

Geology Structure Identification in Ranau Lake with Bathymetry

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Abstract. Lake Ranau is one of the areas planned for the development of geothermal power plants owned by PT PLN (Persero). The Lake Ranau area lies in a tectonically active zone formed by the subduction of the Indo-Australian Plate beneath the Eurasian Plate. This region is also intersected by several faults on the island of Sumatra, including the Sumatran Fault. Faults play a critical role in identifying geothermal potential, as they often serve as pathways for heat and fluid movement. To assess geothermal potential, geological, stratigraphic, and lithological studies are conducted to identify permeable zones connected to heat sources beneath the Earth's surface. However, these studies are typically limited to land areas. Since the Lake Ranau Geothermal Working Area (WKP) includes a lake, a specialized study is required to explore the potential presence of permeable zones within the lake. Research aimed at defining permeable zones in the lake has incorporated bathymetric survey data to identify additional faults or structures that may enhance permeability in the Lake Ranau WKP. By integrating bathymetric methods, researchers can gain insights into subsurface structures beneath the lake bed that could act as permeability pathways, contributing to the area's geothermal potential.

Keywords: *bathymetry, geology, structure, lake, Ranau*

1 Introduction

In 2023, research will be conducted by PT PLN (Persero) in collaboration with PT PLN Enjiniring [1] to perform geoscience studies for the Lake Ranau WKP plan. This study will assess the conditions of the Lake Ranau WKP area through geological, geochemical, and geophysical analyses.

Based on the studies conducted, areas have been identified as either permeable or impermeable. This conclusion was derived from anomaly values, which tend to be low in permeable zones—an indicator often associated with reservoirs and permeability [2]. Additionally, the geochemical study identified manifestations in the form of hot springs around the study area. From the geological study, permeable zones were indicated by the presence of structures such as faults.

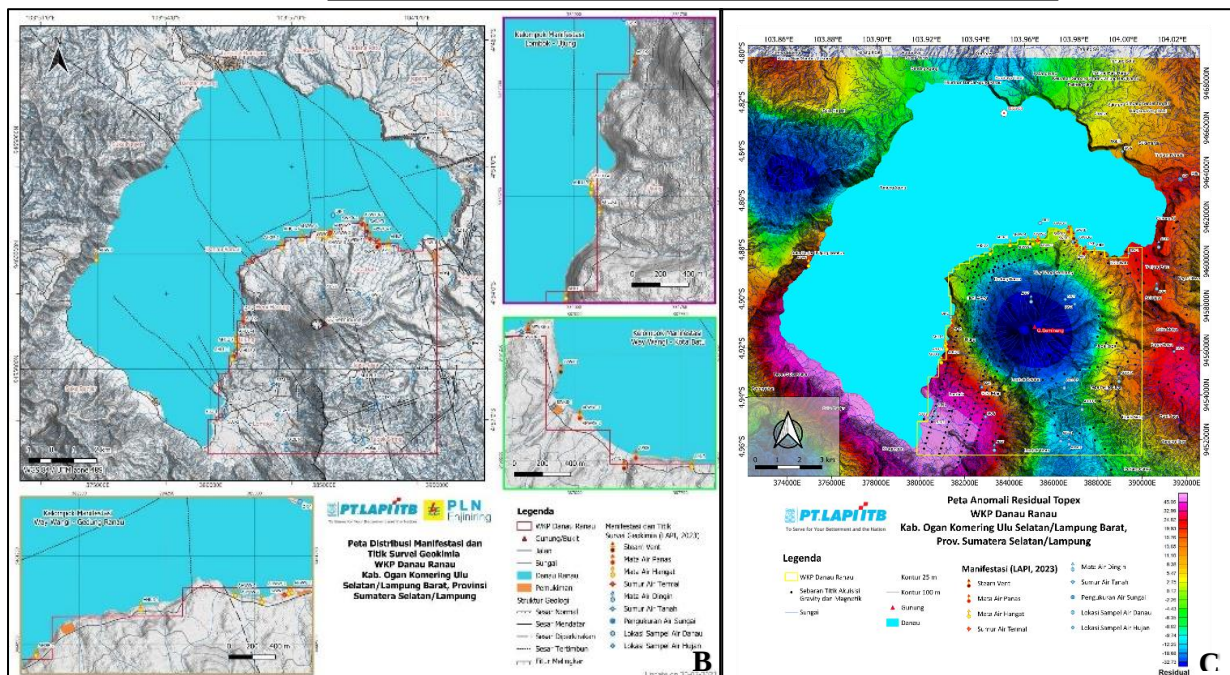
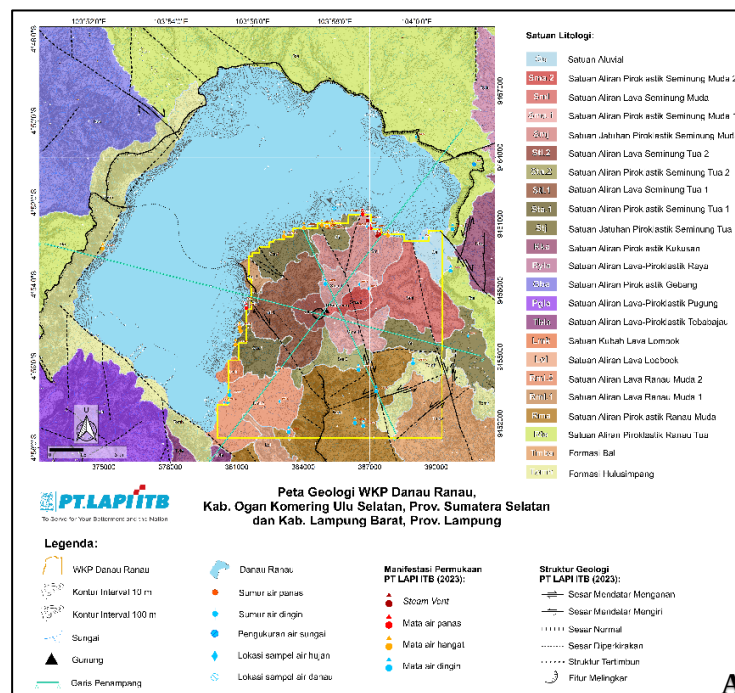


Figure 1 Research Studi of PT PLN (Persero) (A : Geology, B : Geochemistry, C: Geophysics)

These faults can serve as pathways for the permeability process in geothermal systems.

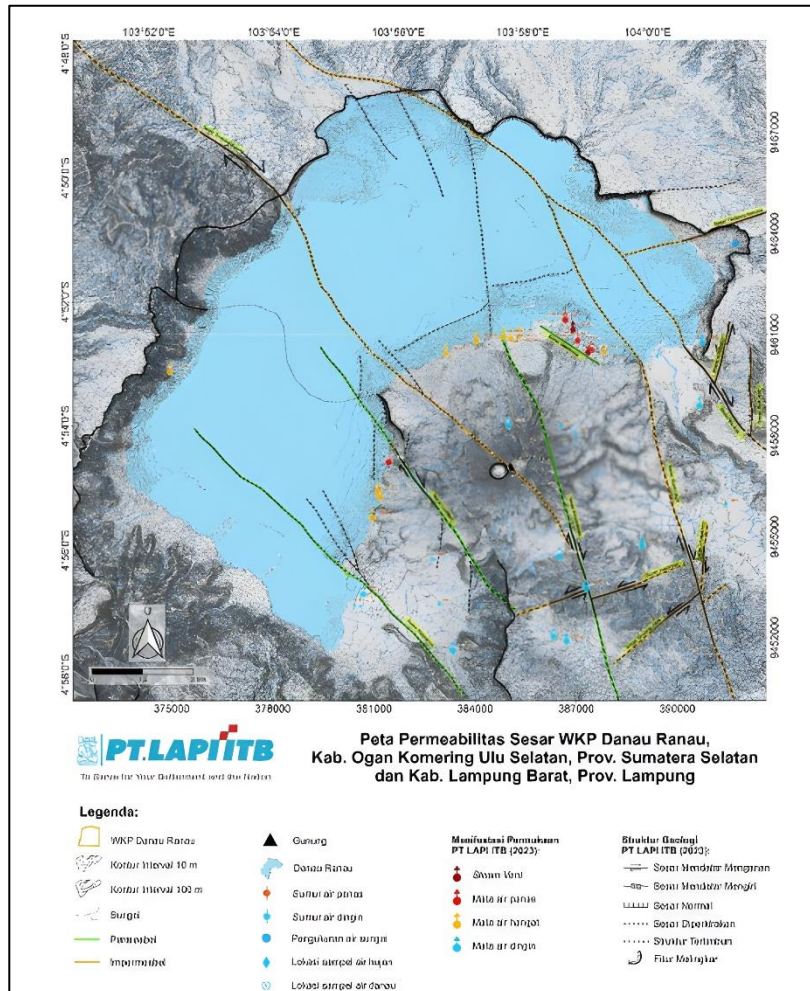


Figure 2 . Permeability Study

The study results also show the interpretation results regarding permeable or non-permeable zones. In Figure 2, the yellow line represents an area interpreted as impermeable. Meanwhile, the green area indicates a permeable zone.

Figure 2 highlights the potential for a permeable zone extending towards Lake Ranau. However, further research has not yet been conducted. Limited data for analyzing locations in aquatic environments presents a challenge in conducting detailed zone studies. For land areas, mapping permeable zones can be achieved

using geological maps, remote sensing, and geophysical measurements. However, these methods cannot provide a precise picture of offshore areas, such as those at the planned Lake Ranau Station, which includes a significant lake region. The difficulty in describing offshore areas stems from the limited accessibility and challenges in obtaining subsurface water data. This limitation can be addressed using bathymetric methods to better understand the underwater terrain and its properties. [5] This activity carried out to obtain subsurface/water morphology. It is also commonly used in petroleum exploration to detect the presence of hydrocarbons. [5]

This study will make it easier to detect depictions of the subsurface area of Lake Ranau to obtain information regarding permeable zones that may exist within Lake Ranau. Bathymetric surveys allow mapping of underwater morphology, and its relationship to specific faults, caldera structures and underwater mud volcanoes.[4]. Furthermore, this approach allows the identification of tectonic structures with increased fluid discharge beneath the lake. Apart from using bathymetric data, data processing was also carried out using multispectral image data which is additional data to be able to see the conditions below the surface of the lake. Geoscience data obtained from previous research results can provide validation of the structural alignment that may outside the area of the lake. This data used to identify the entry of hot acidic water into the holes produced beneath the surface of Lake Ranau. Combining bathymetry and geoscience data can be used to differentiate between permeable and non-permeable areas and relate this to geothermal well productivity. Such information is essential for the understanding of the behavior of geothermal systems. (Brehme et al., 2019) [6].

2 Problem and Research Method

The emergence of geothermal activity in the Lake Ranau area indicates significant geothermal potential around Mount Seminung. This activity is driven by the presence of active geological structures that traverse the region. A geophysical study previously conducted by PT PLN (Persero) identified anomalies in the Lake Ranau area. One major factor contributing to these anomalies is the geological structure crossing the area. Geological mapping revealed a fault that passes through the anomalous zone and appears to extend across the Lake Ranau area, seemingly cutting through the lake itself.

However, defining permeable zones is typically feasible only on land, often utilizing geophysical methods. For aquatic environments, such as lakes, alternative approaches must be employed. One effective method is bathymetry, which provides detailed insights into high points and digital elevation models (DEMs) beneath the lake surface. This method generates data in the form of depth

contours, which can then be used to analyze alignments and geological structures beneath the surface of Lake Ranau..

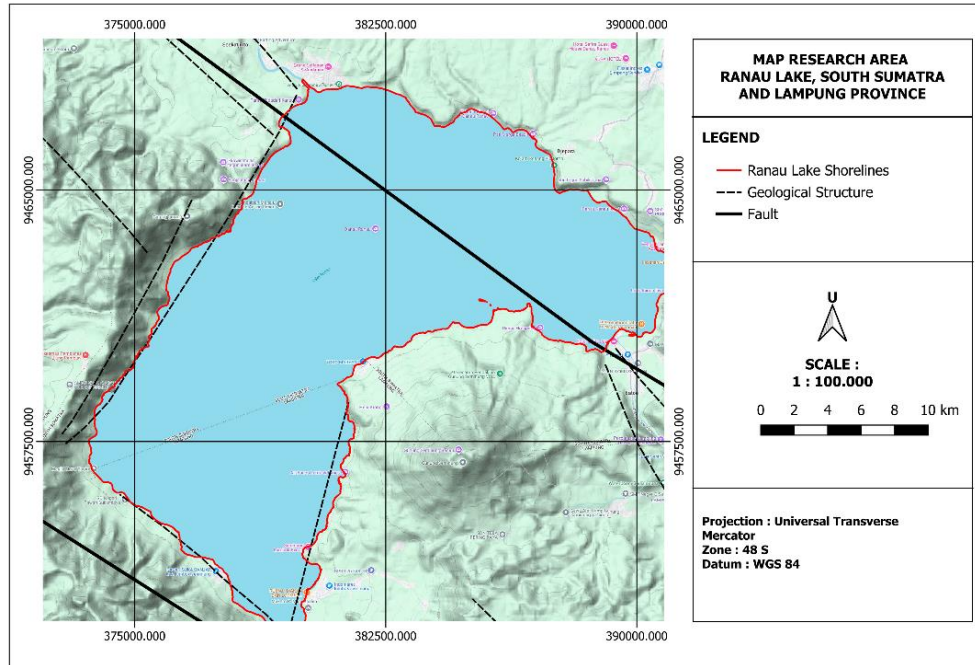


Figure 3 . Research Studi Area on Danau Ranau

2.1 Depth Contour Bathymetry

The bathymetric method is a technique used to measure the depth and topography of seabeds, rivers, lakes, and estuaries. Bathymetry is a subset of hydrography, which also studies the shape and features of coastlines, as well as the characteristics of tides, currents, and waves [4]. The bathymetric data used in this study were obtained from measurements taken by ETH Zurich and subsequently re-analyzed using the QGIS and Civil 3D applications. The depth data were initially provided in geometric coordinates and then converted into Universal Transverse Mercator (UTM) format. High points were processed automatically to generate contour values that link points with the same elevation. The major contours used were multiples of 10 meters. From the resulting map, it was found that the deepest point below the lake surface had a depth of 200 meters, which is the maximum depth in the Lake Ranau area. Depth variations ranged from 10 meters to 210 meters.

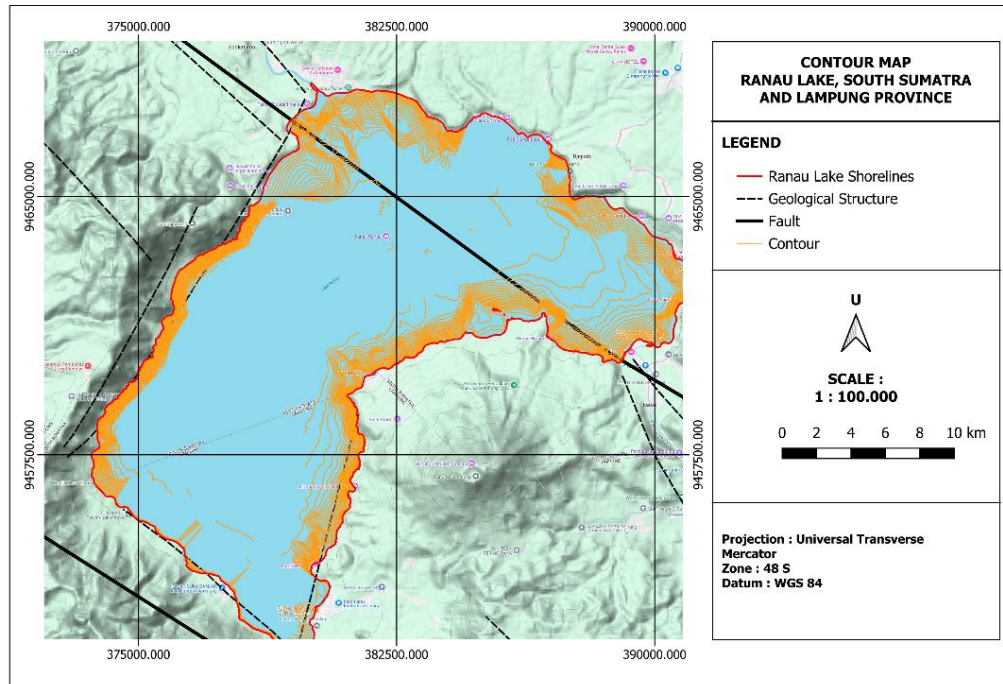


Figure 4 . Depth Contour Bathymetry of Ranau Lake

2.2 Topex Topographic and Gravity Data

In the study area, several locations have missing height or depth data, which results in incomplete contour data across the region. To address this, additional data is needed to fill in these gaps. The data referred to here is the TOPEX data. This data can be freely downloaded by defining boundaries according to the study area being analyzed. The data is then processed using Global Mapper to determine the distribution of points and their respective height values. This process is cross-checked with SRTM Map data, which is also available for free through the Global Mapper application. This approach simplifies the process of drawing additional contours, which can be integrated with the existing data.

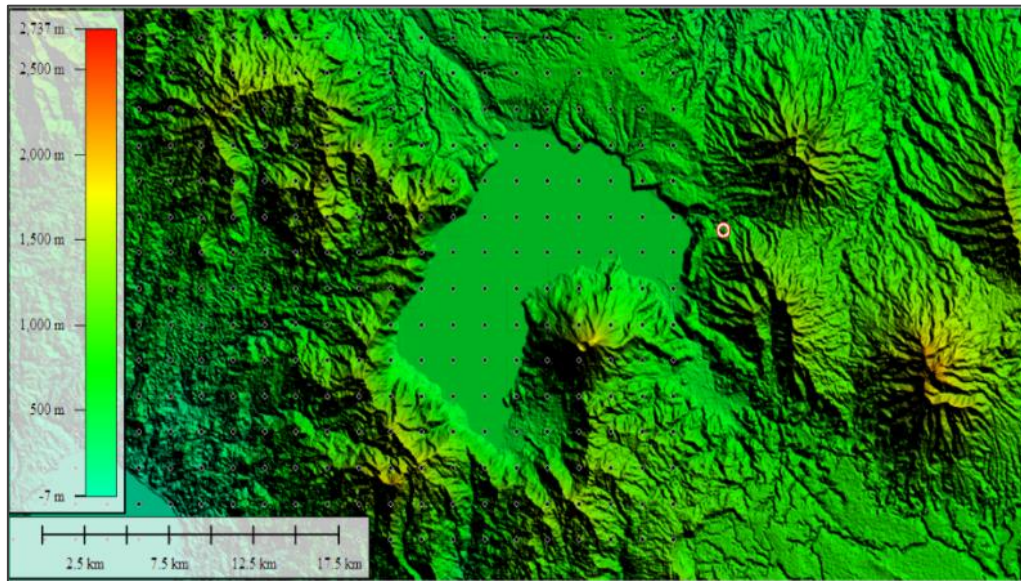


Figure 5 . TOPEX Analysis with Global Mapper

2.3 TIN Interpolation

The contour data from the previous step consists of the elevation data for the study area. This data can be used to create a Digital Elevation Model (DEM), which helps in presenting and analyzing the alignment of the study area. After generating contours from both datasets, we interpolate the data into a TIN (Triangulated Irregular Network) model. This process is carried out using the QGIS application. The steps taken are as follows: First, the contour data generated from the bathymetry data is combined with the contour data from TOPEX. Using this combined dataset, a TIN model is created, which serves as the foundation for generating the DEM. The DEM is then created through TIN interpolation. The result of this process is a DEM model, visualizing the terrain based on the points and contours used.

2.4 Lineament Extraction

The process of defining straightness is carried out using lineament extraction tools. This process utilizes the PCI Geomatics application as the processing platform. The DEM data is imported into the application, where the Lineament Extraction tool is applied. This extraction process generates data in the form of

lineament identifications, which are formed based on the characteristics of the terrain.

3 Result and Discussion

The geological structure of Lake Ranau is crucial for interpreting the potential geothermal areas within the WKP Danau Ranau. Structures in this lake can serve as pathways for thermal fluids from deep reservoirs, connecting with the geophysical anomalies on land. These structures may also act as recharge areas, playing a vital role in the geothermal system cycle. The process of identifying these structures begins with depth profile data obtained from depth contours, which aids in delineating geological structures. After processing the depth contours into DEM data, the fractures and lineaments can be drawn.

Once the DEM data is processed, lineaments can be mapped using PCI Geomatics or other supported applications to detect lineaments around Lake Ranau. These lineaments serve as foundational data for geological structure identification and delineation. The geological structures are then integrated with those on land, resulting in a unified geological model for the Lake Ranau area. The on-land data is sourced from studies by PLN and LAPI in 2017. The interpretation of geological structures, particularly faults, is based on lineament analysis, field investigations, and evidence of surface manifestations, such as fault planes, fractures, and brecciation zones. The faults in the Lake Ranau WKP are primarily oblique strike-slip faults, with orientations including northwest-southeast, north-south, northeast-southwest, and east-west. Some lineament patterns are clearly visible in the topography, but no surface structural symptoms are found to confirm these as predicted faults.

The geological structure map of Lake Ranau WKP indicates faults observed in the field, including fault planes and slickensides. Based on Figure 6, it can be assumed that the structure of the lake's bottom aligns with the existing geological structures. The rose diagram from the map indicates that the structure of the lake's bottom trends toward the northwest-southeast (NW-SE). This aligns with the faults crossing the study area

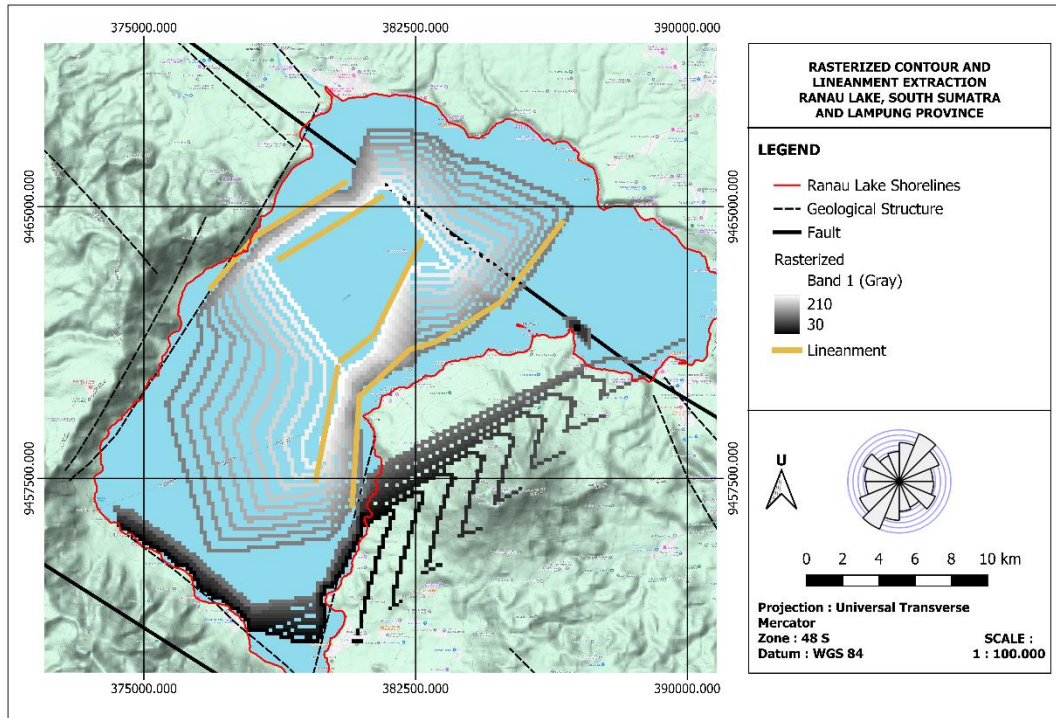


Figure 6 . Rasterization and Lineanment Extraction

4 Conclusion

From this studi we can develop into the identification of permeabel area in Ranau Lake. But this studi must take the geoscience data more specific such as manifestation data, geochemistry and geophysics data to consider. Then from that studi we can track how the permeability was going and how the fluid and steam move to the land from the underground.

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