Moenjodaro 3D: methods note for partners

Larkode, 13 October 2026 (first draft 30 September). Draft for comment. Live pilot: https://moenjodaro3d.larkode.com

1. What this is, and what it is not

Moenjodaro 3D is a browser-based 3D reconstruction of Mohenjo-daro. Wall plans are traced from published excavation plates and placed on real terrain and satellite data. Seventeen pieces are drawn so far: on the Citadel the Great Bath, the Granary, the stupa mound, Block 1 (probably the "College"), the Columned Hall with the rest of the L Area, the Southern Buildings and the bathroom block north of the Bath; two outlines read from Wheeler's plan (a west tower and the south-east fortification masses); and in the lower town the HR area, DK-G (both portions), the VS area and DK sections A, B, C and E. Together these cover about 14 ha of plan, under 6 % of the 240 ha World Heritage property. The rest of the city is not drawn.

Two views share the same traced walls.

- **Documented remains** (the default) draws every wall at one placeholder height of 1.2 m, because the plates are plans and give no heights. It adds pale floors inside the rooms the plans close, three probable kilns and the traced stupa plinth, and nothing else.
- **How it may have looked** is a hypothetical reconstruction of the Mature Harappan period (c. 2600–1900 BCE). Every addition in it is a hypothesis (level E) or an illustration and is labelled so on screen: wall heights, roofs, water, trees and grass, the Indus, boats, fields, people, carts, cattle and goats, birds, smoke, night light and sound.

It is a working reconstruction built from published plates and open data. It has **not** been reviewed by an archaeologist, it is not an official record, and it should not be quoted as a replica of the site.

2. Method

We follow the London Charter and the Seville Principles. Three rules govern the work.

1. **Nothing without a source.** Every element carries an evidence level and a source. If no source exists the element stays a hypothesis and says so.
2. **Every decision is logged.** `docs/paradata-log.md` records the date, the element, the decision, the basis (with plate and page) and the level. The public repository holds the log, the code and the traced dimensions. Corrections are added to the log as new rows, so that errors and their fixes stay visible.
3. **Uncertainty is visible.** Hypotheses appear in the prediction view, the Evidence panel lists every record with its level, and an "Evidence colours" layer recolours the scene by level.

Level	Meaning	Records today
A	Surveyed or measured data (terrain, satellite image, site outline)	3
B	Excavation record: plan, section or photograph, with plate	45
C	Published description, a reading from a site sketch, or a secondary summary	18
D	Analogy from other Indus buildings	0
E	Hypothesis or illustration, no direct evidence	45

The records (111 in all) are in `data/records.json` and are published with the page (`/records.json`). The Evidence panel is generated from that file, so the text on screen cannot drift from the records.

3. Sources

- **Terrain and imagery:** Copernicus DEM GLO-30 (30 m surface model) and Sentinel-2 (10 m); Esri World Imagery was viewed to place pieces (viewed, not redistributed); map data from OpenStreetMap through Overture.
- **Plans:** J. Marshall (ed.) 1931, *Mohenjo-daro and the Indus Civilization*, vol. III (Great Bath, stupa, L Area,

Southern Buildings, HR, VS and DK sections); E.J.H. Mackay 1938, *Further Excavations at Mohenjo-daro*, vol. II (DK-G, the bathroom block, the site plan); M. Wheeler 1953, *The Indus Civilization* (Fig. 6 and Fig. 8, for outlines and for the Granary).

- **Aachen survey:** M. Jansen and G. Urban (eds), *Interim Reports* vols 1 and 2 (1983–87), read in full text, for street and building orientations (an axis table, in gon) and for Verardi's account of the stupa.
- **Text:** Marshall vol. I and Mackay vol. I through archive.org OCR, for a few figures and for readings such as Mackay's on the kilns. **Not seen:** later ARPM plans and brick measurements, the Dales (UM) and Moneer plans, and the reports of the 2025–26 mission.

The plate scans are kept outside the public repository. Only traced dimensions are published. A list of plates, with PDF pages, is in `docs/primary-sources.md`; a complete list of what exists at the site, and what is and is not drawn, is in `docs/site-inventory.md`.

4. How the plates were traced

The same steps were used for each plan. The plate was extracted at its native resolution and enlarged twofold; the red channel was used, so that red numerals and grids drop out; walls were found by a local-darkness threshold and cut into axis-aligned rectangles at least 0.3 m thick. The scale came from the plate's own bar (read by eye on a magnified crop, ±1 to ±3 %). The rotation of each sheet was found by maximising the straightness of the ink, and several sheets (the folded VS, DK B and C sheets) were traced in bands, each with its own angle. Overlays on the plate were checked by eye.

The rectangles cover roughly 50 to 70 % of the black ink. They follow thick walls to within 0.3 to 0.5 m. **They miss walls thinner than 0.3 m, round features and the thin dashed lines that show street drains.** This is why parts of the model look like loose walls: a house of one-brick walls loses some partitions. Coverage figures are in the records for each piece.

The Great Bath (Pl. XXII) and the stupa and monastery (Pl. XVI) were handled separately: the Bath was cut into 157 rectangles and separated into original walls and Marshall's later additions; the stupa's walls are outlines, so its plinth and drum were measured by hand from the plan and section AB (±10 %).

5. How the pieces were placed

Only the Bath, the stupa and the Columned Hall carry a position fitted directly to the Great Bath's own plan. For each other piece the traced plan's footprint was matched to the excavated area visible in satellite imagery: the plan was drawn as a blurred raster and compared with a map of local edge density, over a search window. A fit counts as good where its best peak is clearly above the next one (HR 0.56 against 0.41; DK-G south 0.74 against 0.61; VS 0.71 against 0.56 and 0.60 against 0.48). Pieces are turned by the orientation in Jansen's axis table (for example HR First Street 8.3 gon, DK-G South First Street 7.2 gon, VS First Street 10.2 gon), relative to the Bath's own frame (5.3 gon).

Piece	How placed	Error stated on screen
Great Bath, stupa, Columned Hall	Fitted to satellite imagery and Wheeler's Fig. 6	±5, ±8, ±4 m
Block 1, Southern Buildings, bathroom block, Granary, Fig. 6 outlines	Wheeler's Fig. 6 or Fig. 8	±5 to ±8 m
HR area, DK-G (both portions), VS area	Footprint fit to imagery, checked against the plates where they join	±8 to ±12 m
DK sections A, B, C and E	Read from Mackay's site plan, calibrated on six satellite-fitted places (fit residual about 11 m); no excavation traces show in imagery	±25 m

All positions are relative to the Bath, which is itself ±5 m on the ground, so every error above is worse on the ground by up to that much.

A geodesy check on 13 October 2026 went through the conversions, the rotation signs and the terrain alignment. It found no sign error and no problem larger than 2 m for any piece. The model uses true north (the Aachen grid is astronomical); a UTM overlay would need 0.40° added, because grid north at the Bath is 0.40° west of true north. The metre-per-degree constants are within 0.13 % of the WGS84 values (up to 3.5 m at the edge of the 6

km terrain tile), and the satellite pixel is slightly longer east-west than north-south, which could move a piece by up to 1.8 m (HR). Both are far inside the stated errors and were not corrected. The stated radii mix kinds of error (a maximum for some, a typical value for others) and add in quadrature with the Bath's ±5 m. The Great Bath's own coordinates were not found in a published source, so its position rests on the imagery fit. A Google Earth file of every piece's footprint and error circle is kept with the project files for anyone who wants to compare the model with the real ground.

6. What the prediction view adds, and on what basis

None of these is measured. Each has a record at level E (or C where a source describes the thing) and says what is invented.

- **Heights and roofs.** Two hypothesis heights (3.2 m for thin walls, 4.2 m for walls over 1.3 m thick); flat mud roofs over rooms the traced plan closes; larger enclosed spaces stay open as courtyards. Marshall concluded that the Columned Hall was roofed; nothing documents house roofs.
- **Surroundings.** Scrub trees and grass (Marshall describes a scrub forest on the flood plain), and the Indus drawn about 3 km east of the Bath, its modern distance. Where it ran in antiquity is not known. No hills are drawn: the site lies on a flat plain.
- **Life.** People, bullock carts, cattle and goats, boats, birds and smoke move about on simple invented routines. Terracotta cart models, humped cattle among the figurines and boat seals show that these existed; their number, places and movements are invented. Carts are kept outside the city, because Marshall inferred no wheeled traffic inside it from the unrutted streets.
- **Places of activity.** Bathers on the Great Bath stairs, a water-drawer at the Chamber 16 well, and potters at three circular walls in DK-G read by Mackay as probable kilns (of the final phase of the city).
- **Night and sound.** A sun path computed for the site, stars, a moon, hearth glows, and generated ambient sound. The documented parts are the sun's path and that hearths and cooking places existed.

The people, animals, boats, fields, trees, river, birds, smoke and night glows can be switched off together ("Life and scenery"), which leaves only the structural hypothesis: heights, roofs over enclosed rooms, floors and water.

What is deliberately **not** shown: any ceremony, priest or "priest-king" figure, market stalls, music or voices, a harbour at the Granary, wild or mythical animals walking the city (the "unicorn" is a seal motif), street drains (they could not be placed reliably from the plates), and flooding over the streets.

7. What changed as a result of review

- The Bath's orientation was corrected from 1.5° to 4.8° east of north after the Aachen axis table was found.
- The overall Bath building shrank from the 55 × 33 m of a tertiary source to 50 × 32 m as traced.
- A second review caught wrong sizes and error figures for several pieces, an overclaim in the coverage statement, and image credits that needed qualifying.
- A third check found a sign error in two cross-checks (a bearing applied west of north instead of east). It did not move any wall or piece, but two statements were wrong: the VS sheets' offset (about 12 m between the satellite fits and the plates' own geometry, not 4 m) and the join of the two DK-G portions (about 6 m north-south; east-west not checkable). Both are corrected in the records and logged.
- A review of the prediction view removed wheeled carts from the city lanes and flagged that bead-making workshops are not described in Marshall or Mackay for the lower town, so none is drawn.

8. Open questions

- **Pool length.** The plan gives 33.5 ft (10.2 m), section AB gives 42 ft from stair foot to stair foot, and Marshall's text (through a secondary source) gives 39 ft. The model uses the plan.
- **Steps.** Section AB shows nine to eleven steps; the scan is too soft for a count.
- **The Bath is not perfectly rectangular** according to the Aachen report. The model still draws right angles.
- **Overlaps.** The Southern Buildings still overlap Block 1 (about 9 m²) and the stupa monastery (about 6 m²), so at least one of these pieces is misplaced by several metres. Marshall's Southern Buildings Block 1 and Mackay's Block 1 may be one building drawn from two plates.

- **The stupa.** Marshall reads a Buddhist stupa and monastery of the Kushan period. Verardi (1987) doubts the coins as a date. Verardi and Barba argue that beneath the Buddhist remains lies an Indus stepped platform. The model draws both readings as labelled options and does not choose between them.
- **Bricks.** Marshall measured bricks of 11 × 5½ × 2¼ in (28 × 14 × 5.7 cm) at the Great Bath; the model uses that size for every wall, which is an assumption outside the Bath. The measured proportion is about 1 : 2.4 : 4.9, not exactly the published 1 : 2 : 4.
- **Phases.** The lower-town plans are Late-period plans, and the kilns belong to the last phase. The reconstruction mixes phases and does not claim a single moment.

9. What we ask

1. **Data.** Access to the ARPM plans and measured architecture (RWTH Aachen), the Dales and Moneer plans, and the 2025–26 mission's reports, so that levels can be raised or corrected and the remaining areas drawn.
2. **Permission.** The agreement of the Directorate General of Antiquities and Archaeology, Sindh, on the use of the plans, and on a photogrammetric survey of the mounds.
3. **An archaeological advisor** with Indus field experience, to review levels A to C element by element and to challenge D and E before anything is presented as more than a pilot.

We would present the pilot with the Evidence colours switched on, and we would publish the paradata openly so that any reviewer can trace each element.

10. Reproducing the work

The repository builds the page with `python scripts/build.py`. Every number in the model is in `src/template.html` or `data/records.json`, and each traced dimension has a matching row in `docs/paradata-log.md`. Terrain and imagery are re-downloadable with `scripts/fetch_data.py`.