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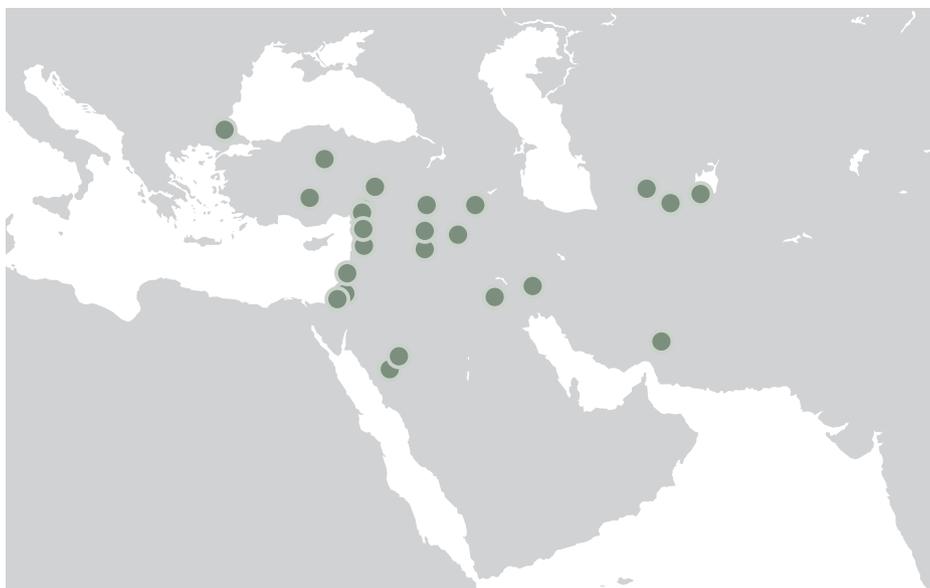
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## WESTERN AND CENTRAL ASIA

### Satellite Imagery for the Study of Conservation and Restoration of Earthen Architecture



Research Carried Out between July and September 2022

**Orient Department of the German Archaeological Institute**

by Luca Volpi



e-FORSCHUNGSBERICHTE DES DAI 2023 · Faszikel 2

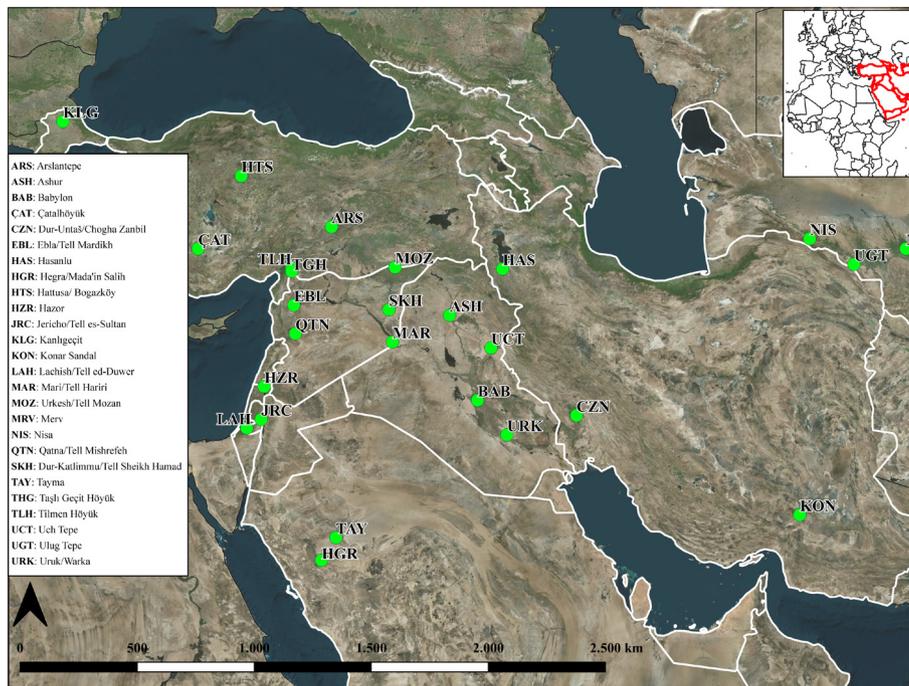
*Die Konservierung und Restaurierung archäologischer Lehmbauten in den Ländern West- und Zentralasiens ist eine kritische, aber schwierige Aufgabe, weil Lehmbauten zum Verfall neigen, sobald sie der Witterung und anderen Zerfallserscheinungen ausgesetzt sind. In diesem Beitrag wird eine vergleichende Analyse der in diesem Gebiet angewandten Praktiken unter Verwendung von satellitengestützten Umwelt- und Klimadaten über Niederschlag, Schnee- und Eisbedeckung sowie durchschnittliche Tages- und Nachttemperaturen auf der Landoberfläche vorgenommen. Ziel ist es, einen Ansatz vorzuschlagen, der es ermöglicht, die verschiedenen angewandten Verfahren und ihre Wirksamkeit auf der Grundlage verschiedener Klima- und Umweltelemente zu vergleichen.*

*Conservation and restoration of archaeological earthen architecture in the countries of Western and Central Asia is critical but challenging due to the tendency of earthen architecture to deteriorate once exposed to weathering and other decay agents. The paper presents a comparative analysis of the*

**Cooperation partner:** Sapienza Università di Roma.

**Financial support:** DAI Research Scholarship 2022.

**Head of project:** L. Volpi.



1 Countries of Western and Central Asia with location of selected sites. (Basemap: Bing Satellite; Elaboration: Luca Volpi)

practices carried out in the area, with the use of satellite environmental and climatic data about rainfall, snow-ice cover, and average land surface temperature data for day and night. The aim is to propose an approach that gives the opportunity to compare the different practices employed and their effectiveness on the basis of various climatic and environmental elements.

### Introduction

- 1 The research investigates the conservation and restoration practices carried out for archaeological earthen architectures in [Western Asia](#) <sup>↗</sup> and [Central Asia](#) <sup>↗</sup> from a comparative perspective (Fig. 1).
- 2 In the area under investigation, archaeological sites are mainly composed of earthen architecture. This is a peculiarity of the environment: the presence of important river basins participates in creating an environment rich in mud and clay. Its widespread presence, together with its cost-effectiveness, has made clay one of the main construction materials in the area nowadays (in contrast to concrete). In antiquity, in places where the presence of stone was effective, earthen masonries were mainly used for the elevation of the walls (stones were used in foundations). Where the environment did not attest to the presence of local stones, e. g. in ancient Mesopotamia (modern-day southern Iraq), unbaked earthen architecture was the main construction technique. The earthen architecture was also in use when the tradition of baked bricks was established.

### Ethical and Philosophical Aspects

- 3 Earth is a weak material that has always been used with the idea of constant maintenance and repair. It has inherent in its nature the difficulty of being restored according to modern practices used on other types of materials (stone, concrete, etc.). Therefore, the conservation of earthen architectures is challenging due to their tendency to decay within a short time once exposed to atmospheric agents (rain, snow, and wind). Other factors may participate in the decay of earthen structures, e. g. moisture, clay salinisation, the wet-dry cycle, as well as roots, animals, fungi, and human activities.



2 Tayma, Saudi Arabia. Examples of conservation and restoration techniques: Backfilling. (Photo: Hausleiter 2018, Fig. 8)

- 4 Archaeologists working in Western and Central Asia have a major responsibility for the management of archaeological remains. Once excavated, the remains of earthen walls are re-exposed to decay agents. How to preserve these remains? Should they be made accessible to the public? Or is the alternative to backfill (Fig. 2) or even let them decay?
- 5 Several ethical and philosophical concerns are beyond those questions. Conservation and restoration interventions should respond (among others) to the following aspects:
- Discernibility: every intervention should be clearly differentiated from the original archaeological structure.
  - Removability: interventions should be (by preference) removable without endangering the structure.
  - Authenticity: interventions that affect the authenticity of the original archaeological structure should be avoided.
  - Immutability: conservation and restoration interventions should not affect or change the characteristics (visual, structural, or physical) of the archaeological architecture.
- 6 Unfortunately, as already pointed out by Chiari in 1990, achieving all these objectives and factual conservation is virtually impossible, and any practice must necessarily make compromises between feasibility and ethical-philosophical aspects:

*Each preservative shows advantages and disadvantages; the perfect treatment has not yet been discovered and probably never will be. Adobe is a weak material that has always been used with the idea of constant maintenance and repair. In most cases, the walls were originally protected by roofs, which are missing in archaeological excavations. One cannot expect to stop the natural evolution and modification of the material. All we can hope to do is to reduce the speed of deterioration [1].*

#### *Conservation and Restoration Strategies in Western and Central Asia*

- 7 Western and Central Asia is characterised by a myriad of dissimilar environments: fluvial basins (i.e., the Euphrates and the Tigris Rivers with their



3a



3b



4a



4b

affluents, the Orontes and the Jordan Rivers, etc.), mountainous areas (such as the Taurus and Zagros Mountains), alluvial plains (e. g. Mesopotamian Plain), deserts (Arabian Desert), coastal zones etc.

- 8 Twenty-six archaeological sites with earthen architectures have been chosen on the basis of the existence of published reports for conservation and restoration works and/or for the presence of detailed scientific analyses carried out on earthen structures.
- 9 In the countries of Western and Central Asia, procedures for earthen archaeological structures are based on four major approaches:
  1. Backfilling (see Fig 2).
  2. The construction of temporary or permanent protective shelters (Fig. 3a. b).
  3. Limited interventions on the structures without using stabilising materials (e. g. encapsulation, capping, filling voids and cracks with mortar, and covering the mudbricks with a plaster made of a lime-clay-straw mixture, Fig. 4a. b).
  4. Interventions on the structures using stabilising materials as a hardener against weathering and other decay agents (Fig. 5).
- 10 The first two approaches consist of indirect, passive interventions that do not directly impact the earthen structure. Backfilling is a preservative method consisting of re-covering the excavated archaeological structure with soil, and it is commonly used in ongoing excavation for protecting the structures from one campaign to another. However, it has its disadvantages in terms of the fruition of the archaeological property. The construction of temporary or permanent protective shelters is another passive, preservative method that does not directly impact the earthen structures but helps in their preservation, especially against weathering. Disadvantages are the following: impact on the landscape from both a structural and a visual point of view; the choice and availability of materials that should be (by preference) local, low-cost, of low impact, and durable; the decay of materials in time; the construction works that can seriously affect and endanger the archaeological structure; the placement of posts that should not affect the archaeological structure or even the underlying stratigraphy.

3 a. Mari, Syria/b. Arslantepe, Türkiye. Examples of conservation and restoration techniques: Protective shelters. (Photo a: Bendakir et al. 2003, Fig. 1; Photo b: Frangipane 2022, Fig. 19)

4 a. Konar Sandal, Iran/b. Area Q of the Western Palace, Ebla, Syria. Examples of conservation and restoration techniques: Interventions without the use of stabilising materials. (Photo a: Dehkordi et al. 2011, Fig. 6; Photo b: Nadali 2023, Fig. 8)



5



6a



6b



7

5 Area Q of the Western Palace, Ebla, Syria. Examples of conservation and restoration techniques: Interventions with the use of stabilising materials. (Photo: Nadali 2023, Fig. 6)

6 a. Kanlıgeçit, Türkiye/b. Hattuša, Türkiye. Examples of conservation and restoration techniques: Integrative reconstruction. (Photo a: Özdoğan 2016, Fig. 2; Photo b: Seeher – Schachner 2014, Fig. 10)

7 Babylon, Iraq. Examples of conservation and restoration techniques: Encapsulation and capping with backed bricks. (Photo: Luca Volpi)

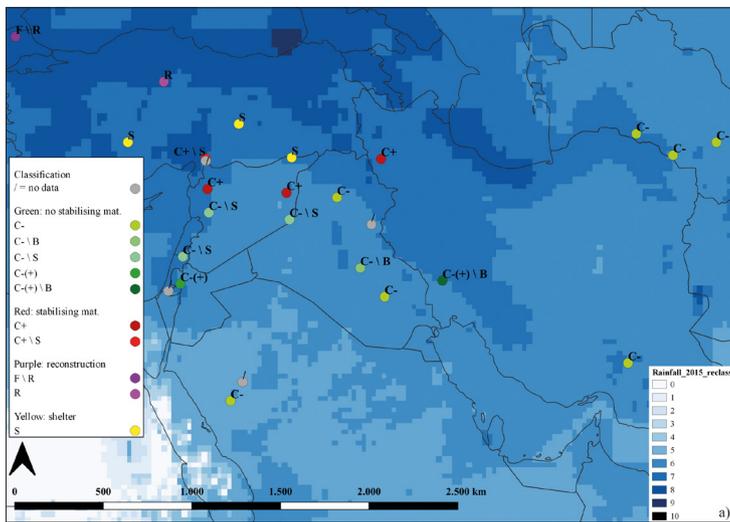
11 The last two approaches consist of direct interventions on the structure. The most widely used procedure to date is the one based on limited interventions without the use of stabilising materials. It is carried out by using local earthen materials, and the new mudbricks are manufactured from the same clay found in the vicinity of the site to be preserved. These interventions appear useful and cost-effective. Maintenance is essential because they require continuous interventions to be effective, i.e. against weathering. These techniques also have the disadvantage of not being applicable when access to the site in question is no longer possible due to external factors. As for the use of stabilising materials, there is debate about the appropriateness of the use of chemical components in earthen architecture. On the one hand, their use as a hardener can be beneficial against weathering and other decay agents; on the other hand, their usage fosters change in the structural composition and stability of the architecture and poses issues related to sustainability and reversibility of interventions. Moreover, chemical components have the risk of being high-cost, hard to find locally, and environmentally unfriendly.

12 There are also two other possibilities, more restricted in terms of use and with several disadvantages, consisting of integrative reconstructions after backfilling (Fig. 6a. b) and encapsulation and capping interventions made with the use of backed bricks (Fig. 7).

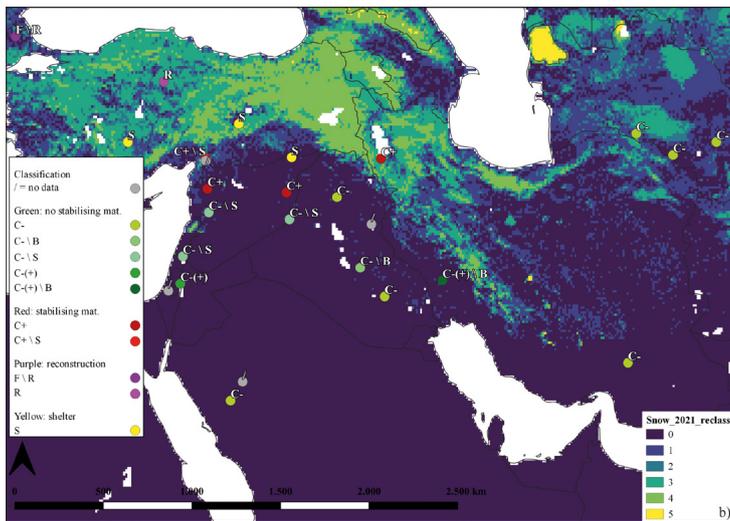
#### *A Comparative Approach Using Satellite Imagery*

13 In order to evaluate the effectiveness of the conservation and restoration practices employed so far in the region and to identify the reasons behind the adoption of one intervention method over another, the research has searched for those elements that would overcome the specific peculiarities of individual sites and allow the solutions adopted to be viewed in a comparative perspective. Satellite environmental and climatic data have been used for this purpose.

14 In the present analysis, I have focused in particular on weathering and wet-dry cycle as decay agents, making use of environmental and climatic data provided by open source by the National Aeronautics and



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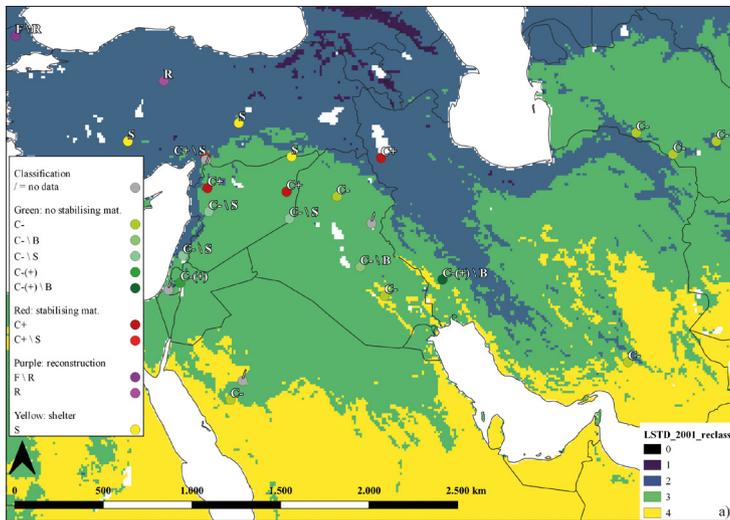
8 Western and Central Asia. Reclassified rainfall map with site classification. (Data: [https://neo.gsfc.nasa.gov/view.php?datasetId=TRMM\\_3B43M&year=2015](https://neo.gsfc.nasa.gov/view.php?datasetId=TRMM_3B43M&year=2015) <sup>↗</sup>, Reclassified map: Luca Volpi)

9 Western and Central Asia. Reclassified snow-ice map with site classification. (Data: [https://neo.gsfc.nasa.gov/view.php?datasetId=MOD10C1\\_M\\_SNOW&year=2021](https://neo.gsfc.nasa.gov/view.php?datasetId=MOD10C1_M_SNOW&year=2021) <sup>↗</sup>, Reclassified map: Luca Volpi)

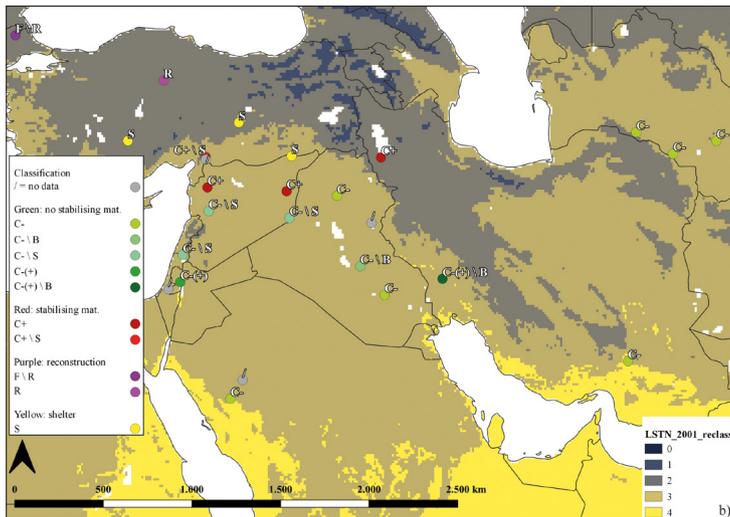
Space Administration (NASA). In particular, **Moderate Resolution Imaging Spectroradiometer (MODIS) data** <sup>↗</sup> have been used as a case study. MODIS is a satellite-based sensor used for earth and climate measurements. The program was launched in 2002 and furnishes images with daily and monthly data. **Rainfall** <sup>↗</sup> and **snow and ice cover images** <sup>↗</sup> have been used for weathering; Average Land Surface Temperature, for **the day** <sup>↗</sup> and **night images** <sup>↗</sup> have been used for wet-dry cycle. One year (as a case study) has been selected for each set of images. Twelve images (each for a single month) have been downloaded; they have been analysed using the open-source software QGIS; they have been merged together, and the value of each cell has been reclassified according to a specific range of values (algorithm GRASS r.reclass) [2]. The analysis has produced four reclassified images that are useful for evaluating the conservation and restoration procedures performed based on the environmental parameters taken into consideration (Fig. 8. 9. 10. 11).

15 Water erosion is one of the most dangerous for earthen structures. The amount and frequency of rainfall during a year is one of the main climatic parameters to be considered (Fig. 8). The selected sites are included in four classes (classes 5–8). The conservation and restoration procedures performed have considered this parameter, considering that where rainfall precipitation is more abundant, various approaches have been used to protect earthen architectures, from backfilling with reconstruction in **Kanlıgeçit** <sup>↗</sup> (KLG) to the use of shelters in **Arslantepe** <sup>↗</sup> (ARS), **Çatalhöyük** <sup>↗</sup> (ÇAT), and Tell Mozan (MOZ), and to the use of stabilising materials, as for example at **Hasanlu** <sup>↗</sup> (HAS), **Tilmen Höyük** <sup>↗</sup> (TLH), and **Ebla** <sup>↗</sup> (EBL). Sites where rainfall precipitation is less frequent, there is a more widespread use of the conservation technique without the use of stabilising materials, as we can see, e. g., in **Mari** <sup>↗</sup> (MAR) and **Uruk** <sup>↗</sup> (URK).

16 Snow is another important parameter among weathering agents (Fig. 9). In most of the selected sites in Western and Central Asia, snow is never attested. However, in the sites where snow is present for one or more months of the year (classes 2 and 3), its presence is dangerous for earthen



10



11

10 Western and Central Asia. Reclassified daily land surface temperature map (LSTD) with site classification. (Data: [https://neo.gsfc.nasa.gov/view.php?datasetId=MOD\\_LSTD\\_CLIM\\_M](https://neo.gsfc.nasa.gov/view.php?datasetId=MOD_LSTD_CLIM_M) <sup>?</sup>, Reclassified map: Luca Volpi)

11 Western and Central Asia. Reclassified nightly land surface temperature map (LSTN) with site classification. (Data: [https://neo.gsfc.nasa.gov/view.php?datasetId=MOD\\_LSTN\\_CLIM\\_M](https://neo.gsfc.nasa.gov/view.php?datasetId=MOD_LSTN_CLIM_M) <sup>?</sup>, Reclassified map: Luca Volpi)

architecture and has to be handled. In those cases, several solutions have been attempted: sheltering for Arslantepe (ARS) and Çatalhöyük (ÇAT) and using stabilising materials for Hasanlu (HAS). Where snow is rare or not present, there is a higher percentage of cases where it was preferred to proceed without using stabilising materials.

17 In order to parameterise the dry-wet cycle, average land surface temperature data during the day and the night have been used. As for daily land surface temperature (LSTD; Fig. 10), a clear prevalence for interventions without the use of stabilising materials is noted in hotter and dryer places (classes 3 and 4). This is the case with sites like [Hegra](#) <sup>?</sup> (HGR), Uruk (URK), and Konar Sandal (KON). On the contrary, sites where the temperature is colder have been preserved using other approaches, as attested for class 2 sites such as Kanlıgeçit (KLG), [Hattusa](#) <sup>?</sup> (HTS), and Hasanlu (HAS).

18 A similar pattern emerges from the analysis of nightly land surface temperature (LSTN; Fig. 11). Sites belonging to class 2 have been variously approached: sheltering, integrative restorations, and conservations with the use of stabilising materials.

### Discussion and Future Perspectives

19 The examination of local aspects of the environment has always been pivotal in the selection of conservation and restoration methods for earthen architecture. Weathering, moisture, clay salinisation, and wet-dry cycle were analysed in detail for the specific areas where conservation and restoration works were carried out from time to time. On the other hand, some environmental and climatic conditions may be considered similar for several sites in Western and Central Asia.

20 An attempt to parametrise environmental and climatic data has been made. The aim is to propose an approach that gives the opportunity to compare conservation and restoration practices and their effectiveness on a larger scale and precisely based on various climatic and environmental elements. The data demonstrates a clear relationship between conservation/restoration interventions and environmental/

climatic data. The choice between passive (backfilling and protective shelters) and active (encapsulation, capping, plaster covering, etc., with or without the use of stabilising materials) interventions has its roots in this relationship.

- 21 Future perspectives include the use of other sets of data and satellite images (e. g. the one furnished by VIIRS – Visible Infrared Imager-Radiometer Suite program), as well as the use of sets of data for various years, in order to also evaluate the effect of climate change through time and its possible impact on conservation and restoration interventions performed in Western and Central Asia.

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*Endnotes*

[1] Chiari 1990, 267.

[2] Software: QGIS (version 3.16.14). Algorithm GRASS r.reclass with the following rules: Rainfall: 0 = 0; 1–50 = 1; 51–100 = 2; 101–500 = 3; 501–2000 = 4; 2001–3059 = 5; 3060 = null; snow-ice: 0 = 0; 1–40 = 1; 41–200 = 2; 201–500 = 3; 501–1000 = 4; 1001–1500 = 5; 1501–2000 = 6; 2001–2500 = 7; 2501–3059 = 8; 3060 = null; LSTD: 0–800 = 0; 801–1500 = 1; 1501–2300 = 2; 2301–2700 = 3; 2701–3059 = 4; 3060 = null; LSTN: 0–500 = 0; 501–1000 = 1; 1001–1500 = 2; 1501–2000 = 3; 2001–3059 = 4; 3060 = null.



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