

Web-Based Geographic Information System For Mapping Non-Metallic Mineral And Rock Mining In North Central Timor Regency

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ARTICLE INFO

Article history:

Received 7 May 2026

Revised 11 May 2026

Accepted 14 May 2026 Available online

25 June 2026

Keywords:

Mining

North Central Timor

Prototype

SIG

Web

IEEE style in citing this article:

E. Naiobe, Y. P. K. Kelen, and A. K. D. Lestari, "Web-Based Geographic Information System for Mapping Non-Metallic Mineral and Rock Mining in North Central Timor Regency," *J-ENSISTEC: Journal of Engineering and Sustainable Technology*, vol. 12, no. 2, pp. 10515-10527, 2026.

Doi :

<https://doi.org/10.31949/j-ensitec.v12i02.18139>

ABSTRACT

The monitoring and dissemination of information regarding non-metallic mineral and rock mining locations in North Central Timor (TTU) Regency remain constrained by conventional, non-digital data collection systems. This study aims to develop a web-based Geographic Information System (GIS) capable of accurately and integrally mapping and presenting mining locations in TTU Regency. This applied research employs a Prototype development model, integrating the Google Maps API for interactive spatial visualization and a role-based data entry mechanism to separate admin and user functions. Black-box Testing results confirm that all functions on both admin and user sides operate as specified, enabling the digitization of mining attribute data (e.g., IUP SK numbers, area size, operational status). The main contributions of this study are: (1) improving the efficiency of mining data management at the ESDM Branch Office Region I, and (2) providing more transparent, real-time public access to mining location information, thereby addressing the limitations of conventional systems.

1. INTRODUCTION

The management of mineral resources is a critical component of regional development, including in North Central Timor (TTU) Regency, which possesses significant potential in non-metallic minerals and rocks [1]–[3]. However, in practice, the management of mining location data in this region faces substantial challenges. The Branch Office of the Department of Energy and Mineral Resources (ESDM) Region I, which oversees TTU, South Central Timor (TTS), Belu, and Malaka Regencies, still relies on conventional, manual data collection methods [4]. Consequently, the monitoring of mining activities (both licensed and illegal), spatial data management, and public information dissemination remain ineffective.

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Previous studies have developed web-based GIS for mapping mining distributions [5]–[7]. However, these studies have several limitations: (1) integration between spatial data and attribute data (e.g., IUP license numbers, area size, operational status) remains partial [5]; (2) they primarily focus on map visualization without centralized attribute data management [6], [7]; and (3) they were developed on desktop platforms with limited accessibility [8]. The most prominent common limitation is the absence of a system explicitly designed to support monitoring and supervisory functions by local government institutions, particularly in TTU Regency.

Addressing this gap, this study aims to develop a web-based GIS for mapping non-metallic mineral and rock mining locations in TTU Regency. The main novelties of this study are: (1) full integration of spatial and attribute data within a centralized database (MySQL) ensuring real-time data consistency; (2) use of an interactive map (Google Maps API) as the primary interface for attribute data exploration through a dynamic pop-up mechanism; and (3) implementation of role-based access control that not only differentiates admin and public access rights but also establishes a structured data verification workflow. The contributions of this study include: (a) providing an operational solution for the ESDM office to improve mining data management efficiency; (b) enhancing monitoring capacity for legal and illegal mining activities through periodically updated digital maps; and (c) facilitating transparent public access without requiring physical visits to government offices..

2. METHOD

2.1. Research Type

This study employs an applied research approach [9], selected due to its alignment with the nature of the problems faced by the Regional Office of the Energy and Mineral Resources Agency (ESDM) Region I, namely a mining location data management system that remains conventional and has not yet been digitized. In contrast to basic research, which is oriented toward theoretical development [10], this approach directly guides all stages of system development to produce a software product (a web-based geographic information system) that can be practically implemented.

The relationship between this approach and the research methods and objectives is reflected in three aspects. First, the identification of end-user requirements serves as the foundation for designing a centralized database (MySQL) and implementing role-based access features, in line with web-based GIS development practices in previous studies [2]–[5], [7], [9]–[15]. Second, the solution is tested collaboratively with the relevant agency to ensure that the interactive map visualization based on the Google Maps API [16] can effectively support the monitoring of mining activities, as also applied in various web-based GIS implementations [17], [18]. Third, the research output is specifically directed toward addressing practical needs, including the digitization of spatial data, the provision of transparent access for the public, and the improvement of data management efficiency at the agency level, representing a further development of prior studies [2]–[5], [7], [9]–[15].

Thus, the applied research approach functions not merely as a background but as a methodological framework that guides each stage of system design and implementation, further supported by software engineering concepts [19], [20] as well as fundamental GIS principles [21].

2.2. System Development Method

This study adopts an applied research approach combined with the Prototype system development model [22]. This model was selected because the system requirements were not fully defined at the outset, primarily due to the limited experience of end users (staff of the ESDM Regional Office Region I) with similar digital systems. The prototype model enables continuous improvement based on user feedback, ensuring that the final system aligns with the actual needs of mining data management.

The methodological flow consists of five main stages, executed iteratively:

1. Initial data collection – Observations and interviews were conducted with agency staff to understand the existing conditions of the mining location data management system in TTU Regency, including both technical and non-technical challenges encountered.
2. Requirements identification (requirements analysis) – Based on the collected data, functional requirements (spatial and attribute data management, map visualization, role-based access) and non-functional requirements (access speed, data security) were formulated.

3. Initial prototype design – An initial system model was developed, featuring a simple interface for displaying maps and inputting mining location points. At this stage, the database structure and system components were described conceptually without detailing the table schema.
4. Prototype testing and evaluation – The initial prototype was tested by users (agency staff) to obtain feedback regarding usability, feature completeness, and compatibility with actual field workflows.
5. Refinement and improvement – Based on user feedback, iterative improvements were made to key features, such as spatial-attribute data integration, pop-up visualization using the Google Maps API, and differentiation of access rights between admin and public users.
6. Implementation and final testing – The refined system was implemented in the actual environment at the Regional Office of the Energy and Mineral Resources Agency Region I and then thoroughly tested to ensure that all requirements were met.

This methodological flow is iterative, in which stages 4 and 5 may be repeated until the system is deemed acceptable by users. The technical details, such as the database table structure and program code, are presented in the Results and Discussion section rather than in this Methodology section.

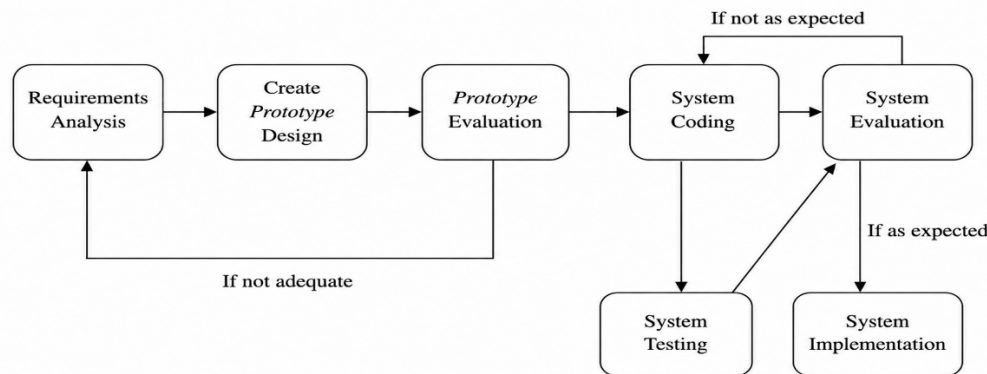


Figure 1. System Development Method

The specific implementation of each stage is described as follows:

1. Requirements Analysis – The researcher conducted interviews and direct observations with the Head of the Mining Subdivision and administrative staff at the ESDM Regional Office Region I. The primary data sources included manual documents of mining location records (coordinate notes, area size, permit status) and reported constraints, such as difficulty in retrieving historical data and the absence of spatial visualization. The outcome of this stage was a list of functional requirements (management of mining location points, map-based search, admin-public access restriction) and non-functional requirements (the system must be lightweight and accessible via common devices).
2. Prototype Design Development – Based on the identified requirements, the researcher designed a simple interface (low-fidelity prototype) consisting of a map page (Google Maps API), a mining data input form, and a location list table. This design was consulted with agency staff to ensure usability aligned with their workflow, such as the placement of the "add point" button and the display of attribute information in pop-ups.
3. Prototype Evaluation – The initial prototype was tested by three agency staff members responsible for mining data management. The evaluation focused on two aspects: (a) whether all required features were available, and (b) whether the interface layout was easy to understand. Feedback obtained included suggestions such as "adding a filter based on permit status" and "including photos of mining locations in the pop-up." If deficiencies were identified, the process returned to the requirements analysis or design stage. In this study, two iterations occurred at this stage.

4. System Coding – Once the prototype was deemed appropriate, full system development was carried out using PHP, MySQL database, and JavaScript (Google Maps API). At this stage, a functional system was produced that accommodated all prior feedback, including role-based access features (admins can add/edit/delete data, while the public can only view) and integration of spatial and attribute data.

5. System Testing – The completed system was tested using the black-box testing method to ensure that each function operated according to specifications. Testing was conducted by the researcher together with one technical staff member. Example test scenarios included: logging in as admin → adding a new mining point → verifying that the point appears on the map; logging in as a public user → attempting to delete data → verifying that the delete option is unavailable.

6. Evaluation of Testing Results – The testing results were evaluated together with end users. If any functional errors or mismatches with requirements were identified, revisions were made at the coding stage (without returning to the analysis phase). In this study, two minor improvements were identified: correction of coordinate formatting and improvement of map loading speed. Once all functions operated as expected, the system was deemed ready for use by users.

The database structure (including tables for admin, location, category, district, and gallery) was designed to ensure integration between spatial data (coordinates) and attribute data (e.g., IUP numbers, area size, operational status). The Entity-Relationship Diagram (ERD) shows the location table as the central entity, linked to district and category tables with one-to-many cardinalities. A system flowchart distinguishes two user roles: admin (full CRUD and report printing) and public (view only). A login activity diagram ensures that only authenticated admins can access data management functions.

Table 1. Admin

No	Field	Type	Size	Key
1	Id_admin	Int	11	Primary Key
2	username	Varchar	50	
3	password	Varchar	100	
4	Created_at	Datetime		
5	Updated_at	Datetime		

Table 2. Gallery

No	Field	Type	Size	Key
1	Gallery_ID	Int	11	Primary Key
2	Gallery_Name	Text	-	-
3	Gallery_Description	Text	-	-
4	Gallery_Photo	Varchar	50	-
5	Created_At	Datetime	-	-
6	Updated_At	Datetime	-	-

Table 3. District

No	Field	Type	Size	Key
1	Id_kec	Int	11	Primary Key
2	name	Text		

Table 4. Category

No	Field	Type	Size	Key
1	Category_ID	Int	11	Primary Key
2	Category_Name	Varchar	60	

3	<i>Created_at</i>	<i>Datetime</i>
4	<i>Updated_at</i>	<i>Datetime</i>

Table 5. Location

No	Field	Type	Size	Key
1	Location_ID	Int	11	Primary Key
2	District_ID	Int	11	Foreign Key
3	Category_ID	Int	11	Foreign Key
4	Location_Name	Varchar	225	-
5	Location_Description	Text	-	-
6	Latitude	Varchar	50	-
7	Longitude	Varchar	50	-
8	Address	Text	-	-
9	Location_Photo	Text	-	-
10	Status	Text	-	-
11	Created_At	Datetime	-	-
12	Updated_At	Datetime	-	-

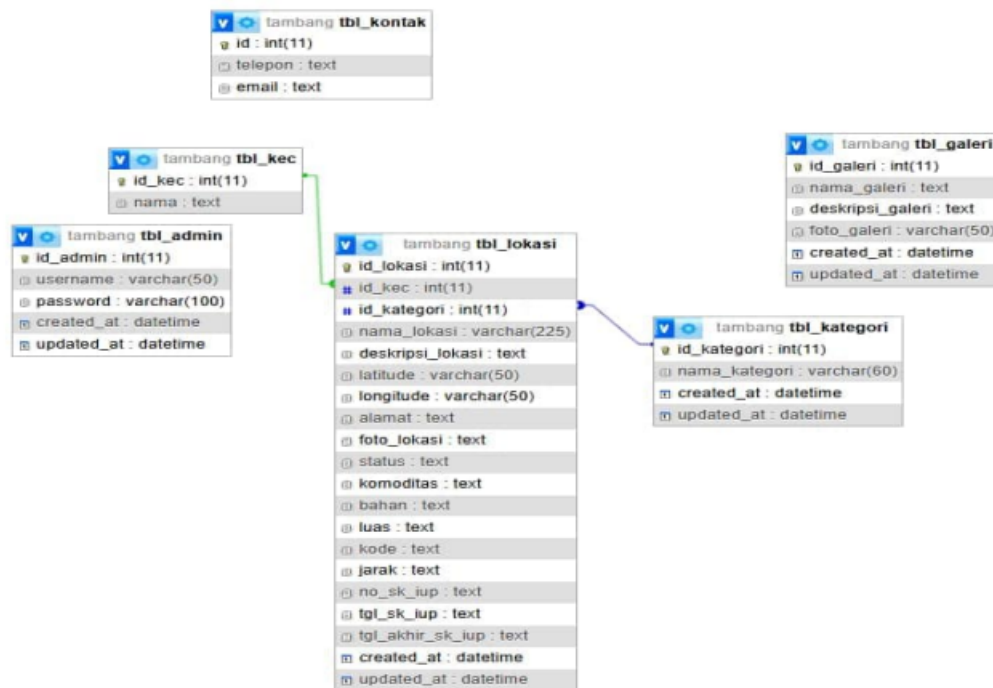


Figure 2. Table Relationships

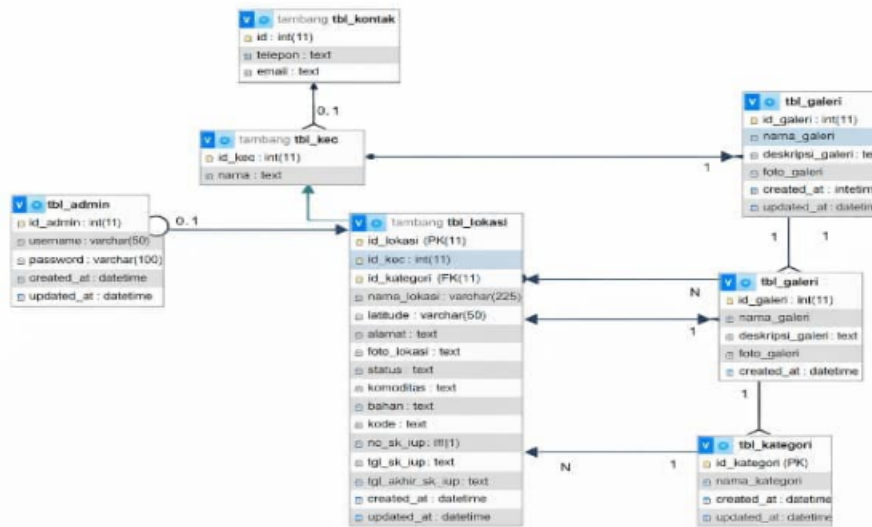


Figure 3. ERD

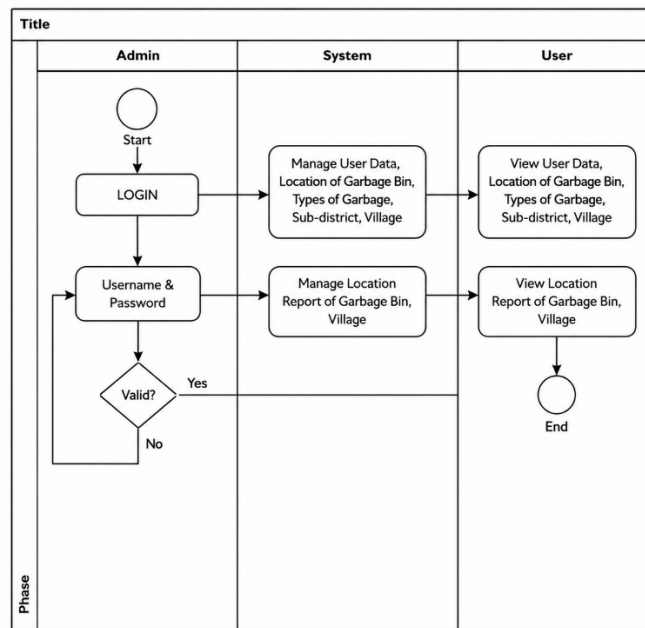


Figure 4. System Flowchart

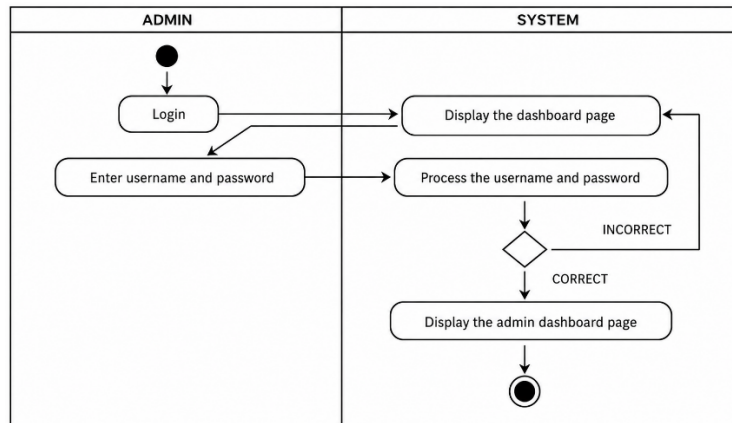


Figure 5. Login Activity Diagram

2.3. Data Collection Techniques

Data collection was carried out through interviews and literature studies. Direct interviews were conducted with two technical staff members of the ESDM Regional Office Region I in Kefamenanu, who are directly responsible for mining location data management. The semi-structured interview process lasted approximately 90 minutes and covered the existing workflow, types of attribute data (mining permit decree number, area size, operational status, mining type, and owner name), as well as technical constraints. The interview results were transcribed and revalidated with the respondents.

The collected data included mining location coordinates, attribute data, and identification of constraints such as the absence of a centralized database and limited public access. These data became the primary input for database design and system functional requirements.

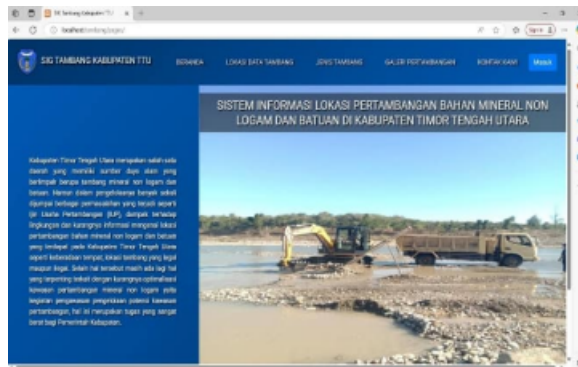
The literature study reviewed regulations such as the Regulation of the Minister of Energy and Mineral Resources No. 05/2017 [23], geographic information system textbooks [21], Google Maps API documentation [16], and accredited scientific journals published between 2019 and 2025. The results of the study were used to determine the system architecture (PHP, MySQL, and Google Maps API) and to develop black-box testing instruments.

2.4. Tools and Materials

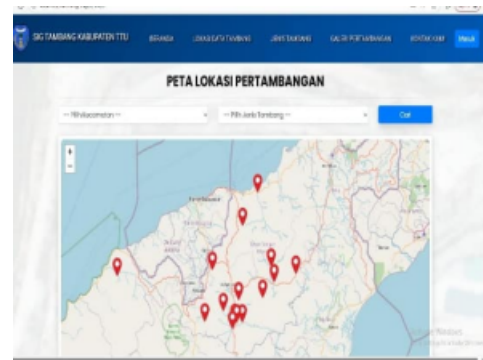
This study utilized hardware and software selected based on the requirements for developing a web-based GIS. The development environment consisted of a standard personal computer with sufficient specifications to run a local web server, while a flash drive served as backup storage for the source code and database. The software stack included: XAMPP (providing Apache and MySQL servers) as the local development environment; PHP for back-end logic and user authentication; MySQL as the relational database management system; the Google Maps API for displaying base maps, markers, and attribute information pop-ups [16]; and UML modeling tools (StarUML, Microsoft Office Visio) for system design and flowchart creation.

3. RESULTS AND DISCUSSION

The developed web-based GIS consists of five main functional modules: homepage, mining location map, mining type classification, photo gallery, and contact page. These modules address the user requirements identified during the requirements analysis stage, particularly the need for spatial visualization of mining locations and integrated attribute data management.



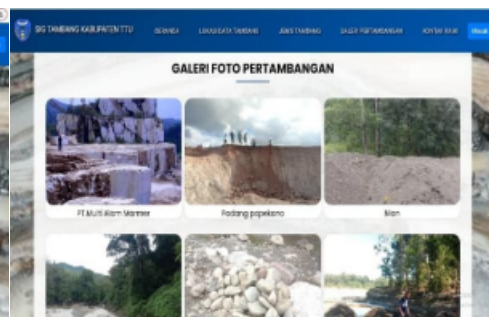
a. Main Page (Homepage)



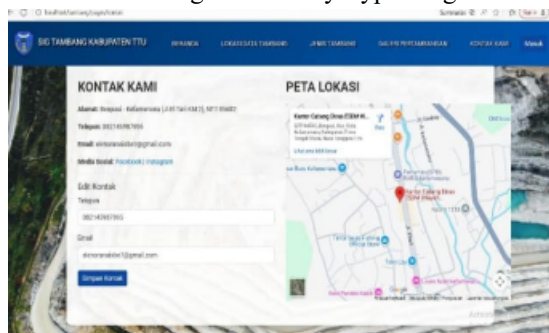
b. Mining Data Location Page



c. Mining Commodity Types Page



d. Gallery Page



e. Contact Us Page

Figure 8. Application Interface

The proposed web-based GIS offers substantial improvements over the previous manual system through four key indicators. First, the system reduces mining location retrieval time from an average of 15–20 minutes to just a few seconds. Users can simply click on a map marker or use the search function instead of sifting through physical notebooks and multiple spreadsheet files. Second, the system ensures greater accuracy and completeness of information through a relational database design (with foreign keys linking Location, Category, and District tables) combined with verified GPS coordinates collected during field observations with ESDM staff. This design eliminates the common manual-system problems of missing IUP numbers or incomplete operational status records. Third, the system enhances monitoring and supervision capabilities by introducing a color-coded marker system: green markers for licensed and active mines, yellow markers for licensed but inactive mines, and red markers for unlicensed or illegal mines. This feature enables field officers and policymakers to identify illegal mining hotspots in less than five

minutes, compared to approximately 30 minutes required under the manual method of cross-referencing multiple paper reports. Fourth, the system provides transparent 24/7 public access via the internet from any device. In stark contrast, under the previous system, citizens had to physically visit the ESDM office, submit a formal request, and wait several days for staff to retrieve manual records. This transformation directly supports the Indonesian government's mandate for open access to natural resource information as stipulated in Ministerial Regulation No. 05 of 2017 [23].

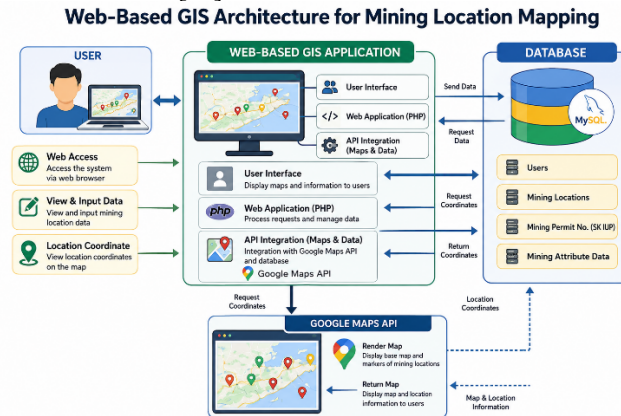


Figure 9. Web-Based GIS Architecture for Mining Location Mapping

The key scientific contribution of this study is the explicit, bidirectional integration of spatial data (coordinates) and mining attribute data (IUP numbers, permit status, area size, commodity type, operational status, and photo documentation) within a centralized MySQL database through three technical layers—the database layer where `tbl_lokasi` stores both coordinate and attribute fields linked via foreign keys to `tbl_kec` and `tbl_kategori`, the server-side PHP layer that executes atomic INSERT/UPDATE queries to prevent orphaned spatial points, and the client-side visualization layer where the Google Maps API and JavaScript retrieve all records as a single JSON object enabling pop-up windows to display complete attribute information without additional queries—which, unlike previous studies [9]–[12] that treated maps and attribute tables separately or used coordinates only for visualization without embedding them into a relational structure supporting monitoring workflows, offers bidirectional and persistent spatial-attribute linkage, database-enforced data consistency, single-query retrieval efficiency, and immediate real-time synchronization, thereby directly supporting ESDM monitoring functions such as instant identification of illegal mining sites via red markers, filtering by operational status, and export of spatial-attribute datasets, while also providing a replicable full-stack integration architecture for other natural resource management contexts including forestry, agriculture, and land use planning.

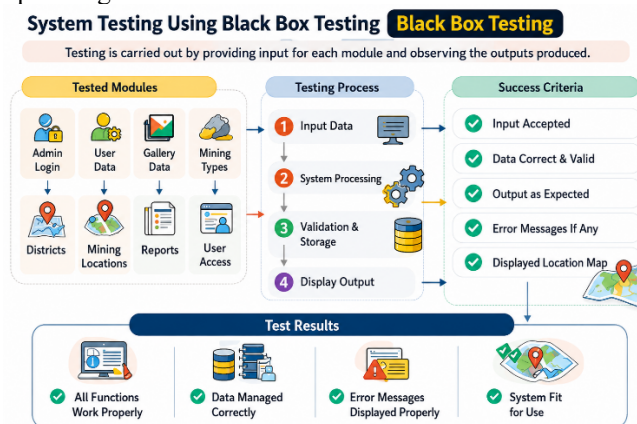


Figure 10. Black-Box Testing

The selection of the Prototype model (Pressman, 2015) was justified by the ESDM staff's lack of prior experience with web-based GIS, making iterative user feedback essential to align the system with their specific workflows including color-coded status markers and role-based access; black-box testing was chosen to verify functional correctness (input validation, CRUD, session management, role-based access) by directly simulating real user interactions without requiring internal code knowledge, providing an objective basis for User Acceptance Testing; and the Google Maps API was integrated because prior studies (Xing & Li, 2016; Liu et al., 2009) have demonstrated its effectiveness for geoscience data visualization, reducing development complexity while offering rich interactive features (markers, info windows, routing) and enabling public access without specialized GIS software—all of which support the study's key practical benefits: centralized data management, color-coded monitoring of legal/illegal mines, and transparent public access.

Table 6. Black-Box Testing of the System

No.	Module Category	Testing Procedure	Number of Scenarios	Testing Result
1	Admin Authentication	Login using correct and incorrect username and password	2	Successful
2	User Data Management	Add and delete user data	2	Successful
3	Gallery Data Management	Add, edit, and delete gallery data	3	Successful
4	Mining Type Management	Add, edit, and delete mining categories	3	Successful
5	District Data Management	Add, edit, and delete district data	3	Successful
6	Mining Location Management	Add, edit, and delete mining location data	3	Successful
7	Report Printing	Print report data based on district	1	Successful
8	Public Menu (User)	Homepage, location map, location details, route view, mining types, gallery, contact us	7	Successful

All eight black-box testing scenarios were declared successful (100%), indicating that the system has fulfilled the established functional specifications and is free from logical errors in main functions such as input validation, CRUD processes, session management, and interface-database integration. However, this result requires scientific interpretation with respect to the limitations of the testing process.

First, the 100% success rate reflects only functional validity (i.e., the system performs what it is designed to do) and does not imply non-functional robustness. Aspects such as response time under concurrent user access, load resistance, and security vulnerabilities (e.g., SQL injection, cross-site scripting, man-in-the-middle attacks) were not evaluated. Second, the testing did not cover edge cases or extreme input conditions, including invalid coordinate formats (e.g., out-of-range latitude/longitude values), upload of large photo files exceeding server memory limits, or database write failures due to network interruption. Third, the testing environment was confined to a localhost server with a single concurrent user, which does not replicate the unpredictable conditions of a production server (e.g., limited bandwidth, shared hosting resources, concurrent admin and public access).

Consequently, the 100% functional success rate should be interpreted as necessary but not sufficient evidence of overall system quality. It provides a strong basis to conclude that the system is

functionally feasible to proceed to the User Acceptance Test (UAT) stage, where end users evaluate usability and workflow compatibility. However, for long-term deployment, future studies must include performance testing (e.g., load testing with simulated concurrent users), security testing (e.g., SQL injection attempts, input sanitization validation), and usability testing with a larger sample of end users. Until such tests are conducted, claims about system reliability under real-world operating conditions remain provisional.

4. CONCLUSION

This study successfully developed a web-based GIS for mapping non-metallic mineral and rock mining locations in TTU Regency, transforming the manual document-based system into a centralized digital platform that integrates spatial and attribute data, as demonstrated by reduced search time (from 15–30 minutes to under one minute), streamlined data updates, and online public access. However, the study is limited to TTU Regency, lacks advanced spatial analysis features, and only performed functional testing (black-box) without usability, performance, or security evaluations; therefore, future studies should expand coverage to neighboring regencies (TTS, Belu, Malaka), add spatial analysis and public reporting features, and incorporate usability testing (e.g., SUS), performance testing (e.g., load testing with concurrent users), and security testing (e.g., SQL injection, XSS) to ensure practical, reliable, and secure deployment at the ESDM office.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to the Rector, Dean, and Head of the Study Program for providing facilities and academic support throughout the implementation of this research. Appreciation is also extended to the supervisors and examiners for their guidance, suggestions, and valuable direction during the research process. The author would also like to thank the Regional Office of the Department of Energy and Mineral Resources (ESDM) Region I for granting permission and providing the necessary data for this study. Finally, the author expresses heartfelt gratitude to family and colleagues for their moral support throughout the research process.

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