investigation Report in Brgy. Mamandil, Talavera, Nueva Ecija

Table 4-1. Estimation of Geotechnical Properties of Soil based on SPT N-Values for BH-1

SPT No.	Depth (m)	N-Values	N60	USCS Classification	Consistency	Type of Soil	**Cu (kPa)**	(deg)	Unit Weight (kN/m³)
BH-1 (water table = 2.00mm)									
SPT-1	1.0	6	4.5	ML	Medium Stiff	silt	32		14.50
SPT-2	2.0	9	7.2	ML	Medium Stiff	silt	47		14.50
SPT-3	3.0	9	7.7	ML	Medium Stiff	silt	47		16.50
SPT-4	4.0	12	10.2	ML	Stiff	silt	54		18.50
SPT-5	5.0	13	12.4	SM	Medium Dense	sand		30°	19.75
SPT-6	6.0	13	12.4	SM	Medium Dense	sand		29°	19.75
SPT-7	7.5	14	13.3	SM	Medium Dense	sand		30°	19.75
SPT-8	9.0	17	17.0	CL	Stiff	clay	66		18.50
SPT-9	10.5	20	20.0	CL	Stiff	clay	74		18.50
SPT-10	12.5	21	21.0	MH	Very Stiff	silt	76		18.70
SPT-11	13.5	23	23.0	MH	Very Stiff	silt	81		18.70
SPT-12	15.0	18	18.0	MH	Stiff	silt	69		16.90

Table 4-2. Estimation of Geotechnical Properties of Soil based on SPT N-Values for BH-2

SPT No.	Depth (m)	N-Values	N60	USCS Classification	Consistency	Type of Soil	**Cu (kPa)**	(deg)	Unit Weight (kN/m³)
BH-2 (water table = 2.00mm)									
SPT-1	1.0	4	3.0	CL	Soft	clay	21		13.0
SPT-2	2.0	6	4.8	CL	Medium Stiff	clay	32		14.50
SPT-3	3.0	7	6.0	ML	Medium Stiff	silt	37		16.50
SPT-4	4.0	9	7.7	ML	Medium Stiff	silt	47		16.50
SPT-5	5.0	11	10.5	SM	Medium Dense	sand		29°	19.75
SPT-6	6.0	13	12.4	SM	Medium Dense	sand		30°	19.75
SPT-7	7.5	14	13.3	SM	Medium Dense	sand		30°	19.75
SPT-8	9.0	15	15.0	CL	Stiff	clay	61		18.50
SPT-9	10.5	15	15.0	CL	Stiff	clay	61		18.50
SPT-10	12.5	21	21.0	CH	Very Stiff	silt	76		19.50
SPT-11	13.5	23	23.0	CH	Very Stiff	silt	81		19.50
SPT-12	15.0	27	27.0	MH	Very Stiff	silt	91		18.70

Table 4-3. Estimation of Geotechnical Properties of Soil based on SPT N-Values for BH-3

SPT No.	Depth (m)	N-Values	N60	USCS Classification	Consistency	Type of Soil	**Cu (kPa)**	(deg)	Unit Weight (kN/m³)
BH-3	(water table = 1.00mm)								
SPT-1	1.0	6	4.5	CL	Medium Stiff	clay	32		15.50
SPT-2	2.0	7	5.6	CL	Medium Stiff	clay	37		16.5
SPT-3	3.0	10	8.5	ML	Medium Stiff	silt	49		16.50
SPT-4	4.0	12	10.2	ML	Stiff	silt	54		18.50
SPT-5	5.0	13	12.4	SM	Medium Dense	sand		30°	19.75
SPT-6	6.0	15	14.3	SM	Medium Dense	sand		31°	19.75
SPT-7	7.5	15	14.3	SM	Medium Dense	sand		30°	19.75
SPT-8	9.0	17	17.0	CH	Stiff	clay	66		17.38
SPT-9	10.5	18	18.0	CH	Stiff	clay	69		17.38
SPT-10	12.0	23	23.00	CL	Very Stiff	clay	81		20.50
SPT-11	13.5	24	24.0	CL	Very Stiff	clay	83		20.50
SPT-12	15.0	29	29.0	CH	Very Stiff	clay	96		19.50

Source: DPWH 1st District, Talavera, Nueva Ecija

4.1.2 Geotechnical Investigation Report in Brgy. Bakal I, Talavera, Nueva Ecija

Table 4-4. Estimation of Geotechnical Properties of Soil based on SPT N-Values for BH-1

SPT No.	Depth (m)	N-Values	(N1)60	N60	USCS Classification	Rel. Density Stiffness	Unit Weight (kN/m³)	Ca (kPa)	(deg)
BH-1	(water table = 0.30m)								
SPT-1	1.0	7	9.4	3.6	ML	Medium Stiff	14.50	37	
SPT-2	2.0	13	9.9	6.8	ML	Stiff	16.00	52	
SPT-3	3.0	18	12.4	9.4	SM	Medium Dense	19.75		29°
SPT-4	4.0	16	11.5	9.4	SM	Medium Dense	19.75		28°
SPT-5	5.0	22	14.7	13.0	SP-SM	Medium Dense	20.00		30°
SPT-6	6.0	30	18.8	17.7	SP-SM	Medium Dense	20.00		32°
SPT-7	7.5	27	17.3	17.8	SM	Very Stiff	20.50	86	
SPT-8	9.0	27	16.2	17.8	SM	Medium Dense	19.75		31°
SPT-9	10.5	29	16.4	19.1	SM	Medium Dense	19.75		31°
SPT-10	12	32	17	21.1	SM	Dense	20.88		31°
SPT-11	13.5	36	18.1	23.7	SM	Dense	20.88		31°
SPT-12	15.0	37	17.8	24.4	SM	Dense	20.88		31°

Table 4-5. Estimation of Geotechnical Properties of Soil based on SPT N-Values for BH-2

SPT No.	Depth (m)	N-Values	(N1)60	N60	USCS Classification	Rel. Density Stiffness	Unit Weight (kN/m³)	Ca (kPa)	(deg)
BH-2	(water table =0.30m)								
SPT-1	1.0	5	11.8	2.6	ML	Soft	14.50	30	
SPT-2	2.0	11	15.3	5.7	ML	Stiff	28.50	47	
SPT-3	3.0	13	13.7	6.8	SP	Medium Dense	20.00		29°
SPT-4	4.0	15	14.9	8.8	SP	Medium Dense	20.00		30°
SPT-5	5.0	21	18.1	12.4	SW	Medium Dense	21.00		31°
SPT-6	6.0	27	20.8	15.9	SW	Medium Dense	21.00		33°
SPT-7	7.5	31	23.6	20.4	ML	Hard	20.50	96	
SPT-8	9.0	36	24.7	23.7	SM	Dense	20.88		34°
SPT-9	10.5	33	20.8	21.7	SM	Dense	20.88		33°
SPT-10	12.0	26	15.3	17.1	SP	Medium Dense	20.00		30°
SPT-11	13.5	35	19.3	23.0	SP	Dense	20.50		32°
SPT-12	15.0	38	19.9	25.0	MP	Dense	20.50		32°

Table 4-6. Estimation of Geotechnical Properties of Soil based on SPT N-Value for BH-3

SPT No.	Depth (m)	N-Values	(N1)60	N60	USCS Classification	Rel. Density Stiffness	Unit Weight (kN/m³)	Ca (kPa)	(deg)
BH-2	(water table =0.30m)								
SPT-1	1.0	6	11.8	3.1	ML	Medium Stiff	16.50	34	
SPT-2	2.0	13	16.9	6.8	ML	Stiff	18.50	52	
SPT-3	3.0	16	16.1	8.3	SP	Medium Dense	20.00		31°
SPT-4	4.0	21	20.3	12.4	SP	Medium Dense	20.00		32°
SPT-5	5.0	24	20.5	14.1	SP	Medium Dense	20.00		32°
SPT-6	6.0	24	18.5	14.1	SP	Medium Dense	20.00		32°
SPT-7	7.5	30	22.8	19.8	ML	Very Stiff	20.50	93	
SPT-8	9.0	26	18	17.1	SP	Medium Dense	20.00		31°
SPT-9	10.5	32	20.3	21.1	SP	Dense	20.50		32°
SPT-10	12.0	37	21.9	24.4	SP	Dense	20.50		33°
SPT-11	13.5	36	20	23.7	SP	Dense	20.50		32°
SPT-12	15.0	39	20.5	25.7	SP	Dense	20.50		32°

Source: DPWH 1st District, Talavera, Nueva Ecija

4.1.3 Analysis of Tables (Soil Profile and Engineering Properties)

The soil profile data from DPWH boreholes show a consistent pattern of layered heterogeneous soil conditions in Talavera, Nueva Ecija. The tables indicate that the upper soil layers are generally composed of loose to medium dense silts and fine sands, as reflected in lower SPT N-values. These low resistance values suggest weaker shear strength and higher compressibility near the ground surface.

As depth increases, the soil transitions into denser sandy layers and more compact silt/clay formations, which is evident from the increasing SPT N-values in Tables 4-3 and 4-5. This increase indicates improved soil stiffness and reduced compressibility, which directly contributes to higher allowable bearing capacity at deeper depths.

Furthermore, Tables 4-2 and 4-6 show that soil classification varies even within short depth intervals, confirming that Talavera's subsurface is not uniform. The presence of alternating silt, clay, and fine sand layers indicates a typical alluvial depositional environment, where soil properties change laterally and vertically due to past fluvial processes.

From an engineering perspective, this variability is critical because it implies that foundation performance cannot be generalized across the municipality. Instead, each site may exhibit different controlling soil layers, especially within the upper 1–3 meters where shallow foundations are typically placed.

Overall, these tables establish that the dominant soil condition in Talavera is cohesive (silt and clay-based soil), with intermittent granular deposits which suggests:

- Lower permeability;
- Higher compressibility; and
- Sensitivity to moisture changes

These properties significantly affect foundation stability, especially for shallow foundations. According to Das and Sobhan (2017), cohesive soils tend to exhibit lower bearing capacity compared to dense granular soils, particularly under saturated conditions.

4.1.4 Technical Note on Data Source

It is critical to distinguish that the Geoportal soil series maps utilized are primarily agricultural and general land-resource maps. While these maps provide a useful preliminary indicator of parent material and texture, they are not dedicated geotechnical engineering maps.

Therefore, the soil classifications used in this study are treated as preliminary engineering proxies only, and are not directly equivalent to USCS-based engineering soil classifications. Their use in bearing capacity estimation is intended solely for regional screening and GIS-based spatial analysis, and should not be used for final structural design or construction purposes.

4.2 Computed Soil Bearing Capacity Using Terzaghi's Equation (Dry Condition)

4.2.1 Fine Sand

Fine sand is classified as a cohesionless soil (c = 0) and a typical internal friction angle of approximately 30° (Das, 2019). Using Terzaghi's standard bearing capacity factors for general shear failure and typical parameters for fine sand such as:

- γ = 18 kN/m^3 (Das, 2019)
- N_q , N_γ at 30° = 22.46 , 19.13

The **ultimate bearing capacity of fine sand** is **approximately 542 kPa.**

Utilizing a Factor of Safety of 3.0 under standard parameters, the **allowable bearing capacity (q_{allow})** for the **fine sand** scenario was determined to be **approximately 181 kPa.**

4.2.2 Silt Loam (Engineering Silt)

Silt loam, treated as Engineering Silt for analysis, exhibits low cohesion and a relatively small friction angle of approximately 20° (Bowles, 1996). Using Terzaghi's standard bearing capacity factors for general shear failure and typical parameters for silt loam such as:

- c = 20 kPa (Soil Mechanics Design Manual, 1986)
- γ = 18.5 kN/m^3 (Bowles, 1996)
- N_c , N_q , N_γ at 20° = 17.69, 7.44, 3.64

The **ultimate bearing capacity of silt loam** is **approximately 625 kPa**.

Utilizing a Factor of Safety of 3.0 under standard parameters, the **allowable bearing capacity (q_{allow})** for the **silt loam** scenario was determined to be **approximately 208 kPa.**

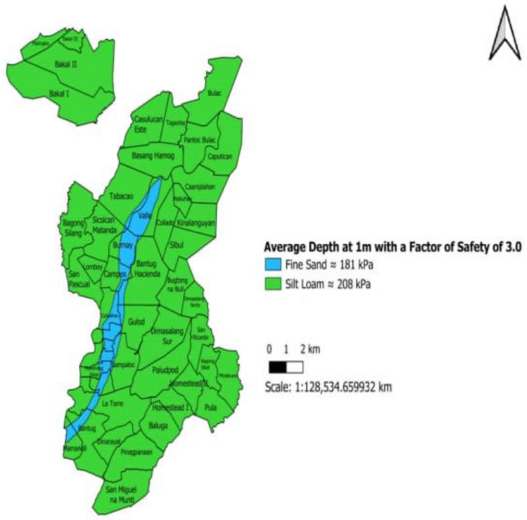

Figure 3. Theoretical Map of Soil Bearing Capacity of Soil Types in Talavera, Nueva Ecija at Depth of 1m (Dry Condition)

4.3 Computed Soil Bearing Capacity Using Terzaghi's Equation (Considering Groundwater Table)

To account for the hydrogeological conditions prevalent in the alluvial plains of Talavera, the allowable bearing capacity (q_{allow}) was recalculated considering the influence of a shallow water table. In accordance with the groundwater scenarios for Terzaghi's method, Case 3 was applied, where the water table is located at or below the base of the foundation. For this study, Case 3 was conservatively represented by assuming the groundwater table at the foundation base, $d = D_f$. (Das & Sobhan, 2017)

In such case, q = γDf and the last term γ should be replaced by an average effective unit weight of soil $\underline{\gamma}$.

$$\underline{\gamma} = \gamma' + \left(\frac{d-D_f}{B}\right)(\gamma - \gamma')$$

Where:

- $\gamma' = submerged\ unit\ weight$

$$\gamma' = \gamma_{sat} - \gamma_w$$

Where:

- γ_{sat} = *saturated soil unit weight*
- γ_w = *unit weight of water*

Assuming a unit weight of water $\gamma_w = 9.81 kN/m^3$ and because site-specific saturated unit weight values were unavailable for all mapped soil units, a representative saturated soil unit weight $\gamma_{sat} \approx 19.62\ kN/m^3$ ($2\ x\ \gamma_w$) was adopted for preliminary comparison for both fine sand and silt loam. (Budhu, 2011). This assumption is a limitation of the analysis.

$$\gamma' = \gamma_{sat} - \gamma_w$$

$$\gamma' = 19.62 - 9.81$$
$$\gamma' = 9.81\ kN/m^3$$

4.3.1 Fine Sand ($c = 0, \varphi = 30°$)

Using Terzaghi’s standard bearing capacity factors for general shear failure and typical parameters for fine sand such as:

- N_q , N_γ at 30° = 22.46 , 19.13
- γ = 9.81 kN/m^3

The **ultimate bearing capacity of fine sand considering groundwater condition** is **approximately 295 kPa**.

Utilizing a Factor of Safety of 3.0 under standard parameters, the **allowable bearing capacity (q_{ult})** for the **fine sand** scenario was determined to be **approximately 98 kPa.**

4.3.2 Silt Loam / Engineering Silt ($c = 20, \varphi = 20°$)

Using Terzaghi’s standard bearing capacity factors for general shear failure and typical parameters for silt loam such as:

- N_c , N_q , N_γ at 20° = 17.69, 7.44, 3.64
- γ = 9.81 kN/m^3

The **ultimate bearing capacity of silt loam considering groundwater condition** is **approximately 547 kPa**.

Utilizing a Factor of Safety of 3.0 under standard parameters, the **allowable bearing capacity (q_{ult})** for the **silt loam** scenario was determined to be **approximately 182 kPa.**

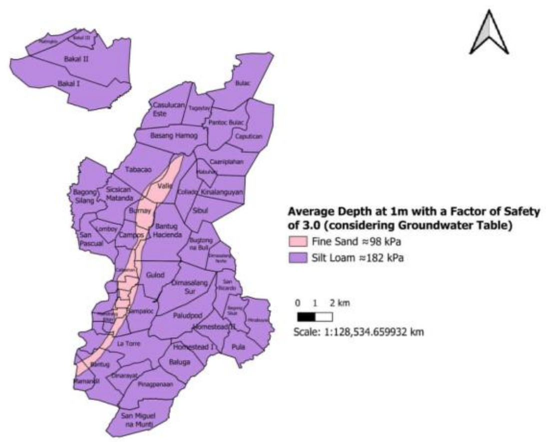

Figure 4. Theoretical Map of the Soil Bearing Capacity of Talavera, Nueva Ecija at Depth of 1m (considering Groundwater Table).

4.4 Analysis of DPWH Geotechnical Data

The study incorporated actual Standard Penetration Test (SPT) data from DPWH geotechnical reports to provide a site-specific context for the soil conditions in the study area. This analysis is intended for **preliminary engineering screening** and assessment only. Due to the limited availability of secondary records, subsurface data were gathered from two selected representative barangays: **Brgy. Mamandil** and **Brgy. Bakal I**. These records provide a localized comparison using established engineering parameters, though they do not represent a full validation of the entire municipal soil map.

4.4.1 Geotechnical Investigation Report in Brgy. Mamandil, Talavera, Nueva Ecija

The borehole logs in Brgy. Mamandil reveals a profile dominated by fine-grained soils in the upper strata. According to the Unified Soil Classification System (USCS), the profile consists primarily of silt (ML) and clay (CL) in the upper 4 meters, transitioning to medium dense sand (SM) and very stiff silt (MH) at deeper layers.

- **Surface Consistency:** Medium stiff silt (N-values: 6–9).
- **Water Table:** Observed at 2.00m depth.

Table 4-7. Summary of Allow. Soil Bearing Capacities with Corresponding Depth & Width

Borehole No.	Foundation Depth, Df (m)	Allowable Soil Bearing Capacity (kPa)	Modulus of Subgrade Reaction, k (kPa/m)
BH-1	1.50	118.0	14,000.0
	2.00	119.0	14,000.0
	2.50	186.0	22,000.0
	3.00	224.0	26,000.0
BH-2	1.50	106.0	12,000.0
	2.00	108.0	12,000.0
	2.50	118.0	14,000.0
	3.00	146.0	17,000.0
BH-3	1.50	118.0	14,000.0
	2.00	119.0	14,000.0
	2.50	165.0	19,000.0
	3.00	200.0	24,000.0

Table 4-8. Recommendation for Allow. Soil Bearing Capacities with Corresponding Depth

Foundation Depth, Df (m)	Allowable Soil Bearing Capacity (kPa)	Modulus of Subgrade Reaction, k (kPa/m)
1.50	77.0	9,200.0
2.00	88.0	10,400.0
2.50	102.0	12,200.0
3.00	103.0	12,200.0
3.50	116.0	13,800.0

Source: DPWH 1st District, Talavera, Nueva Ecija

The data in Table 4-7 shows that Brgy. Mamandil possesses relatively low bearing capacities in the shallow silt layers. The recommended values in Table 4-8 were derived by selecting the minimum allowable bearing capacity observed among the three boreholes at each specific depth. This conservative selection is an engineering safeguard, ensuring that the weakest soil lenses encountered govern the preliminary design parameters to minimize the risk of differential settlement.

4.4.2 Geotechnical Investigation Report in Brgy. Bakal I, Talavera, Nueva Ecija

The profile in Brgy. Bakal I exhibits higher variability and a notable transition to coarse-grained materials at depth. The logs indicate stiff silt (ML) near the surface, with dense sand (SM/SP) appearing at 3 meters and below.

- **Surface Consistency:** Soft to medium stiff silt (N-values: 5–7).
- **Water Table:** Observed at a very shallow 0.30m depth.

Table 4-9. Summary of Allow. Soil Bearing Capacities with Corresponding Depth & Width

Borehole No.	Foundation Depth, Df (m)	Allowable Soil Bearing Capacity (kPa)	Modulus of Subgrade Reaction, k (kPa/m)
BH-1	1.50	118.0	14,000.0
	2.00	119.0	14,000.0
	2.50	186.0	22,000.0
	3.00	224.0	26,000.0
BH-2	1.50	106.0	12,000.0
	2.00	108.0	12,000.0
	2.50	118.0	14,000.0
	3.00	146.0	17,000.0
BH-3	1.50	118.0	14,000.0
	2.00	119.0	14,000.0
	2.50	165.0	19,000.0
	3.00	200.0	24,000.0

Table 4-10. Recommendation for Allow. Soil Bearing Capacities with Corresponding Depth

Foundation Depth, Df (m)	Allowable Soil Bearing Capacity (kPa)	Modulus of Subgrade Reaction, k (kPa/m)
1.50	106.0	12,000.0
2.00	108.0	12,000.0
2.50	118.0	14,000.0
3.00	146.0	17,000.0

Source: DPWH 1st District, Talavera, Nueva Ecija

Brgy. Bakal I presents a unique geotechnical condition where the water table is extremely shallow (0.30m), essentially saturating the surface silt. Despite this, the bearing capacities in Table 4-9 are notably higher than those in Brgy. Mamandil at depths of 2.5m and below. This is attributed to the presence of dense sand layers (SP/SM), which provide superior structural competence compared to the silty-clay layers in Mamandil.

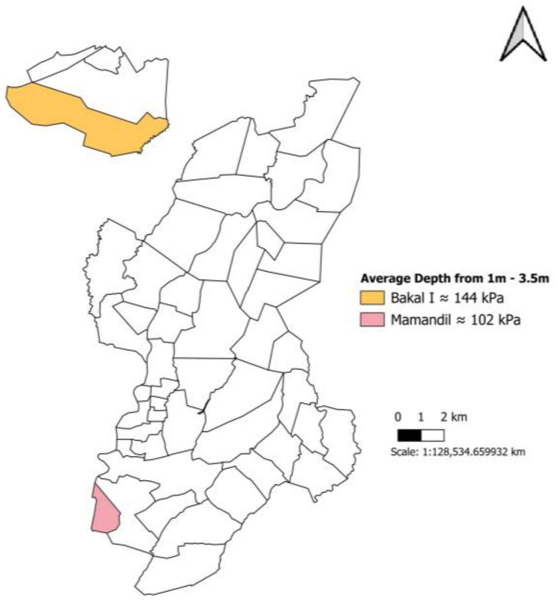

Figure 5. Map of Soil Bearing Capacity in Brgy. Bakal I and Brgy. Mamandil in Talavera, Nueva Ecija at Average Depth from 1m to 3.5m

4.4.3 Discussion of Observed Soil Bearing Capacity of DPWH Dataset

The DPWH dataset provides actual subsurface investigation results, which are essential for understanding the engineering behavior of the study area. These results provide reliable point-based references for the tested locations but should not be interpreted as uniform values for the entire barangay.

These reports typically cater to general foundation recommendations, such as isolated or strip footings, and utilize the Unified Soil Classification System (USCS). This differs from the agricultural soil series (e.g., Maligaya or

Bantog series) used elsewhere in this study, which serve as near-surface proxies rather than direct engineering classifications.

Key Observations:

- **Depth and Densification:** In both barangays, soil bearing capacity (q_{allow}) increases with depth. This confirms that deeper soil layers exhibit improved strength characteristics and higher compaction, making them more suitable for structural loads.
- **Groundwater Impact:** The shallow water table, particularly in Brgy. Bakal I (0.30m), suggests that groundwater is a critical factor in Talavera's geotechnical profile. A shallow water table typically reduces effective stress, which is why the recommended values from DPWH are conservative. Localized engineering must consider dewatering and specialized foundation treatments in these high-water-table zones.
- **Spatial Variability:** The data demonstrates that even within the same municipality, soil properties vary significantly. Bakal I shows a rapid increase in strength due to sand layers, while Mamandil remains relatively weak in its upper silty-clay strata.

These findings emphasize the importance of site-specific borehole data. While surface layers generally consist of weaker materials, the presence of loose/soft zones and high groundwater levels necessitates the use of conservative minimum values for any preliminary engineering assessment. The DPWH data highlights that for any transition from screening to actual design, consistent foundation depths (D_f) and rigorous seasonal groundwater monitoring are required.

4.5 Comparison Between Theoretical (Estimated) and Practical (Observed) Values

This section assesses the relationship between the theoretical allowable soil bearing capacities—calculated under both dry and saturated conditions—and the actual observed values derived from DPWH geotechnical investigations. It is important to note that the DPWH data used in this study were obtained from actual geotechnical investigation reports available for Brgy. Bakal I and Brgy. Mamandil. These values were derived from field subsurface exploration and engineering assessment for the specific tested locations. Rather than a full validation, this serves as a contextual comparison to evaluate how generalized mapping aligns with localized borehole data. This assessment is intended for preliminary engineering screening and regional planning purposes only and must not be used for actual foundation design.

The estimated values utilize Terzaghi’s equations at a foundation depth (D_f) of 1.0 m, while the DPWH observed values are reported starting at a depth of 1.5 m. This discrepancy in depth, along with the difference between agricultural soil proxies and actual engineering classifications, accounts for much of the variance in the results.

Table 4-11. Theoretical (Estimated) and Practical (Observed) Values

Soil Type	Theoretical Estimate (Dry Condition)	Theoretical Estimate (Case 3 Groundwater Table)	DPWH Data Range (kPa)
Fine Sand	181	98	106 - 146 (Brgy. Bakal I)
Silt Loam	208	182	77 - 116 (Brgy. Mamandil)

4.5.1 Analysis of Findings

The observed variance between **idealized mathematical models** and **subsurface conditions** underscores the sensitivity of q_{all} estimations to the theoretical assumption of soil homogeneity. Because these mathematical models typically produce "upper-bound" results, the discrepancy with **DPWH field data** highlights the significant spatial variability inherent in Talavera’s alluvial deposits. This contrast confirms that while regional proxies offer a functional spatial overview, localized geotechnical verification is required to account for in-situ complexities and fluctuating saturation levels.

- **Impact of Groundwater (Dry vs. Case 3):** In this study, **Case 3** is defined as the condition where the groundwater table lies at or below the base of the foundation ($d = D_f$). The transition from dry to Case 3 groundwater conditions resulted in a significant reduction in the allowable bearing capacity (q_{allow}). For Fine Sand, the reduction highlights the sensitivity of cohesionless soils to buoyancy forces. For Silt Loam, the recalculation shows a reduction in capacity when groundwater is considered, maintaining consistent soil parameters (cohesion and internal friction angle) to isolate the hydraulic effect.
- **Discrepancies in Data Resolution:** Theoretical values generally appear higher than the observed values in Brgy. Mamandil. This suggests that while the "Silt Loam" model assumes medium consistency, the actual "ML/CL" layers in the field may contain higher moisture content or looser zones that the generalized agricultural map does not capture. In Brgy. Bakal I, the DPWH values are closer to the Case 3 estimate, likely because the dense sand layers encountered at depth provide higher resistance despite the shallow water table.

4.5.2 Factors Influencing the Variance

Several technical factors explain the gap between the calculated and observed values:

A. **Foundation Depth Inconsistency:** The theoretical estimations are based on D_f = 1.0 m to represent shallow footings typically used in mapping. However, DPWH reports provide recommendations starting at 1.5 m. Because soil strength and overburden effects generally increase with depth, a direct numerical comparison is limited; theoretical estimates at 1.0 m are not directly equivalent to DPWH recommendations beginning at 1.5 m.

B. **Agricultural Proxy vs. Engineering Classification:** This study uses agricultural soil series (e.g., Maligaya and Bantog) from Geoportal PH as proxies for engineering behavior. In contrast, DPWH logs use the Unified Soil Classification System (USCS) based on Standard Penetration Tests (SPT). The difference in data resolution—landscape-level vs. borehole-level—is a primary driver of the variance.

C. **Water Table Depth:** While the Case 3 model assumes the water table is at the foundation base, field observations in Bakal I show groundwater as shallow as **0.30 m**. This near-surface saturation exceeds the Case 3 assumption and further reduces effective stress, which explains why field-observed minimums are lower than idealized dry models.

4.5.3 Engineering Implications

The results confirm that while Terzaghi’s equations provide a necessary baseline for **preliminary engineering assessment**, they must be interpreted with caution. For the Talavera region, the variance between datasets reinforces that GIS-based spatial estimations are screening tools for identifying broad trends and "red-flag" areas with potentially weak soils or high water tables.

Disclaimer: *The generated maps and tables are for preliminary planning and academic reference only. They shall not be used as the sole basis for structural or foundation design. In accordance with the National Structural Code of the Philippines (NSCP) and the National Building Code, a site-specific geotechnical investigation featuring actual borehole drilling and laboratory testing remains mandatory for any construction project to ensure structural safety and account for settlement and seasonal groundwater fluctuations.*

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary

This research evaluates the spatial distribution of estimated soil bearing capacity within the municipality of Talavera, Nueva Ecija, a region undergoing significant infrastructure development. In civil engineering, structural stability is fundamentally dependent on the ground's capacity to support intended loads; however, obtaining high-resolution geotechnical data is often constrained by the high costs of subsurface exploration. Conducted from February to April 2026, this study addresses these constraints by identifying dominant soil types and mapping their estimated engineering capacities for the purpose of **preliminary engineering screening**.

The study utilizes a descriptive, comparative, and GIS-based spatial estimation research design, synthesizing available secondary data from Geoportal Philippines and official geotechnical reports from the DPWH 1st District. Using GIS software, municipal soil maps were digitized and georeferenced to assign engineering properties to specific geographic locations. The core analysis applied Terzaghi’s bearing capacity equation to determine the estimated **allowable soil bearing capacity (q_{allow})** across the municipality, assuming a standard foundation depth (D_f) of 1.0 m.

Analysis of regional soil maps identified the Maligaya and Bantog series as the dominant soil units. It is critical to distinguish that these Geoportal soil series maps are primarily agricultural and land-resource classifications. In this study, they are utilized as **preliminary proxies** for engineering behavior. While they provide a useful indicator of parent material and texture, they do not replace the Unified Soil Classification System (USCS) used in professional geotechnical reports. Therefore, these classifications serve only as a basis for **preliminary engineering assessment** and must not be used for final structural design.

Theoretical estimates using Terzaghi’s equation indicate that under dry conditions, the allowable soil bearing capacity is determined to be approximately 181 kPa for fine sand and 208 kPa for silt loam. To account for environmental factors, groundwater effects were analyzed using **Case 3 conditions**, defined as the groundwater table being at or below the base of the foundation ($d = D_f$). Under these conditions, the computed values adjusted to approximately 98 kPa for fine sand and 182 kPa for silt loam. The reduction in bearing capacity—most notably in the fine sand model—demonstrates the sensitivity of cohesionless soils to buoyancy forces. Contextual comparison with field data indicates that actual groundwater levels in areas like Brgy. Bakal I can be as shallow as 0.30 m, which suggests even greater reductions in effective soil strength than the Case 3 model assumes.

The discrepancies observed between idealized mathematical models and actual DPWH geotechnical data emphasize that theoretical calculations often represent the "upper-bound" limits of soil strength. This study highlights the value of GIS in visualizing regional trends and identifying areas of potential soil consistency issues. However, the variable values found in actual borehole records from selected barangays confirm that this mapping is intended for **preliminary screening** only. Site-specific Standard Penetration Tests (SPT), laboratory testing, and seasonal groundwater monitoring remain mandatory for actual design and construction to ensure structural safety in accordance with the National Structural Code of the Philippines (NSCP).

5.2 Conclusions

Based on the GIS-based mapping and contextual comparison of the gathered geotechnical data, the following conclusions are drawn regarding the soil bearing capacity in Talavera, Nueva Ecija:

1. **Talavera exhibits heterogeneous soil bearing conditions**, where variations in soil type, density, and subsurface layering result in differing load-bearing capacities across locations. This spatial variability reflects the alluvial depositional

environment of the area, indicating that soil properties are not uniform and may significantly influence foundation performance.

2. **The use of GIS-based proxy mapping**, integrating Geoportal PH soil classifications with standard engineering parameters appears useful for preliminary engineering screening and spatial analysis. This approach enables the visualization of general trends and the identification of potentially low-strength zones, serving as a practical tool for regional planning and decision-making.
3. **Comparison with DPWH borehole-based geotechnical data confirms the presence of significant local variability in soil strength and stratification**. The observed allowable bearing capacities differ across barangays and depth levels, demonstrating that actual subsurface conditions cannot be fully represented by generalized soil mapping alone.
4. **The inclusion of groundwater conditions,** particularly through Case 3 of Terzaghi's bearing capacity equation, shows that groundwater assumptions have a significant impact on computed bearing capacity values. The reduction in allowable capacity under saturated conditions highlights the importance of effective stress considerations, especially in cohesionless and partially saturated soils.

Overall, while the study provides a reliable preliminary assessment of soil bearing capacity distribution, it is concluded that site-specific geotechnical investigations remain essential for final design applications. Detailed subsurface exploration, including borehole drilling, Standard Penetration Testing (SPT), and laboratory testing, is necessary to ensure accurate, safe, and code-compliant foundation design.

5.3 Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. Future researchers are encouraged to conduct actual geotechnical investigations such as borehole drilling, Standard Penetration Tests (SPT), and laboratory testing to validate the preliminary GIS-based estimations presented in this study.
2. Seasonal groundwater monitoring is recommended, especially in areas with shallow water tables, since groundwater conditions significantly affect soil bearing capacity and foundation performance.
3. Additional borehole data from other barangays in Talavera may be collected in future studies to improve the accuracy and spatial reliability of the soil bearing capacity maps.
4. Future studies may utilize advanced geotechnical methods such as Cone Penetration Testing (CPT), settlement analysis, and numerical modeling software to provide more detailed assessment of subsurface behavior.
5. GIS-generated maps from this study should be used only for preliminary engineering screening and regional planning purposes. Site-specific geotechnical investigation remains necessary for actual foundation design in accordance with the National Structural Code of the Philippines (NSCP).

VI. ACKNOWLEDGEMENT

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