



REPORT

Metric survey tools in recording:
Mussalah Complex Herat and Minaret Jam,
Afghanistan

REPORT

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APPENDIX:

Daily reports

M.Santana Quintero
T. Stevens

A3 drawings:

Mussalah complex Herat:

- 01 Context map
- 02 Minaret no. 01
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- 04 Minaret no. 03
- 05 Minaret no. 04
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- 10-11 Minaret no. 06
- 12 Mausoleum Gwar-Shad
- 13 Ruins at the Madrassah Hussain Baiqara

Minaret Jam

- 01 Context map (including topography)
- 02 Ground map Minaret
- 03-06 Cross sections through the Minaret

Proposal documentation programm Minaret Jam and Mussalah complex Herat

Evaluation of trainees

THE USE OF METRIC SURVEY TOOLS IN RECORDING: MUSSALAH COMPLEX HERAT AND MINARET JAM, AFGHANISTAN

This report presents the efforts to prepare a preliminary measured record of two sites located in the provinces of Herat and Ghor in Afghanistan:

- Mussalah Complex site (province and city of Herat)
- Minaret Jam (province of Ghor)

These two sites are in imminent risk of destruction for different reasons and they are currently in the focus of international efforts for safeguarding the built heritage of Afghanistan. The mission was composed by M. Santana Quintero and T. Stevens, consultants. It was organized by the section of heritage at UNESCO and under the coordination of Christian Manhart.

Furthermore, the mission was supported by the efforts and advice of Professor Andrea Bruno, Cultural adviser to UNESCO on Afghanistan and president of the R. Lemaire International Centre for Conservation. In addition, Prof. Michael Jansen from the University of Aachen RWTH provided logistic support to purchase the equipment necessary to execute the works of documentation. This report has been written in cooperation with Tarcis Stevens.

5.1 OBJECTIVES

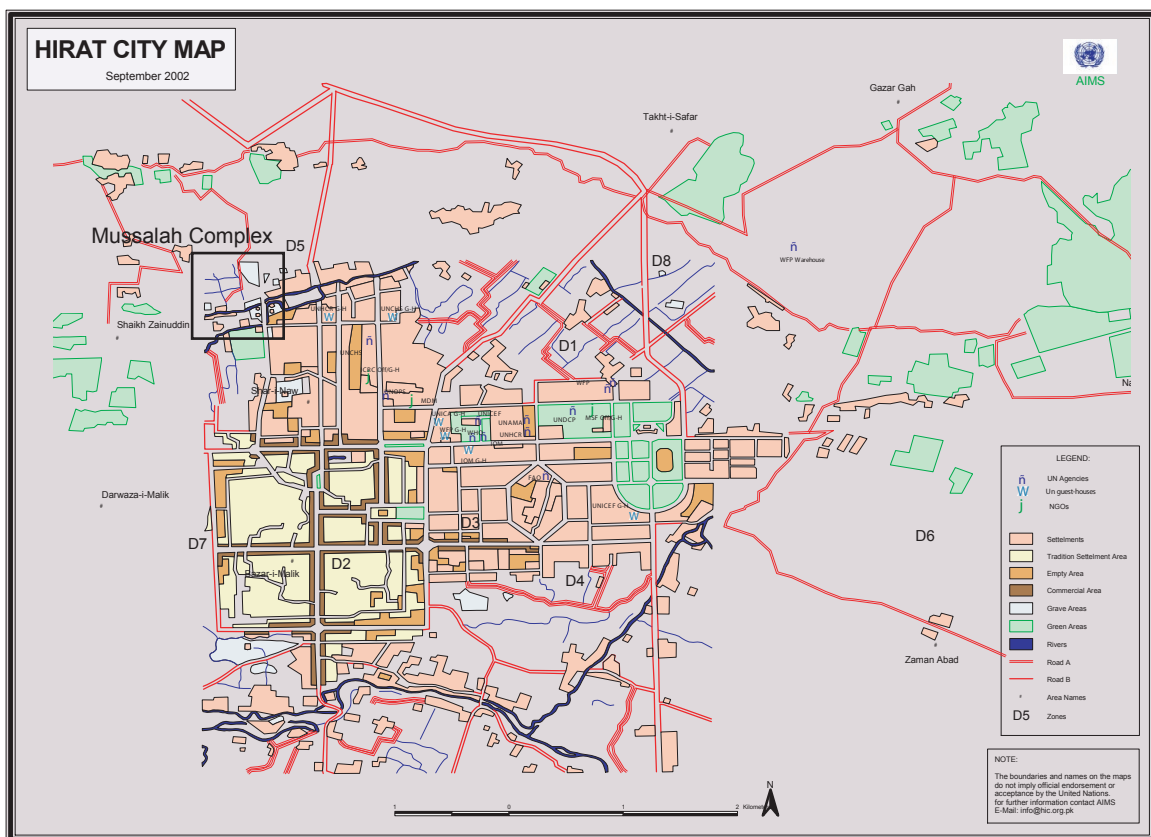
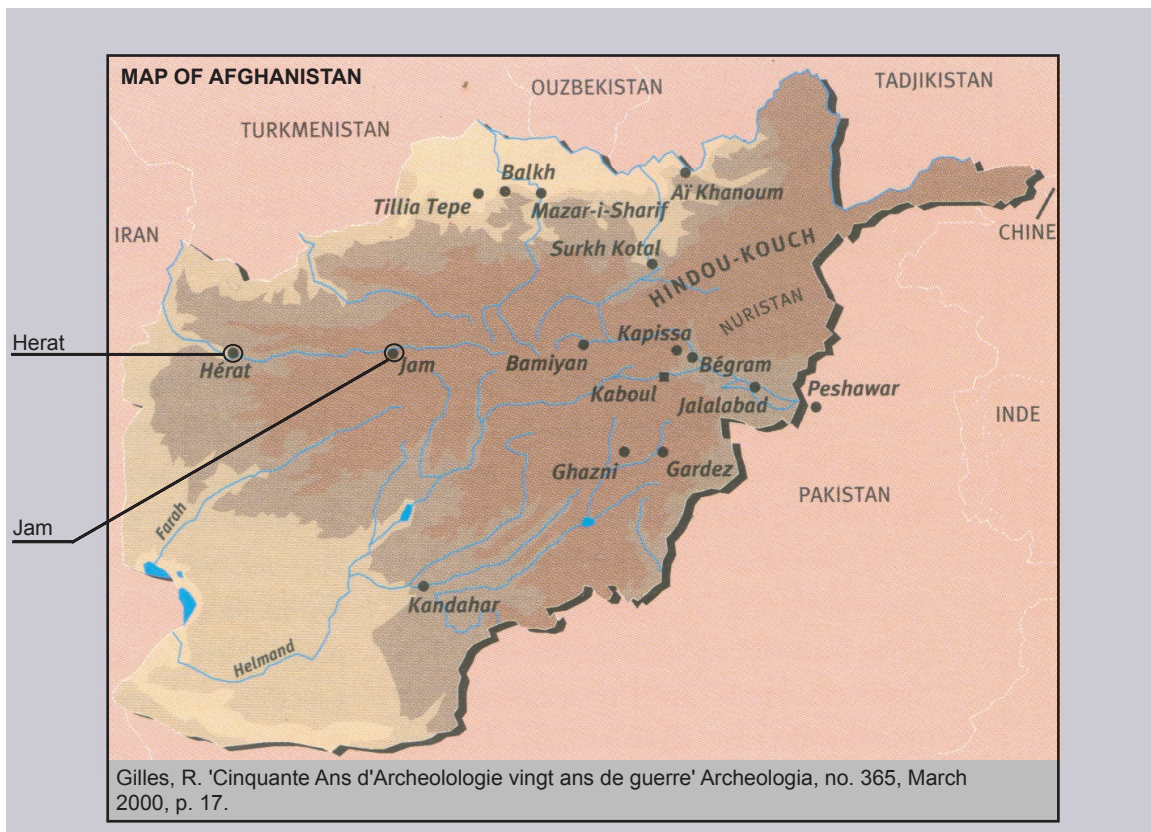
The role of the metric survey tools chosen for this mission is focused in producing a measured assessment or dataset that includes a preliminary record of the geometry and texture of the fabric of context and the subject.

This dataset of measured plans is of importance to prepare an assessment of the structural condition of the elements in most danger of collapsing and as reliable source of information for coming missions that will excavate and further study the monuments.

This report presents the field work carried out in a period of three-weeks in situ in the two sites. Making emphasis in the methodology used, the results, and recommendation for future efforts in documenting Afghan heritage.

The tools used and developed in this example are conventionally used in geodesy and they have been adapted to the needs of the specific area and the available resources, making emphasis in the use of optimal and sustainable methods for the current condition of this country in terms of political, legal, and practical infrastructure for protecting built heritage.

In addition, the equipment used in this mission was donated to the Ministry of Information and Culture in Afghanistan for the documentation of built heritage. Therefore, UNESCO assigned a group of local experts to the mission that was giving a short but intense training in the use of these tools. The knowledge of the trainees will be reinforced by the organization of a series of training in



Map by UNAMA-Herat

Figure 01: Location of sites. Above map of Afghanistan, prepared by the UNDP (United Nations Development Program). Below: Map of Herat, prepared by UNAMA (United Nations Assistance Mission in Afghanistan)

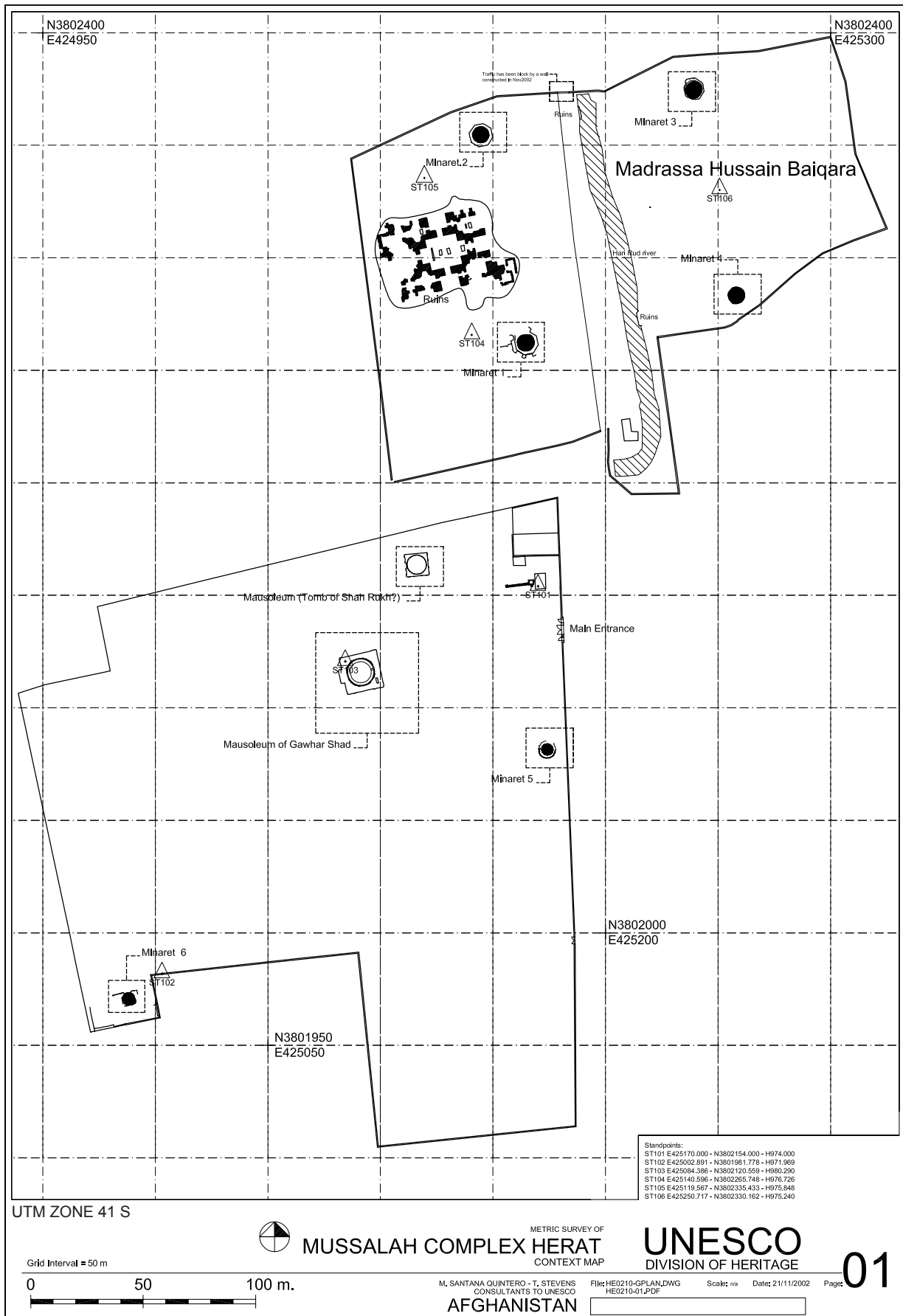


Figure 02: Context Map - Mussalah Complex in Herat. Author.



Figure 03: General views of the Massalah complex in Herat. Author.

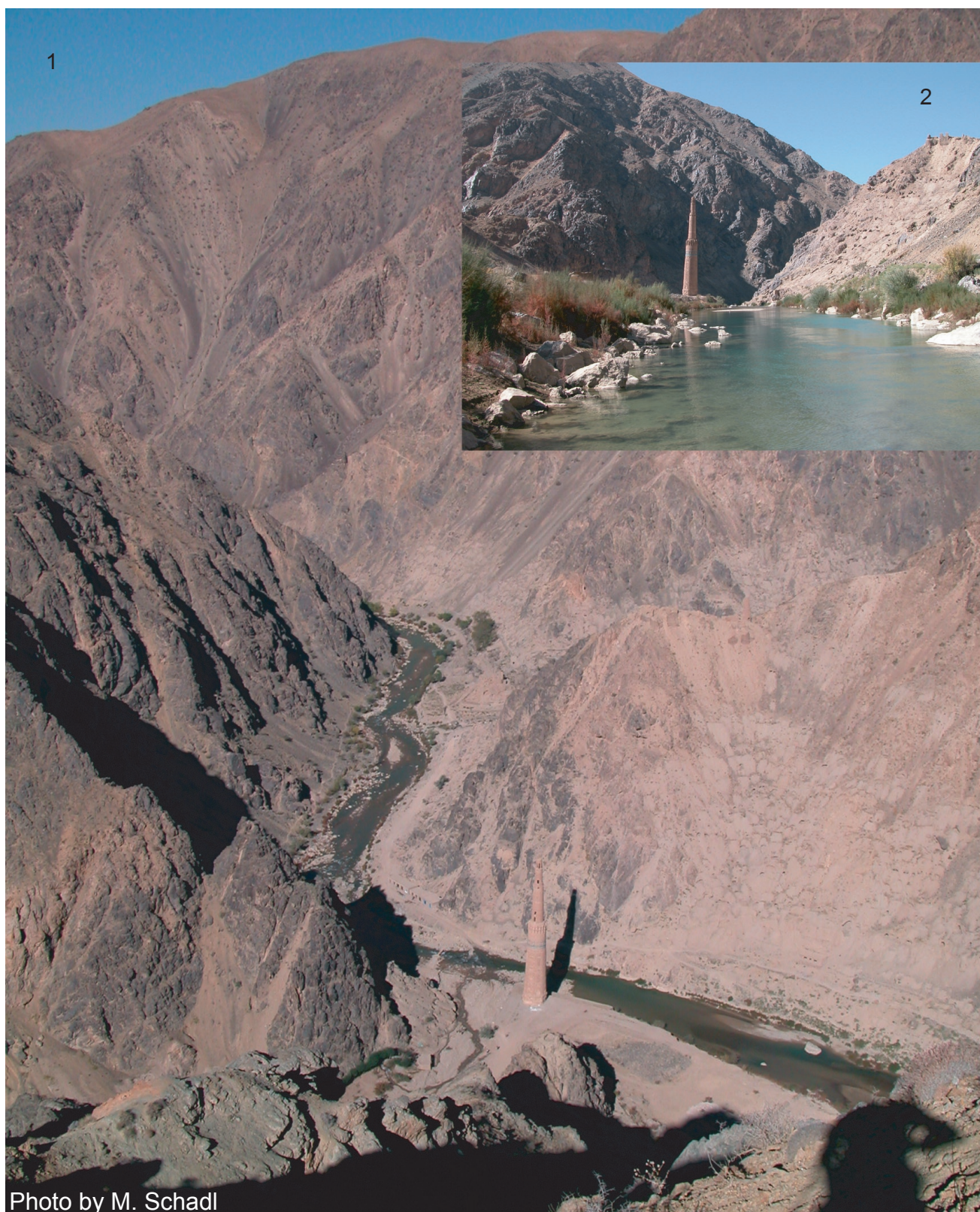


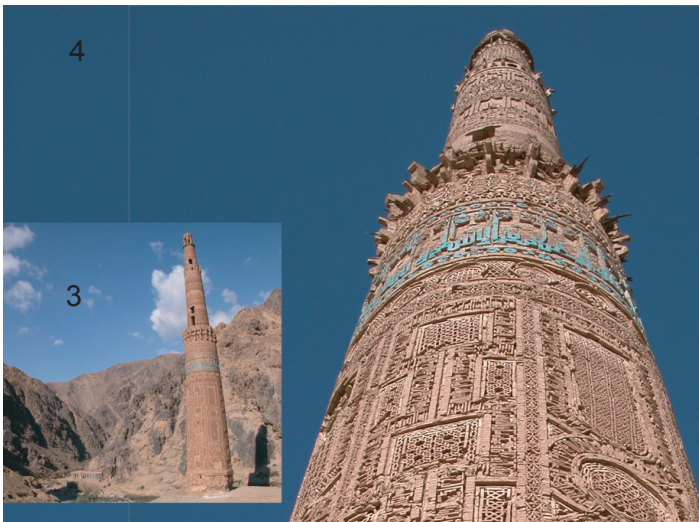
Photo by M. Schadl
General view of the site Oct 2002
southwest

0 10 50 m

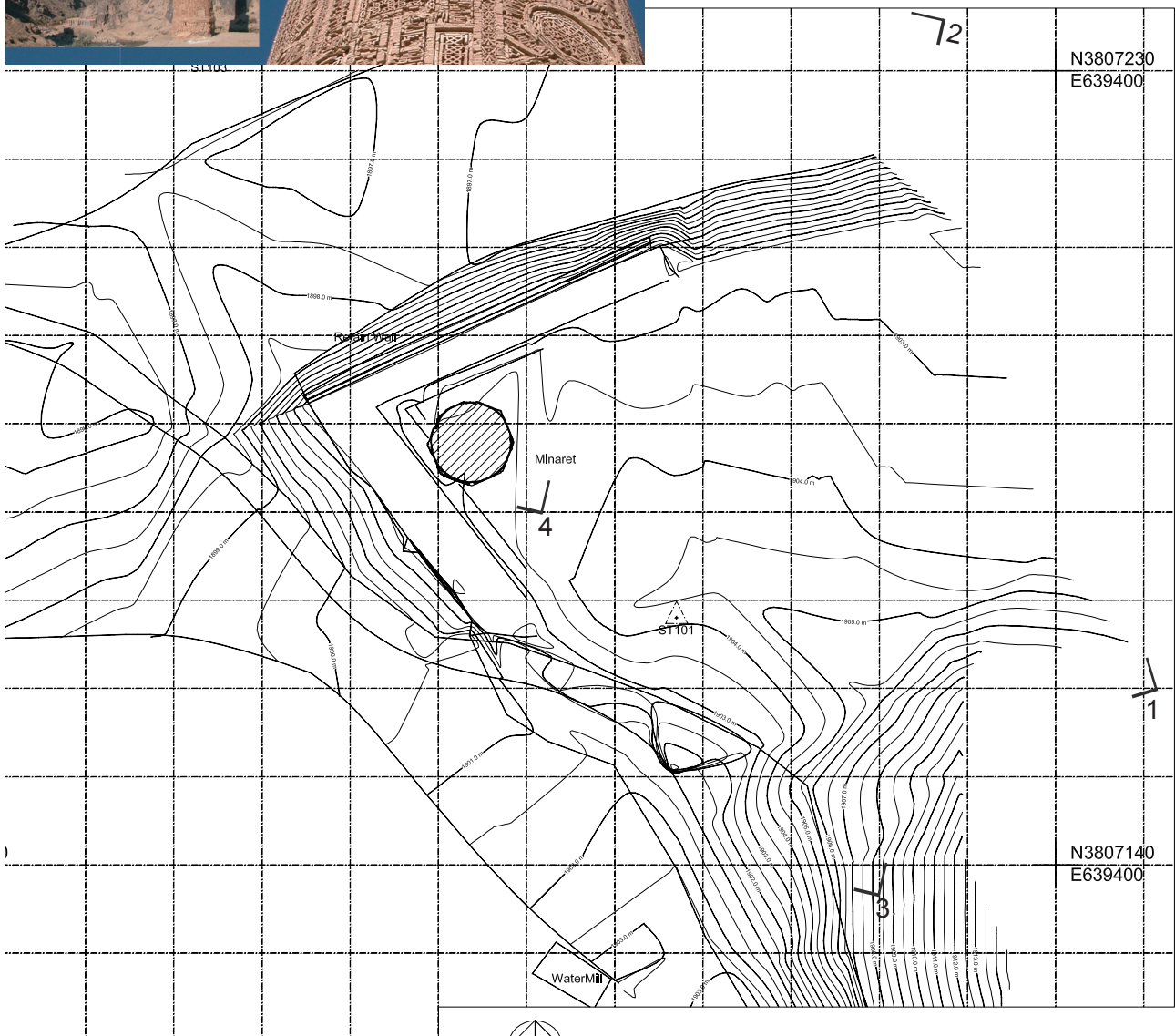
Standpoints:
ST101 E639357.000 - N3807168.000 - H1905.000
ST102 E639619.825 - N3807243.662 - H1901.935
ST103 E639303.970 - N3807231.762 - H1903.444

Countour Interval= 0.5 m - Grid Interval= 10 m

Figure 04: General views of the Minaret Site and context map. Author.



Left: General view of the site
Right: Details of the Minaret



METRIC SURVEY OF
MINARET JAM
CONTEXT MAP

UNESCO
DIVISION OF HERITAGE

01

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CONSULTANTS TO UNESCO

File: MJ0210-GPLAN.DWG
MJ0210-01.PDF

Scale: 1:500 Date: 21/11/2002 Page:

the near future.

5.1.1 MUSSALAH COMPLEX SITE HERAT

The work was concentrated in archiving a geometrically correct measured map of the current situation of the Minarets and its context, including other buildings of historical importance.

The plans prepared are:

- Site plan, containing the location of Minarets, uncovered ruins and historic buildings.
- A study of Minaret no. 5, containing a number of horizontal sections and a cross-vertical section on the main axe of inclination.

Work carried out:

- (a) Site reference grid based on a relative system of coordinates UTM orientated to the north calculated from two readings taken with a hand-held GPS unit.
- (b) Preparation of the site map showing the position of the Minarets using a REDM Total Station, including main features of the site (river, walls, etc) and a preliminary topographic map.
- (c) Measurement of the Inclination of Minaret no.5 using the REDM Total Station, including a vertical cross sections with the main inclination axes defined by the measurement of five horizontal sections, following the concepts described in the UNESCO Technical report on Restoration of Monuments in Herat 'Schematic profiles of minarets', p. 104.
- (d) Measurement of natural targets for future photogrammetric restitution of Minaret no. 5.
- (e) Digital photography of the four Minarets remaining and Minaret no.6 collapsed in the XIX c.

Available time: 10 days:

- Day 1 – Task (a)
- Day 2- Task (b)
- Day 3 – 4- 5- Tasks (c-d)
- Day 6 -7-8– Task (e)
- Day 9-10 Reserve to complete other tasks

5.1.2 MINARET JAM

The work was concentrated in archiving a geometrically correct measured map of the current situation of the Minaret and its context, including natural features and modern constructions surrounding the monument.

The plans prepared are:

- Site plan, containing the location of the Minaret and a topographic map of the site in a radius of approximately 50 m.
- A study of the Minaret, containing a number of horizontal sections and a cross-vertical section on the main axe of inclination. This plan has been combined with measurements made by hand-survey of the interior and the measured representations prepared by Prof. A. Bruno previously.

Work to be carried out:

- (a) Site reference grid based on a relative system of coordinates UTM orientated to the north calculated from two readings taken with a hand-held GPS unit.
- (b) Preparation of the site map showing the position of the Minarets using a REDM Total Station, including main features of the site (river, walls, etc) and a preliminary topographic map.
- (c) Measurement of the Inclination of the Minaret using the REDM Total Station, including two vertical cross

sections with predefined axes and five horizontal sections following the ones described in the report for the Mission for SPACH, 1999 by Andrea Bruno on the Survey of Jam minaret.

- (d) Measurement of natural targets for photogrammetric restitution.
- (e) Digital photography of the Minaret (limited to the first two bodies of the structure, the third highest body can be recorded with a higher resolution camera later on), to be used in a future and possible second phase of work for photogrammetric restitution.

Available time: 3 days

Day 1 - Task (a – c)

Day 2 – Task (b)

Day 3 – Task (e)

5.2 BACKGROUND OF THE SITES

5.2.1 MINARET JAM

The minaret Jam is located in the Ghor province, *'about 100 km farther east up the valley of the Hari Rud', it is difficult to reach. The Minaret lays in complete isolation. It was discovered in 1957* (Knobloch, E., 2002, p. 127)¹. According to a GPS reading in the minaret site, the monument is around 200 km east of the City of Herat.

*'Rises some 65 m. from an octagonal base some 8 m in diameter (SPACH, 2000, p.2)*² *'across and three cylindrical stages. The first is decorated with geometrical patterns in fired bricks, arranged in panels separated by vertical bands of Kufic inscriptions. A wide horizontal band of blue tiles with a further kufic inscription runs around the top end in which, in a line of naskhi, the*

*name of the calligrapher is given as 'Ali'. The second and third stages are decorated with horizontal bands of inscriptions again in fired bricks. The stages were originally separated by galleries, which have not survived, and the top was closed by a lantern which has also collapsed; an interior staircase leads up to the second stage. The inscription confirms that the minaret was erected by Sultan Ghyat ud-Din Muhammad ben Sam, the ruler of Ghor. It was probably built, in all probability, in 1190 and is often linked with the legendary Ghorid capital, Firuzkuh, which was destroyed by Chingiz-Khan in 1222 and the site of which has never been found' (Knobloch, E., 2002, p. 127)*³.

However, according to the measurements of the mission, the diameter of the minaret in its octagonal layer is of 9,786 m. and the height is of 60.734 m (1964.537 m) relative to the 0,00 m of 1903.803 m of height calculated with a hand-held GPS.

The site of Jam was accepted by UNESCO as a World Heritage Site in 2002. It is the first afghan site to be included in the list. It also has been considered the second highest minaret in the world.

5.2.1.1 Current condition and critical issues

A protective Gabion retain wall has been constructed surrounding the west and south fronts of the Minaret along the Hari river by SPACH-HAFO⁴ under the guidance of Prof. Andrea Bruno. However, just few meters from the south front of the retain wall a road with currently heavy traffic is in used and will be improved by a NGO called Afghan Aid in

the coming months.

Major critical issues are:

- Inclination and current condition of conservation of the minaret should be studied.
- Looting: illegal excavations are a constant problem; the number of holes around the site is growing every day.
- New housing around the Minaret, heavy transport vehicles passing can cause damage to the structure and its unique natural surroundings

5.2.2 MUSSALAH COMPLEX SITE HERAT

This site consists of two main areas:

- Mausoleum of Gawhar-Shad, Kuhsan, containing the minaret M5, a second smaller mausoleum not identified and the Madrassah of Gawhar-Shad containing Minaret M6. This site is surrounded by a mud brick and cement wall repaired by SPACH-HAFO in 2000-2001.
- The Madrassah of Sultan Hussain Baiqara, composed by four minarets: numbered M1, M2, M3, and M4 and various uncovered excavations with ruins. It is surrounded by a mud brick wall constructed by SPACH-HAFO in 2000-2001. It is of around 11,000 square meters (Jawed, S. - SPACH, 2001, p. 13)⁵.

Apparently, the Minaret site or also called Musalla 'is known from late fifteenth-century sources (Khondamir, Babur), that Gawhar Shad built a Musalla in Herat -but it is not quite clear what it consisted of. Babur speaks of three buildings -a mosque, a madrasa and a mausoleum while according to Khondamir, the mausoleum was inside the madrasa. Major Yate, in 1885, also speaks of three buildings:

The Musalla consists in reality of the remains of three buildings running north-east and south-west and covering a space of nearly 600 yards from end to end. Of the eastern building -known generally, I believe, as the Madrasah or College -nothing but two high arches facing each other and four minarets remain. The arches must be from 60 to 80 feet in height inside the arches the beautiful mosaic-work is still in many places almost perfect. The minarets of this Madrasah appear taller than the rest, and must be between 120 and 150 feet in height.

Then, 'Between the Madrasah and the Musalla 100 yards or so from each other, is a domed building commonly called the tomb of Shah Rukh ...It is faced on the east by another archway and one solitary minaret.' The third building stood to the west of this 'tomb of Shah Rukh' and was the actual Musalla (Knobloch, E., 2002, p. 132)⁶

In addition, Madrassah of Sultan Hussain Baiqara, composed by four minarets and the uncovered ruins. According to Knobloch:

*The **minaret (M1 and M2)** with one gallery, which now stands inside a modern madrasa, stood in the western corner of the courtyard of the Musalla, which according to a reconstruction measured some 117 x 70m. The minaret can be best seen from the garden called Bagh-i Bihzad. Its octagonal base was once covered with exquisitely carved marble panels, and the whole tower was entirely covered with ornaments in mosaic faience in deep blue, azure and purple, with white marble moulding*

separating the panels and the bands of calligraphy, parts of which survived until recently. The minaret received a direct hit in 1984/5. Only a stump remains.

*The other **minaret (M3 and M4)**, with two galleries and standing to the east of the mausoleum, was probably one of the flanking towers of the entrance iwan of the madrasa. The galleries are supported by lavishly decorated stalactite vaults (mukarnas). On the tower itself brick ornaments alternated with bands of tilework. It, too, was hit by a rocket and is leaning precariously. Both minarets have lost their tops.*

*The madrasa of Husayin Baykara occupied an area of some 100 x 100m, the outline of which is marked by the **four** minarets.*

The ruins located at the west part of the four minaret site, between M1 and M2 and according to Van Eenhoge in 1981 are suspected to be from the Madrassah:

'Little remains of the 15th century religious complex which once stood to the north of the city: of the Musallah and the Madrassah built by Queen Gawhar-Shad, wife of Shah Rukh, only two Minarets and the mausoleum of the Queen are still standing; four tall minarets are all that remains of the big Maddrasah built by another Timurid, Sultan Hussain Baiqara, while of the numerous constructions built by his minister, Ali Sher Navai, and by other members

of the Timurid dynasty, nothing remains'.

This work was carried out in the 70s by the UNDP-UNESCO project lead by Professor Andrea Bruno⁷, the excavation work on the Madrassah yield important discoveries:

A sounding around the base of Minaret 1: 'the main result of this sounding I was the discovery that the lower part of the structures belonging to the Madrassah is still preserved, so that it is very likely, taking into account the topography of the site, that an excavation of the entire site would lead to the uncovering of a large part of the ground plan of the building. It was also established that originally the lower part of the minaret had been octagonal, with deep niches built against the exposed sides of the octagon, the other sides being incorporated in the walls of the building'

This lower part of the minaret was decorated with a revetment _ of "haft rang" tiles, while the upper part was completely covered with very t mosaic panels, set in a lacelike network of white tiles. At the base of Minarets 2, 3 and 4, the erection of a scaffolding was preceded discoveries. At the base of Minaret 2, a black tombstone was found; the inscription on it attributes it to a daughter of Miranshah, son of Tamerlane. Equally exciting was the lng, at the base of Minaret 4, of two carvea marble pilasters, and a fine wall decoration of hexagonal turquoise coloured tiles, part of which were still "in situ". it is thus obvious that a full-scale excavation of the site would not only provide with the plan of a now destroyed but historically important Timurid building, but would also add to our knowledge of the later Timurid decorative arts. The result of such an excavation, and subsequent consolidation of the ruins, would be a monumentality of the four minarets' (Van Eenhoge, 1981, p. 26)⁸..

Current state of the site and critical issues

The site of Sultan

- Inclination and current general condition of Minaret 5 is critical. This Minaret near the Mausoleum of Ghawar Shad present damage in its base and a gap produced by military missile.
- The ruins of Minaret 6 are in danger, they are in an isolated area on the southwest corner of the protection wall surrounding the Mausoleum of Ghawar Shad site and they are remainings of different buildings that should be identified.
- The ruins at the site of the 'Madrassah of Sultan Hussain Baiquara' containing Minarets 1–4 is abandoned and decayed causing diminish of its social value to the community of Herat. Uncovered ruins are being dismantled and destroyed.
- Interventions that have use cement to repair the ornaments in the ruins performed in recent years are questionable.
- The Madrassah of Sultan Hussain Baiqara is constantly crossed by pedestrian, the protection wall should be repair. However, during our visit the traffic was stopped and a wall blocking the access of vehicles was constructed, the change is of significant importance for this area.

5.3 DEFINITION FRAMEWORK IN THE SELECTION OF METRIC SURVEY TOOLS TO ACQUIRE THE GEOMETRY AND TEXTURE OF THE SITE

5.3.1 APPLICATIONS

In this report, and according to the needs of the project, the use of metric survey tools have been concentrated in preparing a rapid 'measured dataset' that can be use for immediate interventions in specific targeted areas in the sites and to prepare a general context plan that can be updated in the near future.

The target audience of this application is purely professional. Making emphasis in the use of metric survey representations to carry our immediate measures to protect the integrity of the fabric of the site.

The sets of representations are prepared for experts studying the stability of this critical areas in the sites and for constant monitoring of the condition of the building. in the site and interventions required to.

Expected Quality and task definition

The 'metric survey study' is composed of measured representations with a reliable completeness of information and that are of the highest possible quality. The tasks of the 'metric study' are of limited extend due to the short term of the mission but procuring the highest possible results (See chart, p .).

Variables in the identification of restrictions in the use and selection of metric survey tools

The variables are ordered according to their relevance in the application (see chart 1).

Budget

The metric survey tools used in the works of documentation of these two sites were selected because of being cost-effective according to the limited budget assigned to the preliminary assessments for documentation, which also includes the fees of other specialist calculating the stability of the monument.

This variable associated to the monument affects the selection of tools that can effectively deal with:

Cost-effective, speed-range, field operability and the level of precision: they should be economically suited to the defined task, which has been limited to calculate the inclination of the minarets and carry out a preliminary of the sites.

Transformation possibilities: of the dataset collected to be use in different representations should be possible to transfer to other computer applications.

Quantification

This variable specially important in this case-study, because the metric survey study is conditioned and limited to fulfill the tasks defined by the measurements to be carried out to calculate the inclination of minaret Jam and minaret no.5 in the Mussalah complex.

During the short mission, the works was concentrated in achieving these tasks, taking into consideration the available time and local available facilities.

This variable associated to the monument affects the selection of tools that can effectively deal with: range of the instrument should be sufficient to measured without reflector the highest areas of the minarets and the field operability capabilities of the tool should be sufficient to operate under battery power for a extended period of time, since in Jam there is no electricity available.

Furthermore, transformation possibilities of the dataset collected to be use in different applications, level of precision should be sufficient for the task, speed should be sufficient to carry out an useful survey in two days, adjustments-corrections are of minor importance, and the capacity of the tool to deal with critical issues in recording built heritage.

To address these problems, two more batteries were purchased to obtain 4 days of power supply. As well as, a REDM total station was chosen that could deliver sufficient range, speed and field operability capacities for a limited budget.

Expected quality

See expected quality

This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications in the field of studying the structural behavior of the monument, level of precision, speed-range, field operability and their capacity to deal with critical issues in recording built heritage.

Expertise

The tools selected has been already tested and used by the experts of the mission, so no particular requirements were associated to this variable. However, the training component of the mission influenced the purchased of the equipment to choose relative simple tools for metric survey that can yield adequate results to the local experts.

This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications, level of precision, speed-range, field

Minaret Jam Mussalah Complex Herat

DEFINITION FRAMEWORK

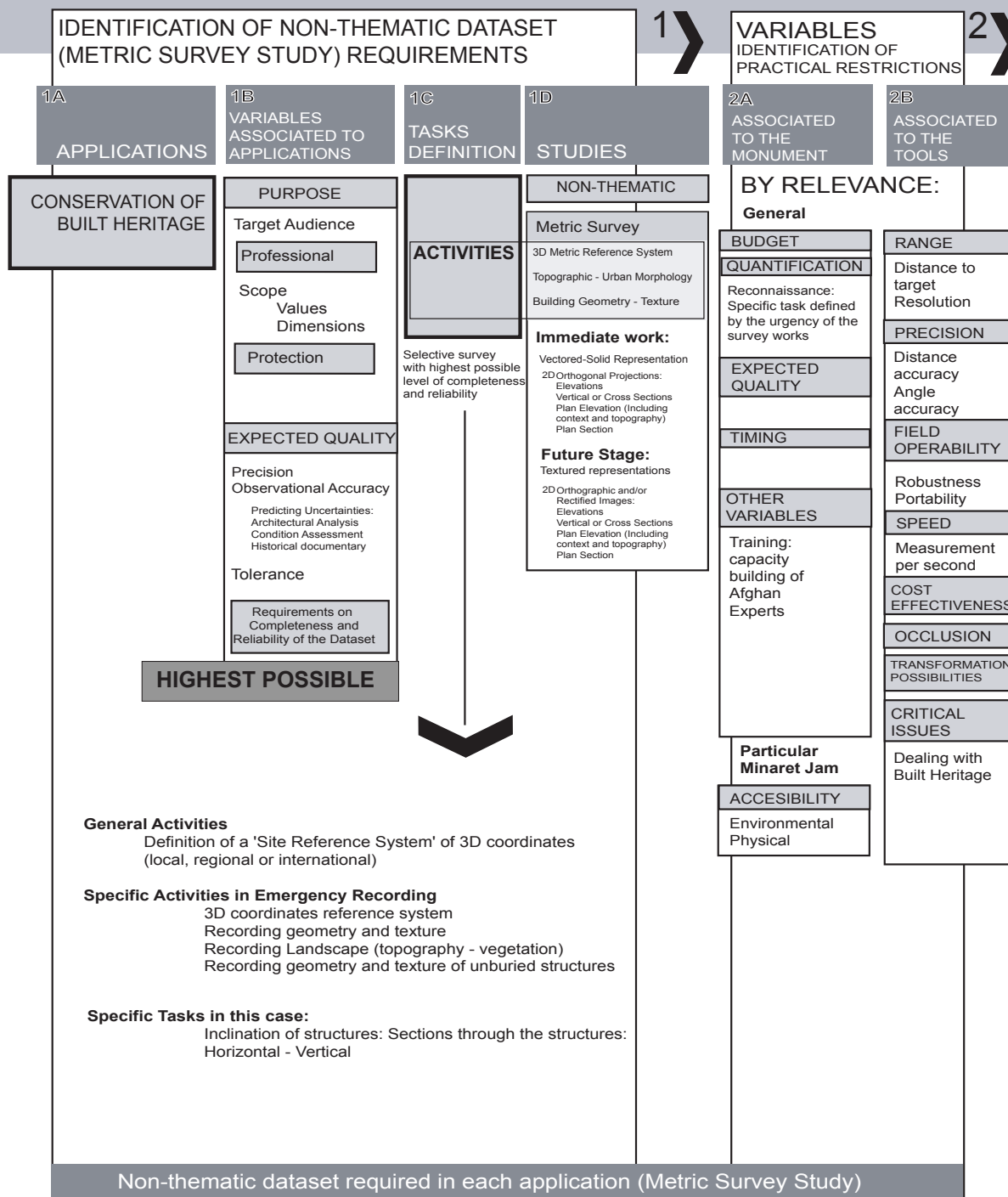


Chart 01: Application framework applied to this case study.

operability and their capacity to deal with critical issues in recording built heritage. But especially attention should be concentrated in their requirements in adjustments-corrections.

Timing

This variable had a major impact in the selection of the tools and execution of the metric survey. The metric tools selected should deliver sufficient data in a relative short time.

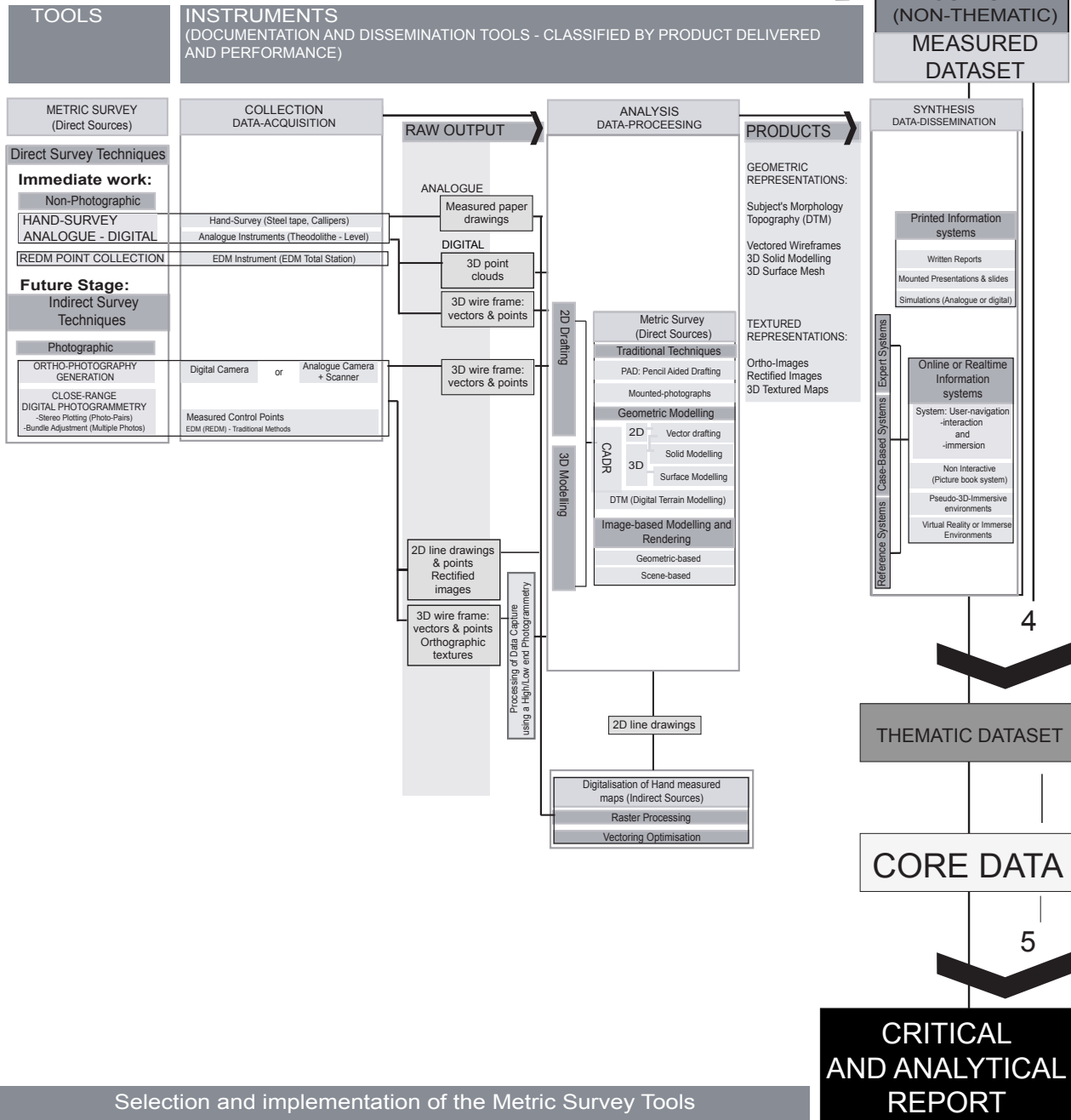
FRAMEWORK: SELECTION OF TECHNIQUES IN PREPARING THE METRIC SURVEY MEASURED DATASET

SELECTION FRAMEWORK

SELECTION OF A COMBINATION OF TOOLS - IMPLEMENTATION OF THE METRIC SURVEY STUDY

3

METRIC SURVEY STUDY OUTPUT (NON-THEMATIC) MEASURED DATASET



This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications, level of precision, speed-range, deal

with occlusion interfering with the survey, adjustments-corrections required, field operability and their capacity to deal with critical issues in recording built heritage.

Accessibility

The particular remote location of minaret Jam is an important variable that was taken into account for the selection of the tools used to measure the monument. The tool should be easy to transport and should be able to operate with battery supply (see quantification).

This variable associated to the monument mainly affects the selection of tools according to: speed-range and field operability.

Other variables

Since the project was made in cooperation with local authorities, accessibility was not restricted.

Training of local experts can be included as a variable to consider, a lot of effort was made to make accessible the procedures and tools used in preparing the measured dataset, this certainly limits a bit the action of the recorder but ensures the successful transitions of the methods to local staff to carry out them during a longer period of time.

Furthermore, the selection of tools took into consideration that the equipment will be donated to the staff of the Afghan ministry of information and culture for capacity building and improvement of the current situation.

These variables associated to the monument affect the selection of tools that can effectively deal with: transformation possibilities of the dataset collected to be use in different representations, level of precision, speed-range, deal with occlusion interfering with the survey, adjustments-corrections required, field operability and their capacity to deal with critical issues in recording built heritage.

5.3.2 METRIC SURVEY TOOLS

The use of metric survey tools in the different sites is associated with the collection of mainly geometric information. The activity was concentrated in:

- Measurements for the conservation of specific areas of the site to calculate the structural behavior of the activities in imminent risk.
- Provide measured representation to prepare a general plan of action for the coming years.

Recording for the conservation of the site

A selective, but detail acquisition of the fabric masonry, horizontally as well as vertically. Identification of the loci of objects by an absolute 3-D co-ordinate system obtained from the REDM total station output thus allowing immediate 3-D identification of each record collected.

For a later phase, this work carried out can serve as based for the inclusion of more advanced metric survey tools, such as close-range digital photogrammetric and/or long range terrestrial three-dimensional laser mapping tools for acquisition of the geometry and texture of the whole site.

The information gathered is recorded and produced simultaneously to the works through the use conventional and sustainable off-shelf application and instruments widely available in the market, such as a the REDM Total Station, Computer-Aided Drafting applications, digital cameras, and raster image processing applications used for enhancing the photographs taken.

Establishing a local reference (coordinate) system: using an EDM Total Station point collection tool

Considering the local situation of Herat and Jam in relation with the non-existent of benchmarks or other features to establish an absolute coordinate system, it was decided to establish a local or relative coordinate system as site reference, based on UTM (Universal Transverse Mercator projection)⁹, these coordinates measured will be measured



Figure 06: recording the site, preparing and measuring standpoints (fix points) covering the entire area. Author.

in two standpoints using a GPS hand-held device.

These two positions had an interval of around 50 m, sufficient to ensure the best possible precision for the location and orientation of the system.

The complementary standpoints created to measure the whole sites will be based on the first to standpoints with UTM readings. These points were fixed in different areas covering the entire site and visible from each other.

In addition, for obtaining more precise measurements of the Minarets, a number of fix points were measured from the initial standpoint. These positions were used to calculate the current position of the instrument by a method called free-station, this programme consists of determining *'the instrument position from measurements to a minimum of two known points and a maximum of five known points, the final computed results are Easting, Northing and Height of the present instrument station'* (Leica Geosystems AG, 1999, pp. 51)¹⁰, these calculation does not necessary needs to measured by metric tape the height of the instrument and therefore it helps to reduce the error involved in the position and height of the Total Station.

Musallah Complex Herat: site reference system

A set of three standpoints have been selected and identified with surveyor nails in order to ensure the preservation of the system in the future. It consists of:

- ST101 located on the top southwest corner of a small house containing the water pump.
- ST102 is located on the corner of a column embedded in a wall near Minaret 6 (east side of the Minaret 6).
- ST103 is located on the northwest corner of the top of the Mausoleum of Gawhar-

Shad, Kuhsan.

- ST104 is located at the Midwest bound of the Madrassah of Sultan Hussain Baiqara.
- ST 105 is located at the northwest of the Madrassah of Sultan Hussain Baiqara, near Minaret No.
- ST106 is located at the mid east bound of the Madrassah of Sultan Hussain Baiqara.

The system has been defined by two GPS readings taken on ST101 and ST102, the first reading provided a relative position, including east, north and height (altitude). The second reading was used to orientate the system.

ST101 GPS Readings: UTM region 41 S:

East (M)	41 S 0425170
North (M)	41 S 3802154
Height (M)	970

ST102 GPS Readings: UTM region 41 S:

East (M)	41 S 0425006
North (M)	41 S 3801985
Height (M)	958

Subsequently, the Total Station was placed in ST101, the standpoint and it was orientated using the readings from ST102.

When the instrument was ready, ST102 was measured again using the Total Station to ensure precision in the records, also ST103 measured from this point.

Coordinates:

Standpoint	East (m)	North (m)	Height (m)
ST101	425170.000	3802154.000	974.000
ST102	425002.891	3801981.778	971.969
ST103	425084.386	3802120.559	980.290
ST104	425140.596	3802265.748	976.726
ST105	425119.567	3802335.433	975.848
ST106	425250.717	3802330.162	975.240

ST103 639303,970 3807231,762 1903,444

A second system of temporary standpoints was measured from ST101, in order to be use for measuring the Minaret No.5 using a 200 numbering system.

Minaret Jam: Site reference system

Two standpoints were constructed and measured with the hand-held GPS device, the had an interval of more than 50 m.

ST101 GPS Readings: UTM region 41 S:

East (M) 41 S 0639357
North (M) 41 S 3807168
1905 1905

This position is located at around 10 m. of the eastbound of the Minaret, near the military post (see figure and map)

ST102 GPS Readings: UTM region 41 S:

East (M) 41 S 0639621
North (M) 41 S 3807244
Height (M) 1888

This position is located at around 300 m. from the north front of the Minaret, near the ruined research house in the stone area (see figure and map)

Subsequently, the Total Station was placed in ST101, the standpoint and it was orientated using the readings from ST102.

When the instrument was ready, ST102 was measured again using the Total Station to ensure precision in the records, also ST103 measured from this point.

Coordinates:

Standpoint	East (m)	North (m)	Height (m)
ST101	639357,000	3807168,000	1905,000
ST102	639619,825	3807243,662	1901,935

ST103 is located around 20 m. from the west front of the Minaret across the river, in a hill close to a large stone.

Methodology: recording with a REDM Total Station

The measurements were made using a Reflectorless Electronic Distance Measurement Total Station Topcon Leica TCR307, the records are stored in the internal memory of the instrument, which has capacity to store 8000 records (around 6000 measured points).

The total station records using two EDM (electromagnetic distance measurement mode) modes:

- By sending an infrared beam to a reflector device (prism or reflective sticker), the TCR307 has a range of 5 km using a reflector.
- By sending a laser beam directly to the surface (the return and range depends on properties of the material), the TCR307 has a range of 80 m but is affected by the material, in difficult situations the range can be reduce to 20 m.

These two modes allow measuring the three-dimensional co-ordinate of the point recorded and if required it can provide the horizontal angle, vertical angle, difference of height, horizontal distance, and absolute distance between the measured point and instrument standpoint.

Furthermore, the records stored in a memory, after surveying they can be transferred to a computer using a communication cable connected to the serial port. The Leica communication software allows generating a list of records in different formats that can be read by a CADR application. This tools

Massalah Complex Herat - standpoints



Figure 07: standpoint fixed in the Massalah Complex in Herat. Author.

has being define in this research as REDM point collection.

The survey and storage of the collected points were divided into different sets of measurements according to the measurements executed and needs of the representation. Mainly a part was devoted to the geometry of the monument and another file containing measurements for Digital Terrain Modelling of the site topography. As well as, for surrounding structures and features of interest for the study.

Moreover, in uncovered ruins, the features are surveyed by placing the reflector in the top and bottom of the object thus providing two known points for it. The measured points will be use to create the elements using the solid or surface modelling extension in the CADR application.

In addition, the topography is surveyed by making a systematic measurement with a specific distance depending on the complexity of the slope. As for instance every 5m in a triangular schema.



ST103

ST101



Minaret Jam - standpoints



ST102

Figure 08: standpoint fixed in the minaret Jam. Author.



Figure 09: views of minaret no.5 - Mussalah complex in Herat. Author.

Each day the information was transferred to the computer and process the data collected. The collected points were introduced into the CADR environment using AutoCAD Land development Desktop version 3 that enables the calculation and representation of the topography of the site using three-dimensional contour lines and surfaces.

Subsequently, the features of the monument fabric are constructed using the commands included in the Computer-Aided Drafting tool (CADR). On conclusion of the survey, the working up and editing of the data required five weeks. The resulting plans showed the topography and archaeological remains in a single three-dimensional representation. The CADR application enabled the drawings to appear in different formats for study or publication.

Measurement of the Minarets using the REDM Total Station

For the measurement of the minarets, an adapted methodology was developed. It consisted in measuring a number of horizontal sections, starting from the bottom to the top, with a number of intervals depending on the different heights corresponding to the stages of the structure.

Moreover, these sections were drawn in the CADR application providing a irregular curved shape that served to draw more regular circles to find the different circumference's centres. These centres definition were aimed to define the different axes of inclination at each stage.

Subsequently, a graphic average of these inclinations help calculating a general risk axe that was extracted from the CADR drawing and defined in the site with the help of the Total Station programme called 'Set out'.

These standpoints defining the axe in the terrain were use to measure the vertical cross section that could yield the most risky

scenario of the current inclination of the structure.

The procedure to set up these positions in the terrain was perform with an instrument(TCR307) application called '*Setting Out*', which '*computes setting-out elements for the polar, Cartesian, or orthogonal setting out points using either coordinates or manually entered angles, horizontal distance and height. In the Setting out program three different displays are available showing setting out values corresponding to the relevant method*' (Leica Geosystems AG, 1999, p. 44)¹¹.

The combination of the vertical section and horizontal sections provided information to define particular inclination angles per stage and a general risk angle of inclination of the minarets.

Finally, for improving the stability study of the structure, the measured sections of the minaret with the aim of the REDM Total Station were combined with hand-survey measurements of the interior; the resulting drawing provides a specific state of conservation of the structure that can be of assistance to study the structural behaviour of the monument.

REDM Total Station measurement of natural targets and digital photography for close-range photogrammetric restitution

Natural targets

A number of measurements were collected of Jam Minaret and Minaret No.5 in Herat for a future stage in photogrammetric restitution. These called natural targets are related to architectural features, which are particular aspect to be recognize immediately in most of the photographs taken, these points will provide the information to calculate the external orientation required

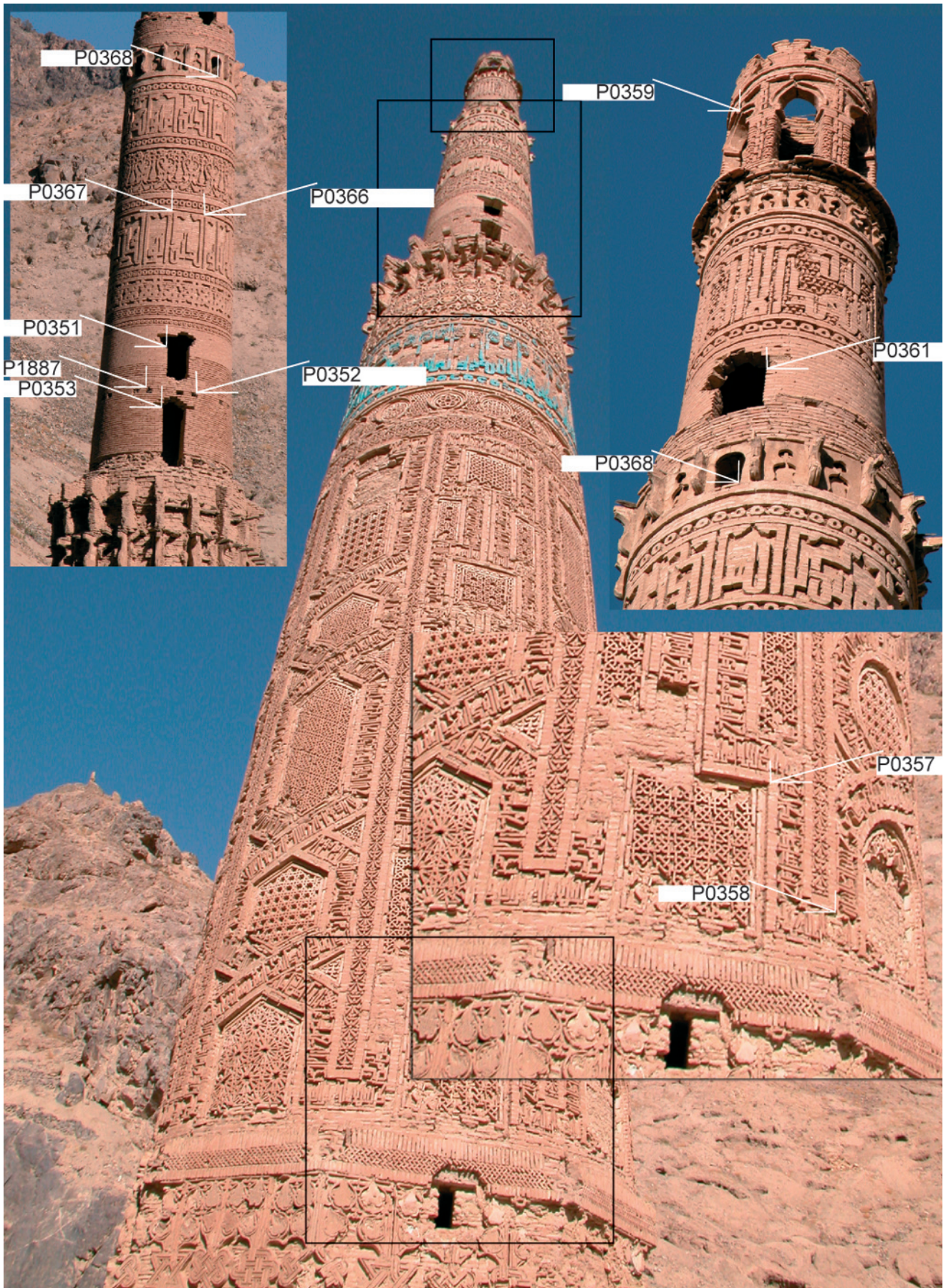


Figure 10: example of natural targets measured with the REDM total station for photogrammetric restitution of minaret Jam. Author.

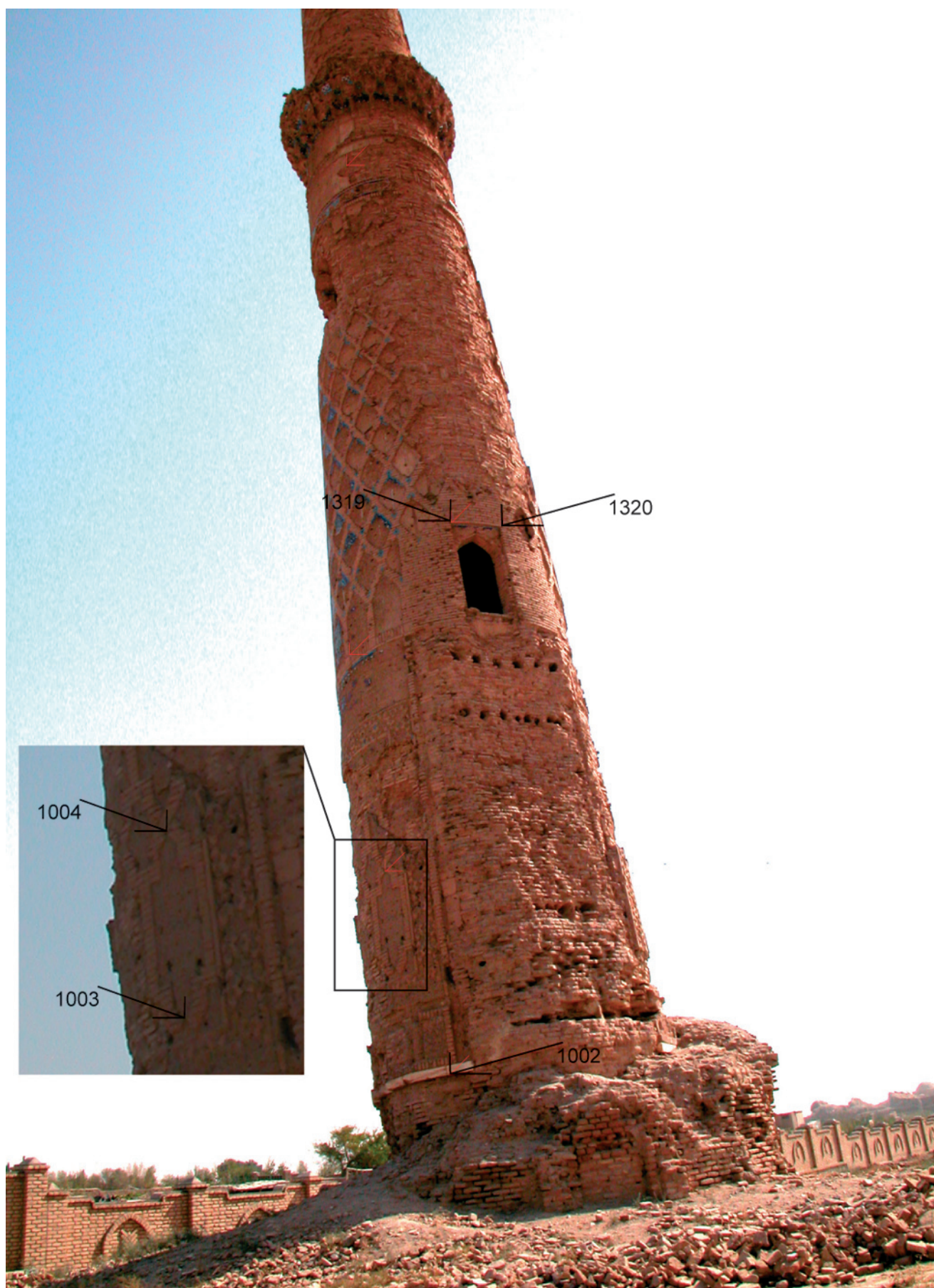
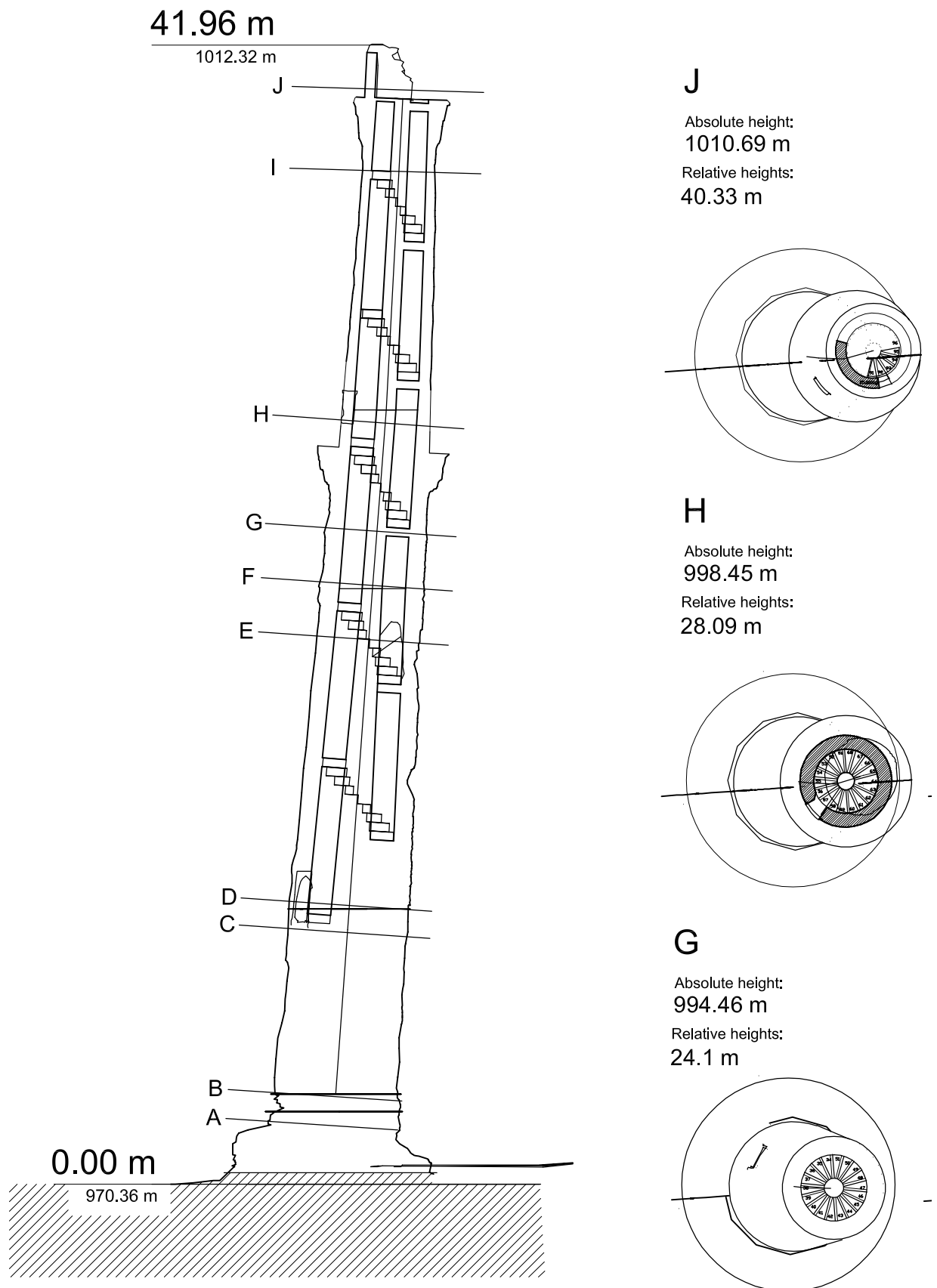


Figure 11: example of natural targets measured with the REDM total station for photogrammetric restitution of minaret no.5 (Mussalah complex Herat). Author.

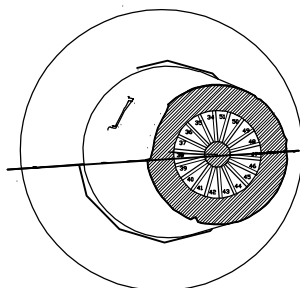


Drawing by: T. Stevens - Complementary CADR: Author

Figure 12: views horizontal and vertical cross section through the minaret no.5, generated with the combination of the readings from the REDM total station and hand-survey measurements.

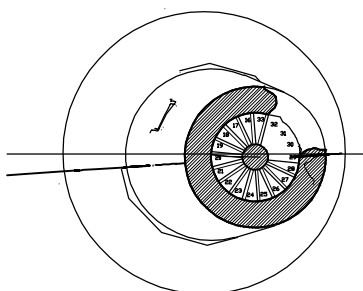
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Absolute height:
992.46 m
Relative heights:
22.1 m



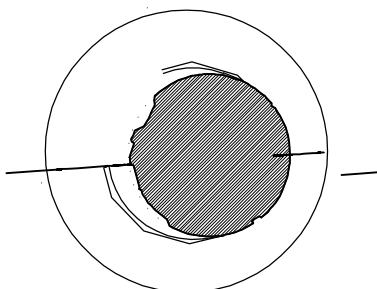
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Absolute height:
990.46 m
Relative heights:
20.1 m



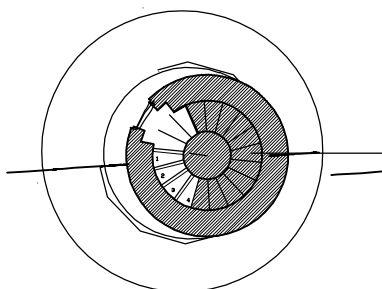
C

Absolute height:
979.66 m
Relative heights:
9.3 m



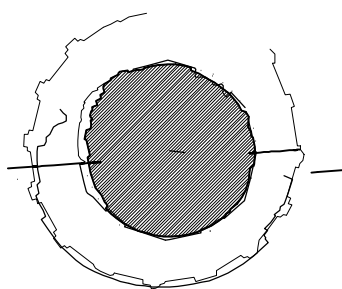
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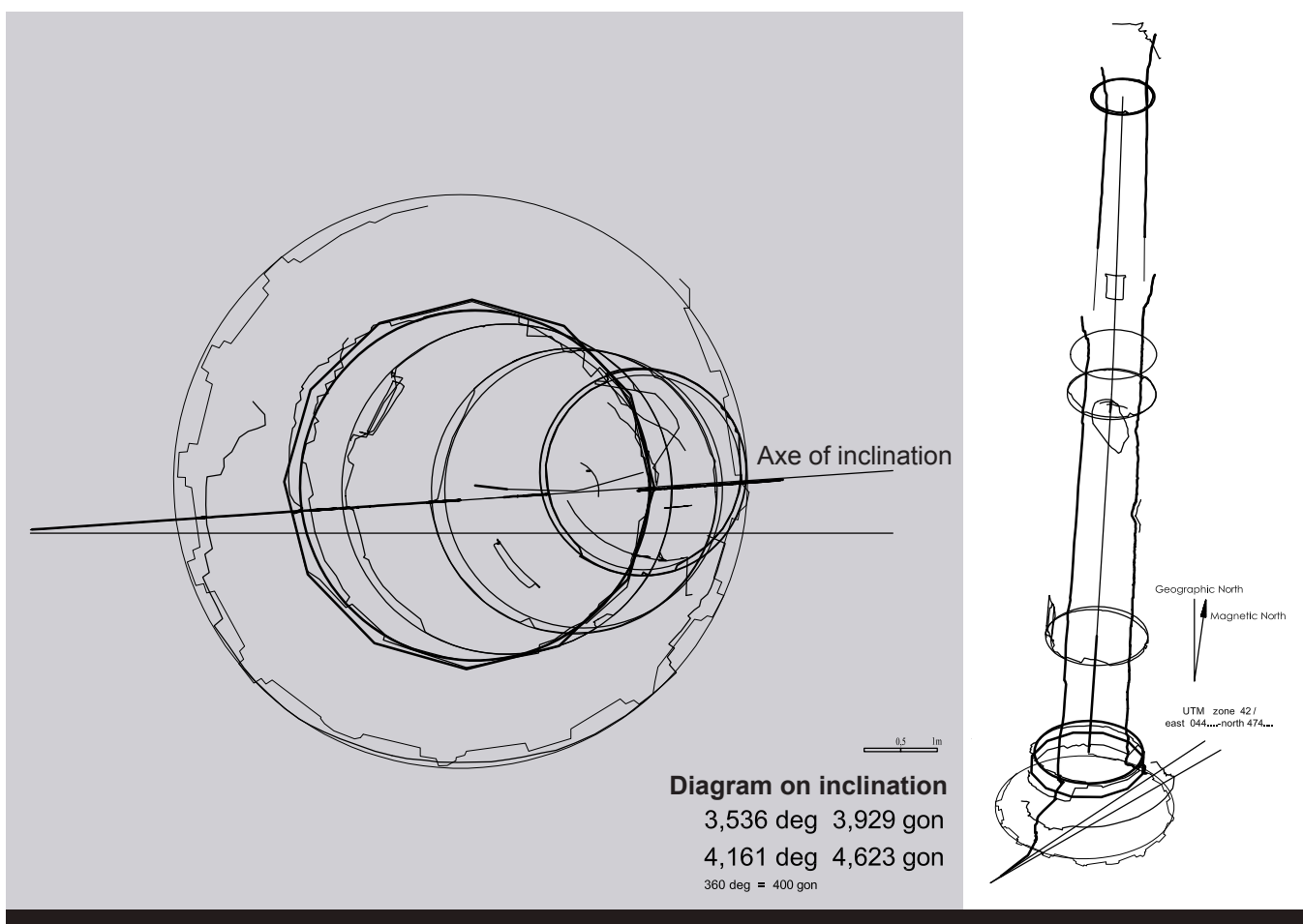
Absolute height:
980.66 m
Relative heights:
10.3 m



B

Absolute height:
973.645 m
Relative heights:
3.285 m





Drawing by: T. Stevens - Measurements: Author - T.Stevens

Figure 13: calculations about the inclination of the minaret no.5 using the most leading axe. Drawing by T. Stevens and measurements by T. Stevens and author.

in photogrammetry (review Chapter V in Part I for more information about this method), meaning scale, position and orientation of the features digitized from the images. The natural targets were measured using the Laser EDM.

Specification in Minaret Jam: due to the lack of a printer to plot the photographs and indicate the natural targets, a number system was introduced to identify the different faces of the Minaret from 1 to 8 clockwise and according to the octagonal bases of the monument, number 1 corresponds to the point facing ST101 and having a gap in the octagonal layer (see figure 87).

Subsequently, a sketch was prepared by M. Schadl of each numbered face and the

targets were indicated. Further the targets were transferred to actual photographs (see figure 87).

Specifications in Minaret no. 5 in Herat: all the natural targets were indicated in plotted photographs of the Minaret. These papers were later digitized (see figure 88).

Digital photography using different lenses

Photogrammetric images for Minaret Jam: a series of oblique and overlapping photographs covering homologous features and taken from different positions of the Minaret were taken. Each photograph is identified by the lens and zooms used to take

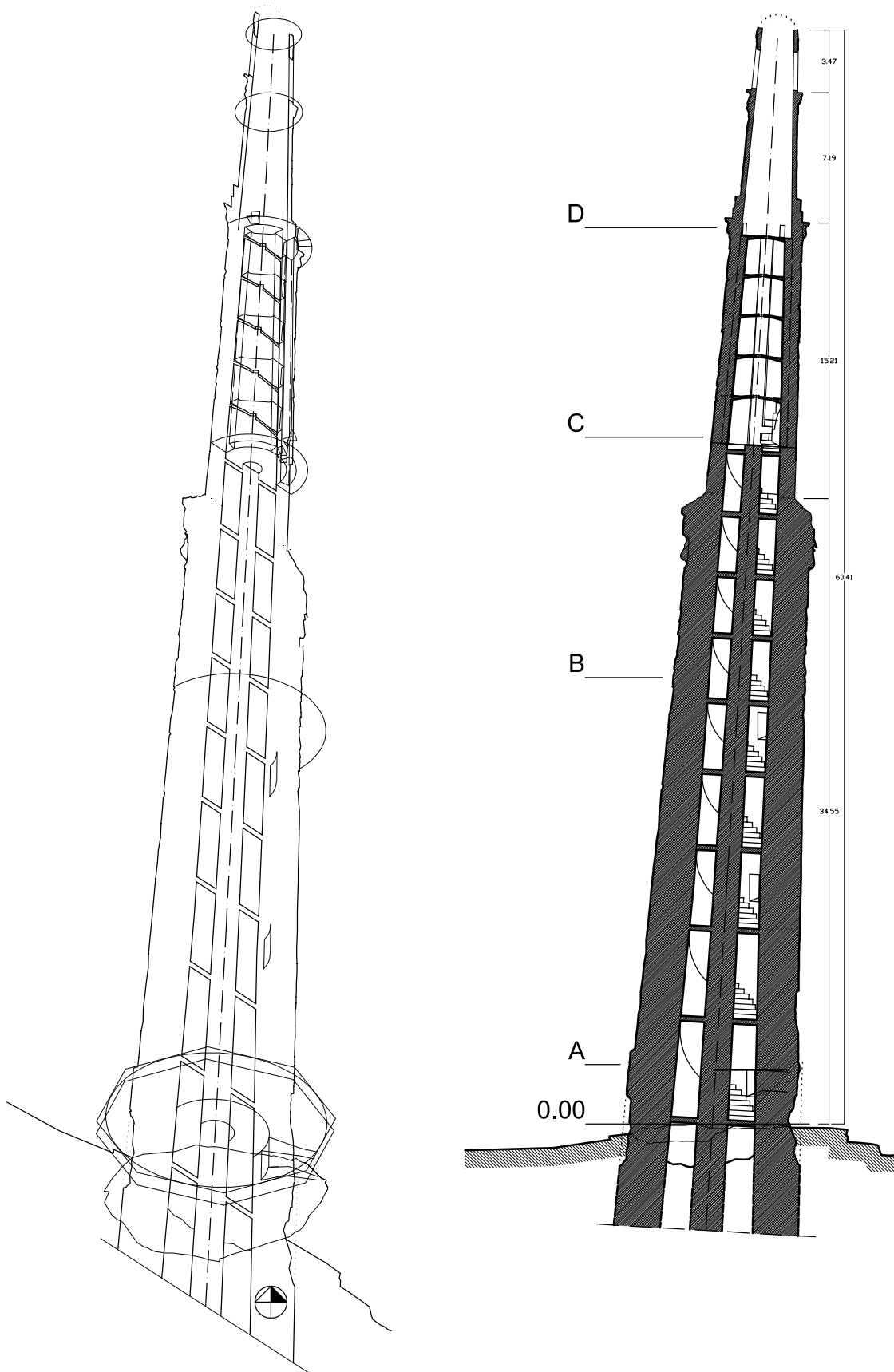


Figure 14: vertical cross section through the minaret Jam, generated with the combination of the readings from the REDM total station and hand-survey measurements.

the shot. This permits to process the internal orientation for photogrammetry along with the natural targets measured to generate the external orientation parameters (see figures 87 and 88).

However, due to the lack of scaffolding, the middle part of the first stage of the Minaret was not adequately photographed; photographs with more detail should be taken in a later stage.

Photogrammetric images for Minaret No.5 in Herat: a number of oblique and overlapping photographs with homologous features were taken covering the entire Minaret. The photographs were made with different lenses and zoom, each photograph is identified with the lens used for achieving internal orientation in the photogrammetric package (see figure 88).

Due to the sun direct light, the north front of the Minaret was not sufficiently photographed, this should be executed in a later stage using more adequate equipment.

Photographs for Minaret No.1, 2, 3, 4 and 6: a sequence of photographs from bottom to top was taken from different angles of each minaret. The angle and orientation of each photograph along with the lens used were included in the name file. The orientation was measured with a hand held electronic compass.

General recommendations for photogrammetric restitution

The photographs taken along with the already known parameters of the camera used can serve to prepare a preliminary photogrammetric restitution that can be improved during future mission aimed at preparing a full set of measured representation of the site.

5.3.3 CAPACITY BUILDING: TRAINING OF LOCAL EXPERTS IN THE USE OF REDM TOTAL STATION, DIGITAL PHOTOGRAPHY AND CADR APPLICATIONS

The main aim of this activity is not only promote the understanding of recording every stage of work during the works of conservation, but also to donated a set of equipments and knowledge to organize a government cell that is capable of recording and monitor the state of conservation of a larger number of afghan sites during the years to come.

The training consisted in the combination of a theoretical and a practical framework. The contents of these two areas were limited by the:

- A short time available to teach the afghan experts in the use of the instruments. Time available: 7 days (3 days in Jam and 4 days in Herat, this last four days were possible due to the support of Mr. Wahid from the Herat authority in preservation of architectural heritage, which provided lodging and local facilities to the trainees of the Ministry of Information and Culture from Kabul).
- Their restricted knowledge in the use of electronic equipment and computers.

To make use of all the time available, the theoretical aspects were integrated into the actual survey work.

Trainees:

Ministry of Information and Culture, Department of conservation and restoration of historical monuments: engineer Abdul Ahad Abacy and engineer Ahmad Fahim Fayeque.



Figure 15: example of capacity building of afghan experts in the use of the instruments and an explanation of the training framework. Author.

Coordination Afghan Humanitarian (CHA – NGO): Engineer Masood Temory from Herat.

In addition, the section of heritage at UNESCO has proposed to prepare a full scale training course next year to improve the capacities of the trainees in the use of these tools.

This programme for capacity building of local afghan experts in the use of these tools consists:

- A broader perceptive of the techniques and instruments available in the market.
- Concepts and principals in recording built heritage.
- An appropriate balance among the quality of the records to be prepared, budget available for the survey, and variables of the recording techniques available

Furthermore, at the end of the course a set of guidelines for preparing an adequate set of measured plans of the site, including three-dimensional topographic models and orthographic representations, rectified photography of standing and buried structures, and other relevant measured representations will be produced, taking into consideration local aspects and available sources.

This course will be structured in the already known international experience in the field of capacity building of experts in developing countries in the use of REDM total station, CADR-DTM applications and digital photography achieved by the University of Technology Aachen RWTH, which in the past has promoted and participated in the organization of training workshop.

The equipment donated consisted of:

Hardware:

- TCR307 Leica Total Station: capable of measuring without reflector to a range of 80 m and with a set of four batteries to operate for 3-4 days.
- Sony Vaio model PCG-GRX316MP notebook with a Pentium IV processor, 30 GB Hard disk, 16x CD-Writer, and a screen of 16" for AutoCAD and other graphic software. An external floppy disk unit.
- Nikon Coolpix 5500 Digital Camera with 5 MP resolution and two memory cards (128MB and 32 MB), along with an adapter to read the memory cards in the computer directly.
- HP Deskjet printer 1220, capable of printing up to A3+ size.
- UPS electricity regulator: to avoid damage of the instrument from electricity fluctuation currently happening in Afghanistan.

Software:

- AutoCAD Land development desktop r3 for CADR processing and Digital Terrain Modeling generation to create representations of the topography and architecture of the measurements collected with the total station.
- AutoCAD Raster Design: a plug-in to AutoCAD that enables the user to rectified plan parallel and aerial photographs directly into the CADR drawing.
- Adobe Photoshop 7, a program for processing of digital images produced by the camera and other raster images work.
- MS Office for word processing, spreadsheet and other features to produce reports.

CAPACITY BUILDING: PROPOSAL

SPRING WORKSHOP

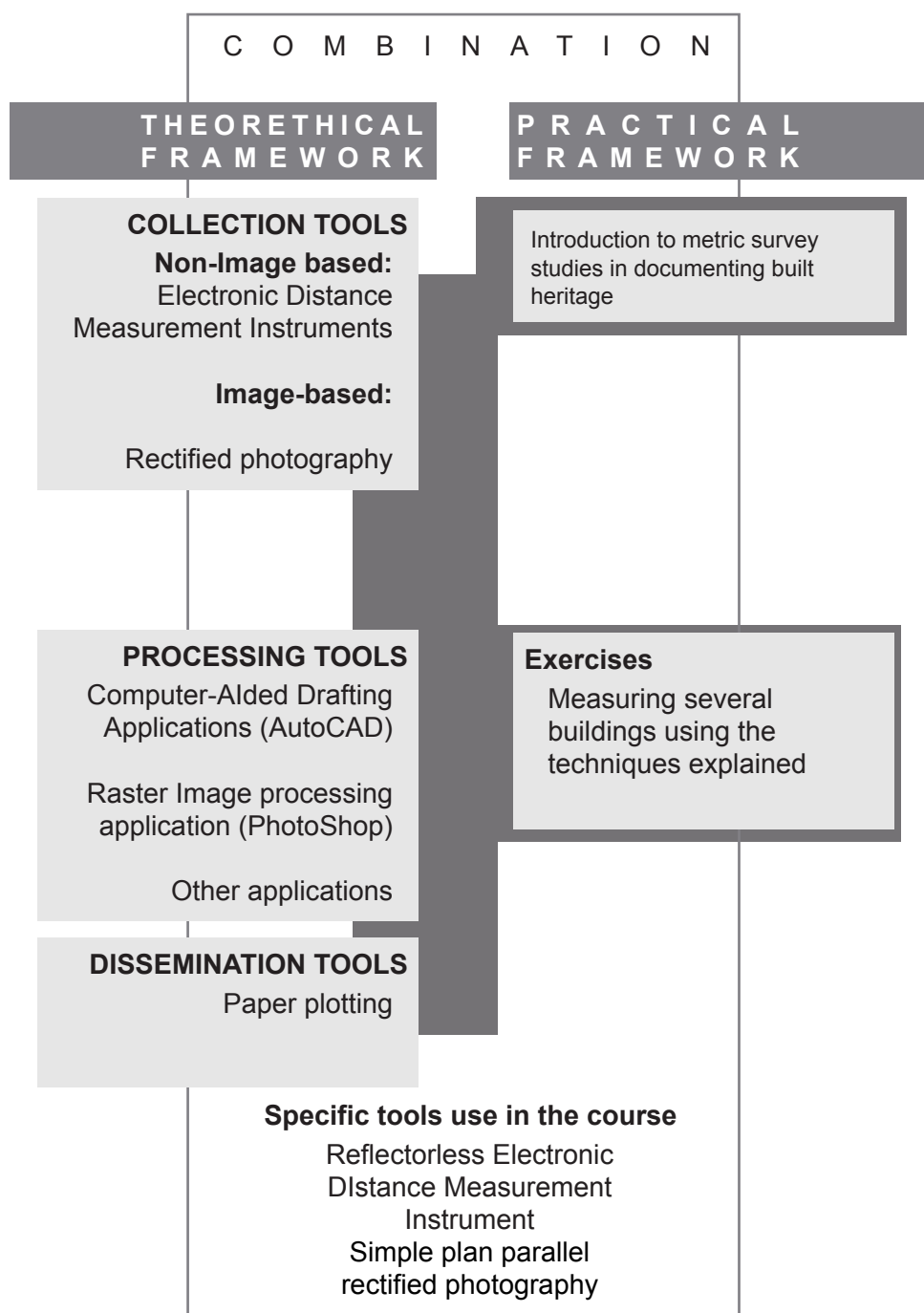


Figure 16: framework for the training course for capacity building of afghan experts in the use of the instruments. Author.

5.4 RECOMMENDATIONS: PLANS FOR THE FUTURE

Metric survey in the Mussalah complex Herat

A full scale image-based and geometric measured dataset should be prepared of the site including:

- Ortho-graphic projections of the six minarets: vectored maps or ortho-photographs (as suggested by Archidata).
- Detailed survey of minaret no. 5 and establishment of a monitoring system to record structural behavior of the monument.
- The preparation of a topographic map of the site, especially of the site of the four minarets and Madrassah Hussein Baiqara by means of a digital terrain model. Including the immediate urban context surrounding the site and the type of vegetation present. This map should also identify the position of illegal excavations around the site.
- 3D dimensional model of the site and Minaret no. 5 and site

Probably photogrammetry will be the most suitable technique to achieve these goals, because is a portable and highly effective technique.

This project should take into consideration the possibility of further training afghan experts in the use of these techniques and the setting up of advanced monitoring system.

Metric survey in minaret Jam

A full scale image-based and geometric measured dataset should be prepared of the minaret including:

- Ortho-graphic projections of the façade: vectored maps or ortho-photographs (as suggested by Olivier Feihl).
- A digital terrain model to represent the topography of the site with a higher density of points that the one presented in this report. Including a hydrographic documentation of the rivers and the type of vegetation present. This map should also identify the position of illegal excavations around the site.
- 3D dimensional model of the minaret and site

Probably photogrammetry will be the most suitable technique to achieve these goals, because is a portable and highly effective technique. However, 3D long-range mapping devices should be taken into account for a quick documentation of the topography and geometry of the monument.

This project should take into consideration the possibility of training afghan experts and set up a monitoring system that could yield results on the structural behavior of the site.

Capacity building of the Afghan Ministry of Information and Culture in the use of Metric Survey tools, follow-up plan

Main goal: creation of a government cell capable of providing services on the documentation of afghan heritage in different fields of action:

Basic objectives:

- (1) Creation and implementation of a methodology for a national record system for inventorying and monitoring the actual state of conservation of historical sites across the country, this point can be done in cooperation with the already created database of monuments in Afghanistan by the University of Aachen RWTH in Germany. Training should be

concentrated in the use of basic referential tools for recording, such as digital cameras and scanner. Furthermore, the use of Geographic Information System and image databases should be included as an advanced course.

- (2) Metric Survey of historic sites, training should be concentrated in the use of electronic distance measurement (EDM) devices (Total station – Laser scanning?), Computer-Aided Drafting application, Digital Terrain Modeler applications, and photogrammetry.
- (3) Training to university and other educational institutions in the country, the documentation cell should be encourage to spread knowledge to other institutions, such as department of geodetic engineering, architecture, archaeology, art history, etc. Perhaps a programme on conservation of heritage should be establish in the university that could offer a course on documentation techniques, ranging from creating inventories to the use of metric survey tools.

Equipment required:

Point (2): a set of instruments and software has been already donated to the Ministry of Information of Culture by UNESCO, however for a second stage, more material should be made available to set up a metric survey cell, including:

Hardware:

PC desktops

A large format Plotter

A server and other items to set up a network.

Software:

Photogrammetric software

Action plan:

The members of this cell have been already selected by UNESCO in cooperation with

the Ministry, these persons should have a fluent English capability and sufficient technical knowledge to operate the equipment, therefore the following action plan is proposed:

Before spring (March or April 2003):

- Intensive English course, available locally.
- Computer basic use course, showing the main features of a computer, such as word-processing, spread sheet, and general operation, available locally

Workshop March or April 2003: Theoretical and practical framework in the use of electronic distance measurement devices and image-based application in preparing a measured dataset of built heritage sites:

- Intensive course on the use of metric survey tools, including EDM devices and simple image-based tools: tentative contents:

Theoretical framework:

Introduction to metric survey studies in documenting built heritage

Use of a REDM Total Station, working with the already donated TCR307 Leica, explaining all the procedures for recording measurements and transferring them to the computer.

Computer-Aided Drafting and Digital Terrain Modeling processing of measurements course, working with the already donated version of a AutoCAD land desktop v3.

Simple rectification of plan parallel photography, using a mechanic technique and automatic applications, working with the already donated software of Adobe PhotoShop and Raster

Design. As well as, the digital camera.

Preparing Monitoring forms for a historic site: conclusion combining all the documentation tools explained in the course.

Practical framework:

The explanation of each of the contents will be introduced by directly working with case-studies.

- Intensive course of the use of image-based techniques, making emphasis in photogrammetry. This part of the course can be introduced to the trainees in the spring workshop and further developed in a second stage. However if it is relevant, it can be already be integrated in the course.

This workshop can be organized by the University of Aachen in Germany and in conjunction with Aga Khan Trust for Culture, which has plans of acquiring the same type of equipments and give training to their staff. This is aimed at having two instruments for give training.

Moreover, the University of Aachen in Germany and the R. Lemaire International Centre for Conservation (University of Leuven) in Belgium could offer short term internships to some of the trainees to experience the use of these techniques in a different environment.

5.5 CLOSING REMARKS

This report demonstrates that the adapted use of sustainable tools for urgent work in recording historic buildings, with specific variables dealing with the expected quality and precision requirements of the measured representations adjusted to the specific needs of a problem and the desired dissemination product.

representation prepared can yield results to evaluate:

- The structural stability in relation with the inclination of the minarets.
- Evaluating the surveys carried out by previous missions.
- Prepare a permanent document showing the different problems and the initial work needed to measure in more detail the monuments.
- Evaluate the development of the works, speed and constraints

Furthermore, it proposes a model for capacity building of local experts including the development of local structure that is capable of documenting and caring the heritage of the country. This cell should have strong links to academic institutions, providing further training to experts in this area.

Notes:

¹ Knobloch, E. 'The Archaeology and Architecture of Afghanistan, Tempus Publishing Inc., Gloucestershire 2002, p. 127

² Society for the Preservation of Afghanistan's Cultural Heritage (SPACH) 'Jam Minaret', SPACH newsletter, Issue 6, May 2000, Islamabad, p. 2.

³ Ibid 1.

⁴ SPACH: Society for the Preservation of Afghanistan's Cultural Heritage – HAFO: Helping Afghan farmers organization, NGOs working on conservation of monuments in Afghanistan.

⁵ Jawed, S. 'The Rehabilitation of the Musallah Complex in Herat Begins' Society for the Preservation of Afghanistan's Cultural Heritage (SPACH) newsletter, Issue 7, Jul. 2001, Islamabad, p. 12-13.

⁶ Ibid 1. P. 132.

⁷ Van Eenhooge, D. 'Preliminary Report on the Archaeological Excavations at the Qala-I Ikhtiaruddin and the Madrassah of Sultan Hussein Baiqara, in Herat' UNESCO – UNDP 'Restoration of Monuments in Herat: Strengthening Government's capability for the preservation of Historical Monuments' Technical report, Paris 1981. Pp. 25-26.

⁸ Ibid 4, p.26.

⁹ See Appendix for the explanation about UTM.

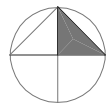
¹⁰ Leica Geosystems AG 'TPS Basic Series: User Manual TCR307', Leica, Heerbrugg 1999. p. 51.

¹¹ Ibid 4. p. 44.



Standpoints: UTM zone 41 S

ST101	639357,000	3807168,000	1905,000
ST102	639619,825	3807243,662	1901,935
ST103	639303,970	3807231,762	1903,444



METRIC SURVEY OF
MINARET JAM
CONTEXT MAP

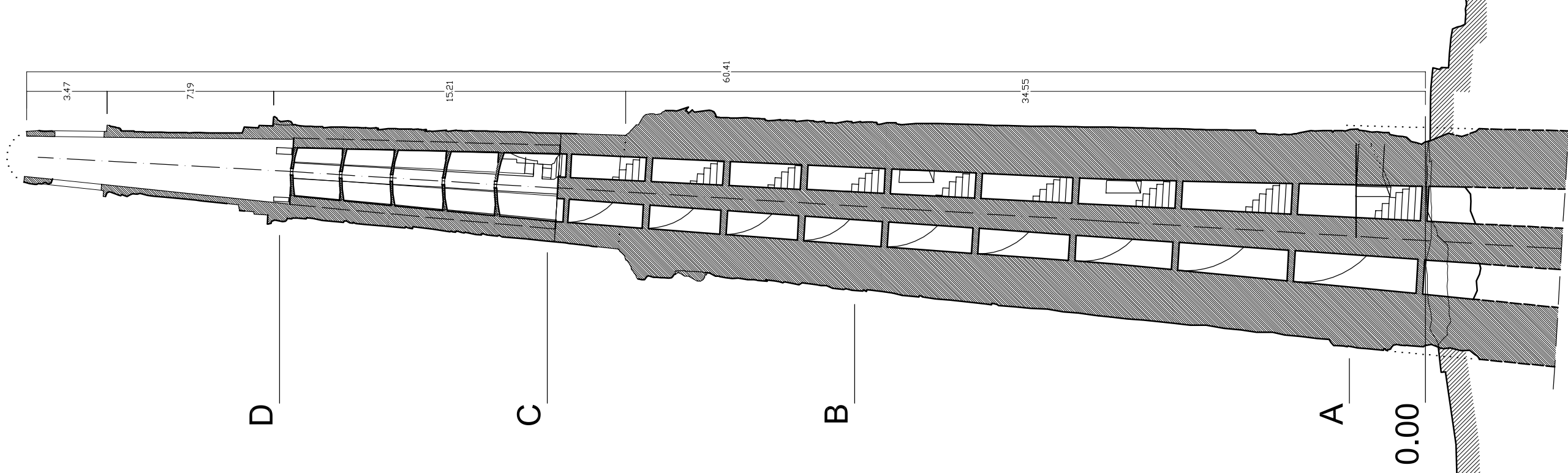
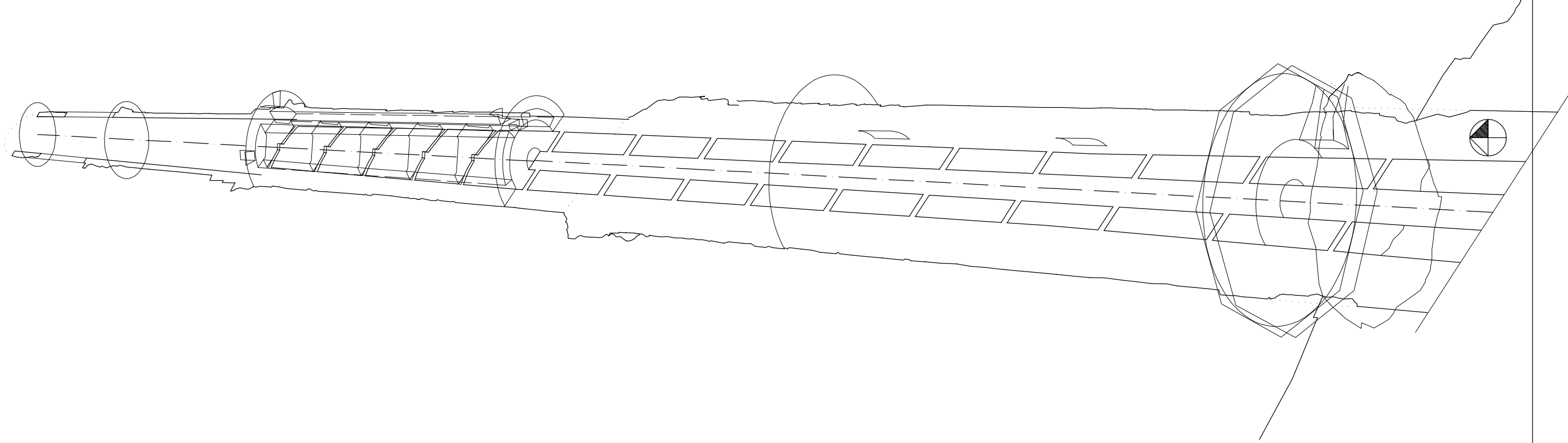
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METRIC SURVEY OF
MINARET JAM
VERTICAL SECTION

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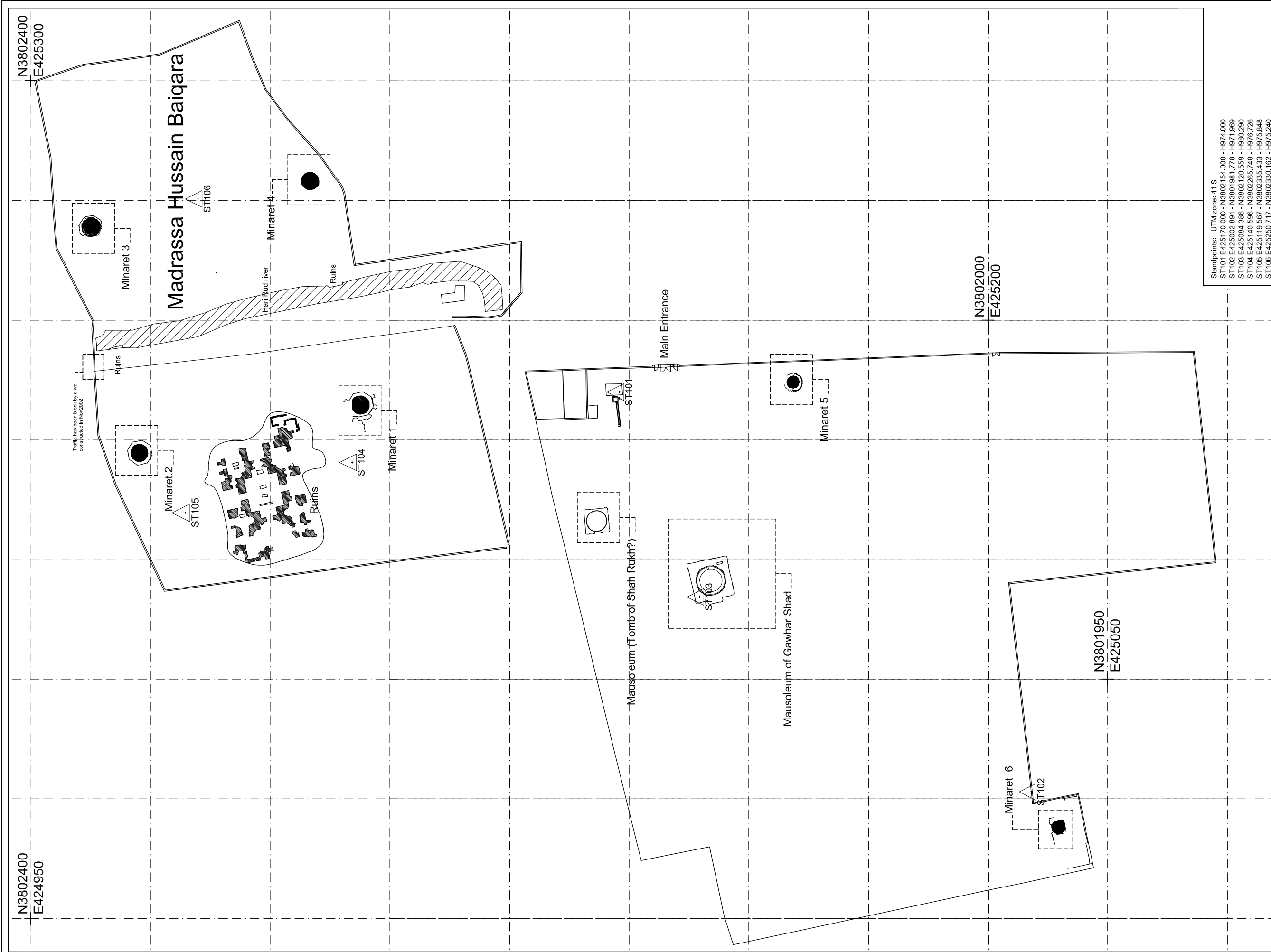
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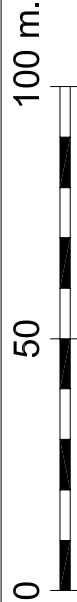
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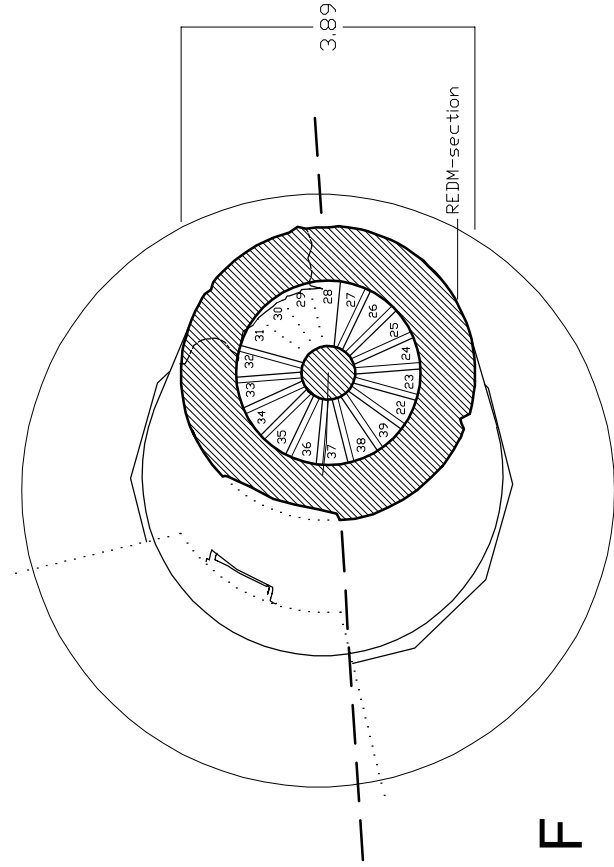


METRIC SURVEY OF
MUSSALAH COMPLEX HERAT
CONTEXT MAP

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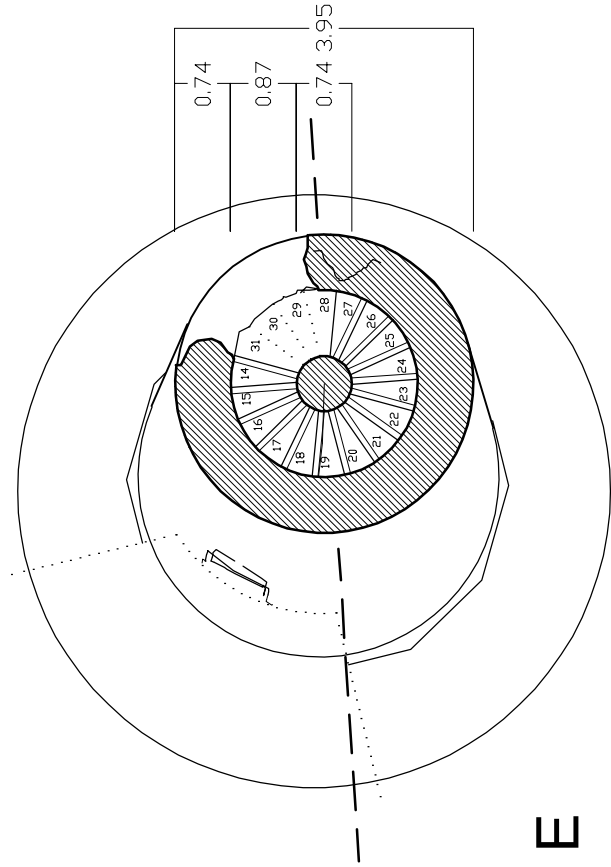
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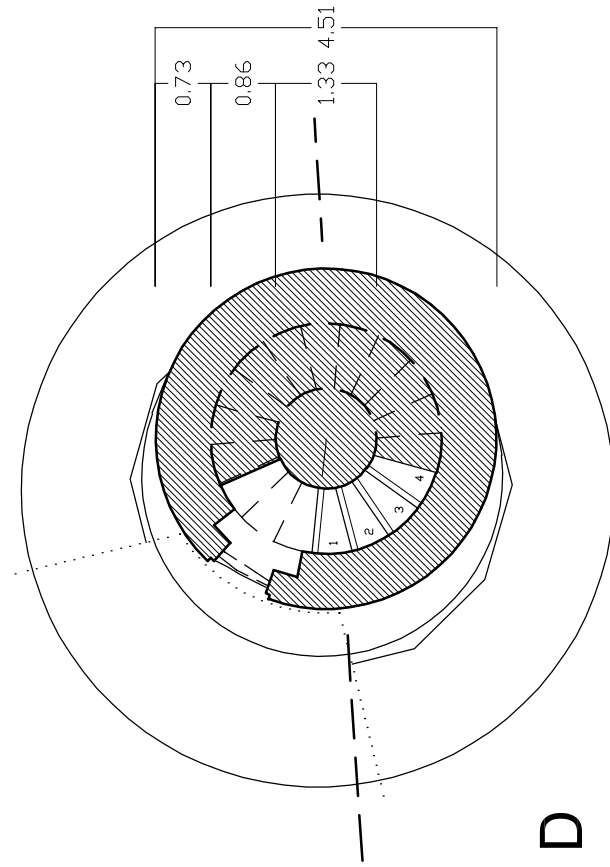
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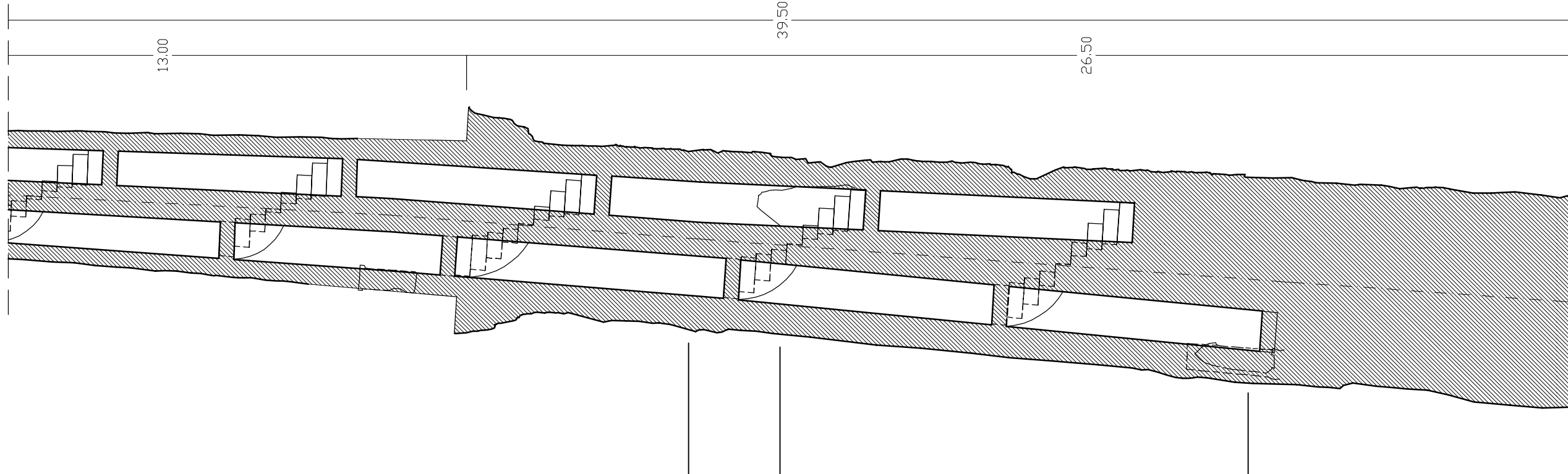
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D

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Relative height:
10.00



MUSSALAH COMPLEX HERAT
MINARET 5 SECTIONS

METRIC SURVEY OF

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08

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