

Digitized bathymetry from legacy contour maps for Lake Yojoa (Honduras)

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Data Note

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Abstract

Developing countries face persistent challenges in preserving, digitizing, and disseminating environmental information. Foundational scientific records frequently remain embedded in printed reports or legacy technical publications that are not georeferenced, machine-readable, or openly accessible. Lake Yojoa—the largest freshwater lake in Honduras—provides a clear example: its most complete bathymetry is available only as a static figure in a 2007 ESNACIFOR technical article (Romero & Mejia, 2007).

Here, we present a cost-effective and reproducible workflow to recover such legacy environmental data using open-source geographic information systems (GIS). The printed bathymetric map was scanned, georeferenced, manually digitized, and transformed into structured geospatial layers, including depth contours, depth vertices, a validated shoreline polygon, and a continuous interpolated bathymetric raster. All outputs were standardized to EPSG:26716 (NAD27 / UTM Zone 16N) and are accompanied by metadata, documentation, and QGIS symbology to facilitate reuse.

The resulting dataset is an openly available, georeferenced bathymetric resource for Lake Yojoa. This dataset establishes a foundational baseline that can be used for hydrological modeling, limnological research, conservation planning, and the long-term monitoring of environmental changes in the lake. Although contemporary in situ survey methods might offer higher accuracy, this work demonstrates a replicable approach for extracting and revitalizing legacy scientific data. By systematically converting printed figures into FAIR (Findable, Accessible, Interoperable, and Reusable) geospatial datasets, this project enhances data accessibility and strengthens the capacity for environmental reconstruction, particularly in contexts where resources are limited.

Background & Summary

Lake Yojoa, Honduras' largest natural freshwater body and a Ramsar-designated wetland, it plays a pivotal role in regional biodiversity, fisheries, recreation and local livelihoods (Lopez, R.D,2024). The lake sits at approximately 650 m above sea level and occupies a north–south–elongated basin measuring roughly 16 km in length and 6 km in width, with a surface area of $\sim 79 \text{ km}^2$. Lake Yojoa's surface area had a decreasing trendline of $\sim 6 \text{ km}^2$ over the last four decades according to satellite observations (Reyes-Avila & Baxter, 2024).

The basin is bounded by steep mountainous terrain, including the Santa Bárbara Massif to the west and the Cerro Azul–Meámbar range to the southeast, both of which influence the lake's drainage patterns and sediment inputs. Lake Yojoa is a warm monomictic system (A lake that experiences complete mixing of its water column at least once per year.) with a depth regime that supports seasonal stratification and a gradient from shallow littoral zones to deeper central basins reaching approximately 28–30 m.

The watershed includes agricultural valleys, forested highlands, and protected areas, creating a heterogeneous landscape that shapes hydrological behavior and water-quality dynamics. These physical characteristics make Lake Yojoa an important reference system for understanding limnology and environmental change in Central American lake basins.

The lake has faced mounting environmental stress stemming from nutrient-rich effluents (agricultural runoff, aquaculture, urban wastewater) that have triggered recurrent cyanobacterial blooms and chronic eutrophication, impairing water clarity, fish habitats and ecosystem stability (Tovar et al., 2012). Recognizing its ecological and social importance, a multi-million-dollar sustainable recovery program—including over US\$100 million of European Union-backed investment—is underway to restore watershed health, strengthen monitoring systems, and safeguard ecosystem services (EEAS, 2025). Bathymetric structure governs the lake's circulation, nutrient residence time, stratification dynamics and high-risk zones for bloom formation, yet until now, no open, machine-readable depth datasets have existed for Honduras.

This data gap constrains hydrodynamic modelling, conservation planning, aquaculture regulation and long-term monitoring—linking directly to SDG 6 (clean water) and SDG 11 (sustainable cities and communities). The digitized bathymetry datasets presented here enable modern environmental analysis, monitoring and governance across ecological, hydrological and socio-economic domains.

Methods

a. Legacy Data Source

The bathymetric information for Lake Yojoa was obtained from a printed figure published in a 2007 ESNACIFOR technical article. The figure contained a complete set of depth contours but lacked georeferencing, coordinate grids, or accompanying digital files. The objective of this work was to transform this legacy, non-digital source into reproducible, machine-readable geospatial data.

b. Georeferencing of the Historical Map

The printed map was scanned at high resolution and georeferenced in QGIS. Tie points were selected using stable, identifiable shoreline features that appear consistently in both the historical map and modern satellite basemaps. A first-order polynomial (affine) transformation was applied, balancing map fidelity and geometric stability. All processing was standardized to **EPSG:26716 (NAD27 / UTM Zone 16N)**, the historical coordinate system used in the original regional cartographic resources.

c. Digitization of Depth Contours

Depth contours from **0 to 26 m** were manually digitized using QGIS editing tools. Digitization followed each printed isobath closely to preserve the geometry of the legacy source. Each contour polyline was assigned its recorded depth value as an attribute. The 0 m isobath was retained separately for shoreline construction and validation.

d. Extraction of Depth Vertices

Vertices were extracted from all depth contours to generate a dense set of depth-attributed points. These vertices represent the most detailed sampling of the original bathymetric information and served as the primary input for raster interpolation.

e. Shoreline Polygon Construction

The digitized 0 m contour was cleaned and converted into a closed polygon representing the lake boundary. Topological corrections were applied using *Fix Geometries* and manual inspection to ensure watertight, valid geometry. Lake Yojoa contains no permanent islands; therefore, no interior rings were created.

f. Raster Interpolation

Depth vertices were interpolated into a continuous bathymetric surface using a triangulated irregular network (TIN) method, followed by inverse distance weighting (IDW) smoothing. The resulting raster was clipped to the shoreline polygon and exported as a **5 m resolution GeoTIFF**, ensuring compatibility with hydrological and ecological modeling workflows.

g. Hillshade Generation

A hillshade was derived from the interpolated raster to aid in visual interpretation of subaqueous terrain features. The hillshade is provided alongside the depth raster for visualization and cartographic applications.

h. CRS Standardization and Data Packaging

All vector and raster layers were stored in **EPSG:26716** for consistency. The dataset is accompanied by metadata, processing documentation, and QGIS style files to facilitate reuse and reproducibility. All files follow open formats recommended for long-term archival (GeoTIFF, GeoPackage, CSV, and plain-text metadata).

Technical Validation

a. Contour-to-Raster Consistency

To assess how accurately the interpolated bathymetric surface reproduced the original legacy map information, we sampled raster depths at 4,976 vertices of the digitized contour lines (1–30 m). The raster-to-contour differences yielded a root mean square error (RMSE) of **0.27 m**, indicating excellent agreement between the reconstructed surface and the historical depth geometry. This sub-meter RMSE is consistent with the expected uncertainty arising from map scanning, contour digitization, and interpolation of legacy hydrographic surveys.

b. Shoreline Alignment

Vertical alignment at the lake boundary was evaluated by sampling the raster along the 0 m contour. A total of 145 shoreline vertices produced depth values ranging from **- 0.62 to 0.00 m**, with a mean of **- 0.13 m** and a standard deviation of **0.15 m**. These small deviations confirm that the raster surface closely matches the shoreline and exhibits no significant vertical offset. The minor negative values likely reflect slight differences between the historical shoreline delineation and the raster interpolation resolution.

c. Maximum Depth Comparison

The maximum depth derived from the reconstructed raster (**≈ 28–30 m**, depending on sampling resolution) is consistent with historical limnological measurements reported for Lake Yojoa, which typically indicate maximum depths between **27 and 30 m**. This agreement provides additional evidence that the interpolation retained the large-scale structure of the original survey.

(A) Signed interpolation errors (err_m) from sampling the reconstructed raster at all digitized contour vertices ($n \approx 5,000$). Errors are tightly centered around 0 m with a narrow interquartile range and symmetric outliers ($< \pm 4$ m), demonstrating high agreement with the original depth contours.

(B) Shoreline validation based on raster sampling along the 0 m isobath ($n = 145$). Depth values range from **- 0.06 to 0.00 m** and show an exceptionally tight distribution around the expected shoreline elevation.

d. Internal Consistency and Visual Inspection

Visual examination of slope, curvature, and depth gradients confirmed that the reconstructed surface behaves hydrologically as expected for a steep, volcanic-influenced basin. No artificial sinks, spikes, or internal No-Data zones were observed within the lake footprint. Depth contours remain topologically correct, and interpolated surfaces respect the monotonicity expected from closed bathymetric lines.

e. Limitations and Uncertainty

The bathymetric dataset is derived exclusively from a printed figure contained in a 2007 ESNACIFOR technical publication. As such, the original source lacks georeferencing, raw survey measurements, and metadata regarding the methods used to generate the depth contours.

Uncertainty in the dataset originates primarily from the digitization of the scanned legacy map, the generalization of original contours, and the lack of permanent interior islands in the historical source. Lake Yojoa contains no stable islands; floating vegetation mats and shallow wetland projections occasionally visible in satellite imagery represent ecological features rather than bathymetric structures and were therefore not digitized. While minor vertical deviations (< 0.6 m) occur along the shoreline due to map scanning and interpolation, these fall well within acceptable limits for legacy-data reconstruction.

Data Records

All data produced in this study are openly available on Zendo:

<https://doi.org/10.5281/zenodo.17623895>

The repository contains digitized vector layers, interpolated raster products, and supporting documentation required to reproduce and reuse the dataset. A summary of this files can be found on Table 1

a. Depth Contours (Shapefile / GeoPackage)

This file contains the digitized bathymetric isobaths extracted from the 2007 ESNACIFOR printed map. Contours span depths from **0 to 26 m** at 1-meter intervals. Each polyline includes a depth attribute specifying its measured depth value.

b. Depth Vertices (Shapefile / GeoPackage)

This file stores the point geometries derived from contour line vertices. Each point carries a depth attribute inherited from its parent contour. These vertices were used as the input dataset for generating the interpolated bathymetric raster.

c. Lake Boundary Polygon (Shapefile / GeoPackage)

A validated and topologically clean shoreline polygon derived from the digitized **0 m** contour. The file contains no internal holes or islands, consistent with the source map, and represents the authoritative lake extent for clipping and masking operations.

d. Bathymetric Raster (GeoTIFF)

A continuous depth surface at **5-meter spatial resolution**, generated using a combined TIN/IDW interpolation workflow applied to the depth vertices. Pixel values represent water depth in meters (positive values). This raster is suitable for hydrological modeling, environmental analysis, and visualization.

e. Hillshade Raster (GeoTIFF)

A shaded-relief raster derived from the interpolated bathymetry. The file provides an enhanced visual representation of underwater terrain and can be combined with the bathymetry for cartographic or interpretive purposes.

f. Metadata, Documentation, and Styles

These supporting files include:

- **README** describing the dataset structure
- **CRS summary** confirming all layers are provided in EPSG:26716
- **QGIS style files (QML)** for consistent visualization
- a **license file**

No	Fil	Content Description
1	Depth Contours (Shapefile)	Digitized isobaths representing depth intervals from 0 to 26 meters. Each contour includes a depth attribute.
2	Depth Vertices (Shapefile)	Point geometries extracted from contour lines, each carrying a depth value and used to support interpolation.
3	Lake Boundary Polygon	A validated, topologically clean polygon representing the shoreline, derived from the 0 m contour.
4	Bathymetric Raster (GeoTIFF)	A continuous depth surface at 5-meter resolution generated using IDW/TIN interpolation.
5	Hillshade Raster (GeoTIFF)	A shaded-relief model derived from the depth raster, used for visualization.
6	Metadata, Documentation & Styles	Includes README, CRS summary, QGIS style files (QML), license file, and an evidence/provenance PDF documenting the digitization process.

- an **evidence/provenance PDF** documenting the digitization process, georeferencing, interpolation, and validation steps

Together, these materials ensure full transparency and reproducibility of the dataset

Table 1 Data Description (<https://doi.org/10.5281/zenodo.17623895>)

Declarations

Declaration Of Competing Interests

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

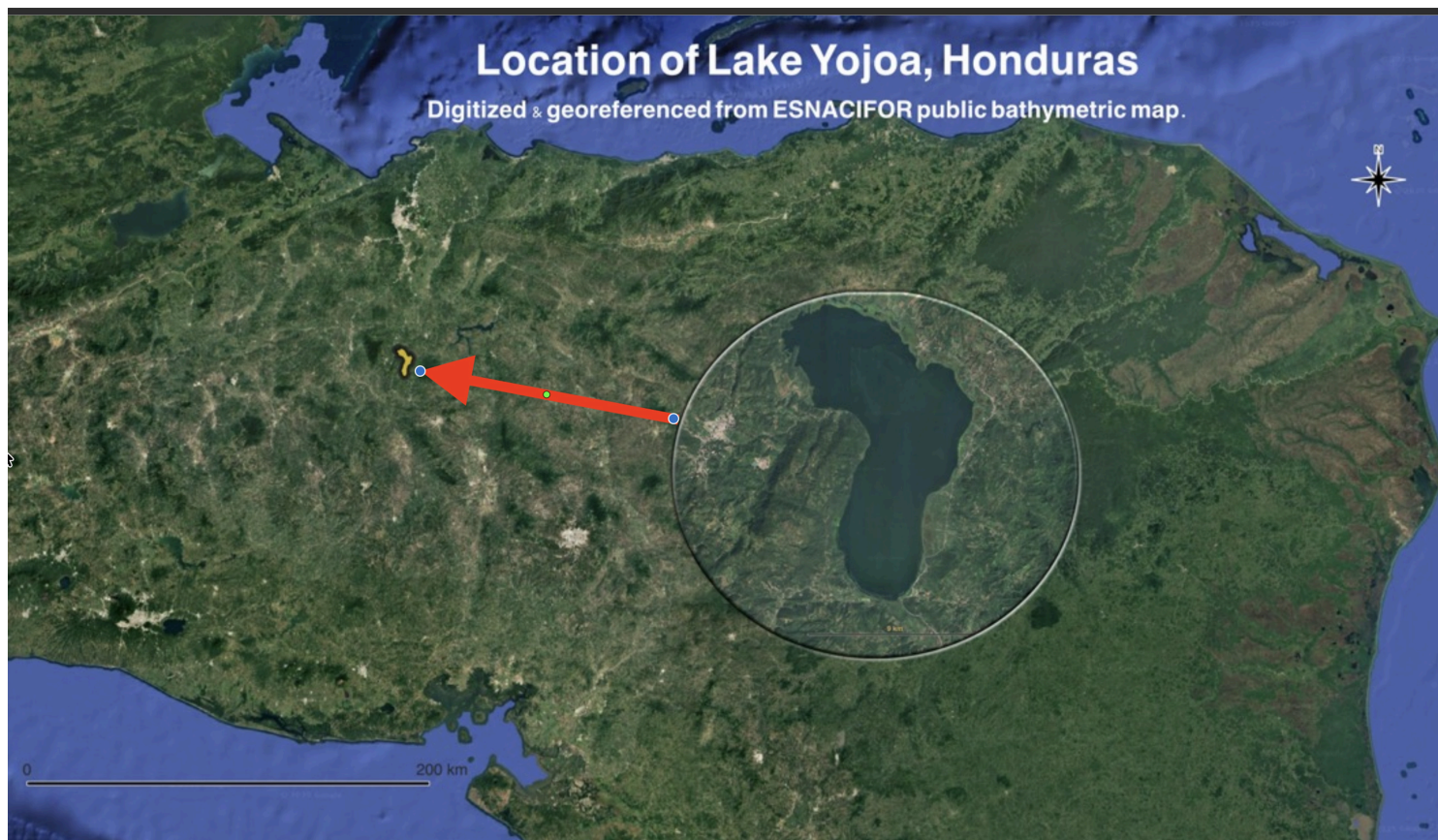


Figure 1

Honduras, Yojoa Lake Location

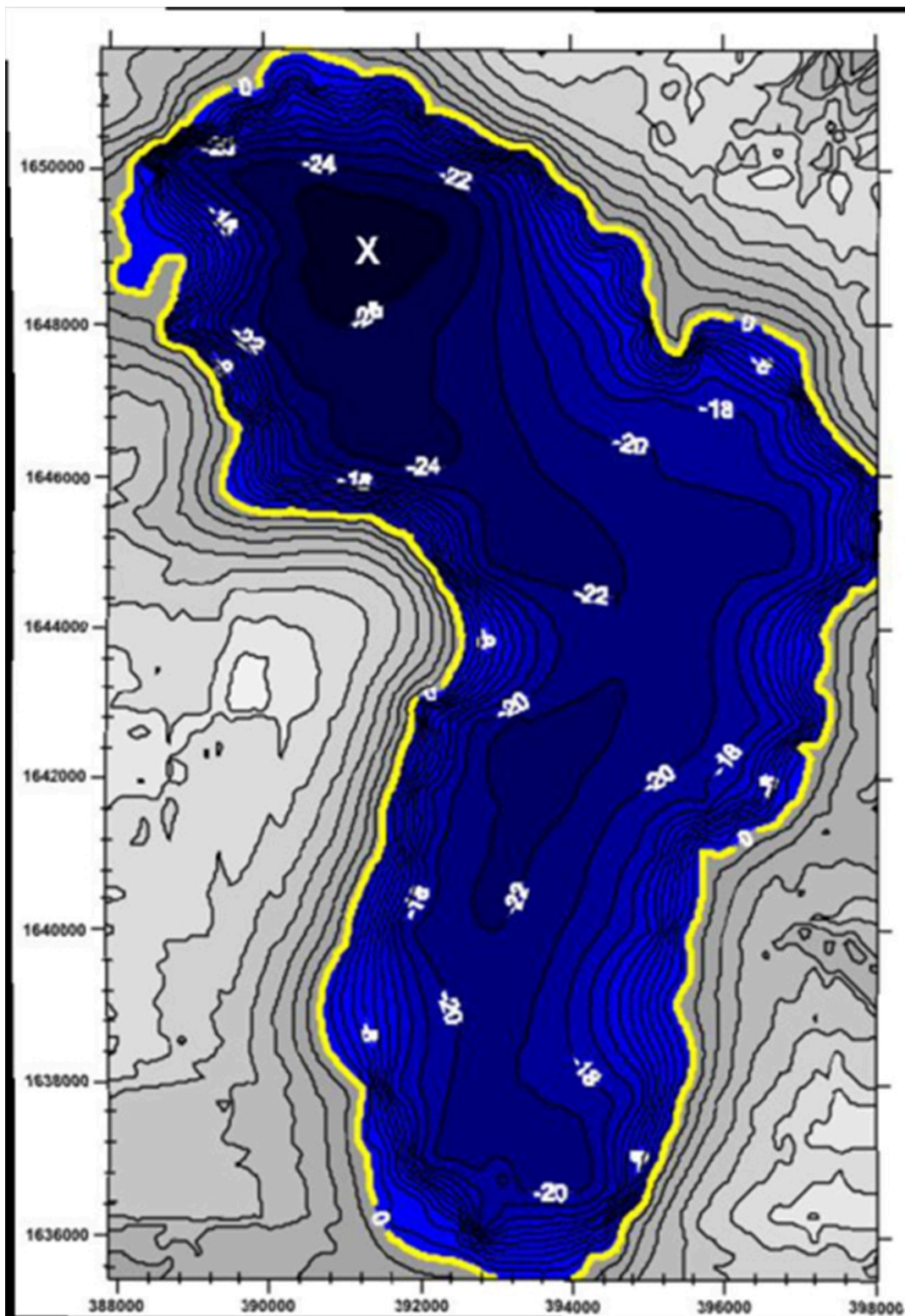


Figure 2

ESNACIFOR Bathymetry

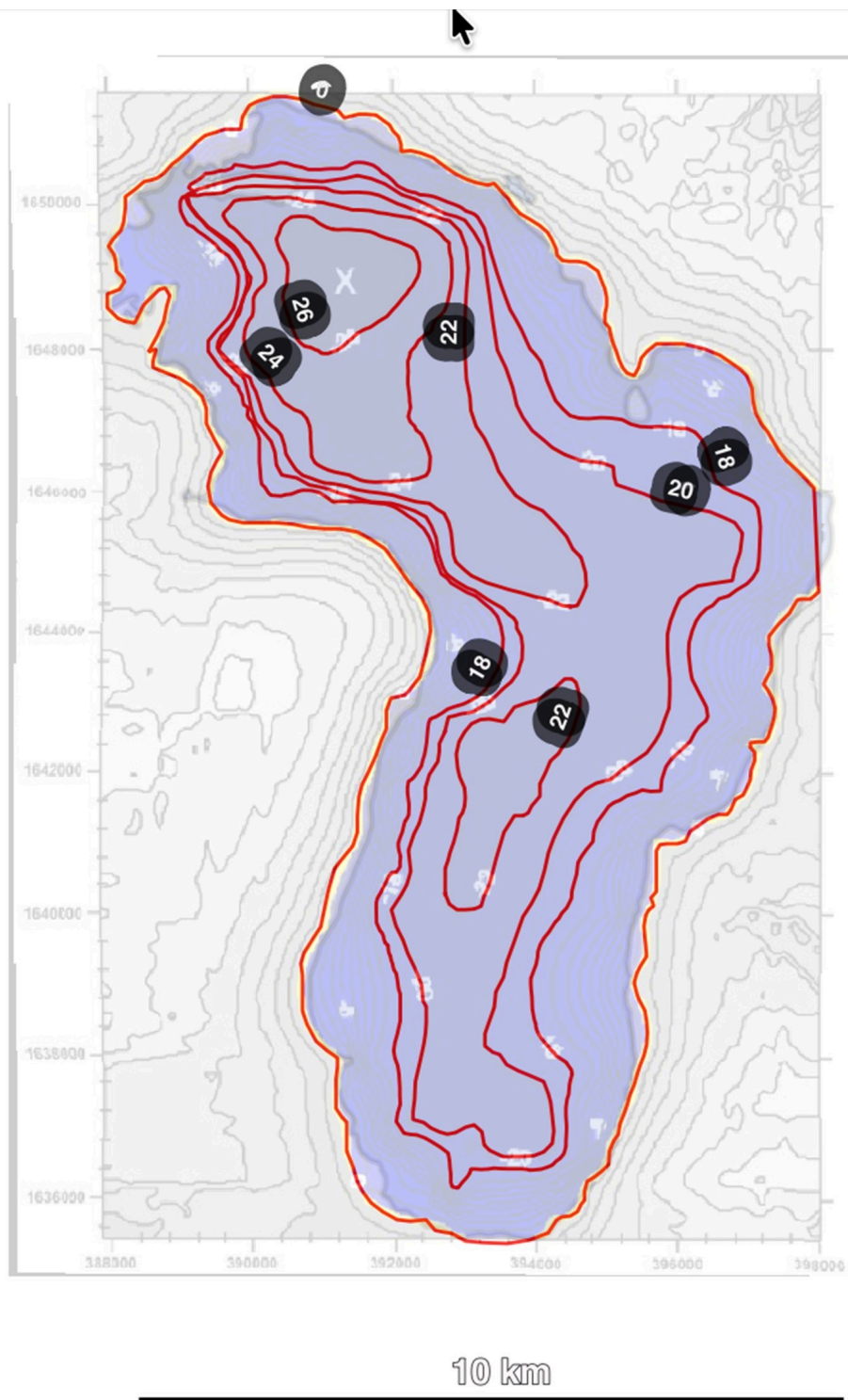


Figure 3

Digitized depth contours (0–26 m)

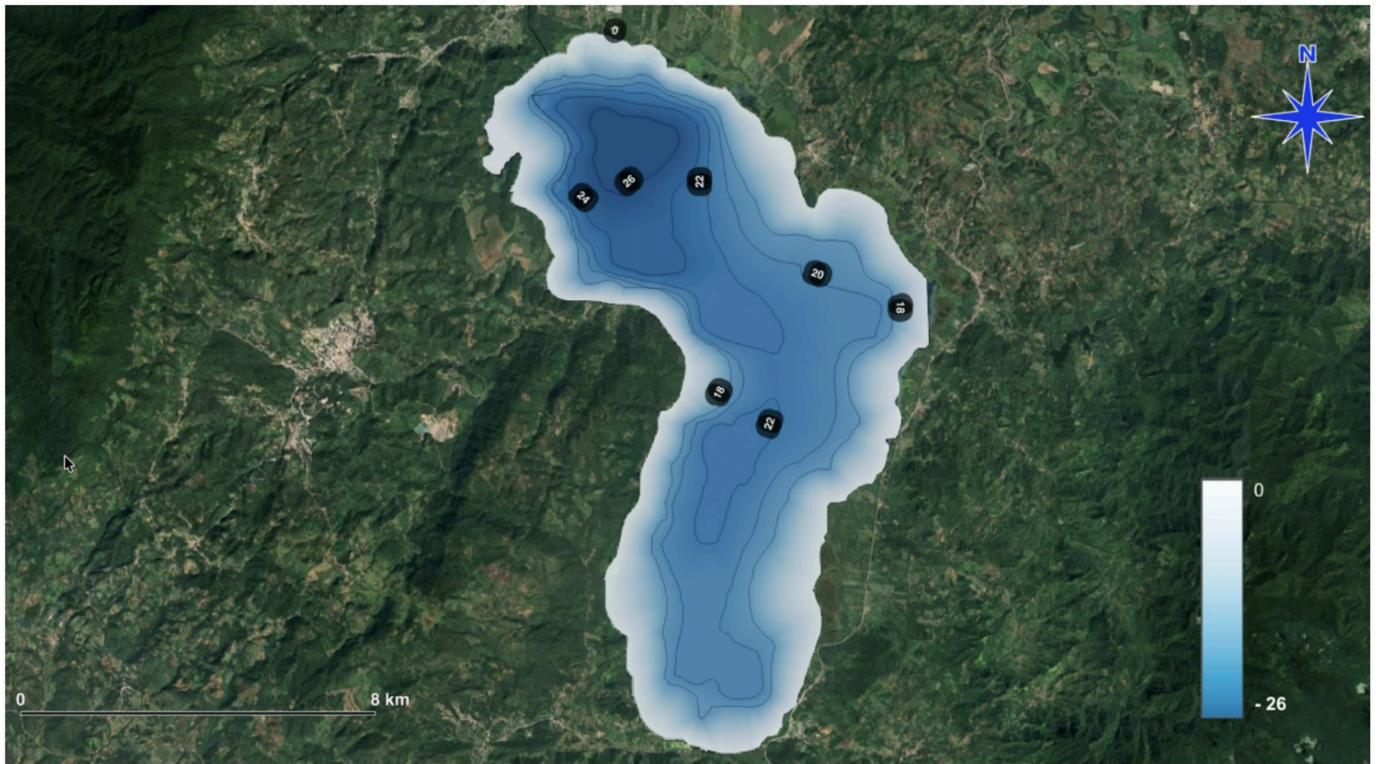


Figure 4

Yojoa Lake Final Bathymetry

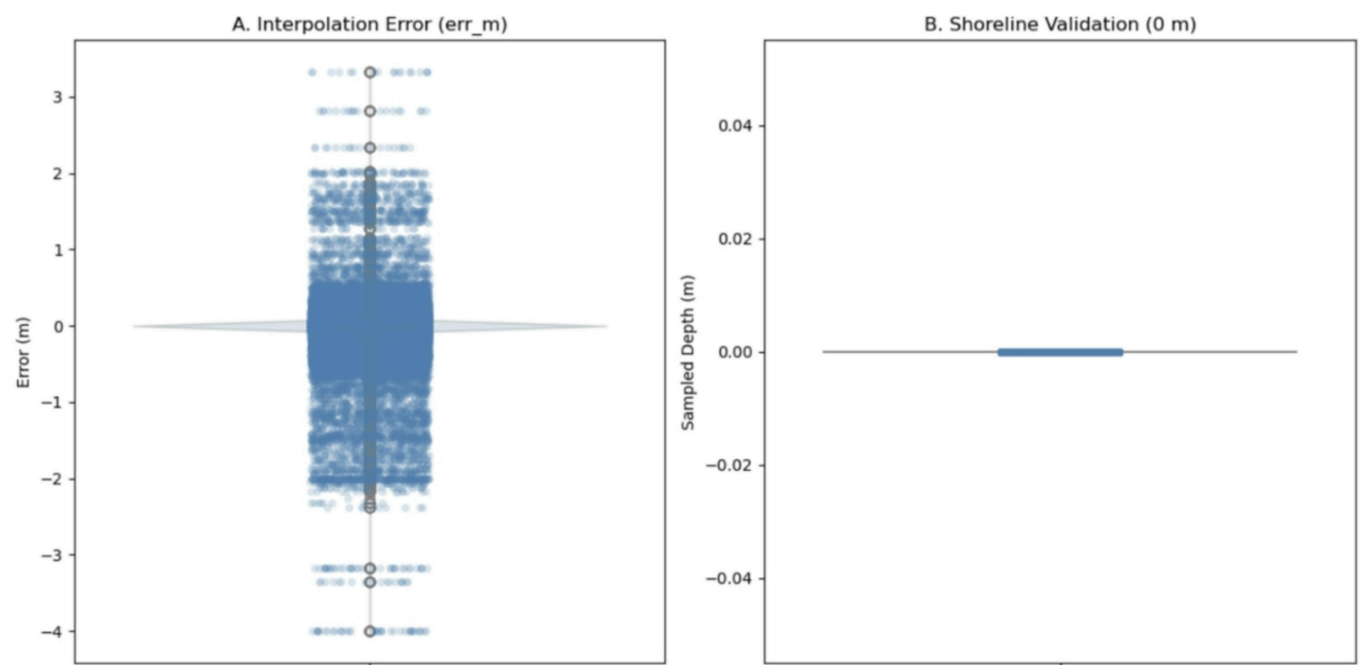


Figure 5

Bathymetric validation using contour sampling and shoreline consistency.

(A) Signed interpolation errors (err_m) from sampling the reconstructed raster at all digitized contour vertices ($n \approx 5,000$). Errors are tightly centered around 0 m with a narrow interquartile range and symmetric outliers ($< \pm 4$ m), demonstrating high agreement with the original depth contours.

(B) Shoreline validation based on raster sampling along the 0 m isobath ($n = 145$). Depth values range from -0.06 to 0.00 m and show an exceptionally tight distribution around the expected shoreline elevation.