Digitally Reconstructing the Past: Mapping the Historical Water Storage Structures at Gwalior Fort using GIS-based Inventories

Richa Mishra[1*], Harshita Mishra[2], S.S. Jadon[3], Akash Meena[4]

[1]Assistant Professor, Madhav Institute of Technology & Science, Gwalior
[2] Assistant Professor, Madhav Institute of Technology & Science, Gwalior
[3] Professor, Madhav Institute of Technology & Science, Gwalior
[4] Student 3rd Year, Madhav Institute of Technology & Science, Gwalior
[*]Corresponding Author: ar.richamishra01@gmail.com

Abstract— Gwalior Fort is one of the known examples for its Architectural as well as engineering interventions, one of its significant marvels is water management, including an extensive system of water collection and storage through a network of tanks, Baolis, wells, reservoirs, etc. This paper aims to use Geographic Information Systems (GIS) as a tool to develop heritage inventories which could help decision-makers in the cultural significance of these structures. The site visit was conducted to collect the required data and further GIS techniques adopted to achieve the objectives. The paper structure first highlights the historical significance of the study area and how water management evolved over a period of time through primary and secondary data. Looking at the present scenario these structures have lost their importance and their functionality has declined to leave behind them as a tourism element. With the help of GIS, their spatial context could be understood along with architectural, historical, social, and cultural significance. The paper depicts the results which will include a study area map with prominent structures and associated attributes that may be an efficient tool in Heritage management. The paper concludes by highlighting the potential for GIS technology to be used in future research on historical sites and structures.
Keywords— GIS, Heritage Inventories, Water storage structures, Gwalior Fort

INTRODUCTION

1.1 Background of the Study

The integration of Geographic Information Systems (GIS), Remote Sensing, and modeling technologies have become increasingly important in recent years, providing decision-makers with a crucial tool for analyzing spatial data and developing management strategies for the preservation and protection of cultural heritage sites (Droj, 2010).

GIS can prove to be a powerful tool for the inventory and mapping of heritage sites and facilitates the identification, documentation, and conservation of cultural heritage. GIS-based inventories can provide detailed information about the existing conditions and determine the values/ significance of these structures which may help prioritize their protection measures as per the present conditions and determine the level of interventions. This information can help heritage managers develop effective conservation and management plans that consider the water structures' importance and sustenance to the site's heritage.

Gwalior Fort, located in the state of Madhya Pradesh, India, is a significant historical monument that has played a crucial role in the history of India. The fort has witnessed the rules of the Gupta, Hunas, Pratihars, Kachhwahas, Tomars, Pathans, Mughals, English, and Marathas who have left their significant landmarks (Archaeological Survey of India, n.d.).

One such landmark includes its effective Water management system which has also addressed various cultural diversities. To better understand the evolution and management of this complex site, a GIS-based inventory was created to explore the Historic Water management system.

Through the case of the water structures of Gwalior Fort, the possibility of GIS-based inventories has been explored to manage and

preserve cultural heritage over the traditional inventory procedure.

1.2 Objectives

Objective 1: To create a comprehensive inventory of the historical water storage structures at Gwalior Fort using the GIS tool by adding attributes related to location, age, capacity, present status, associated values, and conservation needs.

Objective 2: To digitally document the historical water storage structures using GIS, thus contributing to the documentation and preservation of cultural heritage and also analyzing the historical, social, and cultural significance of the water storage structures in the context of the fort's history.

Objective 3: To leverage the information collected through GIS-based inventories of the historical water storage structures at Gwalior Fort for effective management.

METHODOLOGY

2.1 Primary Data Collection

The site visit was conducted to collect tangible data for the documentation of water structures and intangible data through stakeholder interviews.

After having a basic idea about the site context through a literature study, the site visit was conducted to have an insight into the water structures to be listed. A set of structured questionnaires has been made for the collection of on-site data to develop digital inventories.

For understanding the current usage and maintenance status of water structures a qualitative survey for different stakeholders has been conducted through open-ended questionnaires. The stakeholders identified to extract such data were local tourist guides, management staff, and residents living in site proximity for ages.

2.2 Secondary Data Collection

The historic books and maps (**Error! Reference source not found.**) were collected from the local library and museums. Historical and cultural significance has been referred from the Archeological Survey of India published reports. The historic text has also helped in identifying the quantitative data (like, year of construction, dimensions, reconstruction if occurred, etc.) of targeted water structures.

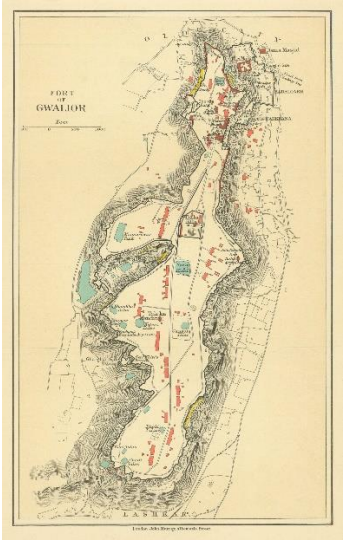

Figure 1 Historic Map of Study Area (Gwalior Fort), *(Murray, 1911)*

2.3 Base Map Preparation

GIS tool has been used to synthesize data on a single platform, accordingly, the base map of the study area is created through Google imagery and later the historical map of the study area has been georeferenced to have the location of water structures. The site contours at the interval of five meters have been extracted from the digital elevation model (DEM). The road networks have been taken from the open street map. The neighboring built-up of fort water structures have been marked within the study area to understand their influence and dependency on the water structures.

2.4 Making Digital Inventories

Through GIS all the collected data were synthesized on a single platform. To achieve that the questionnaires and survey forms provide all the available information for each water structure and were converted into digital format i.e. excel format. This file shows the inventories which are ultimately linked with the spatial dataset on GIS in the form of attributes. The attributes listed

below have been incorporated for water structure inventories-

- Historic name of Water structure
- Typology (tanks, baolis, wells, reservoirs, etc)
- Water source (runoff, groundwater recharge)
- Age
- Indigenous/New
- Dimension
- Construction Material
- Current condition
- Significance/Relevance
- Associated Values
- Grading/Prioritization

LITERATURE REVIEW

3.1 About the Site

Gwalior Fort is a hill fort measuring about 3 km long and 1 km wide, measuring about 3 square km located in Madhya Pradesh at a latitude and longitude of 26.2313° N, and 78.1695° E respectively. The fortress is rich in cultural heritage including Palaces, temples, water structures, etc.

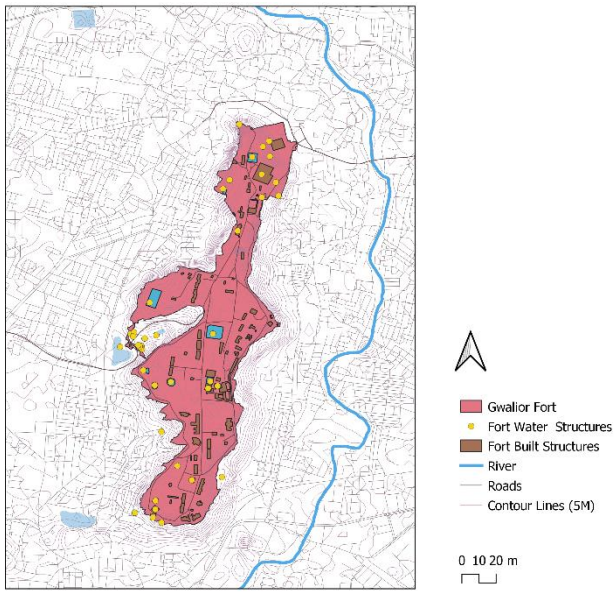

Figure 2 Study Area Map (Gwalior Fort) with water Structures

Figure *2* above represents the base map of the study area which has been generated on QGIS. The map represents the road network which is connecting the city to the fort complex, along with other details of the fort complex like buildings (fort-built structures), water bodies of all typologies (fort water structures), and others.

3.2 Existing Literature and Secondary data

Gwalior Fort lies at an elevated citadel that rises to a height of around 100 meters where a network of natural and manmade water sources was integrated to collect, store and supply the water demands of the fortress. Varied water heritage structures here include structures for water collection and structures for water storage. The water-collecting structures are composed of Taals (which serve as a catchment area that collects rainwater), Baolis (step-wells that store the rainwater), and Kunds (small reservoirs that collect water). The water storage structures include Tanks and Baolis.

The Fort has witnessed various reigns which have also evolved its water management system in terms of functionality as well as in terms of social, political, and cultural events. Gwalior's fort has been successful in terms of water supply because in historic times no enemy could ever capture it due to lack of water, its reservoirs are of adequate size and do not dry up even in extreme heat, and water supply in times of crisis.

For the management of water on the Gwalior Fort, ponds and step-wells were constructed so that the water requirements of the residents of the fort, members of the royal family, and soldiers could be met throughout the year (Batham, 2016).

The various water structures explored during the research includes about 39 water bodies including Gujari Baoli, Assi Khamba, Dhondha Baoli/Ek ankh ki Baoli, Shrad anar, Gargaj Baoli, Suraj Kund, Trikoniya taal, Johar Taal, Shah Jahan Taal, Mansarover taal, Rani Taal / Cheri Taal, Gangola Taal, Katora Taal, Ek Khamba Taal, Dhobi Taal, Noori Sagar, Saas Bahu Taal, Ek Pathar ki Baoli, Laxman Talaiya, wells, etc. which were mapped and laid based on various attributes like Location, Historic name of Water structure, Typology (tanks, baolis, wells, kunds, reservoirs, etc), Water source, Age, Indigenous/New, Dimension, Construction Material, Current condition, Significance, Associated values, and Grading.

These mentioned water structures have not only served the water needs of the population but have also contributed to shaping historical, cultural, political, scientific, architectural, and religious significance. Few water structures are discussed highlighting their value and significance.

a) Suraj Taal: The Suraj Kund, the solar reservoir, is an important historical and cultural structure in Gwalior. It is the earliest tank in the city, measuring 350 ft. x 150 ft., and was dedicated to the all-purifying sun by Sürajpál, who was cured of leprosy after drinking from its bed. The temple of Surya, located on the west bank of the tank, is a testament to the religious significance of the structure. Additionally, the large fair held at this place every year on the last Sunday of Kartik showcases the cultural importance of the Suraj Kund. (Chakravarty, 1984)

b) Gujari Baoli: The Gujari Baori is a small deep tank with steps down to the water's edge about 80 feet long by 30 feet broad. It is situated at the foot of the cliff in the Gujari Mahal outwork (Cunningham, 2000). Its historical significance lies in the fact that the establishment of this baoli was due to the water source which was to come from Rai village through canals and drains for Mansingh Tomar's beloved wife Mrignayani. (Dr. Shanti Dev Sisodhiya, 2016)

c) Johar Taal: Johara Talao is a 200-foot square tank situated at the north end of the fort, named after the Johar sacrifice performed by the females of the garrison when the fortress was captured by Altamsh in A.D. 1232. It holds historical significance for the sacrifice and the events surrounding the capture of the fort. (Cunningham, 2000)

d) Ek Pathar Ki baoli: The rock-cut Jain caves in Gwalior fort were built by Tomar rulers and consisted of 24 caves and a stone stepwell, showcasing the religious significance of Jainism in the region during that time. (Dr. Shanti Dev Sisodhiya, 2016)

e) Assi Khamba Baoli: There are three different parts of this Baoli, which there are doors, pillars, and steps. Large stones have been used in its construction. The doors are made in Mughal style and the building is mandapnuma which is dependent on the pillars. The number of pillars in the mandap is about 80, which is why it is called Assi Khamba. According to popular legends, at the time of Rajamansingh, this construction was a Shiva temple, in which he used to worship Shiva in the morning. On one side of the building, there is a stone stepwell in which stairs have been constructed to go inside. The water in the stepwell does not dry up even in summer and probably its water was used for drinking purposes. (Dr. Shanti Dev Sisodhiya, 2016)

f) Shard Anar Baoli, is constructed by making a small arched entrance in Sharad and Anar Baoli, a square tank has been made by cutting it inside the hill, in length, width, and depth. Its roof is based on pillars cut into the hill (Batham, 2016) significantly demonstrating the procedure of rainwater harvesting, water filtration, and the collection of clean water into the stepwell.

g) Man-Sarovar: This lake is in the west part of the fort and near Urvahi Gate. It is said that the lake is built by Tomar Raja Mansingh Sir from 1486 to 1516. It is believed that the stones for the building of various monuments have been drugged, shaping this area as a pond that came to be known as Mansarovar. (Batham, 2016)

3.3 Heritage management through GIS Based Inventories

Heritage Protection and management is a complex issue in a country like India, catering to varied typologies and scales of heritage, and varied social, political, geographical, and cultural circumstances. Heritage inventory may emerge as an important tool in Heritage Management. It may include the Identification, Location, Boundary, physical features, functions, present conditions, and value as well as in prioritization which may be helpful in decision-making related to conservation and management (Shah, 2016). GIS may emerge as a tool to protect and manage all typologies of heritage under one umbrella so that the overall layers can be looked upon

together as well as in isolation for efficient decision-making.

It can offer a variety of features including automated cartography display, historic property characterization and inventory, past landscape visualization and view sheds, impact assessment, and predictive modeling, etc (Limp, 1999). In terms of heritage protection, GIS can provide the following benefits over regular inventories accessibility and dissemination of information, efficient and accurate map storage and updating, Monitoring and risk preparedness, Site maintenance, and preservation plan and analysis (Hardy, 1997).

The paper covers the listing of water structures and linking inventories spatially through GIS. Figure 3 attached below shows the attribute table linked to each listed water structure.

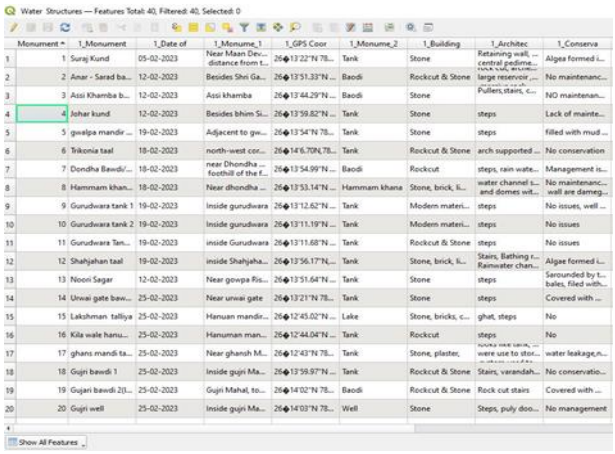

Figure 3 GIS Atributte table showing Inventories

RESULTS

Our analysis of the historical water management system at Gwalior Fort revealed several key findings.

First, we were able to identify the location and spread of water resources throughout the fort. We found that there were numerous natural springs and wells as well as numerous manmade baolis, tanks, kunds, etc. located throughout the fort, which were used to supply water to different areas within the fort complex. Visualization of the overall Historic water landscape could be done through the produced maps.

Second, we analyzed the water network designed to supply water to different areas of the fort, including the palaces, temples, and residential areas as per the distribution pattern. Thirdly, the current conditions were explored as compared to the historic maps for clear demarcation of shrinkage of existing water bodies and the evolution of newer ones. As a result, it has been the observation that the water structure footprint does not look much changed compared to that of historical data. Also, the current conditions give a fair idea of the functionality and level of interventions required for protection and management. In most cases, the water is covered by a layer of algae and the structures are facing deterioration. If the water harvesting channels could be revived, it may ensure clean water.

Finally, we determined that the water system had a significant impact on the fort's development over the centuries, and GIS can be an effective tool for its management and sustenance as varied stakeholders are involved in its protection. The produced set of inventories can be updated and maintained centrally, with ASI and other stakeholders. A centralized monitoring system can help in effective and collective decision-making for the protection and management of the site as well as visitors. The status of heritage could be monitored.

Through GIS we have synthesized all the above points on a single platform. The collected data has been converted to excel format (inventories) which is ultimately linked with the spatial dataset on GIS. Kindly refer to the GIS map (Figure 4) mentioned below showing the typology of structures. With the help of GIS, the collected inventories (example-typology) have been marked on actual location/coordinates.

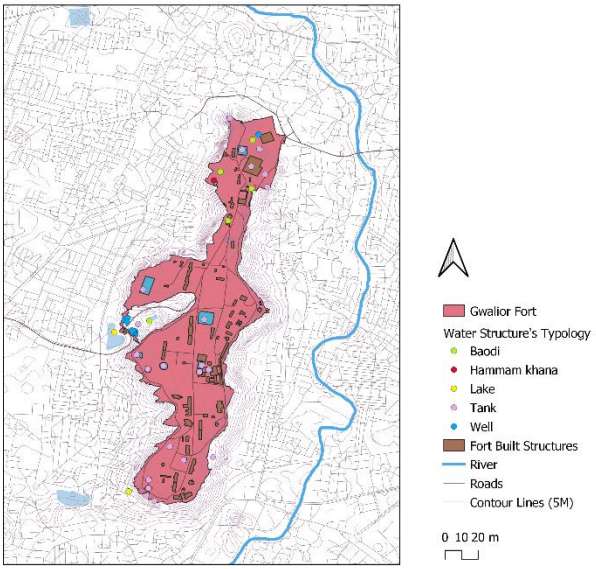

Figure 4 Map showing different Typology of water structures

Similarly, Figure 5 and Figure 6 depict the used construction material for each water structure and the status of restoration or reconstruction that occurred in the past for each water structure within the fort complex respectively.

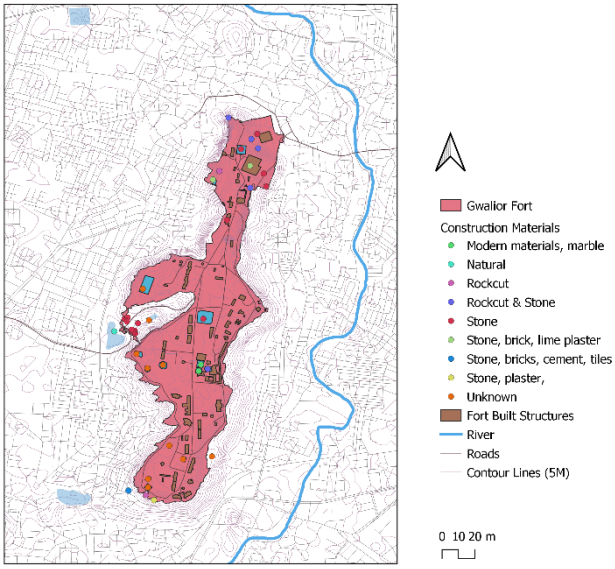

Figure 5 Map showing construction material used per water structure

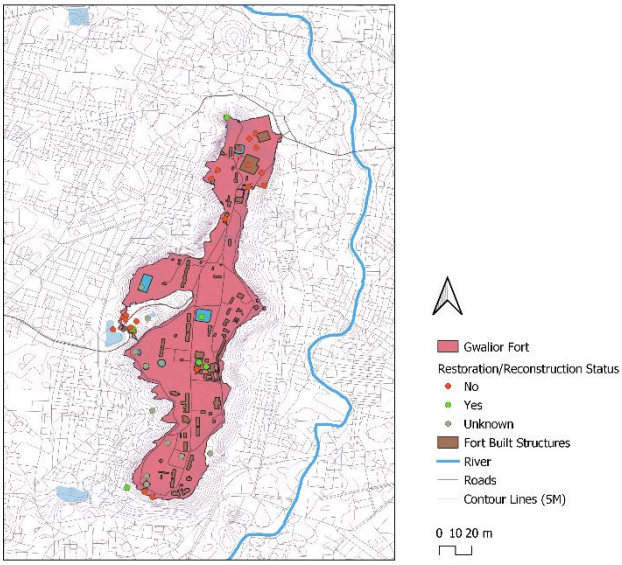

Figure 6 Map showing the restoration/reconstruction status of water structures

Thus various attributes could be analyzed and help in coming up- with effective actions and measures to protect and conserve historic structures by helping the decision-making process.

CONCLUSION

In conclusion, our research demonstrates the potential of GIS technology for mapping and analyzing historical water management systems. Our analysis of the historical water management system at Gwalior Fort provides new insights into the fort's history and highlights the importance of water management in ancient times. Our findings also demonstrate the potential for GIS technology to be used in future research on historical sites and structures.

According to (M.G. Masciotta, 2019), for effective Conservation and monitoring of cultural heritage, integrated documentation is crucial to support decision-making processes for preventive conservation purposes as well as for accessibility and longevity of the information. Digital Tools like G.I.S may prove beneficial in implementing such integrated decision-making.

Overall, this paper demonstrates the value of GIS as a tool for reconstructing and analyzing the past, and for informing the management and conservation of historic water storage structures.

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