# *THE SPATIAL ANALYSIS OF AN HISTORICAL PHENOMENON: USING GIS TO DEMONSTRATE THE STRATEGIC PLACEMENT OF THE UMAYYAD "DESERT PALACES."*

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by

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I dedicate this dissertation to my mother, father and to my country.

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**ABSTRAK**

Istana Umaiyah adalah merupakan struktur binaan peringatan yang telah dibina semasa pemerintahan Khalifah Islam yang pertama. Struktur binaan ini dianggap oleh kebanyakan pengkaji sejarah termasuk Cresswell (1969), Hilllenbrand (1982), Bisheh (1985 dan 1998) sebagai sebuah *Istana Percutian* atau *Istana Persinggahan* untuk aktiviti memburu binatang. Namun sesetengah pengkaji masa kini mula memberi hujah bahawa struktur binaan yang unik ini sebenarnya adalah merupakan campurtangan strategik manusia ke atas landskap (Addison 2000, Almagro 1992, Arce 2008, King 1992). Pusat-pusat pentadbiran utama pada zaman tersebut ialah bandar Kufa, Madina dan Damascus. Bandar Damascus adalah merupakan pusat pentadbiran Khalifah Umaiyah. Oleh yang demikian Khalifah Umaiyah mempunyai sebab yang munasabah untuk menjaga dan memantau dengan rapi laluan menghala ke bandar Damascus tersebut daripada pesaing-pesaing lain iaitu pusat-pusat pemerintahan yang terdapat pada ketika itu. Dapat disimpulkan di sini bahawa hujah-hujah yang disebutkan tadi akan menjadi lebih mantap dan teguh jika dapat ditunjukkan dalam bentuk hubungan ruangan yang diwakilkan melalui analisis sistem maklumat geografi (GIS).

Sehingga kini, ahli sejarah sangat bergantung kepada analisis tekstual, seni bina dan sejarah-sastera istana bagi memahami seni bina zaman Umaiyah. Perbincangan dalam kajian ini menggunakan hujah analisis ruangan sebagai membuka lembaran dan satu dimensi baru. Dalam menggunakan analisis ruangan, struktur binaan tidak dlilihat sebagai satu unit arkiologi yang

berasingan tetapi dilihat sebagai satu sistem secara menyeluruh. Sistem maklumat geografi (GIS) telah mula digunakan dalam bidang sains sosial, alam sekitar, dan juga kejuruteraan. Penghujahan permasalahan kajian dalam penyelidikan ini menggunakan GIS sebagai pembuka ruang kepada bidang kajian kemanusiaan.

Kajian ini menyatakan bahawa *Istana Umaiyah* dibina secara strategik di kawasan sumber air bagi memantau laluan pergerakan penduduk di dalam kalangan pusat-pusat sosio-politik pada zaman itu.

Objektif kajian ini ialah untuk membina pangkalan data geografi dan peta digital *Istana Umaiyah* dalam konteks geografi dan untuk membuat analisis kesalingnampakan (visual) dan analisis ruangan ke atas taburan istana-istana tersebut.

Kajian ini merumuskan bahawa terdapat bentuk yang signifikan di dalam taburan lokasi *Istana-Istana Umaiyah*, kedapatan garisan komunikasi kesalingnampakan yang tidak terhalang di antara setiap istana dengan istana kejiranan puak berhampiran yang terletak di bahagian barat *Harrah* dan wujud perhubungan yang boleh dikirakan di antara istana dan sumber air dan laluan perdagangan. Taburan sedemikian menunjukkan bahawa lokasi istana mempunyai kedudukan yang strategik.

Kaedah yang digunakan di dalam kajian ini bermula dengan membangunkan pangkalan data dan peta digital. Ia disusuli dengan menguji kesalingnampakan antara istana, menjalankan analisis kedekatan dan penilaian quadrant.

Penemuan kajian menunjukkan bahawa *Istana-Istana Umaiyah* telah dibina dengan teliti pada kedudukan laluan pergerakan manusia dan di lembangan sumber air. Corak taburan *Istana-Istana Umaiyah*, berkelompok di outlet Wadi_Sarhan, wujud komunikasi garisan kesalingnampakan di antara *Azraq, Amra, Haranah, Muwaqqar, Umm Awlaid, Mushatta, dan Qastal,* dan terdapat assosiasi positif di antara *Istana-Istana Umaiyah* dan lembangan sumber bekalan air. Penemuan kajian menunjukkan bahawa dengan menggunakan sistem maklumat geografi (GIS) dan analisis ruangan hasil kajian adalah selaras dan menyokong hujah dan pandangan yang dibuat oleh Addison, Almagro, Arce and King seperti yang dinyatakan sebelum ini.

# ABSTRACT

The Umayyad qusour are monumental structures built during the reign of the first caliphate of Islam. The Umayyad qusour are usually dismissed as "pleasure palaces" or "hunting lodges," even by prominent scholars (e.g., Cresswell 1969; Hilllenbrand 1982; Bisheh 1985, 1998). Some scholars of the period are, however, beginning to argue that these prominent structures were strategic interventions in the landscape (Addison 2000, Almagro 1992, Arce 2008, King 1992). The major political centers of the time were Kufa, Madina and Damascus. Damascus was the center of the Umayyad caliphate. Kufa and Madina were the centers of opposition to the Umayyads. Therefore the Umayyad caliphs had good reason to monitor carefully the routes which led to Damascus from these rival political centers. The argument summarized above becomes much more powerful when these spatial relationships are represented and analyzed in GIS.

Until now, historians have relied mainly on textual, architectural and art-historical analyses of the qusour in order to understand Umayyad state architecture. This argument uses spatial analysis to lend a new dimension to the discussion. Using spatial analysis the structures are treated not as individual archaeological exempla, but as a system. GIS has typically been employed for the social sciences, environmental and engineering disciplines. This argument uses GIS to shed light on a research problem in the humanities.

This argues that the Umayyad qusour were built strategically at perennial water sources in order to monitor routes of transhumance amongst the socio-political centers of the period. The objectives of the study are to construct a geo-database and digital map of the Umayyad qusour in their geographical context and to conduct a visualization and spatial analysis of the distribution of the qusour.

This study suggests that there are significant patterns in the locations of the Umayyad qusour, there is unobstructed line-of-sight communication between each qasr and its neighboring qusour among the group located west of Harrah, and there is a quantifiable relationship between the qusour, perennial water sources, and established trade routes. These patterns suggest strategic placement of the qusour.

Methods used were construction of a geo-database and digital map, a visualization, as well as proximity analysis and quadrant analysis.

The results of the analysis show that Umayyad qusour are carefully situated at routes of transhumance and the water sources. The distribution pattern of the Umayyad qusour is clustered at the out let of Wadi Sarhan, There is actually line-of-sight communication between Azraq, Amra, Haranah, Muwaqqar, Umm al wlaid, Mushatta, and Qastal, and there is a positive association between Umayyad qusour and their water sources. These results derived from GIS and spatial analyses, support the argument of Addison, Almagro, Arce and King.

# CHAPTER ONE

# AN INTRODUCTION

## 1.1 Introduction.

The Umayyad *qusour* are monumental structures built during the reign of the first caliphate of Islam (VIIIth century AD/ I-II century AH). The architectural remains of the qusour are largely found in Jordan, and there are a few in Syria and one on the West Bank. One group of the qusour are referred to, however, as the "Desert Castles of Jordan." They stand out as a group because of their size and elaborate architecture, their concentration in what, today, seems like the deserted arid steppe, and by the fact that they were all constructed with in a 30-year period.

The Umayyad qusour are usually dismissed as "pleasure palaces" or "hunting lodges," even by prominent scholars (e.g., Cresswell 1969; Hilllenbrand 1982; Bisheh 1985, 1998). Some scholars of the period are, however, beginning to argue that these prominent structures were strategic interventions in the landscape (Addison 2000, Almagro 1992, Arce 2008, King 1992). Spatial depiction of the co-occurrence of the qusour, trade/ travel routes and perennial water sources support the notion that the Umayyad dynasty poured resources into building the qusour for highly functional purposes.

The major political centers of the time were Kufa, Madina and Damascus. Damascus was the center of the Umayyad caliphate. Kufa and Madina were the centers of opposition to the Umayyads. Therefore the Umayyad caliphs had good reason to monitor carefully the routes which led to Damascus from these rival political centers.

Furthermore, the Umayyads established a "fast post" or *bari̱d* route between the Hijaz and Damascus There were two routes that the barid took:

Damascus > Busra > `Amman > Ma'an > Tayma;

Damascus > Busra > `Amman > `Azraq > Wadi Sirhan > Jawf

All of these pass through the "screen" of the qusour – and all of them connect water sources.

Thus, if someone wanted to reach Damascus from Kufa or the Hijaz, they would encounter the Umayyad official presence on the way. The Umayyads ensured the security of this network by placing the qusour in control of water sources. In an arid landscape water is power – travel routes are essentially connections between water sources; to control water is to control movement on the landscape.

Most of these relationships between the qusour and their geographical context are only hinted at in the historical sources. The argument summarized above becomes much more powerful when these spatial relationships are represented and analyzed in GIS.

## 1.2 Background of the study.

The Hashemite Kingdom of Jordan is located between the latitudes 29° and 32° north, and between longitude 35° and 39°. It is bounded by the Syrian Republic to the north and Palestine from the west, Saudi Arabia to the south and east, and Iraq to the east. It has an area 89,000.

The capital of Jordan called Amman. The Desert castles consist of a number of minor castles distributed over the desert in Jordan. Most of the remaining castles are located east of the capital Amman.

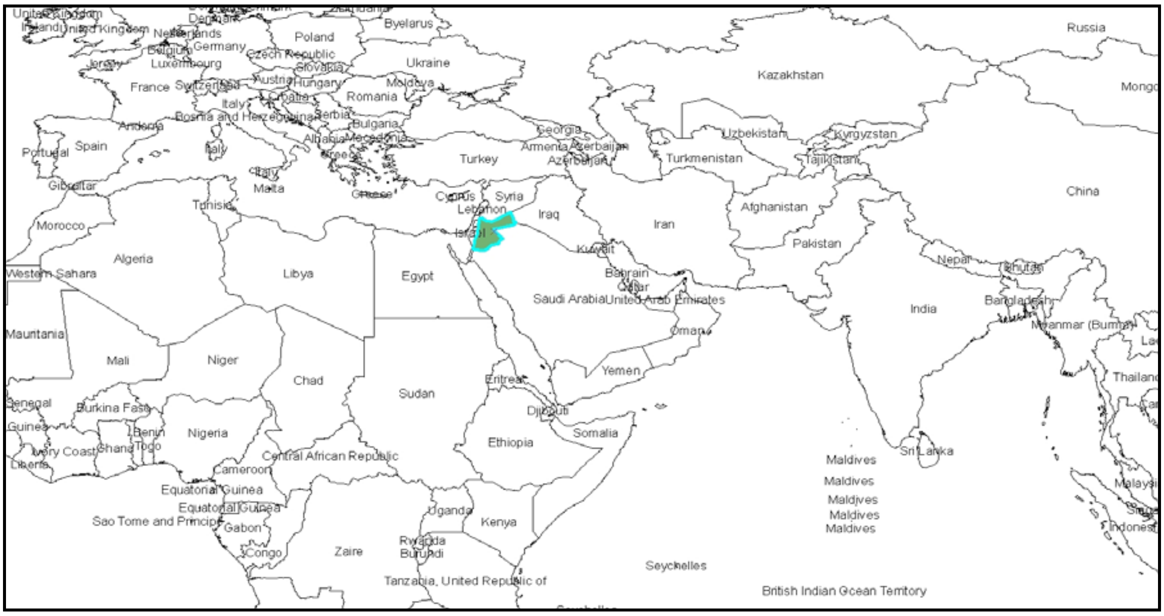

Figure 2.1: Jordan in international context

For thousands of years Wadi Sirhan has been a primary trade route from Arabia into the eastern Mediterranean world (*bilad ash-sham*), because all the way along this low depression in the landscape there are perennial water sources (Parker 1987). At the north northwest end of Wadi Sirhan was the Azraq oasis; at the south end is the oasis of al-Jauf. Travelers would come from Kufa and Madina to al-Jauf, water their animals and stock up with water for the journey, then move up through Wadi Sirhan to `Azraq where they would rest again before continuing the journey (al-Muqaddisi, quoted in Bisheh, 1998).

`Azraq lies at the southern edge of the *harra*, the black basalt desert. This basalt is extremely hot and dry, and impossible to cross on horseback or camel because of the size and dense cover of the basalt stones. There are no significant settlements from the Roman or Islamic periods in the harra, and there are extremely few perennial water sources. Therefore, from `Azraq, the traveler wanting to reach Damascus had two choices: he could go west toward the plateau, to the King's Highway and the Hajj route (`Azraq > `Amman > Busra > Damascus or `Azraq > Al-Hallabat > Busra > Damascus); or he could go northeast around the eastern edge of the harra, then turning west/ southwest to arrive at Damascus. In order to have skirted north of `Amman one would have to pass Al-Hallabat and Umm al-Jimal before reaching Busra (Kennedy, 1983).

Figure 1.2: Harrah.

The placement of the sites becomes especially interesting when one looks at the placement of the qusour in the eastern desert: Tubah, Haranah, Amra, Azraq and Burqu` effectively surround the outlets from Wadi Sirhan in every direction. Moreover, the qusour constructed in Bilad ash-Sham during the Marwanid period *without exception* control a perennial water source. It would have been nearly impossible to reach Damascus from the eastern route without stopping for water at qasr Burqu`, which stands on the very edge of the only perennial water source for hundreds of kilometers (King, 1992).

Wadi Sirhan is the name of a wadi (valley) that runs southeast from the ancient site of Al-Azrak in eastern Jordan that eventually crosses the border into Saudi Arabia and ends at the wells of Maybuu. It is about 140 km in length, and 5-18 kilometers (13-11) miles wide. (*Encyclopedia of Islam)*.


Figure 1.3: Wadi Sirhan.

### 1.2.1 Qasr Tubah & Mushatta.

Qasr Tubah and qasr Mushatta were both built under Walid II ibn Yazid in the mid-700's – at any rate before Walid II died in 744.

They grouped together because they are unusual architecturally - built of mud brick with marble details, rather than limestone – and with much more imaginative structural design – and because they are both the latest Umayyad qusour and both were left unfinished.

Qasr Tubah was probably earlier, because it was more complete when it was abandoned. It sits in the bottom of Wadi Ghadaf, one of the access routes from Wadi Sirhan onto the plateau. Qast Tubah has three enormously deep wells, large pools for watering livestock, and complex water-raising systems unusual for the time period.

It seems likely that qasr Tubah was placed on Wadi Ghadaf late in the construction of the Umayyad system, because as the other qusour were built the traveller would have had to depart from Wadi Sirhan further and further south to escape being detected by the network. Wadi Ghadaf is the latest and southernmost of the network around Wadi Sirhan.

Qasr Mushatta is located on a hill between qasr al-Qastal and qasr al-Muwaqqar, placing it within the line-of-site communication network.

It has at least 30 cisterns associated with it, and seems to have had a system of pools and elaborate pipes – these may have been intended for a bath complex, but we will never know, since the qasr was left unfinished.

It is important to note that the "patrol" network of the Umayyad qusour would be complete without qasr Mushatta.

Figure 1.4: Qasr Tubah.


Figure 1.5: Location of Qasr Tubah and the well at wadi Ghataf.

Figure 1.6: Well of qasr Tuba.

Figure 1.7: Qasr Mushatta.

### 1.2.2 Qasr Haranah.

Haranah is the earliest of the Desert Castles, built in the Sufyanid Umayyad period (between AD 661-685). it is very different in architectural style and function from the other qusour (it is built more like a fortified *khan* than a palace), and it does not have the water infrastructure that the other qusour have.

It was, however, used during the Marwanid Umayyad period (685-750) – we know this because there is a very early Kufic inscription in one of the reception rooms which refers to a governor of the Jund al-Balqa` who served under `Abd al-Malik. It is clear, however, that Haranah was never intended for permanent residence.

What Haranah has shares in common with the Marwanid qusour is its position monitoring a wadi (Wadi Dab3a) which is an outlet from Wadi Sirhan via Wadi Ghadaf. It is also in line-of-sight communication with Muwaqqar, to the east, and Qusayr `Amra's watchtower to the northeast.

Although Haranah was built earlier, it was incorporated into the network of Desert Castles designed by the Marwanid Umayyads.

Figure 1.8: Qasr Harranah.

Figure 1.9: Location of qasr Haranah between two wadis.

### 1.2.3 Qasr Burqu.

We believe that Burqu` was built in 708, because there is an inscription to that effect at the qasr – it was reconstructed and improved from an old Byzantine building. It is built exactly on a lake which is still the only year-round watering place in eastern Jordan for migratory birds. In fact, the northwest-facing wall of the qasr actually disappears into the lake.

It is thought that Walid I built it because it is clearly part of the network patrolling the outlets from Wadi Sirhan, and Walid I was in charge of that region in 708, during his father `Abd al-Malik's reign when Burqu` was built.

Figure 1.10: Qasr Burqu.


Figure 1.11: Location of qasr Burqu at the lake.

### 1.2.4 Qasr Jabal Sais.

There were two water points on the edge of the harra between `Azraq and Damascus: Burqu` and Jabal Sais. Walid ibn `Abd al-Malik (Walid I) seems to have constructed both of them. We believe that Burqu` was built in 708, because there is an inscription to that effect at the qasr – it was reconstructed and improved from an old Byzantine building. Jabal Sais was probably built later – it is an original building constructed in that place on purpose, no doubt to guard the lake. Because of the style of construction, it appears to be later, when the Umayyad buildings took on a typical form. It is thought that Walid I built it because it is clearly part of the network patrolling the outlets from Wadi Sirhan, and Walid I was in charge of that region during his father's reign (when Burqu` -- and probably Jabal Sais) were built.

Notice the volcano just to the left (northwest) of the qasr. Typically the eruption of volcanoes opens springs – cracks and faults which allow underground water to escape to the surface. It is clear that two lakes were so formed -- just northwest and just southeast of the volcano, where there are massive silt deposits.

Figure 1.12: Qasr Jabal Sais.


Figure 1.13: Location of qasr Jabal Sais, volcano and two lakes.

As the water table has dropped all over the Middle East in recent decades, these lakes and springs recede. If you look due east of the volcano, you will see a modern reservoir which is now harvesting water. Between the lake and the modern reservoir is an earlier (but modern) reservoir, now dry. It isn't clear why the reservoir has been moved – the bottom of the dry lake shows a lower elevation than the two reservoirs. Maybe they were just moved because they are more accessible from the marrab from the harra. I suspect, however, that as the water table has dropped, the springs which feed the reservoirs are dropping, too.

The main point is this: Jabal Sais and qasr Burqu were the only perennial water sources on the edge of the harra on the route to Damascus: if someone was trying to reach Damascus (the capital of Umayyad power) from Kufa or Madina through Wadi Sirhan, they would have to skirt the edge of the harra – and they would need to use these water points. So the Umayyad's built qusour there.

Furthermore, if someone tried to come from Kufa (where the main opposition to the Umayyads was based) around Wadi Sirhan and `Azraq, they would have to come past Burqu` for water – because it would be the first water source for hundreds of miles.

### 1.2.5 Qusayr Amra.

Usually it is called "qusayr" – little qasr – because it is not a fort or palace. Qusayr `Amra is a reception hall and bath-house situated in the main watercourse of Wadi Butm, The baths are in the traditional Hellenistic style, with a cold room, tepidarium and calderium. They are conceived in a rather personal, miniature scale – apparently intended for two people, as there are two small seating alcoves in the calderium.

Qusayr `Amra is best known for the dramatic and lively frescoes which cover every centimeter of its interior. In the main reception hall these combine sporting and leisure themes with royal themes. In fact, the western wall is dominated by a portrait of six kings extending their hands in a traditional gesture of obeisance. The six kings portrayed are precisely those who were defeated during the reign of Walid ibn `Abd al-Malik. This is how the qasr has been dated quite precisely to 714-715 AD.

As noted, the qasr was constructed in the very flow of the watercourse – presumably in order to take full advantage of seasonal water which is still relatively close to the surface. There is a flood-wall protecting the qasr from the brief but powerful seasonal flash floods typical to the region. Just outside the qasr doors is a very deep well which once fed the baths.  Though the surrounding landscape is harsh hammada, even today the long line of "butm" trees (*Pistacia atlantica*) is visible in satellite images of eastern Jordan – the main thread of trees extends 11km up Wadi Butm, still tracing out the deep flow of underground water.  Thus the baths at `Amra could be supplied year-round.

On the ridge just a few hundred meters northwest of `Amra are the ruins of a watchtower and a small garrison.  Whereas the qasr is elegantly constructed and remains in beautiful condition today – it's frescoes and mosaic floors still amazingly well preserved – the garrison and watchtower were of humbler construction, and have never been restored.  However, even a modest watchtower set on this ridge would have been visible from qasr Haranah to the south.

Figure 1.14: Qusayr Amra.

### 1.2.6 Qasr al-Hallabat.

qasr al-Hallabat was originally a Roman fort constructed to the 2nd or 3rd century AD. It was rebuilt under the Umayyad Caliph Hisham ibn `Abd al-Malik.

The qasr includes the important elements of:

a. It is located in an area of numerous springs and water sources.

b. The qasr includes a complicated water system, huge reservoir, at least five large cisterns and an elaborate bath complex (Hammam as-Sarah) – again, this is all richly decorated, displaying the Umayyad celebration of their water infrastructure and their control over water resources.

c. It is situated on the top of a mountain which overlooks a broad area to the southeast towards `Azraq, from which travelers would be observable for many kilometers approaching the plateau and the Amman-Bosra-Damascus road.

Figure 1.15: Qasr al-Hallabat.


Figure 16: Location of qasr al-Hallabat, its reservoir and Hammam as-Sarah.

### 1.2.7 Qasr al-Muwaqqar.

Qasr al-Muwaqqar is the least-preserved of all the qusour. However we know that Muwaqqar was constructed by `Abdallah ibn Sulaym by order of Caliph Yazid II ibn `Abd al-Malik in AD 723 (AH 104) -- because of an inscription on a huge, beautifully carved capital on the top of the water gauge-column in the qasr's reservoir.

We don't know that much about the qasr, but it fits into the network of the other qusour for the following reasons:

a. The importance placed on the water infrastructure (the dedication of a structure is usually placed in a position of importance to the founder).

b. The number of cisterns (at least 18 still remaining) and the large reservoir.

c. Its position in line-of-sight communication with Qastal & Mushatta to the west and Haranah to the east.

d. Muwaqqar is actually visible at dusk on a clear day as far away as Thuleithewat – which means it would have been visible to anyone travelling out of Wadi Sirhan toward `Azraq or the plateau.

### 1.2.8 Azraq.

We don't know exactly what was built at `Azraq. What we do know is that a huge reservoir was there, as well as some strange, decorated pools and channels. Based on basalt carvings from `Azraq and some of the paintings at

`Amra it seems perhaps that an Umayyad official or prince or caliph some kind of "water park" at `Azraq, for water sports. There were also large, wealthy Umayyad farms with substantial houses around `Azraq. More importantly, we know that `Azraq was the 3rd largest wetlands in southwest Asia. The journey from the Jauf oasis in Arabia into Bilad ash-Sham ended at `Azraq, where travelers could rest and replenish their supplies and water their livestock.

What is also interesting is that the Roman and Byzantine armies fortified `Azraq: they saw `Azraq and the western rim of Wadi Sirhan as the outer edge of the Roman frontier (the *limes exterior*). The Umayyads did *not* fortify it – and they seem not to have re-used the old Roman fortifications. The Umayyads saw Wadi Sirhan – and of course the oases at Jauf and `Azraq – as the central corridor of the Islamic world: the conduit between Arabia, Iraq and Syria (al-Madina, Kufa and Damascus). So instead of "protecting themselves from the barbarians" as the Romans did, they used `Azraq for recreation, rest and relaxation – and they patrolled the traffic that went *beyond* `Azraq. So the Umayyad installations do not fortify: they "monitor" – there is no way out of `Azraq that is not patrolled by an Umayyad qasr.

As discussed before, `Azraq lies on the edge of the black desert, or *harra,* which cannot be traversed "off road" (even now with a 4WD vehicle it is difficult or impossible) – the black lava boulders cover the sand, very close together, and it is extremely hazardous to cross by horse or camel. Walking is slow. The black desert is the result of volcanic eruptions from the Hauran in Syria, and small, extinct volcanoes continue down into what is today Jordan – some are visible from `Azraq.  Thus it was not possible to reach Damascus quickly (or without being detected) unless one circumnavigated the harra.

But even so, one needed water.  Thus all the water points on routes leading out of `Azraq are patrolled by an Umayyad qasr:  Qusayr `Amra watches Wadi Butm, leading south and west out of the Qa` al-Shaumari.  Across the hammada, or limestone-chert desert to the northwest, one passed qasr al-Hallabat and its associated springs.  Then the way was blocked by the black desert from the northwest to northeast.  If one attempted to pass east around the harra, there were qasr Burqu` on Lake Burqu` and qasr Jabal al-Sais on its volcanic lake.

Figure 1.17: Qasr Azraq.

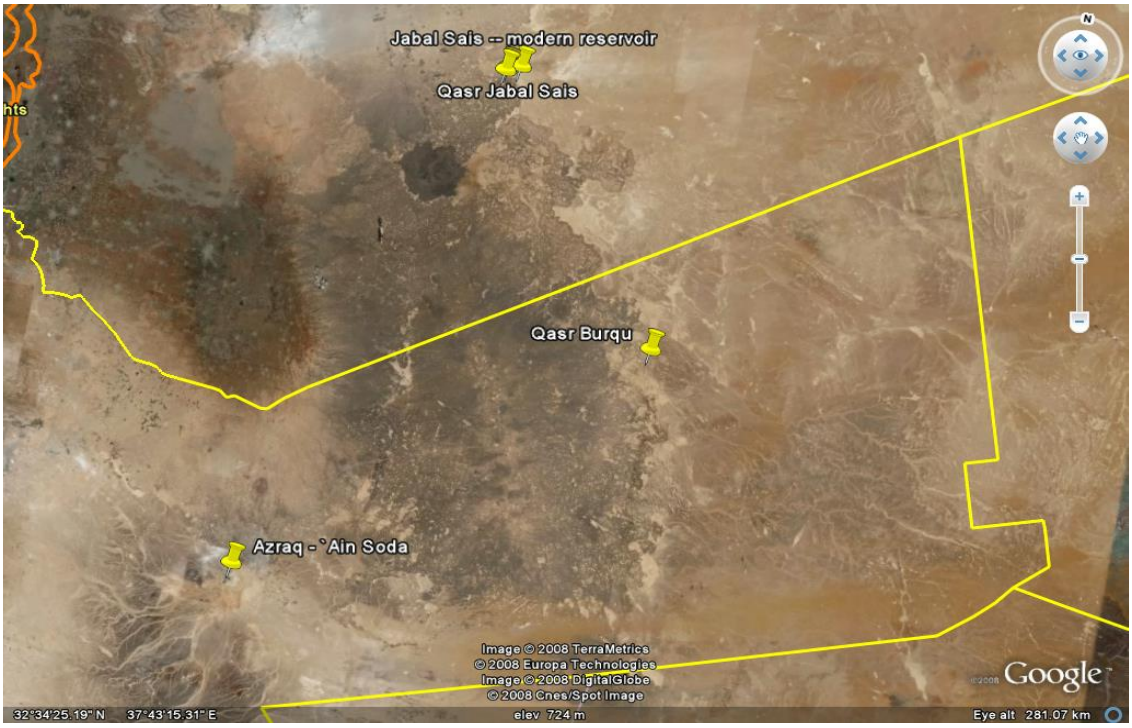


Figure 1.18: Locations of qasr Azraq, Jabal Sais and Burqu around the Harrah.

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### 1.2.9 Qasr al-Qastal.

Qasr al-Qastal is part of a larger complex which included the qasr, a small and elaborate mosque, an extensive water system and probably a bath complex. There is also a very early Islamic cemetery there, some of whose headstones bear the earliest known examples of Kufic script. The minaret of Qastal's mosque is the oldest existing minaret in the world.

Qasr al-Qastal may have been built under the patronage of Yazid II ibn `Abd al-Malik, who ruled from AD 720-724. This assumption is based on two quotes from the poet Kuthayyir bin `Abd al-Rahman `Azza (AH24-105/ AD644-723), found in a panegyric in praise of Yazid II (Bisheh, 2000) The style of construction and ornamentation on the qasr is also remarkably like what is found at the qusour of Muwaqqar and Amman, also built under the patronage of

Yazid II. Since `Azza died in 723, the qasr must have been constructed before then. Certain details of the mosque construction suggest a date after AD 708. It is likely that the complex was begun earlier than the reign of Yazid II, as it could not have been completed in only three years, and it was impressive enough when it was built to have been mentioned by `Azza before 723.

The qasr was enormous (70x70m) and solidly built of ashlar-cut limestone. The stone was ornately carved; interior walls were covered with frescoed plaster and rich mosaics on both walls and floors, like qasr al-Hallabat, Qastal also had an elegant bath complex situated nearby. The baths' mosaics and marble-tiled floors, frescoed walls and carved stone are even richer than the qasr((Bisheh, 2000) .The baths complex is remarkably similar to the "little palace," or "Qusayr" `Amra.

All that remains of the original mosque is part of its minaret and west wall. It is also possible that a cistern in the former forecourt supplied an ablution fountain or pool. A19$^{th}$ century British traveler drew the minaret at Qastal and described the building's "perfection" and the marble columns and carved capitals that flanked the mihrab (Tristram, 1873).

Today, however, nothing remains of the original mihrab or prayer hall. The minaret is built of the same stone and mortars as the qasr, and what remains is beautifully constructed and carved as well. The minaret is significant because it is accessed from the courtyard by a beautifully constructed spiral staircase which is the core of the construction. This internal staircase means that it was constructed as a minaret, for the call to prayer – as opposed to being adapted from a church tower (Addison, 2000).

Maybe the most interesting thing about Qastal is its water infrastructure. The qasr was built with a careful and skillfully constructed roof catchment system: set into each join between buttress towers and the qasr wall are ceramic pipes which conduct water into cisterns which are built into the foundations. The forecourt of the qasr was some 50x70m of cream-colored mosaic pavement, and at the northeast corner was a reflecting pool and pavilion. The low wall around the pool was stuccoed and painted with frescoes. There is evidence to suggest that there was a matching pool and pavilion at the southeast corner of the forecourt.

The qasr is built on limestone that is naturally bubbled with caves of various sizes. These caves were turned into sturdily constructed cisterns with three layers of plaster lining – much of which was found intact in excavations between 1998-2001. Surrounding the qasr six of these cisterns were excavated to reveal a system of channels and filters linking them to a spring on the top of the hill above the qasr. Surrounding Qastal, within an area $2km^2$, are over 70 cisterns. Under the central courtyard of the qasr is a huge cistern, which once held over 1000 $m^3$. This cistern was also fed by roof & hardscape catchment. It was accessed through a carved and decorated mouth at the center of the courtyard, but also at least one marble-lined stairwell in the southwest corner of the courtyard. Over the entrance to the cistern is a beautiful shell-niche with an intricately carved arch over it.

Qastal had three large reservoirs, which together held over 10,000$m^3$ (see Google Earth image). One of these appears to have been associated with the baths. The qasr looked out over a lake which was formed behind a 400m+ dam, holding water from Wadi al-Qastal, which ran from west to east below the north side of the qasr and mosque complex. The dam was strongly constructed – more than four meters thick and equipped with large spill pipes constructed hollowed from solid chunks of marble. Also on Wadi al-Qastal is another, smaller dam – the remains are 24m long, but they are not complete. In what was probably the center of this dam are double sluice-gates, again carved carefully and ornamentally from limestone. It appears that this dam, which runs from NW > SE almost parallel to the wadi course, held runoff from the slopes to the southwest, which was then released through the sluice-gates into Wadi al-Qastal.

The whole complex was built precisely on the famous hajj, or pilgrimage road. qasr al-Qastal was in line of site communication with Muwaqqar and – later – Mushatta. It seems likely that Qastal was built earlier than Muwaqqar, on this main traffic route (the hajj road). Then Muwaqqar was situated so as to link communications between `Amra/ Haranah and Qastal.

The water infrastructure at Qastal was fabulous, and it is clear that its builder wanted to display the water. There is also the question of why so much water was being captured – far, far more than was necessary for the size of settlement at Qastal. It is likely that it was expected that travellers would stop at

Qastal, water their livestock, and register their presence with officials there. Once again, the control of water corresponded with control of travel routes.

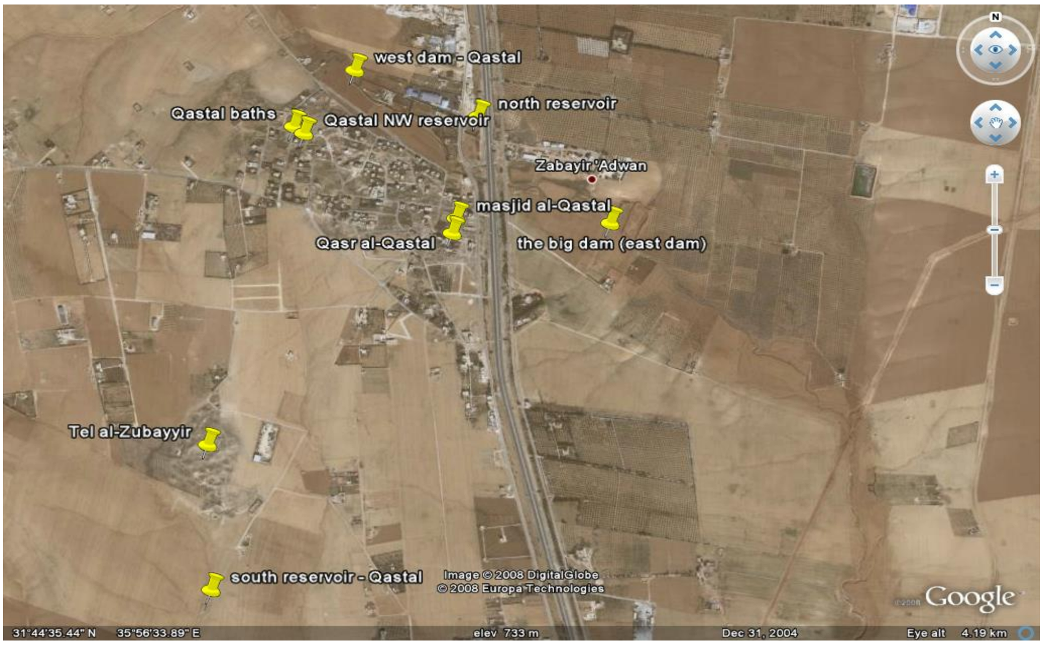


Figure 1.18: Locations of qasr al-Qastal , reservoirs,dams, masjid and paths.

### 1.2.10 Hammam as_Sarah.

Its complex bath consists of 3 principal elements: The Audience Hall, The Bath Complex, and The Hydraulic Structures. The audience-hall is roofed by 3 tunnel-vaults resting on the sidewall and two intermediate transverse arches. The northeastern corner of this hall had a fountain, which received its water from an elevated tank to the east. The bath proper consists of 3 rooms corresponding to the cold, warm, and hot rooms.

### 1.3 The Qusour of Bilad-ash-Sham.

TABLE 1.1: List of qusour of Bilad-ash-Sham in order of construction.

| Qusour Name | Period |
|---|---|
| Haranah | Sufyanid, but used into (661-683) the Umayyad period |
| Azraq | continuous settlement from Roman period – or earlier – to resent |
| (Jerusalem - | `Abd al-Malik ibn Marwan) 685-705 |
| Jabal Sais | Walid I ibn `Abd al-Malik 705-715 |
| Burqu | Walid I ibn `Abd al-Malik 705-715 |
| `Amra | Walid I ibn `Abd al-Malik 705-715 |
| Ramlah | Suleiman ibn `Abd al-Malik 716-717 |
| Qastal | Yazid II ibn `Abd al-Malik 721-724 |
| `Amman | Yazid II ibn `Abd al-Malik 721-724 |
| Muwaqqar | Yazid II ibn `Abd al-Malik 721-724 |
| Hallabat | Hisham ibn `Abd al-Malik 724-743 |
| Mushatta | Walid II ibn `Abd al-Malik 743-744 |
| Tubah | Walid II ibn `Abd al-Malik 743-744 |
| Umm al-Walid | Unknown |

.

## 1.4 Thesis statement.

The Umayyad qusour are monumental structures built during the reign of the first caliphate of Islam. The Umayyad qusour are usually dismissed as "pleasure palaces" or "hunting lodges," even by prominent scholars (e.g., Cresswell 1969; Hilllenbrand 1982; Bisheh 1985, 1998). Some scholars of the period are, however, beginning to argue that these prominent structures were strategic interventions in the landscape (Addison 2000, Almagro 1992, Arce 2008, King 1992). This study states that the Umayyad “Desert Castles” were built strategically at perennial water sources in order to monitor routes of transhumance amongst the socio-political centers of the period.

## 1.5 Significance.

*Historical:* It has long been thought that the desert castles, or *qusour*, were merely elaborate hunting lodges or pleasure palaces isolated in the desert. However, the Umayyad dynasty invested an unprecedented amount of money and resources into these structures. This argument shows that the desert castles had practical and political significance for the Umayyad regime.

*Methodological (1):* Until now, historians have relied mainly on textual, architectural and art-historical analyses of the *qusour* in order to understand Umayyad state architecture. This argument uses spatial analysis to lend a new dimension to the discussion. Using spatial analysis the structures are treated not as individual archaeological exempla, but as a system.

*Methodological (2):* Until now GIS has typically been employed for the social sciences, environmental and engineering disciplines. This argument uses GIS to shed light on a research problem in the humanities.

## 1.6 Objectives.

The objective of the study is to construct a geo-database and digital map of the Umayyad qusour in their geographical context, and to use the resulting database and map to conduct a visualization and spatial analysis of the distribution of the qusour.

## 1.7 Research questions.

I. How to construct a geo-database and digital map of the Umayyad qusour?

II. How to conduct a visualization and spatial analysis of the distribution of the qusour?

## 1.8 Hypothesis

I. There are significant patterns in the locations of the Umayyad qusour.

II. There is unobstructed line-of-sight communication between each qasr and its neighboring qasr, among the group located west of Harrah.

III. There is a quantifiable relationship between the qusour, perennial water sources, and established trade and courier routes.

IV. These patterns suggest strategic placement of the qusour (vs. merely ornamental or recreational constructions).

## 1.9 Scope and Limitations of Study

I. This study includes only the qusour known as the Desert Castles (Tubah, Hallabat, `Amra, `Azraq, Burqu`, Muwaqqar, Harranah, Mushatta, Umm al-Walid, Jabal Sais and Qastal).

II. Because a high resolution DEM was unavailable from the Royal Jordanian Geographical Society, a low resolution DEM from a free internet resource will be utilized in this study.

## 1.10 Thesis Layout

This thesis is divided into six chapters. The first chapter is an introduction which includes the Background of the Study, introduction to the qusour of the *Bilad ash-Sham*, Thesis Layout, Thesis statement, Significance, Objectives, Research questions, Hypothesis and Scope and Limitations of Study. The second chapter includes the Literature Review, highlights Archaeological Research, Spatial Analysis and Computing in the Discipline of History, Geographical Information Systems in Historical Research, GIS in Cultural History, GIS and Spatial Analysis, and Buffering. The third chapter is the research methodology: it discusses Methodological Application, What is GIS?, Components of a GIS, Data Capture, Building a Geodatabase, Database, Relational Database Model and Database design**.** The fourth chapter is the analysis; it discusses Visualization, Proximity Analysis, Exploratory Digital Mapping, Line-of-sight Communication and Point Pattern Analysis. The fifth chapter discusses the results of the study: Digital Mapping and Geodatabase, Exploratory Digital Map, Line-of-sight Communication and the results of the Quadrant Count Method. The sixth chapter includes the Research Discussion, Conclusion and Recommendations.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 Archaeological Research

Although the researcher has for many years been interested in the Umayyad qusour, during the period of May-June 2008 he was fortunate to have access to three scholars of the Umayyad period in Jordan: Dr. Ghazi Bisheh (former Director General of the Department of Antiquities of Jordan), Dr. Ignacio Arce (of the Spanish Archaeological Mission), and Dr. Erin Addison (former Director of the Qastal Conservation & Development Project). These scholars were kind enough to direct me to articles and books on the Umayyad qusour (see References), as well as guiding me to visit the sites themselves. So the basic data for this study came from historical research on the qusour themselves, and from site visits. In the process of the site visits the researcher gathered the data to use in the spatial analysis.

## 2.2 Spatial Analysis and Computing in the discipline of history

Historians (and other scholars in the humanities) have a documented reluctance to use computers in their research. O. Boonstra, et al., claim that :

"*if we look back at what 'history and computing' has accomplished, the results are slightly disappointing. They are not disappointing because 'computing' failed to do what it intended to do, which was to provide 'history' with computerised tools and methods historians could use to expand the possibilities and to im-*

*prove the quality of their research, but because 'history' failed to acknowledge many of the tools 'computing' had come up with*" (2004).

In the United States computers were first incorporated into historical research by social and economic historians, focusing on computation and quantitative aspects (Greenstein, 1997). From the 1980s on computing – first in the form of databases and searchable texts – has become more thoroughly integrated into the social sciences and historical research (Greenhalgh, 1987). Relational models and data modeling techniques such as the "Entity Relationship Model" of Lou Burnard and Charles Harvey, multilevel regression analysis, event history analysis (Raffalovich et al, 1983) and other, less quantitative techniques have become widespread. Today, in the 21st century, there are several journals devoted to computing in the humanities, e.g., *History and Computing.* In the 1990s the British Library Research Series published a monograph series devoted to computing in the humanities (Katzen, 1990; Kenna and Ross, 1995; Mullings, 1996).

While the role of computing in the humanities and social sciences has come far since the 1960's, "the profession is still divided between the small minority of historians who uses computers as tools for analysing historical data and the vast majority who, while they might use a pc for wordprocessing, remain unconvinced of the case that it can become a methodological asset.' (Speck, 1994). Since GIS is primarily a methodological tool, its role in historical research is still far behind the role that it is performing in other disciplines.

### 2.3 Geographical Information Systems in Historical Research

So far, only limited uses of spatial statistical techniques have been made by historians. A. K. Knowles' *Past Time, Past Place: GIS for Historians* was the first collection of case studies on the application of GIS to historical research. Except for Knowles, the literature on using GIS for historical applications is sparse. However, 'Historical GIS' is a term that is now used to describe approaches to historical research involving the use of GIS (2002, ESRI Press).

In the 1970s and '80s GIS was marketed for its ability to handle complex sets of spatial information more quickly and more cost-effectively that could humans. In the words of Michael Goodchild, "although humans have highly developed visual systems, they are easily misled by optical illusions and unable to perform the kinds of precise rapid manipulations of data that computers are design for. The computer seemed much better at the kinds of rigorous and logical analysis demanded by the scientific method than common researchers" (2000).

An overview of the field in 1994 documented the use of GIS in historical research in several countries in Europe as well as the U.S. (Goerke, 1994), but that number has risen dramatically. GIS has improved in visual quality, in its flexibility in handling data in a variety of formats, and in its availability. "Most important, the problem of geographic changes over time has been noted by historians, geographers and information scientists alike." In the 21st century GIS is most widely used in resources management, utilities management, telecommunications, urban and regional planning, vehicle routing and parcel delivery, and in all of the sciences that treat problems associated in some way the surface of the earth. (Boonstra et al, 2004).

Several examples illustrate the growing use of techniques of spatial analysis GIS in history-related disciplines. In the early 1990s several introductions to cluster analysis in historical research were published (Bacher, 1989; Boonstra ea al, 1990). In historiography "cluster analysis" uses geographical information systems to visualize the results of historical research, and since the 1990s this ability to visualize information has made the method more appealing to historians. GIS has also been used to test historical hypotheses about nations (Obinger et al, 2001), provinces (Delger, 2003), districts (Debuisson, 2001), municipalities (Boonstra, 2001), parishes (Song, 2002) and households (Galt, 1986) and (Spree, 1997). Nearest neighbor analysis was used in an article by Vasiliadis and Kobotis use "nearest neighbor anlayisis" to analyze the distribution of tourism locations in Macedonia in their article in 1999.

In 2001 Ian Gregory, Daniel Dorling and Humphrey Southall published an analysis of 20$^{th}$ century patterns of poverty in England and Wales. The data was drawn from census records. Their study tried to distinguish between patterns of real change in income vs. apparent change that actually results from changing administrative areas and means of collecting and publishing census data. In order to deal with the mechanical changes, they "interpolate data published for a variety of mosaics of spatial units onto a single set of administrative units. Once on a common geography, it is possible to compare patterns on different dates using a combination of simple statistics and sophisticated visualizations" (Gregory et al, 2001).

Because it integrates spatial and attribute components of geographical information, GIS becomes a powerful tool in historiographical methodology. GIS can analyze the information in traditional historical texts describing places, and from other forms of historical geographical investigation (e.g., historical topography). Bertrum MacDonald and Fiona Black's work on the spread of print culture demonstrates the importance of spatial analysis in historical research. Their argument is that print culture spread across continents and oceans as a result of the interaction of a complex set of spatially distributed variables, and that the diffusion of new reading practices can be modeled using spatial analysis (MacDonald et al, 2000).

### 2.4 GIS in Cultural History

Research problems in cultural history, however, are different from socioeconomic questions in that the data is rarely as quantitative. Also, simply, the deeper past is more obscure than the present or recent past. In the question of historical sites such as the Umayyad qusour, for example, there is no textual record of the "intentions" of their builders, nor even of the builders' names. State patronage is assumed because of the massive richness of the structures and anchored by a very few textual references to the caliphs' activities. The data to be analyzed in this, as in many such studies, is hardly quantitative at all – the qusour are exempla, not data.

D.J. Unwin claims that "what is required... is an ability to explicitly incorporate uncertainty into geographical information" (1995). Commercial GIS software as yet is awkward at "managing uncertainty." So the researcher is more or less on his own in figuring out how to make cultural and historical exempla into quantitative data. As one author says, "history and computing is not only about historical research, but also about historical resource creation" (Woollard, 1999).

One example of this kind of problem is seen in the study of Bartley and Campbell regarding land use in medieval England. In the1990s Bartley and Campbell used GIS to produce a land use classification for medieval England based on 6,000 records in the Inquisitiones Post Mortem, a detailed record of information about the estates of deceased landholders. They identified the records as points on a map of England using a gazetteer of place names. Many of the points overlapped, so they may have represented large areas with a variety of land uses; so they then used kernel estimation to construct a raster grid to overlay the map of England. They then used a weighted ranking to assign primary and secondary categories of land use to each cell in the grid. The result is a land use map for medieval England (Bartley et al 1995).

The very expression "historical site" denotes an intersection between space ("site") and time ("historical"). As such, an historical site should be an ideal candidate for analysis by GIS. In this regard it is worthwhile to quote in full the following paragraph from the study of Chiu, Lee, and Koshak:

"*Historical sites are proof of history. They represent interaction between different cultures throughout history reflecting the social values, economic situations, and behaviors of a particular time. Documenting historic sites is important. It preserves information for future generations to learn from the past. A rich architectural and urban heritage provides future architects and urban planners and designers with design and planning solutions to various problems. There are many related documents describe in detail the historical sites' spatial structures, characteristics, categories, value of arts, and educational meanings. However, these documents that use paper-based static media have several shortcomings. They represent the past historical events for a specific site using descriptive lists, words, and simple marked maps to display the urban environment information despite that these historical sites should belong to a structure of spatial-temporal data. Historical sites interact dynamically with the place they locate and over time. Using the traditional ways cannot fully describe the past historical events which occurred, the reasons for their occurrences, their impact on historical buildings, and the evolution of these historical buildings. In other words, they lack the capability to represent the meanings and changes of historical sites in a spatial and temporal manner*" (Chiu et al, 2002).

In *Past Time, Past Place* Knowles asserts that "if we define geography as the study of spatial differentiation, and history as the study of temporal differentiation, historical GIS can be defined as the study spatial patterns of change over time" (Knowles, 2002). In the case of the proposed research, however, the question is posed about the relationships between several disparate sets of spatial data in the past. It is – just as described by Chiu, et al. – a matter of describing spatial-temporal data relationships fully in ways that paper-based media are not capable of doing.

In summary, spatial analysis draws data from archival and archaeological research and reconfigures it spatially and visually. This reconfiguration not only makes it easier to draw and demonstrate relationships between phenomena, it can actually reveal relationships that are invisible in textual description or on the ground.

**2.5 GIS and spatial analysis**

The origins of spatial analysis lie in the development in the early1960s of quantitative geography and regional science and many developments have taken place ever since (Chou, 1997). Spatial analysis and GIS have enjoyed a long and productive relationship over the past decades (Goodchild et al, 1992). GIS has been seen as the key to implementing methods of spatial analysis, making them more accessible to broad range of users, and hopefully more widely used in making effective decisions.

GIS is unlike other statistical analysis because tabular data has established links to maps for visual analysis (Clarke, 1997).Any statistic we can think of to describe the data then automatically has geographic properties and as a result can be placed on maps for visual processing.

It has been argued that in this sense the relationship between Spatial analysis and GIS is similar to that relationship between statistics and statistical packages .Specialized GIS packages directed specifically at spatial analysis have emerged Bailey & Gatrell(1995). Chou (1997) has discussed the ways in which implementation of spatial analysis methods in GIS are leading to a new exploratory emphasis.

### 2.6 Buffering

The U.S. Government in late 1997 released the results of a twenty year long study on the effects that large power lines have on neighboring communities property values. The outcome of this study illustrated that when residential houses were within 150 m of power lines there was a significant decrease in the property value of the houses that were located closer to the power line. The report suggested that communities should take localized action to test whether or not the findings of this study were applicable to their specific area. If the findings of the study were found to be similar in the High Rolls/Mountain Park area the report suggested tax breaks for those individuals that were affected by the power line. The study also recommended other actions which could be taken by communities including the rerouting of the existing power line away from the affected area or relocating those households that were within the buffer zone (Gis.usu, 2008).

# CHAPTER THREE
# METHODOLOGY

## 3.1 Methodological application

The spread of geographic information science and systems (GIS) have prompted researchers in many areas to review the methods of conducting research or problem-solving process. GIS tools have enabled users to effectively capture, management, analysis and presentation their geographically referenced data. With GIS, researchers can now process larger volumes of data within a shorter time and with greater precision. Furthermore, similar analytical processes can be easily repeated for different data sets. What used to be labor-intensive tasks are now often performed within minutes or even seconds with computers. Researchers are less likely to be limited by computation time. They do not need to avoid working with large volumes of data when they explore new ways of processing data. As a result, new approaches to exploring spatial and non spatial data have been developed to execute processes that once were only dreamed of. The commercialization of GIS technology also elevated the uses of GIS to a higher level than ever before. With packaged computer programs available to everyone at a reasonable cost, mapping complex geographic data and overlaying thematic data layers for site selections have become routine tasks that can be performed even by novice GIS users (Lee et al, 2001).

One important characteristic that separates GIS from other information systems is their ability to handle spatial data. Spatial data are sensitive to scales and to the way they are measured (scales of measurement). A qasr or lake is only a point on a large scale. The same qasr, however, occupies an entire sheet of map when all of its rooms, corridors, squares, plazas and paths, and so on are displayed in detail, become an areal phenomenon when it is mapped at a local scale. The ability to manage geographic objects across different scales has made GIS valuable tools for many research fields and applications.

Another characteristic that makes spatial data unique is that location information is embedded in the observations. In addition to the attributes describing the characteristics of the observations (geographic features), locations of features can be extracted from the data and analyzed. GIS are valuable tools to accomplish this (Lee et al, 2001).

## 3.2 What is GIS?

A definition quoted in William Huxhold's Introduction to Urban Geographic Information Systems.

*"The purpose of a traditional GIS is first and foremost spatial analysis. Therefore, capabilities may have limited data capture and cartographic output. Capabilities of analyses typically support decision making for specific projects and/or limited geographic areas. The map data-base characteristics (accuracy, continuity, completeness, etc) are typically appropriate for small-scale map output. Vector and raster data interfaces may be available. However, topology*

*is usually the sole underlying data structure for spatial analyses."* (William. H, 1991).

Dana Tomlin's defined GIS as:

A geographic information system is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth. This is a broad definition, a considerably narrower definition, however, is more often employed. In common parlance, a geographic information system or GIS is a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data. ( Dana, 1990).

Jeffrey Star and John Estes say:

A geographic information system (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-reference data, as well as a set of operations for working with data. In a sense, a GIS may be thought of as a higher-order map. (Jeffrey .S, and John E, 1990).

And from ESRI:

A GIS is "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information."(1990).

## 3.3 Components of a GIS

According to Dr. Helmut Kraenzle, A GIS can be divided into five components: People, Data, Hardware, Software, and Procedures. All of these elements need to be in balance for the system to be successful. No one part can run without the other.

### 3.3.1 People

The people are the element who actually makes the GIS work. They include a plethora of positions including GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for maintenance of the geographic database and provide technical support. People also need to be knowledgeable to make decisions on what type of system to use. People related with a GIS can be categorized into: viewers, general users, and GIS specialists.

A. Viewers are the public at large whose only need is to browse a geographic database for referential material. These constitute the largest class of users.

B. General Users are people who use GIS to conducting business, performing professional services, and making decisions. They include facility managers, resource managers, planners, scientists, engineers, lawyers, business entrepreneurs, etc.

C. GIS specialists are the people who make the GIS work. They include GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to the other two classes of users.

### 3.3.2 Procedures

Procedures involved how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the step taken to answer the question needs to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information systems. The transformation processes includes such duties as adjusting the coordinate system, setting a projection, correcting any digitized errors in a data set, and converting data from vector to raster or raster to vector.

### 3.3.3 Hardware

Hardware consists of the technical equipment needed to run a GIS including a computer system with enough power to run the software, enough memory to store large amounts of data, and input and output devices such as scanners, digitizers, GPS data loggers, media disks, and printers.

### 3.3.4 Software

There are many different GIS software packages available today. All packages must be capable of data input, storage, management, transformation, analysis, and output, but the appearance, methods, resources, and ease of use of the various systems may be very different. Today's software packages are capable of allowing both graphical and descriptive data to be stored in a single database, known as the object-relational model. Before this innovation, the geo-relational model was used. In this model, graphical and descriptive data sets were handled separately. ARC GIS 9.2 and Global Mapper 7 were used in this study.

### 3.3.5 Data

Perhaps the most time consuming and costly aspect of initiating a GIS is creating a database. There are several things to consider before acquiring geographic data. It is crucial to check the quality of the data before obtaining it. Errors in the data set can put in many unpleasant and costly hours to implementing a GIS and the results and conclusions of the GIS analysis most likely will be wrong.

There are several guidelines to look at include:

I. Lineage: This is a description of the source material from which the data were derived, and the methods of derivation, including all transformations involved in producing the final digital files. This should include all dates of the source material and updates and changes made to it.

II. Positional Accuracy: This is the closeness of an entity in an appropriate coordinate system to that entity's true position in the system. The positional accuracy includes measures of the horizontal and vertical accuracy of the features in the data set.

III. Attribute Accuracy: An attribute is a fact about some location, set of locations, or features on the surface of the earth. This information often includes measurements of some sort, such as distance or area or a temperature. The source of error usually lies within the collection of these facts. It is vital to the analysis aspects of a GIS that this information be accurate.

IV. Logical Consistency: Deals with the logical rules of structure and attribute rules for spatial data and describes the compatibility of a datum with other data in a data set. There are several different mathematical theories and models used to test logical consistency such as metric and incidence tests, topological and order related tests. These consistency checks should be run at different stages in the handling of spatial data.

V. Completeness: This is a check to see if relevant data is missing with regards to the features and the attributes. This could deal with either omission errors or spatial rules such as minimum width or area that may limit the information.

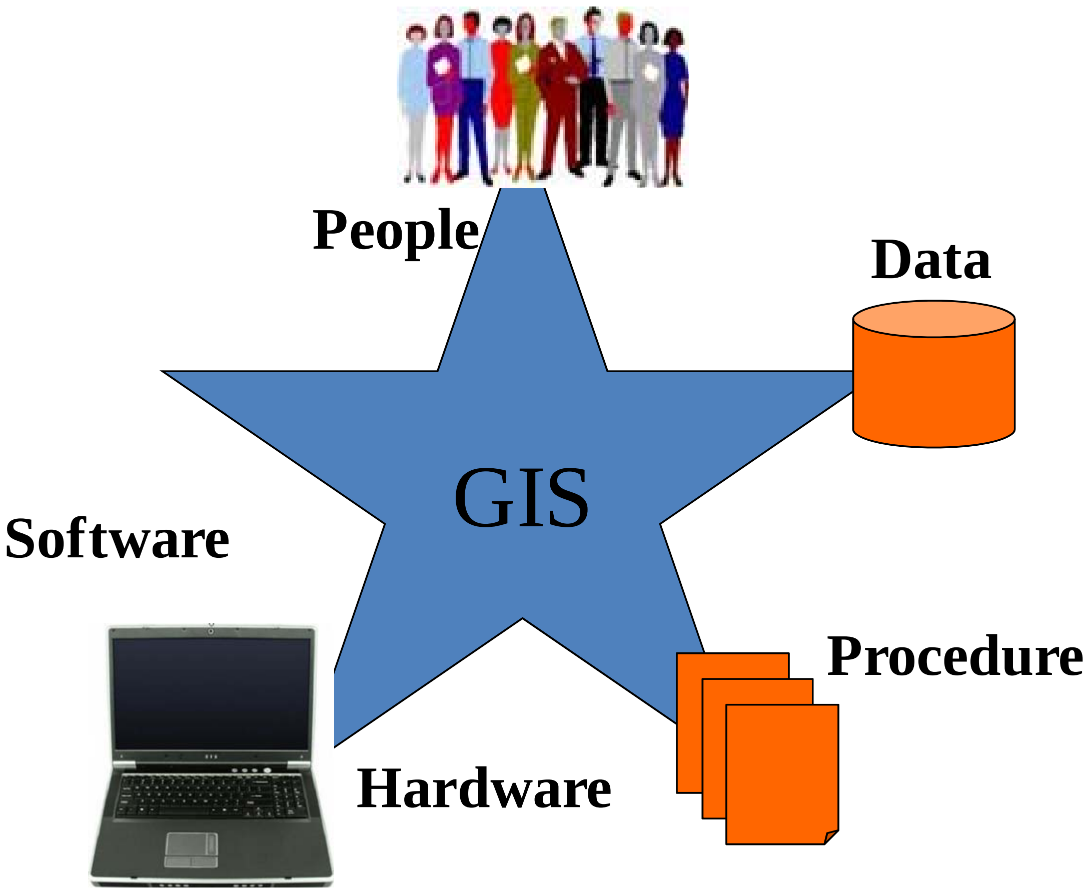


Figure3.1: Components of GIS.

### 3.4 Data Capture

Data input to a geographical information system can be best broken into three categories: entering the spatial data, entering non-spatial data, and linking the two together. Entering the spatial data can be done in many ways. Spatial data can be acquired from existing data in digital or paper form, or it can be collected from scratch or using GPS.

In this study were used two types of data; spatial data and non spatial data.

### 3.4.1 Spatial data

a) Satellite images; obtained from Google Earth for the entire study area with Geographic Coordinate System: GCS_WGS_1984, Datum: D_WGS_1984, Prime Meridian: Greenwich and Angular Unit is Degree.

b) A digital elevation model (DEM) is a digital representation of ground surface or terrain heights. Usually X, Y and Z locations It is also as a digital terrain model (DTM). It's three dimensional representations, a DEM can be represented as a triangular irregular network (TIN) or as a raster .DEMs are generally built using remote sensing techniques or can be also built from land surveying. The U.S. Geological Survey (USGS) produces many types of elevation data, such as: 7.5-minute DEM, 15-minute Alaska DEM, 1-degree DEM, 7.5-minute Alaska DEM, and. 30-minute DEM. Digital elevation Model for this study was obtained from International Centre for Tropical Agriculture (CIAT) the data in ARC GRID, ARC ASCII and Geotiff format, in decimal degrees and datum WGS84. With accuracy 90m, they are derived from the USGS/NASA SRTM data (Jarvis et al, 2006).

c) Documentation of the location of routes of transhumance, obtained from historian researcher's studies, like. Kennedy, MacAdam, etc...

d) Direct measurement using GPS. The GPS device which used in this study is eTrex® from Garmin , it was used to capture the locations of the qusour, the sources of water and Wadis. with Geographic Coordinate System: GCS_WGS_1984, Datum: D_WGS_1984, Prime Meridian: Greenwich and Angular Unit is Degree.

#### 3.4.1.1 Global Positioning System (GPS)

The GPS is a collection of 24 well-spaced satellites that orbit the Earth, developed by the United States Department of Defense. and allowed for people with ground receivers to get their geographic location, the time, and their velocity. The location accuracy is anyplace within 10 and 100 meters for most equipment. To get better Accuracy within one meter need a special military approved. GPS equipment is extensively used in science and for general use around the world, and has now become adequately low cost.

Four methods were used in this study to represent the Real world in building the digital map for the Ummayad qusour:

#### 3.4.1.2 Point feature

Points are zero dimensional objects which have locations and attribute information but are too small to be represented as areas. For example: the qusour and source of water.

#### 3.4.1.3 Line feature

Lines are one dimensional object which have length but no area. Each line must begin and end at a node. For example the transhumance routes.

#### 3.4.1.4 Arial feature

Polygons are closed mathematical figures of any shape or size. They are formed by a series of connected lines. For example: Harrah and Wadi-Sarhan

#### 3.4.1.5 Triangulated Irregular Network (TIN)

A data model typically used to represent terrain heights, usually X, Y and Z locations for measured points are entered into the model. It's three dimensional representations. For example DEM.

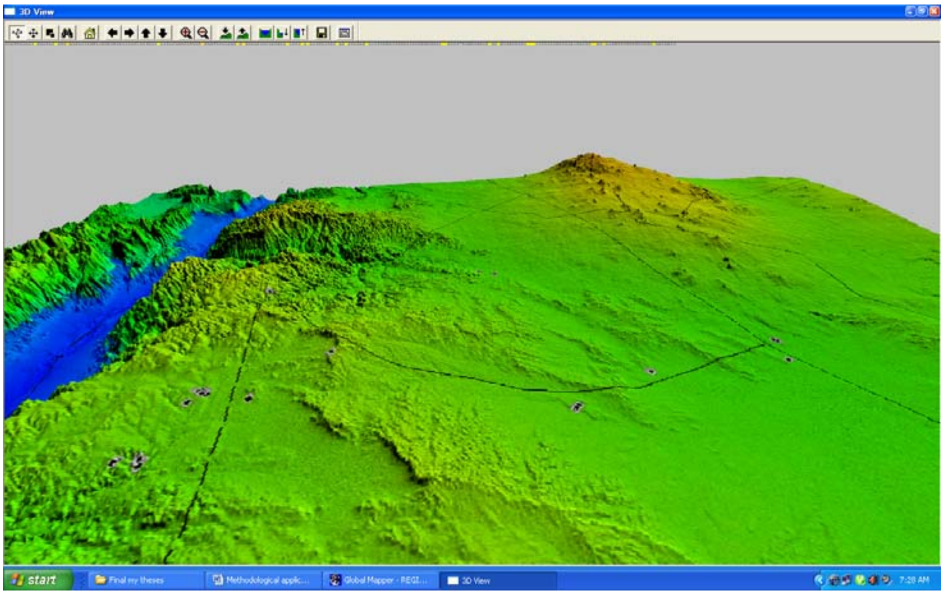

Figure 3.2: DEM for the study area using Global Mapper7.

#### 3.4.1.6 Projection and Rectification

In order for the spatial data of a 3-dimensional earth to be represented in a 2-dimensional GIS, the data must make use of one of the various projection methods Because different projections place the same special entities on different coordinates on the flat surface, it is very important that a projection be set for the specific data set being used. One of the main features of a GIS is the ability to overlap different data layers for better analysis. These different layers must have the same projection, datum, and reference ellipsoid so that all coordinates are lined up correctly. Therefore the researcher converts the projection of the data into Palestine Grid Projection, this done by using the utility of The Middle East Map Reprojection (Reproject, 2008).

#### 3.4.1.7 Palestine Grid Projection

Most of the Jordanian local maps used Palestine Grid Projection, in order to match the maps in the region, this study used Palestine Grid Projection.

TABLE 3.1: Parameters of Palestine Grid Projection.

| | |
|---|---|
| Projected Coordinate System: | Palestine_1923_Palestine_Grid |
| False_Easting: | 170251.5550 |
| False_Northing: | 126867.9090 |
| Central_Meridian: | 35.21208056 |
| Scale_Factor: | 1.00000000 |
| Latitude_Of_Origin: | 31.73409694 |
| Linear Unit: | Meter |
| Geographic Coordinate System: | GCS_Palestine_1923 |
| Datum: | D_Palestine_1923 |
| Prime Meridian: | Greenwich |
| Angular Unit: | Degree |

### 3.4.1.8 Data Modeling

Spatial modeling represents the structure and distribution of features in geographical space. In order to model spatial processes, the interaction between these features must be considered. There are several types of spatial data models including: vector, raster, surface, and network (Burrough et al, 1998).

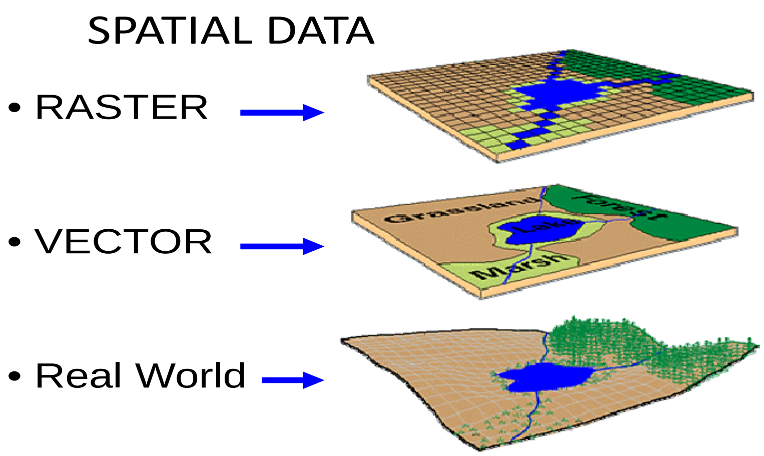


Figure 3.3: As an illustration of transferring a real world geographic area into the raster and vector formats. (Source: Defense Mapping School National Imagery and Mapping Agency)

### 3.4.1.9 Raster Data Model

The raster data model uses a grid composed of rows and columns to display map entities. Each cell in the grid is equivalent to one map unit or one pixel. Spatial resolution determines the precision of spatial representation by raster data. The smaller the size of the pixel, the higher the resolution and the better the precision of spatial representation (Lo et al, 2002). An entity code is assigned to each cell that is connected to a separate attribute table, which provides information to the user as to what entity is present in what cell.

The raster data model represents spatial phenomenon such as topography, land use cover, and air quality as categorical or continuous surfaces. This makes raster-based methods particularly suitable for spatial modeling that involves multiple surface data sets. However, this method is not suitable for applications that rely on individual spatial features represented by points (qusour), lines (routes), and polygons (Lo et al, 2002).

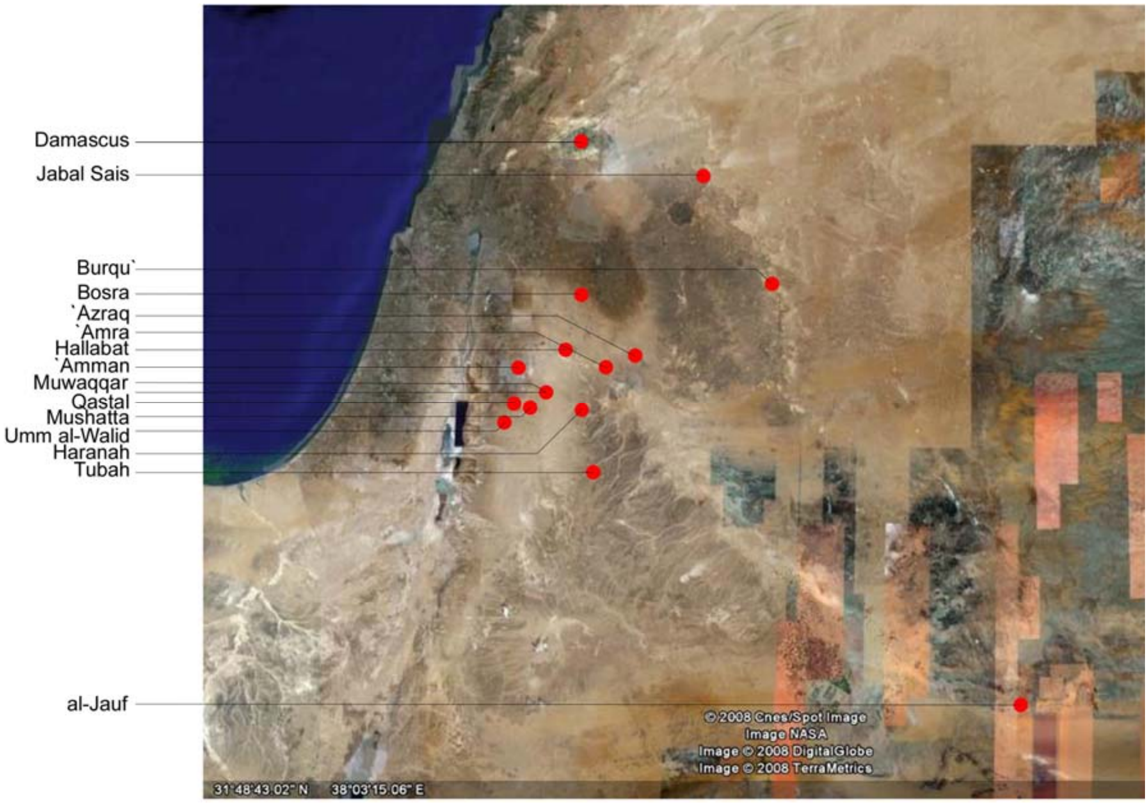

Figure 3.4: Raster image from Google Earth used in this study.

#### 3.4.1.10 Vector Data Model

Real world entities represented by a set of coordinates with associated attributes. The vector data model is a method of storing and representing data on an X,Y Cartesian plane. A coordinate and an equation defining the curvature of each feature is stored for both the beginning and the end point of each feature. The building block of the vector structure is the point; lines and areas are composed of a series of points in a specific order that gives the object direction (Clarke, 1997) the attribute data in the vector model is stored in a separate table that can be linked to the map. Because every item on the map has its own separate attribute data, analysis can be very easy. For example, if a vector the transhumance route network in this study is being used to analyze the amount of the locations of perennial source of water, each route would be capable of having separate attributes, thus allowing the GIS user to view or select each route and access information associated with just that route.

Vector data entities in a GIS hold individual values, for example, if two lines overlap, unique values are recorded for each line in the database (spaghetti model). Selecting an appropriate number of points is another consideration to be made with vector data; if too few points are chosen, the shape and properties of the entity will be compromised and if too many points are used, duplicated information can be stored resulting in data overload (Burrough et al, 1998).

The vector modle used in this study was result of GPS points represented the qusour, Wadis, and source of water. And also wadi_Sarhan, routes and Harra after being digitized.

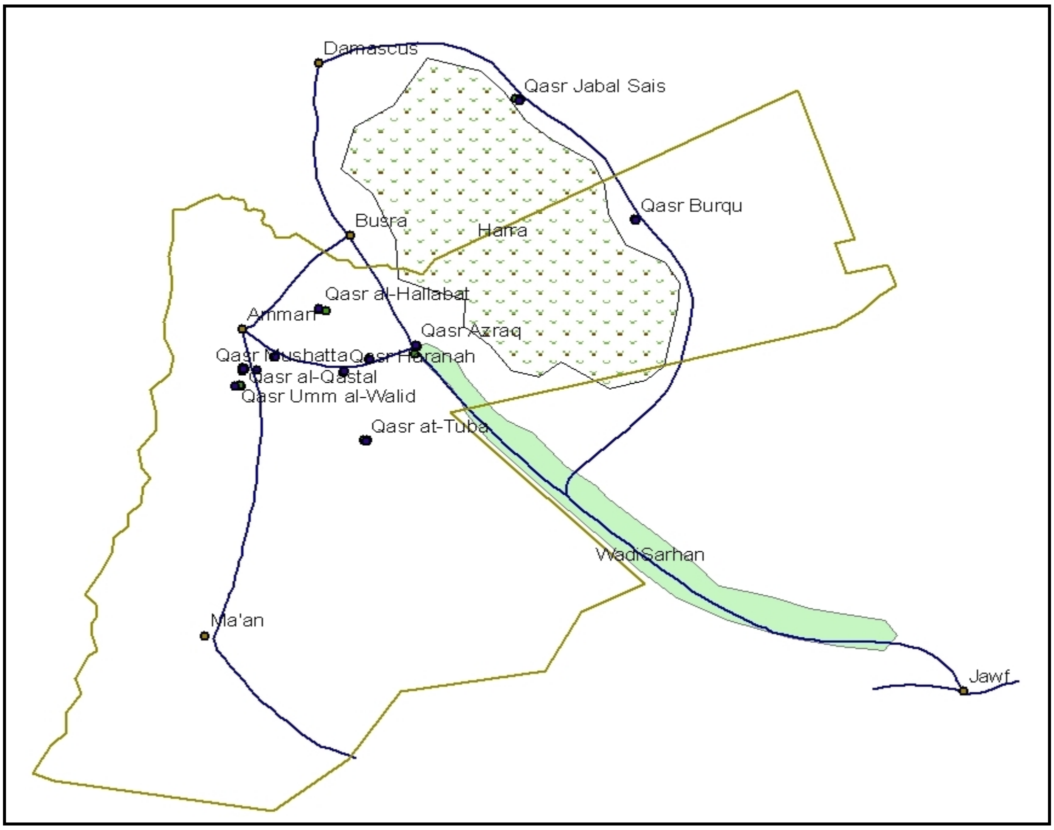


Figure 3.5: Vector model.

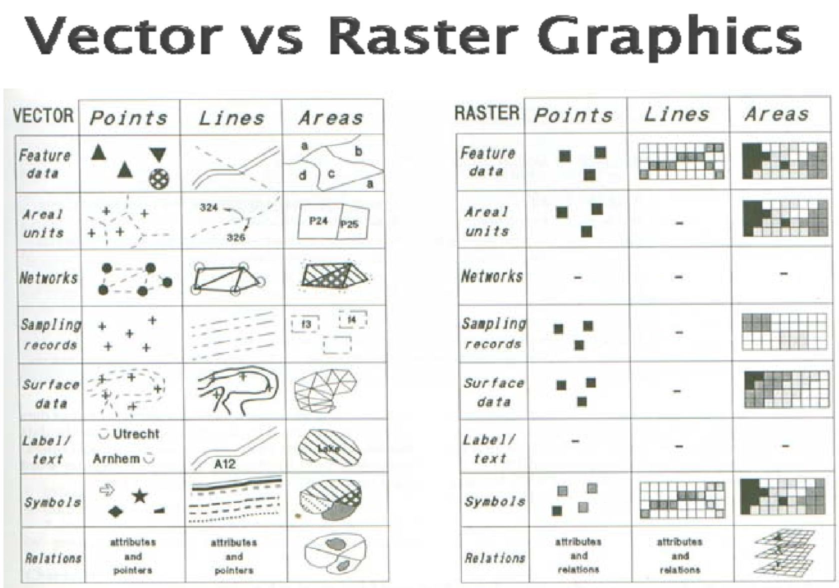


Figure 3.6: Different ways of graphically displaying data with vector and raster models. (Burrough et al, 1998).

#### 3.4.1.11 Shapefile

The shapefile format is the geometry and attributes of geographically-referenced features in as many with specific file extensions that stored in the project. They are:

a) .shp - the file that stores the feature geometry. Required.

b) .shx - the file that stores the index of the feature geometry. Required.

c) .dbf - the dBASE file that stores the tabular information of features. And it is required.

d) .sbn and .sbx - the files that store the spatial index of the features. This one is optional.

There are seven layers were built during the digital map process as the following table:

TABLE 3.2: Layers used in the study.

| No | Layer Name | Type of Feature | Type of Data Source |
|---|---|---|---|
| 1 | qusour | point | Shapefile |
| 2 | water_source | point | Shapefile |
| 3 | cities | point | Shapefile |
| 4 | Routes | Line | Shapefile |
| 5 | wadi_Sarhan | polygon | Shapefile |
| 6 | Jordan | polygon | Shapefile |
| 7 | Harrah | polygon | Shapefile |

### 3.4.2 Tabular Data.

Tabular data, also called attribute or descriptive data, is one of the most important elements in a GIS. It is statistical, numerical, or characteristic information that can be attributed to spatial features. Similar to spatial data the tabular data is stored by the GIS software in a method that allows it to be accessed and viewed, usually in a relational database format. The attribute data about the study were obtained, these data contains the description of the qusour, the name of the qusour, sources of water and wadis and also some historic data about the objects being study. (qusour, source of water, routes transhumance, Wadi_Sarhan and Harrah).

The GIS software (Arc GIS.9.2) allows the attribute data to be linked to the spatial data in such a way that it gives the attributes a location. A GIS package knows a specific location geographically from the storage of spatial data. By linking attribute data to the spatial data, the GIS package knows some of the characteristics of a feature in the spatial data set.

Two or more tabular databases can be linked when there is a common data filed. This allows the GIS to become a powerful spatial analysis tool. A GIS user, after integrating both spatial and attribute data, has the capability to learn a great deal about the defined study area.

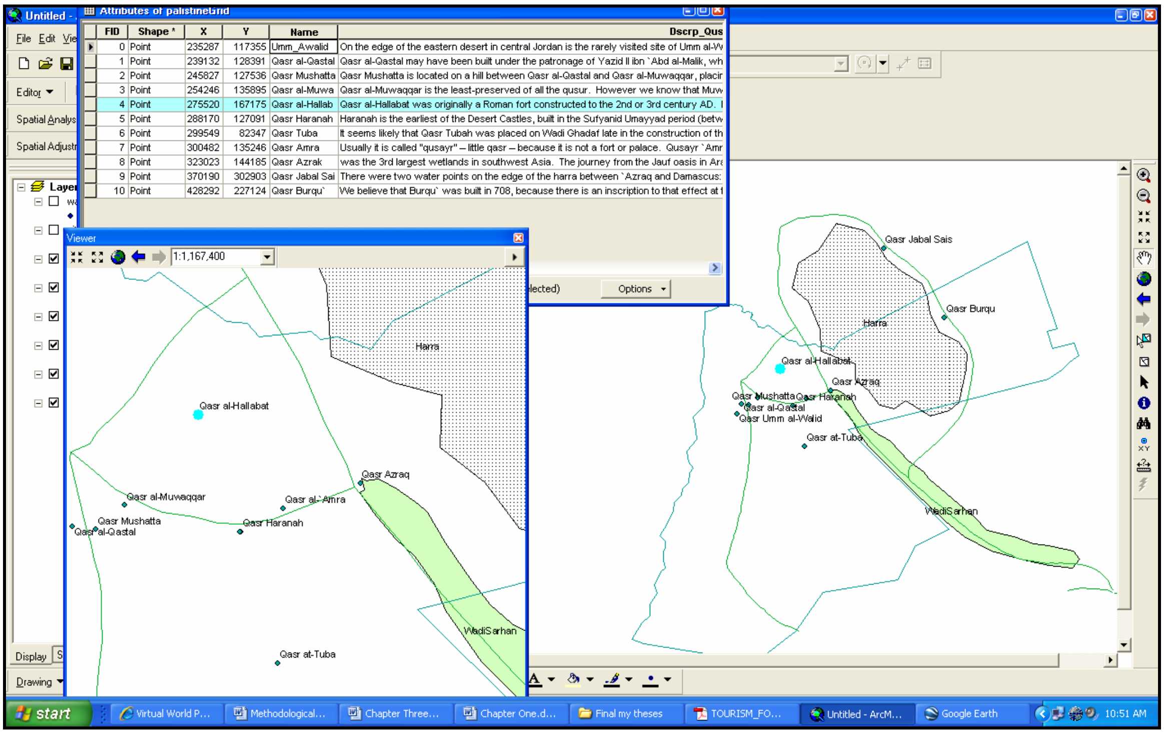

Figure 3.7: Linking between features and their attributes.

## 3.5 Building a Geodatabase

All geographic information systems (GIS) are built using formal models that describe how things are located in space. A formal model is an abstract and well-defined system of concepts. It defines the vocabulary that we can use to describe and reason about things. A geographic data model defines the vocabulary for describing and reasoning about the things that are located on the earth. Geographic data models serve as the foundation on which all geographic information systems are built. We are all familiar with one model for geographic information—the map. A map is a scale model of reality that we build, using a set of conventions and rules (for example, map projections, line symbols, text). Once we construct a map, we can use it to answer questions about the reality it represents. For example, how far is it from qasr Amra to Hallabat? Or, what qasr lie along the Wadi Ghataf ? The map model also serves as a tool for communicating facts about geography visually: Is the terrain rough? Which way is north? In fact, when we *see* a map, we often understand things that might not even occur to us as specific questions.

Maps work because we know the “rules” of conventional map reading: blue lines are rivers, North is toward the top of the page, and so on. In a similar way, geographic data models define their own set of concepts and relationships, which must be understood before we can expect to create or interpret your own data model. These concepts relate to how we can represent geographic information in a computer system, rather than, as in the map example, on paper.

In Modeling Our World, Michael Zeiler has written an excellent primer for understanding the various models used to represent geographic information in ArcInfo™ 8 software. He presents, using straightforward text and excellent illustrations, the concepts and vocabulary employed in the design, implementation, and use of the ArcInfo 8 geographic database. In addition to explaining the ArcInfo data model (objects, features, surfaces, networks, images, and so forth) in detail, Michael also provides good insight into how to use this framework to design useful information models that fit your particular needs. (Michael , 1999).

### 3.6 Database

A database is a mechanism that is used to store information, or data. Information is something that we all use on a daily basis for a variety of reasons. With a database, users should be able to store data in an organized manner. Once the data is stored, it should be easy to retrieve information. Criteria can be used to retrieve information. The way the data is stored in the database determines how easy it is to search for information based on multiple criteria. Data should also be easy to add to the database, modify, and remove. A personal address book is a good example of a dynamic database that many of us use on a daily basis. And the Database elements are the database schema, Schema objects, Tables, Fields and columns, Records and rows, Keys, Relationships and Data types (Ryan  et al, 2001).

### 3.7 Relational Database Model

The relational model was designed by the IBM research scientist and mathematician, Dr. E.F. Codd. Two of Dr. Codd's main focal points when designing the relational model were to further reduce data redundancy and to improve data integrity within database systems. The relational model originated from a paper authored by Dr. Codd entitled, "A Relational Model of Data for Large Shared Data Banks," written in 1970. The relational database model is the most popular database model used today. Many improvements have been made to prior database models that simplify data management, data retrieval, and change propagation management. Data is easier to manage, mainly through the use of integrity constraints. The retrieval of data is also a refined process, allowing the user to visualize the database through relational table structures and to ask for specific data without a detailed knowledge of the database layout. Changes are also easier to propagate, thanks to features such as integrity constraints and the benefits that normalization (reduction of data redundancy) provides. The primary unit of storage in a database is a table, or group of related data. A table consists of rows and columns, a row is associated with an individual record in the table, and a column contains values for all rows associated with a particular field. Tables can be related to one another through common column values, called keys (Ryan  et al, 2001).

Three different types of table relationships are allowed: one-to-one, one-to-many, and many-to many. Different relationships should be allowed to exist between tables in a database. For example, one table might be required to have a record based on the existence of a record in another table. Some tables might optionally have one or more existing records that correspond to records in another table.

Table relationships are defined by referential integrity, which suggests the use of primary key and foreign key constraints. Referential integrity is the use of these constraints to validate data entered into a table and manage the relationship between sub table and main tables. Other types of constraints can also be created to control the permissible data in particular table columns and to establish relationships between tables (Ryan  et al, 2001).

| FID | name | X | Y | shape f | discreption |
|---|---|---|---|---|---|
| 1 | dam 2 - Umm al-Walid | 237983 | 117042 | point | at Ureynbeh wadi It appears that this dam, which runs from NW > SE al |
| 1 | dam - Umm al-Walid | 237490 | 118045 | point | at Ureynbeh wadi It appears that this dam, which runs from NW > SE al |
| 2 | south reservoir - Qastal | 238208 | 126862 | point | Surrounding Qastal, within an area 2km2, are over 70 cisterns. Under th |
| 2 | east dam - Qastal | 239741 | 128450 | point | 403m long, this dam formed a lake behind it, which the Qasr overlooked. |
| 2 | west dam - Qastal | 238750 | 129087 | point | The qasr looked out over a lake which was formed behind a 400m+ dam |
| 2 | Qastal baths | 238520 | 128839 | point | Big reservoir 4000+ cubic meters - is the square diagonally down and to t |
| 2 | Qastal North reservoirs | 239230 | 128884 | point | Qastal had three large reservoirs, which together held over 10,000m3 |
| 3 | Mushata cisterns | 245701 | 127719 | point | at least 30 cisterns associated with it, and seems to have had a system |
| 4 | Muwaqqar reservoirs | 253968 | 136106 | point | beautifully carved capital on the top of the water gauge-column in the qas |
| 5 | Hammam as-Sarah | 278848 | 166165 | point | Elegant bath complex with waterworks very similar to the baths at Qusay |
| 5 | Halabat reservoir | 275333 | 166870 | point | an area of numerous springs and water sources ,the qasr includes a com |
| 6 | Harranah Wadi1 | 288006 | 126731 | point | and it does not have the water infrastructure that the other qusur have. |
| 6 | Harranah Wadi2 | 288357 | 127539 | point | it is very different in architectural style and function from the other qusur |
| 7 | Tubah Well | 300201 | 82956 | point | Qasr Tubah has three enormously deep wells, large pools for watering liv |
| 7 | Tubah Wadi Ghadaf | 298609 | 83233 | point | Wadi Ghadaf, one of the access routes from Wadi Sirhan onto the platea |
| 8 | Amra Wadi | 300362 | 135040 | point | the qasr was constructed in the very flow of the watercourse û presumabl |
| 9 | Azraq - 'Ain Soda | 322424 | 138958 | point | An extensive area of Umayyad ruins and waterworks |
| 9 | Azraq oasis | 323558 | 143795 | point | a huge reservoir was there, as well as some strange, decorated pools an |
| 10 | Jabal Sais lake1 | 368483 | 304109 | point | the eruption of volcanoes opens springs û cracks and faults which allow |
| 10 | Jabal Sais lake2 | 370639 | 303454 | point | two lakes were so formed -- just northwest and just southeast of the volc |
| 11 | Burqu Lake | 427644 | 228047 | point | It is built exactly on a lake which is still the only year-round watering plac |

Figure 3.8: Relational database used in this study represents the source of water and water infrastructure database.

## 3.8 Database design.

According to Ryan Stephens and Ronald Plew, the Design methodology of this study involves the following three phases:

A. Requirements analysis.
B. Data modeling.
C. Design and Normalization.

### 3.8.1 Requirements analysis

Requirements analysis involves capturing the needs of the qusour database, and converting those needs into the requirements for a qusour database system. Information is gathered in order to begin modeling the database in the data modeling phase. During data modeling, entities are visually represented in order to get good understanding of the qusour database system's needs. Finally, objects in the data model are designed into tables and normalized to reduce the amount of redundant data stored in the database. Most methodologies follow these three steps.

The analysis plan is basically an outline of the events that will occur during the requirements phase of the design process One of the most important products of the requirements phase is an entity relationship diagram that illustrates the qusour model. This diagram is also referred to as an analysis ERD. The point of this initial ERD is to provide the researcher with a picture of the different categories of data for the qusour, as well as how these categories of data are related to one another. The analysis ERD might also be used during researcher feedback sessions to see that the work has actually been performed so far. The ERD can also be used when compiling summarized documentation of what occurred during the requirements phase. With respect this ERD should be simple and focused on the qusour, not the actual system.

The ERD is used to generate the physical model. The physical model consists primarily of tables which are based on the entities defined during logical modeling and should be shown in the ERD. After the tables have been defined, columns are defined, which more specifically identify rows of data, or records, that are stored in a particular table.

Entity relationship modeling is the process of visually representing entities and attributes that are defined as a result of interviews, one of the initial steps during the qusour-analysis process. The entity relationship diagram (ERD) is an iterative tool and process that models logical data structures during the analysis phase of system development. ERD components are data entities, the attributes of those entities, and the relationships among the entities. The complete ERD is used later in database design to physically design database tables.

The creation of an ERD first involves the definition and identification the entities. Entities are classes of things of importance about which data must be stored or manipulated in the course of qusour processes, for example qusour or source of water. Entities are the nouns of the study information system.

The first step in creating an ERD, then, is to capture an unconstrained group of entities that represent all the objects in data model and then draw them into ERD. Over time, as working on data model, that group of entities will evolve toward completion. As the process continues, was creating, deleting, and modifying entities in the ERD to fit the qusour database requirements (Ryan et al, 2001).

#### 3.8.1.1 Entities

There are various definitions of an entity:

"Any distinguishable person, place, thing, event, or concept, about which information is kept" (Brus, 1992).

"A thing which can be distinctly identified" (Chen, 1976).

"Any distinguishable object that is to be represented in a database" (Date, 1986).

"anything about which we store information (e.g. supplier, machine tool, employee, utility pole, airline seat, etc.). For each entity type, certain attributes are stored". (Mart, 1989).

Once researcher has identified a list of potential entities and placed them into an ERD, the next step is to identify the relationships between the entities. Relationships are the verbs of the system. a relationship is a bidirectional connection between two entities or between an entity and itself.

Relationships were represented by diamonds between entities in an ERD. Entities were represented by rectangle and attributes were represented ellipsoid.

Table relationships are modeled in the logical model and implemented in the physical model using primary key and foreign key constraints. Each primary key value of a table was a unique. Foreign keys do not have to be unique, although a unique constraint might be placed on a foreign key column. The primary key represents the parent record, whereas the foreign key represents the child record of some primary key.

Two basic table relationships was used in this study with the relational model. These relationships are:

A. One-to-one.
B. One-to-many.

In a few words, a one-to-one relationship involves the existence of a maximum of one record of sub table per one record of main table. With the one-to-many relationship, a record of main table might have many records of sub table.

Once the entities and their relationships captured in the ERD, the next step is to capture and identify the attributes of the entities. the first task was to identify a unique identifier attribute or combination of attributes for each entity. Every entity must start with a unique primary key.

Attribute and column names should not include space for hyphens, commas, or other formatting punctuation. Such items are not stored in the database and are not allowable characters for most relational database management systems (RDBMSs). Sometimes, entity and attribute names include spaces. When the converting entities to tables and physically designing those tables, spaces that are found in entity and attribute names are replaced with underscores (Ryan et al, 2001).

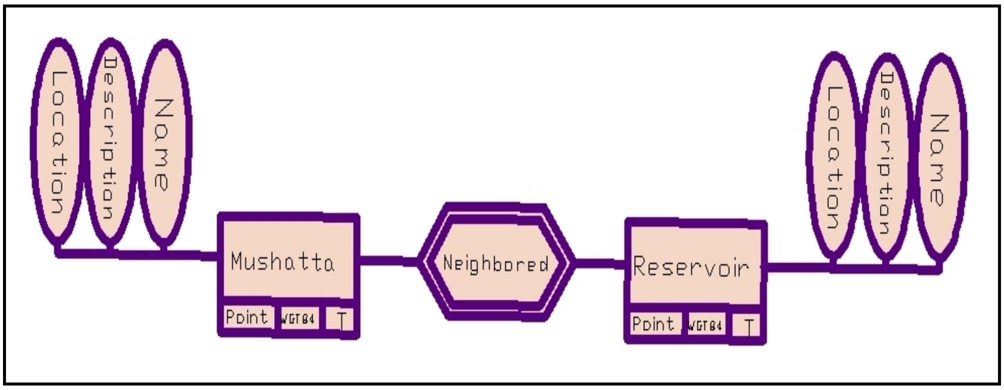


Figure 3.9: One-to-one relationship in ERD

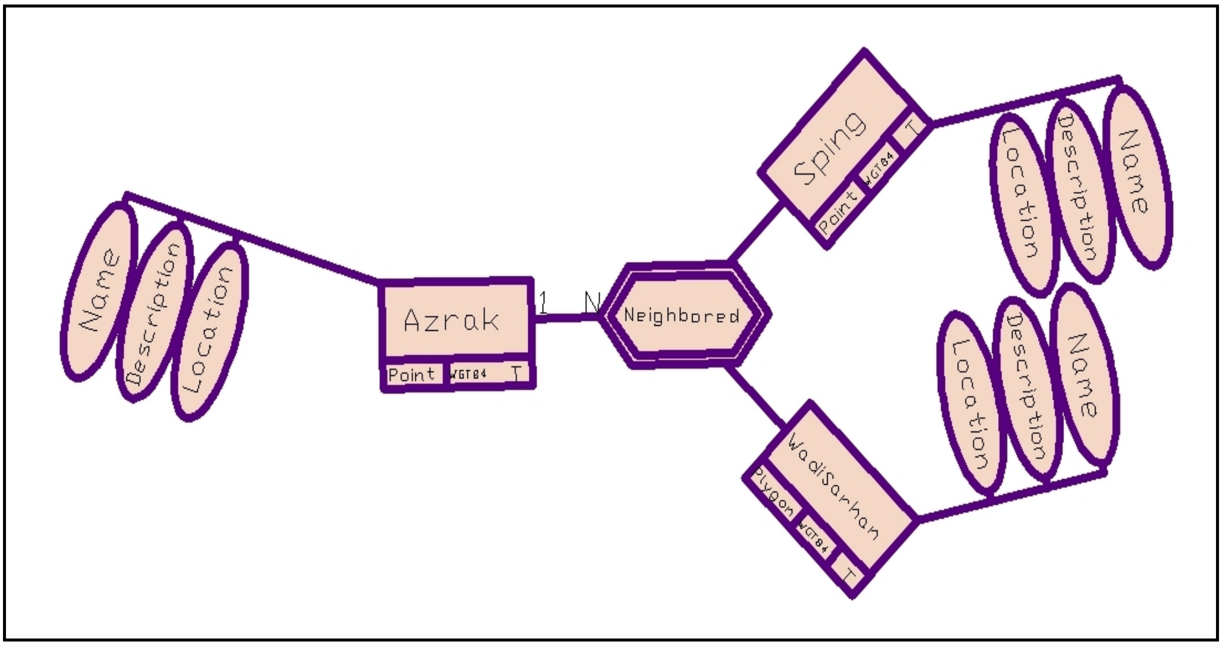


Figure 3.10: One-to-many relationship in ERD

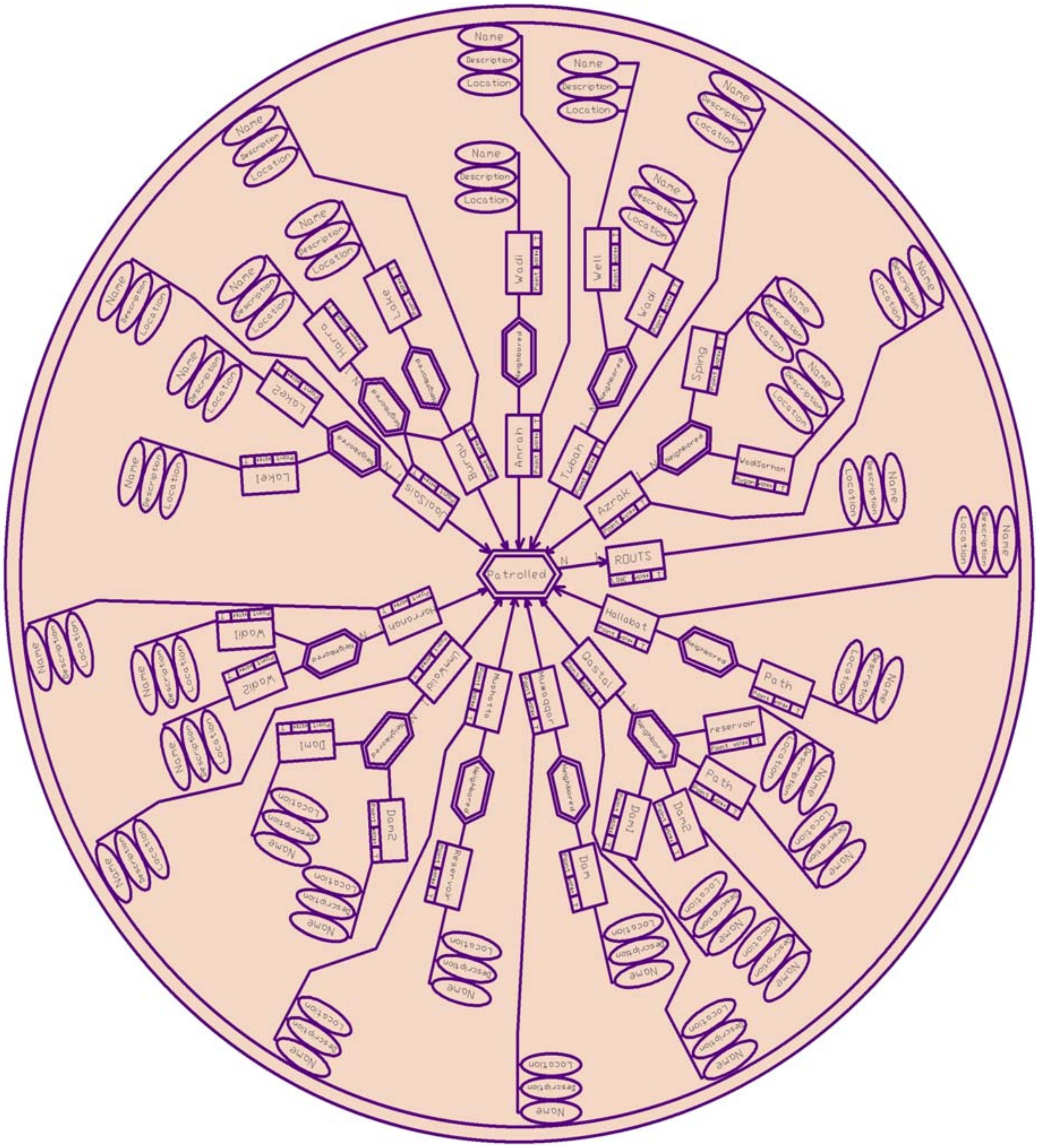

Figure 3.11: ERD for the entire study.

### 3.8.2 Data modeling

According to Ryan Stephens and Ronald Plew, two types of modeling of the data, as follows:

I. Logical modeling.
II. Physical modeling.

#### 3.8.2.1 Logical Modeling

Logical modeling deals with gathering the digital map requirements and converting those requirements into a model. The logical model revolves around the needs of the digital map, not the database, although the needs of the digital map are used to establish the needs of the database. Logical modeling involves gathering information about digital map processes, digital map entities (categories of data), and organizational units. After this information is gathered, diagrams and reports are produced including entity relationship diagrams, digital map process diagrams, and eventually process flow diagrams. The diagrams produced showed the processes and data that exists, as well as the relationships between digital map processes and data.

#### 3.8.2.2 Physical Modeling

Physical modeling involves the actual design of a database according to the requirements that were established during logical modeling. Logical modeling mainly involves gathering the requirements of the digital map, with the latter part of logical modeling directed toward the goals and requirements of the database. Physical modeling deals with the conversion of the logical or digital map model, into a relational database model. When physical modeling occurs, objects are being defined at the schema level. a schema is a group of related objects in a database. A database design effort is normally associated with one schema.

During physical modeling, objects such as tables and columns are created based on entities and attributes that were defined during logical modeling. Constraints are also defined, including primary keys, foreign keys, other unique keys, and check constraints. Views can be created from database tables to summarize data or to simply provide the researcher with another perspective of certain data. Other objects such as indexes and snapshots can also be defined during physical modeling. Physical modeling is when all the pieces come together to complete the process of defining a database for a digital map.

Physical modeling is database software specific, meaning that the objects defined during physical modeling can vary depending on the relational database software being used. For example, most relational database systems have variations with the way data types are represented and the way data is stored, although basic data types are conceptually the same among different implementations. Additionally, some database systems have objects that are not available in other database systems (Ryan et al, 2001).

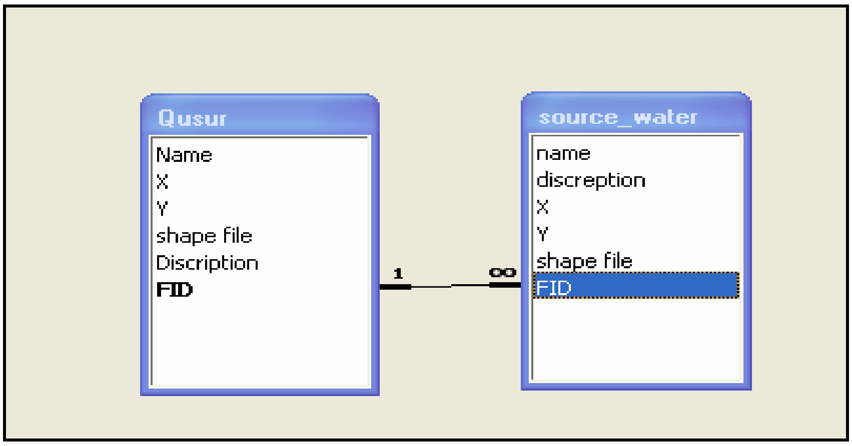

Figure 3.12: One-to-many relationship in Physical modeling.

### 3.8.3 Automated Design Tools

Automated design tools formerly known as CASE tools are graphical user interface (GUI) applications that are used to aid in the design of a database or database application. Automated design tools are used to automate and expedite the task of designing a digital map system. These automated tools store information about digital map requirements and assist in the overall design and generation of a digital map system.

### 3.8.4 Normalization

Normalization is the process of reducing the redundancy of data in a relational database. Redundant data refers to the data that is stored in more than one location in the database. Data should not be redundant, which means that the duplication of data should be kept to a minimum for several reasons. For instance, it is unnecessary to store qasr al_Hallabat in more than one table. With duplicate data, unnecessary space is used. Confusion is always a threat when, for example, the description for qasr Amrah in one table does not match the description of the same qasr in another table. Which table is correct?!! As if data management is not difficult enough, redundancy of data could prove to be a disaster. On the other hand, there are also benefits to databases that have not been normalized, mainly related to increased database performance (Ryan et al, 2001).

# CHAPTER FOUR
# ANALYSIS

## 4.1 Visualization

Visualization is the cheaper way in GIS and the easiest to implement. Seeing the data on a digital map, rather than a spreadsheet, makes possible more informed and faster decision making. After completing the digital map the researcher will examine the distribution of all of the features on the map in order to grasp visually an imagination of the landscape and how the Umayyad qusour were distributed along the routes of transhumance. The visualization will also allow us to place the qusour in the context of other geographically determinative features such as water sources, wadis (seasonal washes), etc.

Visualization, the representation of data in a viewable medium or format. In GIS, visualization is used to organize spatial data and related information into layers that can be analyzed or displayed as maps, for example: three-dimensional, tables, summary charts, time-based views, and schematics. (ESRI, 2006).

Visualizing information interactively is one of the most attractive and useful capabilities of GIS. High-powered computers can change any element of the display "on the fly," changing not just the look of the graphic image but also its interpretation. This ability to create multiple perspectives enhances a viewer's perceptive abilities to understand the phenomenon being studied like never before. Visualizing data using current computing technology and interactive GIS has many advantages over doing so using traditional paper maps (ncgia, 2008).

Maps have conventionally been used to represent the real world. GIS technology has improved the effectiveness traditional cartography. Through a process known as visualization, a GIS can be used to produce images not only maps, but animations, drawings, and other cartographic products. These images allow researcher to view the objects in ways that he can't see by traditional map.

## 4.2 Proximity analysis

Proximity analysis is a type of analyzing locations of features points, lines, polygons, or raster by measuring the distance between them and any features in the study area. The distance between one point and another can be measured as straight lines directly or by topologic network's paths, in this study the measurements conducting directly without paths, because of no routable network involved. After getting the database and digital map done, viewer can easily measure the distance between any qasr and its source of water or between any two features in the map. Or can search which qasr closer to the transhumance routes, etc…

### 4.2.1 Buffering

It is a type of proximity analysis that is supported by most GIS, buffer can be a polygon of a specified width around a point, line, or area. And is defined in such systems by real-world distances from one or more map elements.or a polygon enclosing a point, line, or polygon at a specified distance. A buffer is useful for proximity analysis (magic.gov).

Therefore using the query and buffer tool would answer for the question which points located within specific distance from any other point in study area? For example which source of water located within 500m from qasr Al-Qastal?.

### 4.3 Exploratory digital map

The researcher examined the Umayyad qusour's digital map and fined out that there are three matters concern of the features being study:

First: the distance between Hammam as-Sarah and qasr Hallabat is 3,477m. Because the bath complex and qasr were constructed at the same time, and the baths built in order to serve the qasr, it is reasonable to assume that this distance (three and a half kilometers) was satisfactory to the Umayyad caliphate. Because they decided the location of the qasr and the baths, this is mean they dicided the distance between their buldings. Seeing Hammam as-Sarah as a part of the complex of water systems serving the qasr, we might generalize that three and a half kilometers is a typical radius of buffer for the water infrastructure of the Umayyad qusour. Thus the researcher drew a circular buffer zone with a 3.477 radius around each of the desert qusour in the study area in order to examine whether there is a water source within every buffer zone. By this method we can demonstrate a positive association between water sources and the qusour.

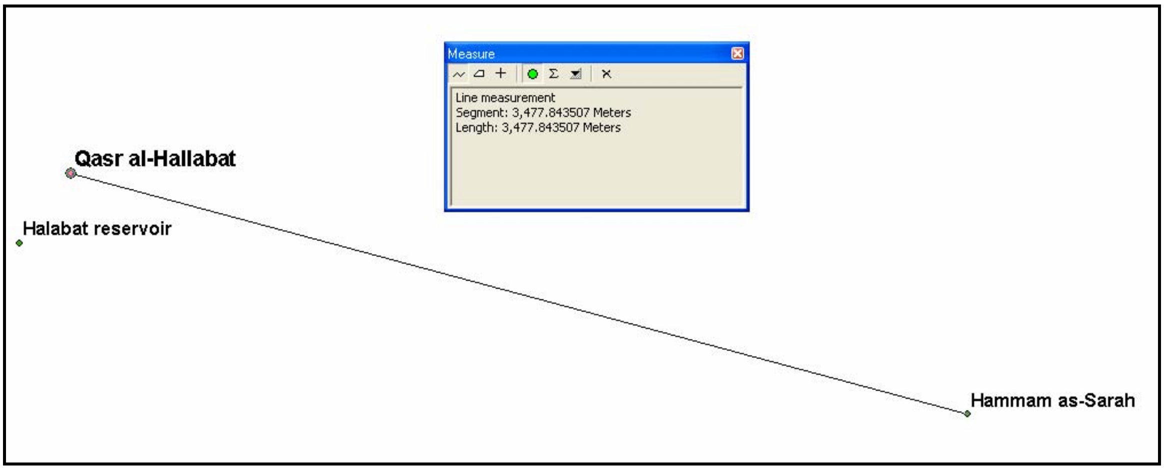

Figure 4.1: The distance between Hammam as-Sarah and qasr Hallabat.

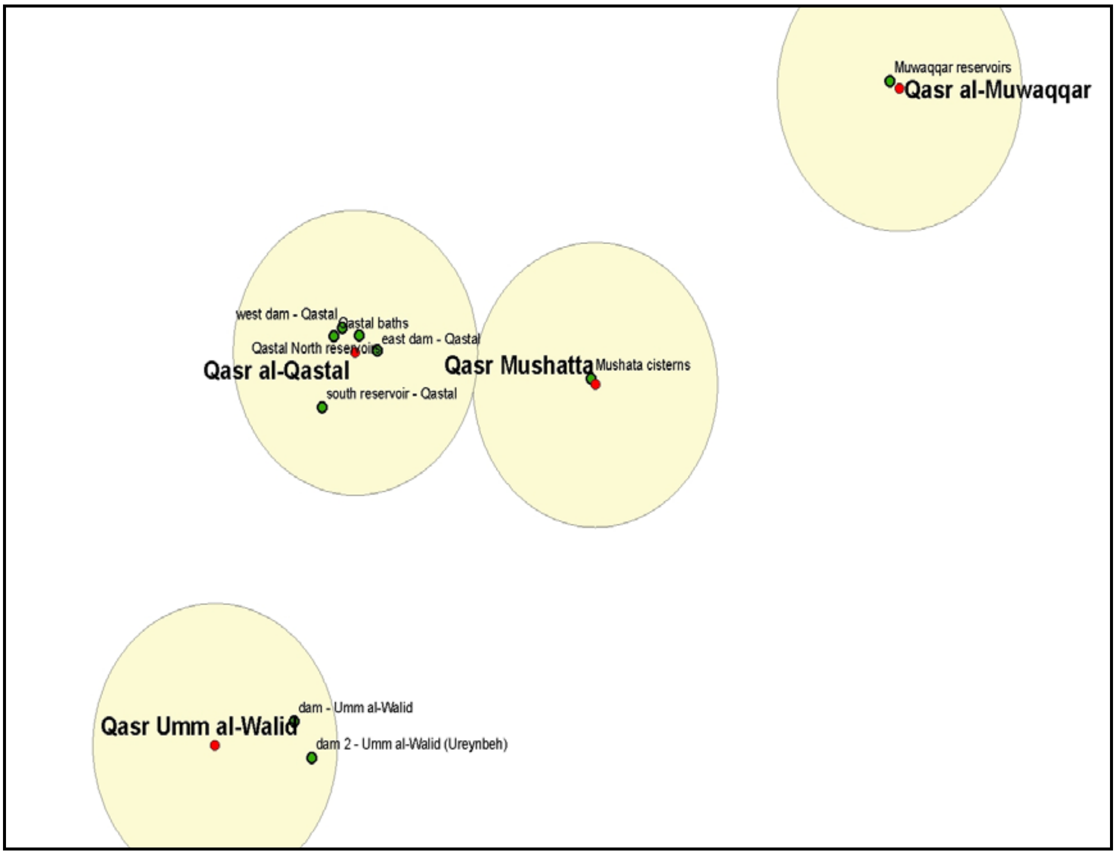


Figure 4.2: Buffer zone with radius 3,477m.

Second: the routes connected three cities together (Busra, Azraq and Amman), with a triangle shape, qasr Al-Hallabatlocated almost in the center of these cities, the qasr deviated form the mean 9km toward the west, this is make sense with respect of the rugged terrain, because at the east of the mean is a flat area, it would become rough as you go toward the west of the mean, rugged terrain would delay a movement.  Besides that qasr Tuba in the south located in between two routes.

A movement in Umayyad period was through animals, like horses and camels, camels can run at speeds up to 64 km/h in short sprints, and they can keep a speed of 40 km/h for an hour (Camel-racing, 2008). Therefore the researcher made a circle buffer around qasr Al-Hallabatwith radius 40km in order to examine if the routes around the qasr would be covered in that distance or not, the distance between qasr Tuba and the two routes was measured, then a circle with radius 52km was made in order to show that qasr located almost in the middle.

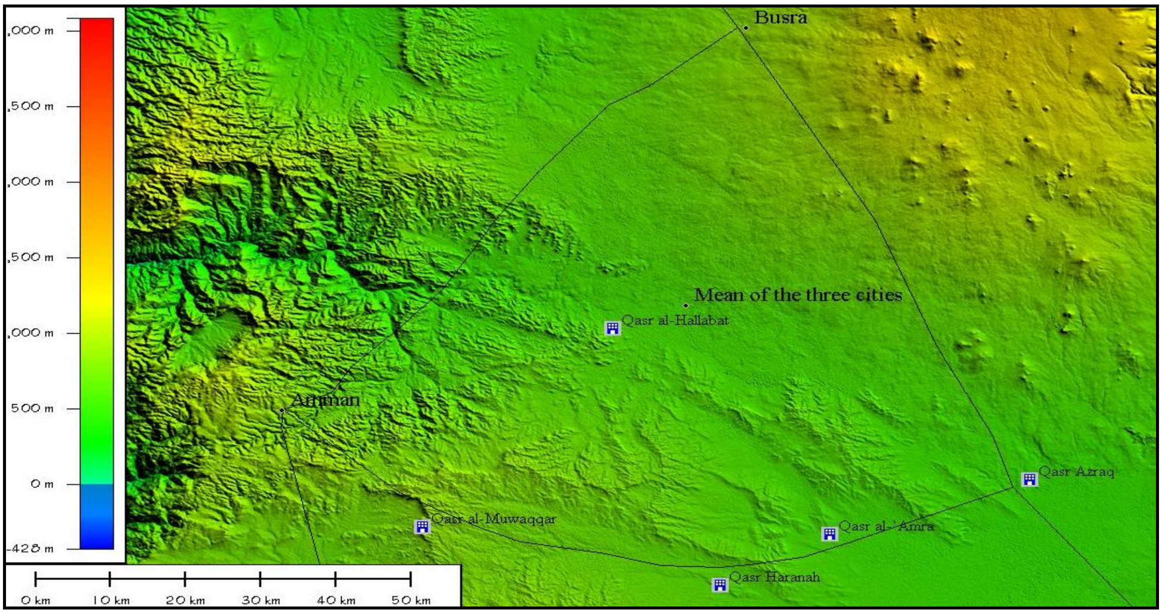


Figure 4.3: Cities, triangle shape, mean and the terrain.

Third: there are two groups of desert castles; one of them located east of Harrah and the other located west of Harrah, once the one located east of Harrah and its qusour are dotted fitly on the route, therefore the researcher considered their locations as points for patrolled station on the transhumance routes at the east of Harrah.

The second group of desert castles is located west of Harrah, This group is distributed in a sort of diamond-shape, for better understanding the distribution and ease for analysis,  the researcher highlighted the diamond shape , the four vertices point to the four cardinal directions (north, south, east, west); qasr Hallabat is at the north vertex, qasr Tubah at the south.  The other qusour are located along the diagonal lines connecting the east and west vertices. After that circle buffer made around each qasr of which located a long of the diagonal, with radius 17km, the radius length was 17km to cover the whole diagonal distance. The distance of qasr Halabat and the closest qasr is measured (37.82km), the distance between qasr Tuba and closest qasr is measured (46.16km).

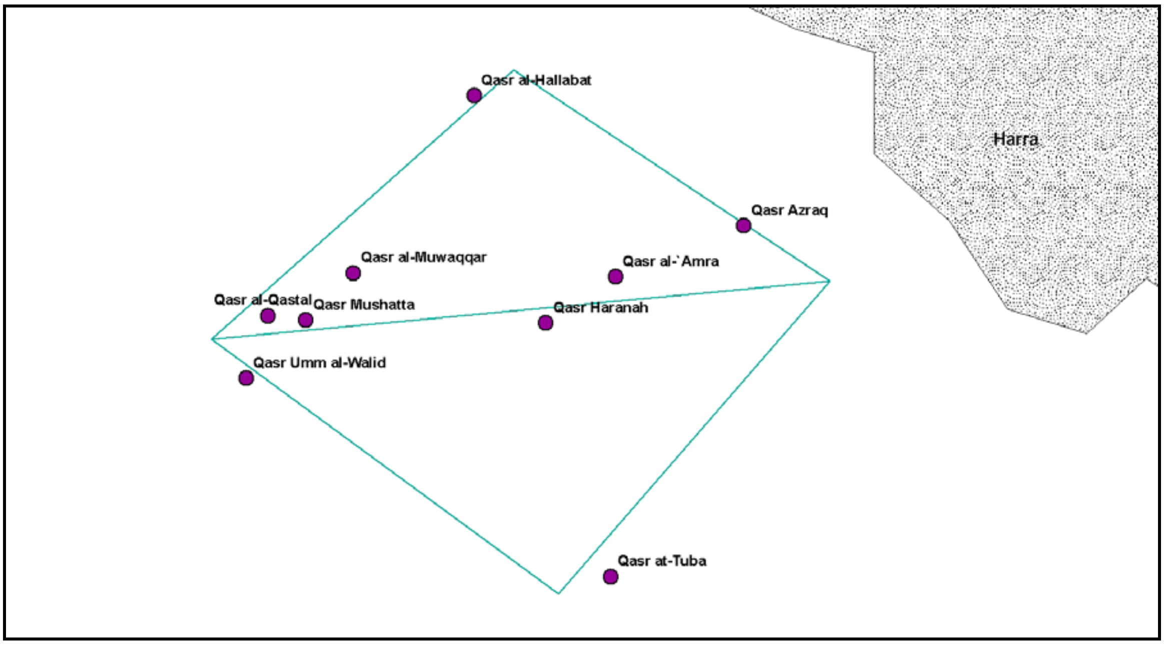


Figure 4.4: Distribution of qusour in second group looks like a diamond shape.

## 4.4 Line-of-sight communication

The proximity analysis was made in previous step, next the second step is to examine the line-of-sight communication between the desert castles, for that the writer used Global Mapper7 software and DEM, then the SHP file of the desert castles imported into Global Mapper7 software as a qusour layer at that time DEM installed as the second layer and then overlapping two layer in one map, then simply the researcher examined the profiles between each qasr with consideration of the earth curviness and the height of qusour as 20m, the height of qusour were choose arbitrarily because most of the qusour are damaged but still some of them which higher than 20m.

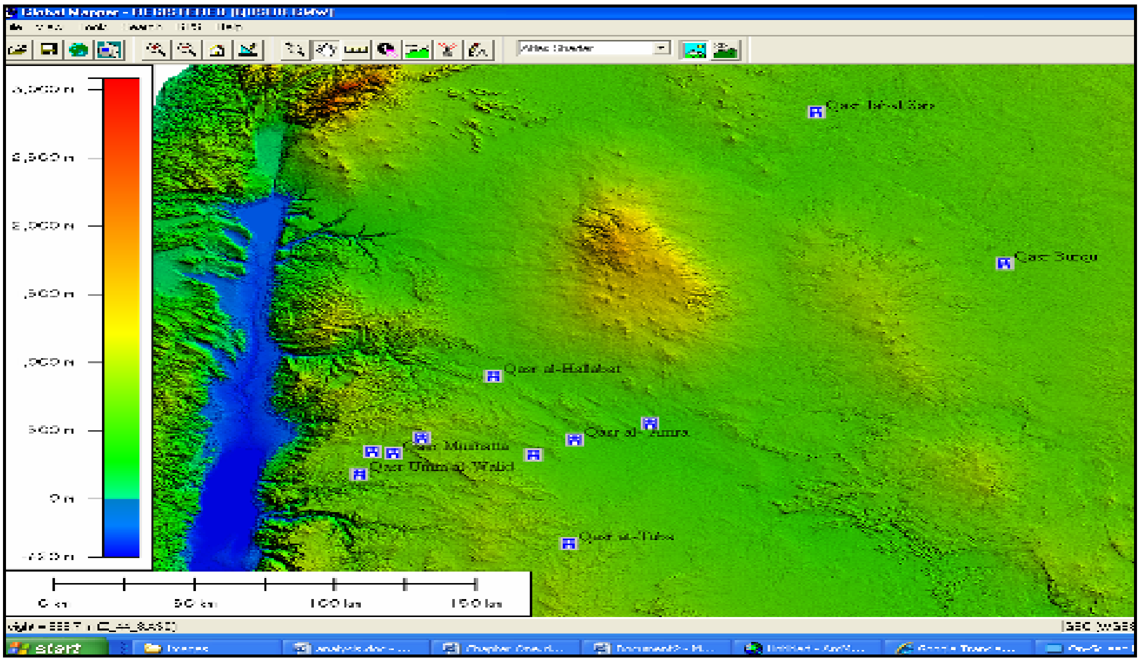


Figure 4.5: Desert castles in the context of terrain and DEM.

### 4.5 Point pattern analysis

Point Pattern Analysis engages the ability to describe patterns of locations of point events and then test whether there is a significant occurrence of clustering of points in a particular area. The spatial pattern of a distribution is distinct by the arrangement of points in the space and also the geographic relationships among them. The ability of evaluating spatial patterns is a requirement to understanding the spatial processes original the distribution of a phenomenon.

There are three general patterns:

I. Random any entity is equally likely to happen at any location and the location of any entity is not affected by the location of any other entity. There is no apparent ordering of the distribution.

II. Uniform every entity is as far from all of its neighbors as possible.

III. Clustered many entities (points) are concentrated close together, and large areas that contain very few, if any, entities (Upton ea al, 1985).

The most common methods for measure the spatial pattern analysis are as follows:

A. Quadrant Count Method.
B. Kernel Density Estimation.
C. Nearest Neighbor Distance. (Erum T, 2004).

According to Erum .T in the Introduction to Point Pattern Analysis, The criteria would use to determine if a data set is appropriate for study area's type of point pattern analysis is given by the following:

I. Spatial data must be mapped on a plane.

II. The study area must be selected and determined before to the analysis.

III. Point data should not be a selected sample, but whole set of data must be analyzed.

IV. There should be one to one correspondence between objects in study area and events in pattern.

V. Points must be true incidents with real spatial coordinates; latitude and longitude coordinates are needed.

The researcher selected the Quadrant Count Method for analyze the distribution pattern of the qusour. While the other techniques listed can be more descriptive and more accurate it is also true that many of these other methods are more complicated and difficult to implement. Quadrant Count Analysis is relatively easy method to implement and it has provided several opportunities to apply basic mathematical and statistical concepts, and also allowed for Test Statistic.

### 4.5.1 Quadrant Count Method

Quadrant Count Methods: This method simply record and count the number of events that occur in each quadrant. Based on a measure resulting from data obtained after a uniform grid network is drawn over a digital map of the desert castle, Quadrats don’t have to be square and their size has a big influence and they should be the same size and same shape among the entire grid. The frequency count, the number of qusour occurring within each quadrat is recorded, These data are then used to compute a measure called the variance, then The variance compares the number of qusour in each grid cell with the average number of points over all of the cells, Then the variance of the distribution of the qusour is compared to the characteristics of a random distribution.

The Mean and Variance are then computed to calculate the Variance-to-Mean Ratio (VTMR). The following is the way we will interpret the VTMR:

If VTMR>1, the pattern is clustered. This means that the data set has one or more groups of points in clusters and large areas of maps without points.

If VTMR<1, the pattern is regularly dispersed implying the events are distributed more or less regularly over the region.

If VTMR=1, the pattern is random. This means that the data set has no trend towards clustering or dispersion.

Weakness of Quadrat Analysis:

a) If the quadrats are too small, they may contain only a few points. If they are too large, they may contain too many points.

b) It is suggested that area of the quadrat should be twice as big as the study mean area.

$$Width = \sqrt{2\frac{Total\ area}{n}}$$

c) Actually a measure of dispersion, is not really pattern, because it is based primarily on the density of points, and not their arrangement in relation to one another.

d) Results in a single measure for the entire distribution, so variations within the region are not recognized.

e) Different sizes or orientations of the quadrad would effects the results. (Arthur J, Lembo .Jr).

The Mean can then be calculated as:

$$Mean = \frac{No.\ of\ qusur.in\, the\, studyarea}{No.of\ quadrants}.$$

Let $x_i$ be the frequency of qusour in each quadrant and n number of all qusour. Then Variance can be calculated as:

$$Variance = \frac{\sum x_i^{\,2} - \frac{(\sum x_i)^2}{n}}{n-1}.$$

The Variance to Mean Ratio or VTMR is calculated as:

$$VTMR = \frac{Variance}{Mean}.$$

H0: The distribution of desert castle is not significantly different than random.

Ha: The distribution of desert castle is significantly different than random.

Test Statistic: use the D statistic of the Kolmogorov-Simirnov , K-S test:

If D calculated> D critical at a given significance level reject the null-hypothesis.

Calculate the test statistic D:

D = max [Cumulative Observed Frequency _Cumulative Expected Frequency]

The critical value Dcritical at the 5% level is given by:

$$D_{0.05} = \frac{1.36}{n_Q}$$

$n_Q$ is the number of quadrats (Upton ea al, 1985).

The researcher conducted the quadrant analysis using Arc view GIS 3.2 software, with category projections of the world and type geographic as the projection systems. The type of coverage quadrats was complete and the Quadrat shape was square, with 16 quadrats.

# CHAPTER FIVE
# RESULTS

## 5.1 Digital map and geodatabase

The digital map and geodatabase for the desert castle, represent the Umayyad qusour, source of water, wadi_sarhan, Harrah, mager cities in Umayyad period and the transhumance routes, by the aid of GIS and its capability the viewer can linking between features on map and its attributes and get the information he need, the information can be obtained of this digital map and geodatabase; the position of any feature and its coordinates, the names, brief historic information about each feature and others, as will as viewer can proceed a all kind of analysis to get better understanding for Umayyad qusour, Any statistic we can think of to describe the  data then automatically has geographic properties and as a result can be placed on maps for visual processing. "history and computing is not only about historical research, but also about historical resource creation" (Woollard, 1999). So digital map and geodatabase of the desert castle as a result of this research would be a historical resource for Umayyad qusour.


Figure 5.1: Resulted digital map.

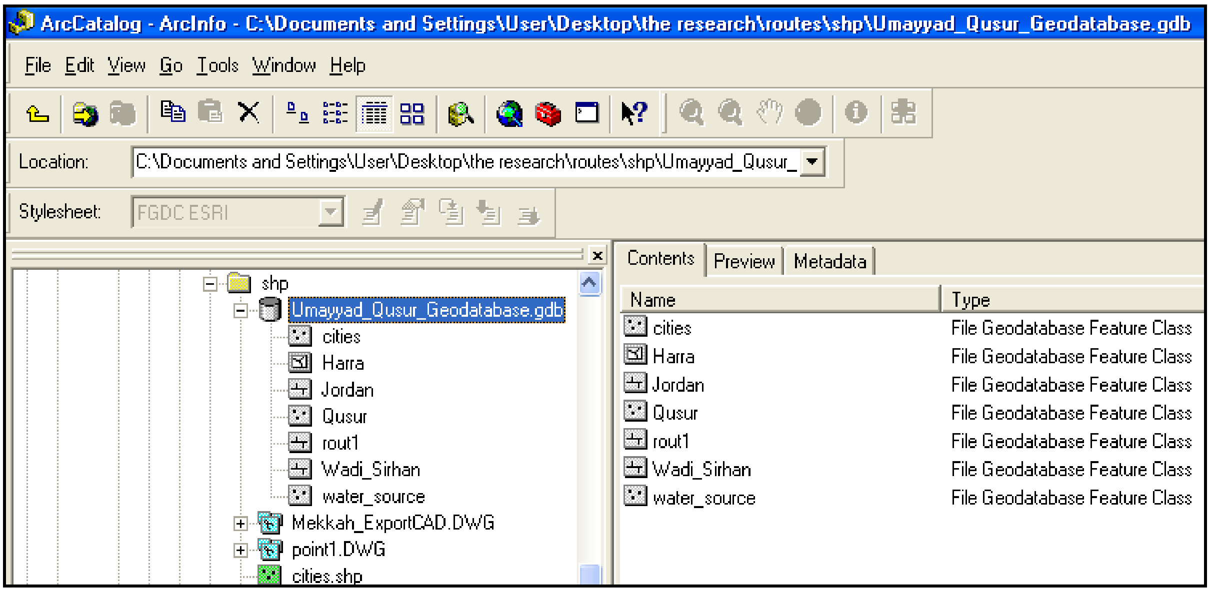

Figure 5.2: Resulted geodatabase made by ArcCatalog_ArcInfo.

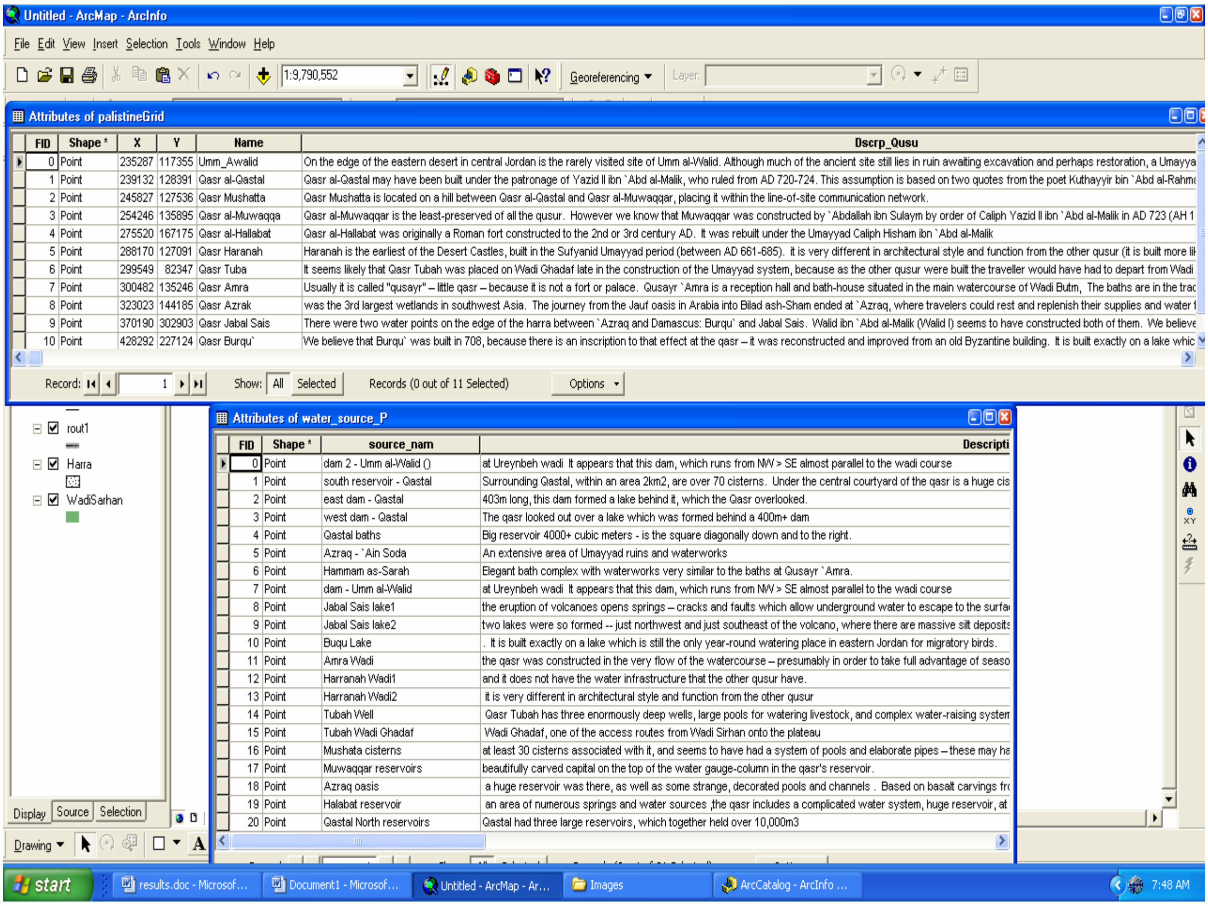

Figure 5.3: Resulted attributes of geodatabase made by ArcGIS 9.2.

TABLE 5.1: Database of Umayyad qusour.

| Umayyad qusour | | | | | |
|---|---|---|---|---|---|
| FID | qasr Name | X | Y | shape file | Description |
| 1 | Umm al-Walid | 235287 | 117355 | point | On the edge of the eastern desert in central Jordan is the rarely visited site of Umm al-Walid. Although much of the ancient site still lies in ruin awaiting excavation and perhaps restoration, a Umayyad qasr and Mosque have been excavated and preserved. |
| 2 | qasr al-Qastal | 239132 | 128391 | point | qasr al-Qastal may have been built under the patronage of Yazid II ibn `Abd al-Malik, who ruled from AD 720-724. This assumption is based on two quotes from the poet Kuthayyir bin `Abd al-Rahman `Azza (AH24-105/ AD644-723), found in a panegyric in praise |
| 3 | qasr Mushatta | 245827 | 127536 | point | qasr Mushatta is located on a hill between qasr al-Qastal and qasr al-Muwaqqar, placing it within the line-of-site communication network. |
| 4 | qasr al-Muwaqqa | 254246 | 135895 | point | qasr al-Muwaqqar is the least-preserved of all the qusour. However we know that Muwaqqar was constructed by `Abdallah ibn Sulaym by order of Caliph Yazid II ibn `Abd al-Malik in AD 723 (AH 104) -- because of an inscription on a huge, beautifully carved c |
| 5 | qasr al-Hallabat | 275520 | 167175 | point | qasr al-Hallabat was originally a Roman fort constructed to the 2nd or 3rd century AD. It was rebuilt under the Umayyad Caliph Hisham ibn `Abd al-Malik |
| 6 | qasr Haranah | 288170 | 127091 | point | Haranah is the earliest of the Desert Castles, built in the Sufyanid Umayyad period (between AD 661-685). it is very different in architectural style and function from the other qusour (it is built more like a fortified khan than a palace), and it does n |
| 7 | qasr Tuba | 299549 | 82347 | point | It seems likely that qasr Tubah was placed on Wadi Ghadaf late in the construction of the Umayyad system, because as the other qusour were built the traveller would have had to depart |

| Umayyad qusour | | | | | |
|---|---|---|---|---|---|
| FID | qasr Name | X | Y | shape file | Description |
| | | | | | from Wadi Sirhan further and further south to escape being detected by |
| 8 | qasr Amra | 300482 | 135246 | point | Usually it is called "qusayr" û little qasr û because it is not a fort or palace. Qusayr `Amra is a reception hall and bath-house situated in the main watercourse of Wadi Butm, The baths are in the traditional Hellenistic style, with a cold room, tepid |
| 9 | qasr Azrak | 323023 | 144185 | point | was the 3rd largest wetlands in southwest Asia. The journey from the Jauf oasis in Arabia into Bilad ash-Sham ended at `Azraq, where travelers could rest and replenish their supplies and water their livestock |
| 10 | qasr Jabal Sais | 370190 | 302903 | point | There were two water points on the edge of the harra between `Azraq and Damascus: Burqu` and Jabal Sais. Walid ibn `Abd al-Malik (Walid I) seems to have constructed both of them. We believe that Burqu` was built in 708, because there is an inscription |
| 11 | qasr Burqu` | 428292 | 227124 | point | We believe that Burqu` was built in 708, because there is an inscription to that effect at the qasr, it was reconstructed and improved from an old Byzantine building. It is built exactly on a lake which is still the only year-round watering place |

The next figure 5.4 is report for Umayyad qusour made via Access 2003 software, it contains four pages (A,B,C,D); the report represents names of Umayyad qusour, coordinates(X,Y), the relative water_source or water infrastructure and its coordinates (X,Y). Palestine Grid was used as a coordinate system.

# Umayyad_Qusur

| Name | Qasr al-Hallabat |
|---|---|
| Coordinate_X | 275520 |
| Coordinate_Y | 167175 |

| its water source name | Halabat reservoir |
|---|---|
| Coordinate_X | Coordinate_Y |
| 275333 | 166870 |

| its water source name | Hammam as-Sarah |
|---|---|
| Coordinate_X | Coordinate_Y |
| 278848 | 166165 |

| Name | Qasr al-Muwaqqa |
|---|---|
| Coordinate_X | 254246 |
| Coordinate_Y | 135895 |

| its water source name | Muwaqqar reservoirs |
|---|---|
| Coordinate_X | Coordinate_Y |
| 253968 | 136106 |

| Name | Qasr al-Qastal |
|---|---|
| Coordinate_X | 239132 |
| Coordinate_Y | 128391 |

| its water source name | east dam - Qastal |
|---|---|
| Coordinate_X | Coordinate_Y |
| 239741 | 128450 |

| its water source name | Qastal baths |
|---|---|
| Coordinate_X | Coordinate_Y |
| 238520 | 128839 |

Figure 5.4.A: Report of Umayyad qusour, page1.

| its water source name | Qastal North reservoirs |
|---|---|
| Coordinate_X | Coordinate_Y |
| 239230 | 128884 |

| its water source name | south reservoir - Qastal |
|---|---|
| Coordinate_X | Coordinate_Y |
| 238208 | 126862 |

| its water source name | west dam - Qastal |
|---|---|
| Coordinate_X | Coordinate_Y |
| 238750 | 129087 |

| Name | Qasr Amra |
|---|---|
| Coordinate_X | 300482 |
| Coordinate_Y | 135246 |

| its water source name | Amra Wadi |
|---|---|
| Coordinate_X | Coordinate_Y |
| 300362 | 135040 |

| Name | Qasr Azrak |
|---|---|
| Coordinate_X | 323023 |
| Coordinate_Y | 144185 |

| its water source name | Azraq - `Ain Soda |
|---|---|
| Coordinate_X | Coordinate_Y |
| 322424 | 138958 |

| its water source name | Azraq oasis |
|---|---|
| Coordinate_X | Coordinate_Y |
| 323558 | 143795 |

| Name | Qasr Burqu` |
|---|---|
| Coordinate_X | 428292 |
| Coordinate_Y | 227124 |

Figure 5.4.B: Report of Umayyad qousur, page2.

| its water source name | Burqu Lake |
|---|---|
| Coordinate_X | Coordinate_Y |
| 427644 | 228047 |

| Name | Qasr Haranah |
|---|---|
| Coordinate_X | 288170 |
| Coordinate_Y | 127091 |

| its water source name | Harranah Wadi1 |
|---|---|
| Coordinate_X | Coordinate_Y |
| 288006 | 126731 |

| its water source name | Harranah Wadi2 |
|---|---|
| Coordinate_X | Coordinate_Y |
| 288357 | 127539 |

| Name | Qasr Jabal Sais |
|---|---|
| Coordinate_X | 370190 |
| Coordinate_Y | 302903 |

| its water source name | Jabal Sais lake1 |
|---|---|
| Coordinate_X | Coordinate_Y |
| 368483 | 304109 |

| its water source name | Jabal Sais lake2 |
|---|---|
| Coordinate_X | Coordinate_Y |
| 370639 | 303454 |

| Name | Qasr Mushatta |
|---|---|
| Coordinate_X | 245827 |
| Coordinate_Y | 127536 |

| its water source name | Mushata cisterns |
|---|---|
| Coordinate_X | Coordinate_Y |
| 245701 | 127719 |

Figure 5.4.C: Report of Umayyad qusour, page3.

| Name | Qasr Tuba |
|---|---|
| **Coordinate_X** | **299549** |
| **Coordinate_Y** | **82347** |

**its water source name** **Tubah Wadi Ghadaf**

| **Coordinate_X** | **Coordinate_Y** |
|---|---|
| 298609 | 83233 |

**its water source name** **Tubah Well**

| **Coordinate_X** | **Coordinate_Y** |
|---|---|
| 300201 | 82956 |

| Name | Umm_Awalid |
|---|---|
| **Coordinate_X** | **235287** |
| **Coordinate_Y** | **117355** |

**its water source name** **dam - Umm al-Walid**

| **Coordinate_X** | **Coordinate_Y** |
|---|---|
| 237490 | 118045 |

**its water source name** **dam 2 - Umm al-Walid**

| **Coordinate_X** | **Coordinate_Y** |
|---|---|
| 237983 | 117042 |

Wednesday, December 17, 2008

Figure 5.4.D: Report of Umayyad qusour, page4.

## 5.2 Exploratory digital map

The Second part of results about the analysis done by this research as the following:

A) The result buffering zone with radius 3,477m.

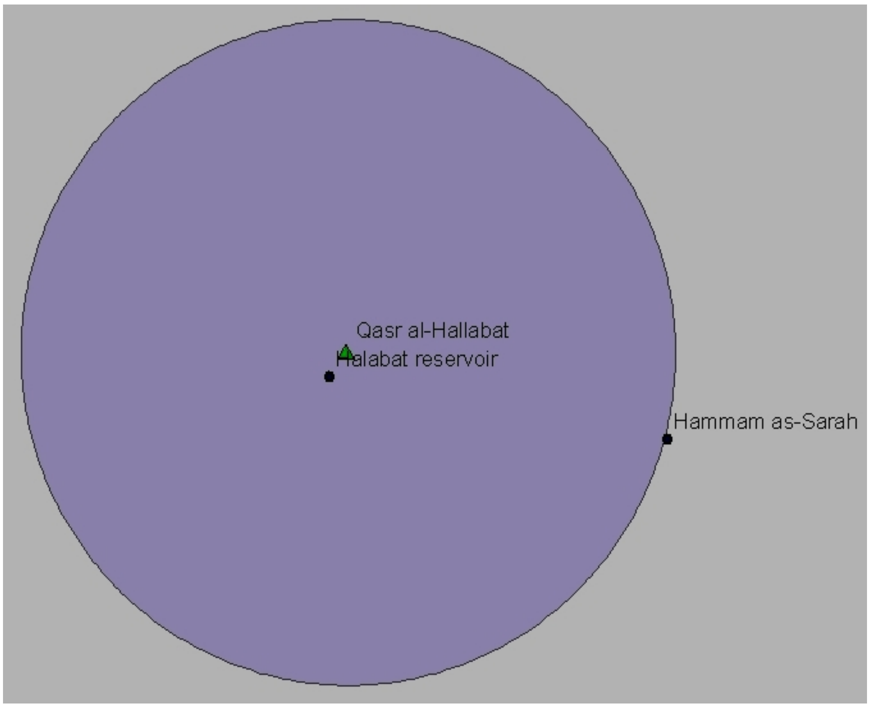


Figure 5.5.A: Buffer zone around qasr Al_Hallabat.

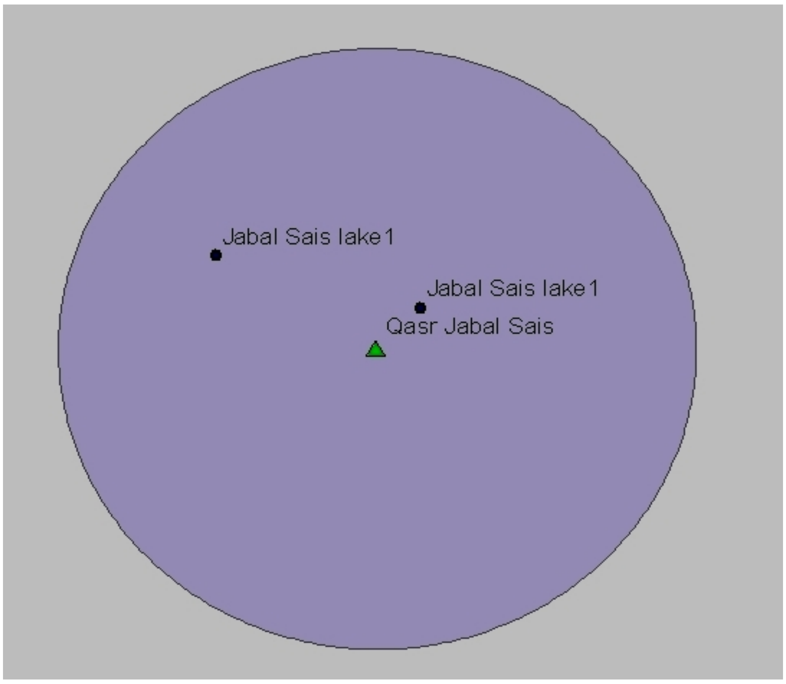


Figure 5.5.B: Buffer zone around qasr Jaba Sais.

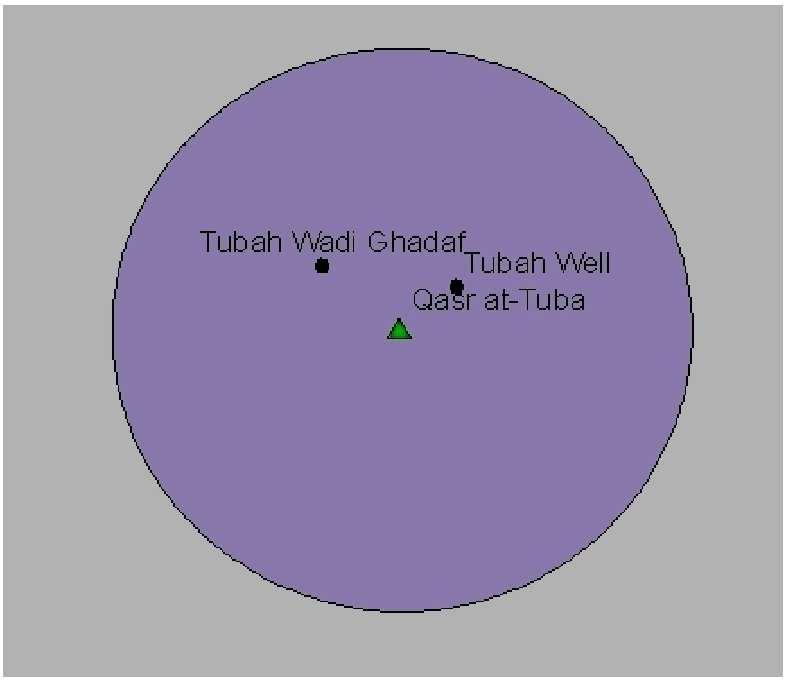


Figure 5.5.C: Buffer zone around qasr Al_Tuba.

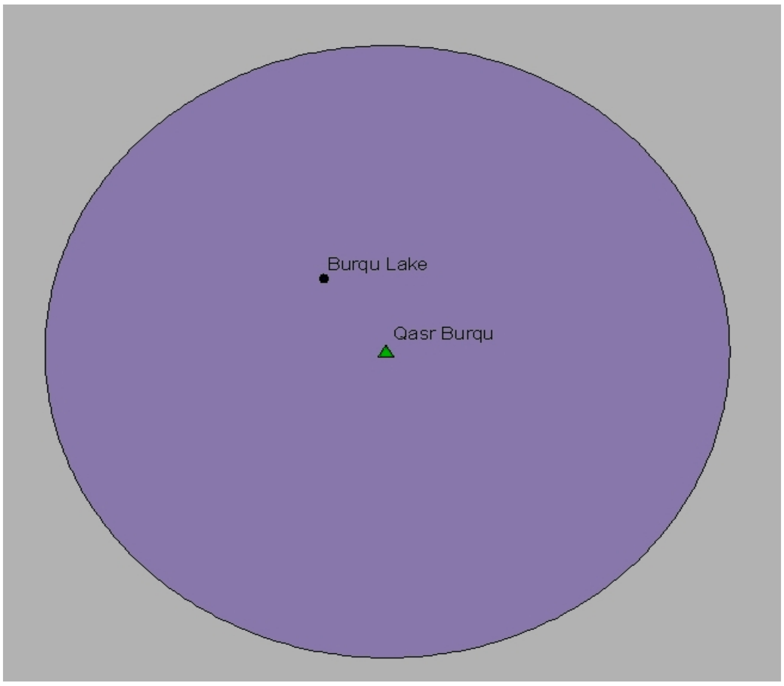

Figure 5.5.D: Buffer zone around qasr Burqu.

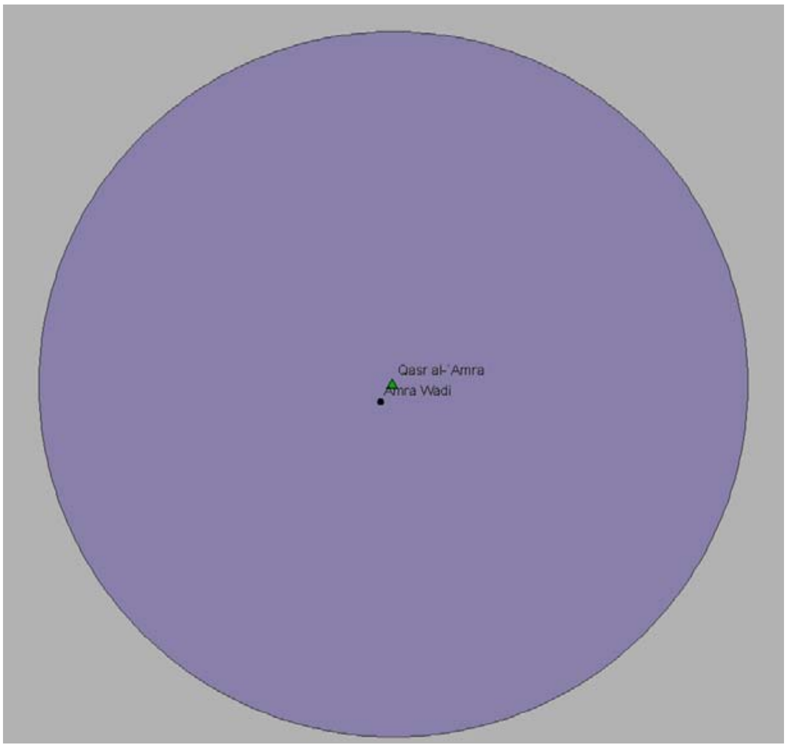

Figure 5.5.E: Buffer zone around qasr Al_Amra.

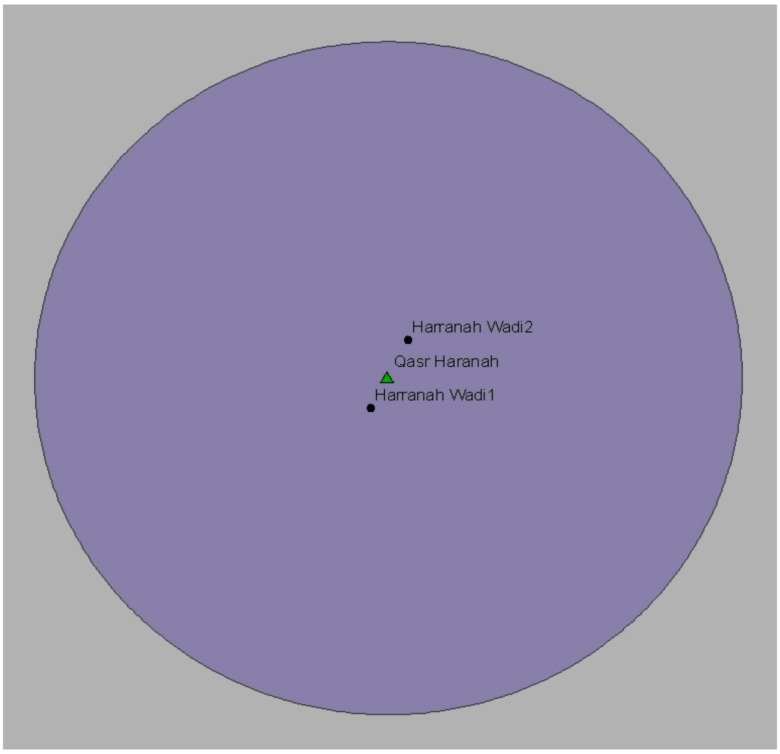

Figure 5.5.F: Buffer zone around qasr Haranah.

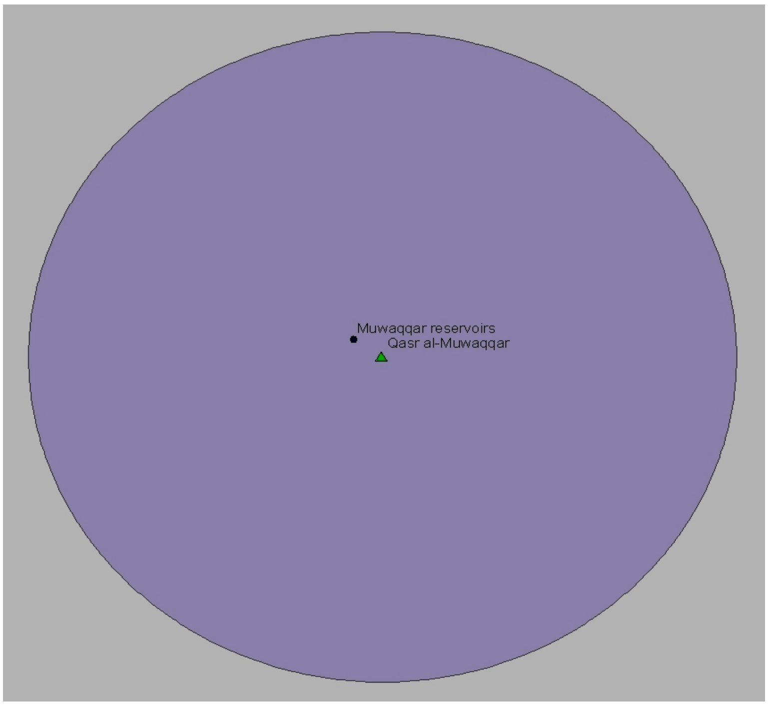

Figure 5.5.G: Buffer zone around qasr Al_Muwaqqar.

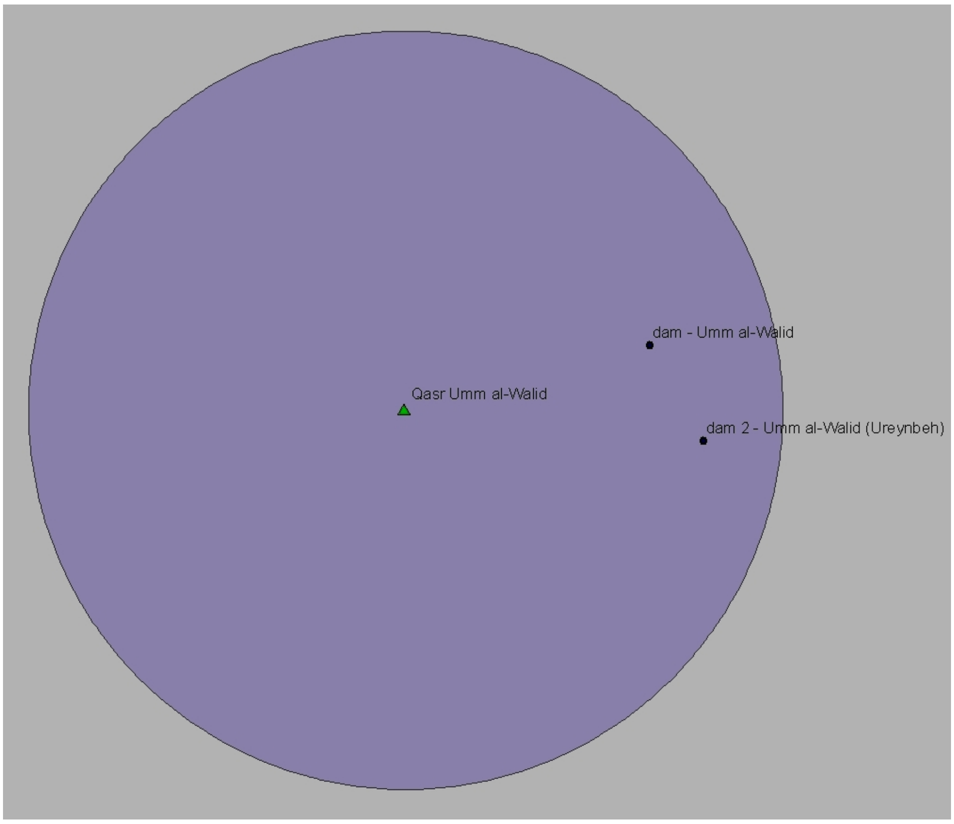

Figure 5.5.H: Buffer zone around qasr  Umm Al_Walid.

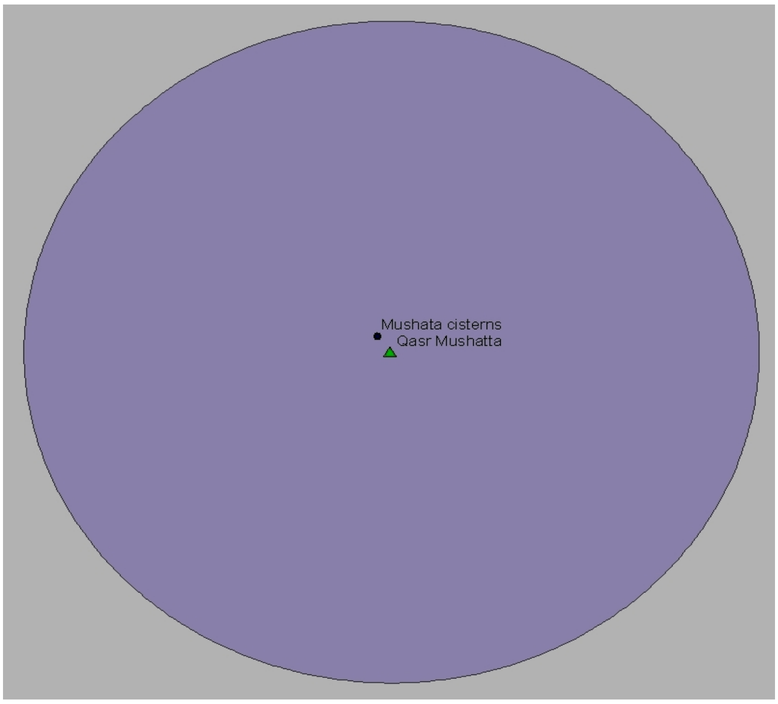

Figure 5.5.I: Buffer zone around qasr Mushatta.

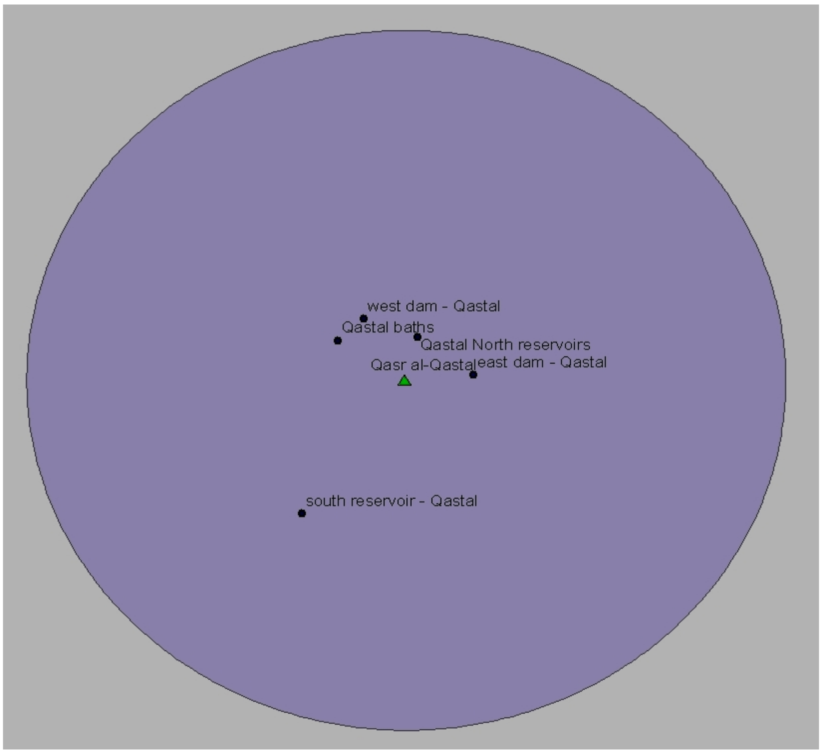

Figure 5.5.J: Buffer zone around qasr Al_Qastal.

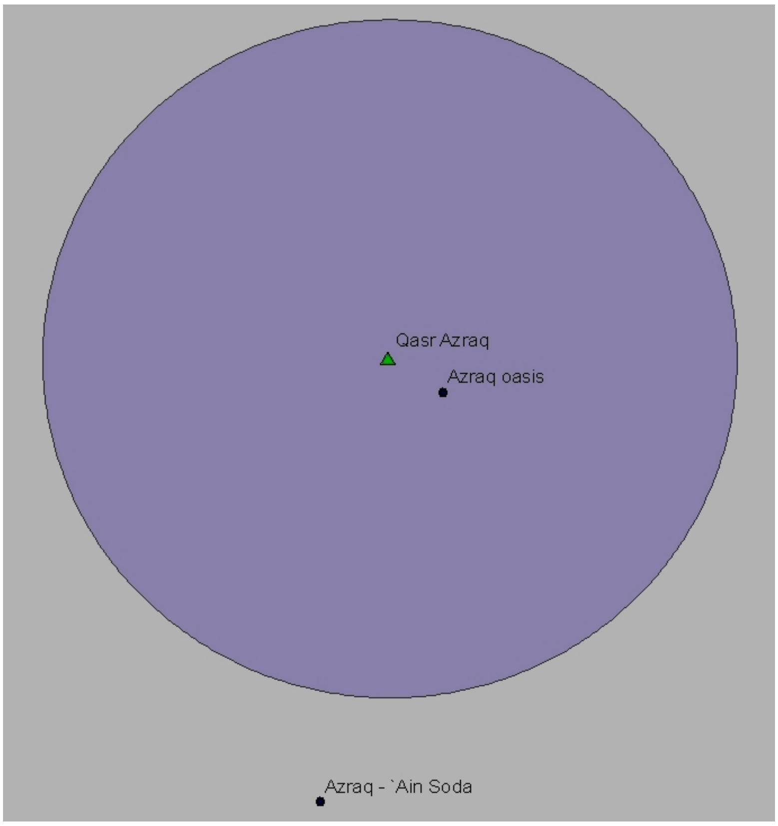

Figure 5.5.K: Buffer zone around qasr Al-Azraq.

B) The distance between qasr Tuba and the two routes is 52km and the buffer with radius 40km around qasr Al-Hallabat was made, look at the following figures:

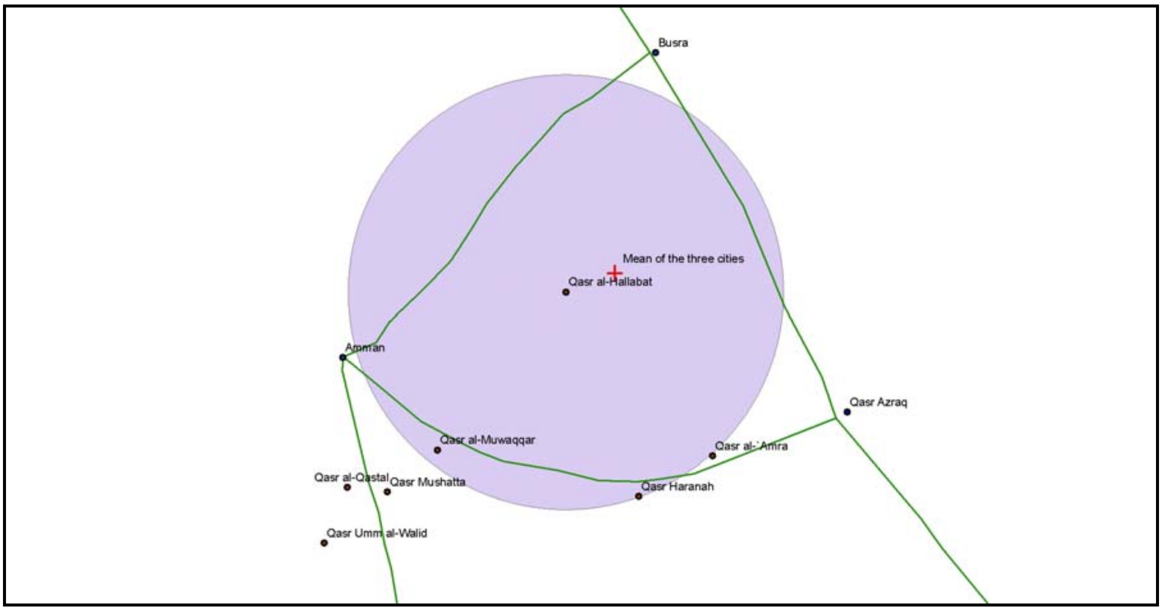


Figure 5.7: Shows how can qasr Al-Hallabat patrolled the routes within in one hour.

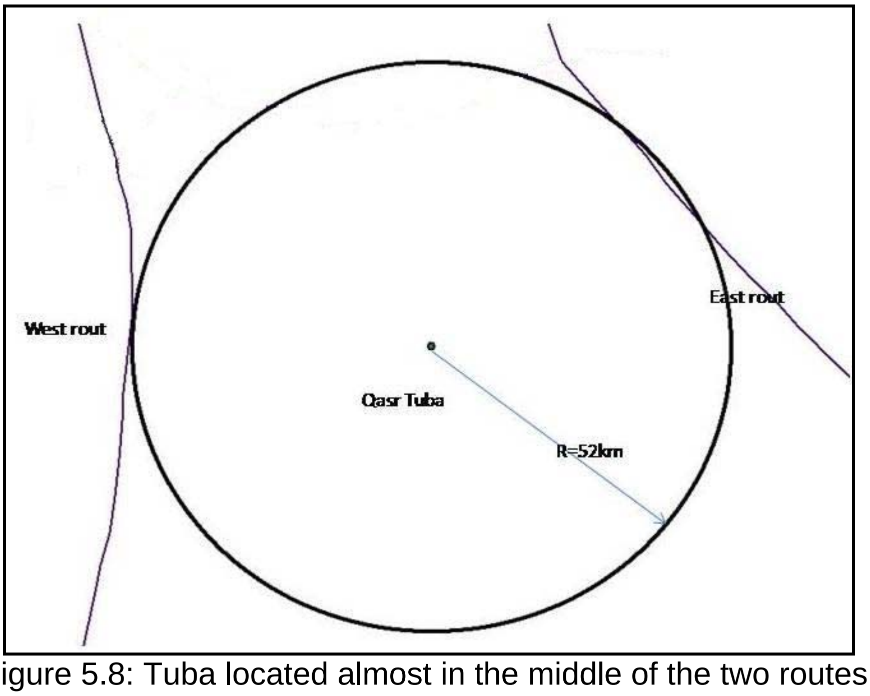


Figure 5.8: Tuba located almost in the middle of the two routes.

C) Figure5.9 illustrates the two groups of desert castle, note that the desert castles are dotted precisely on the route in the first group; see figure 5.10.

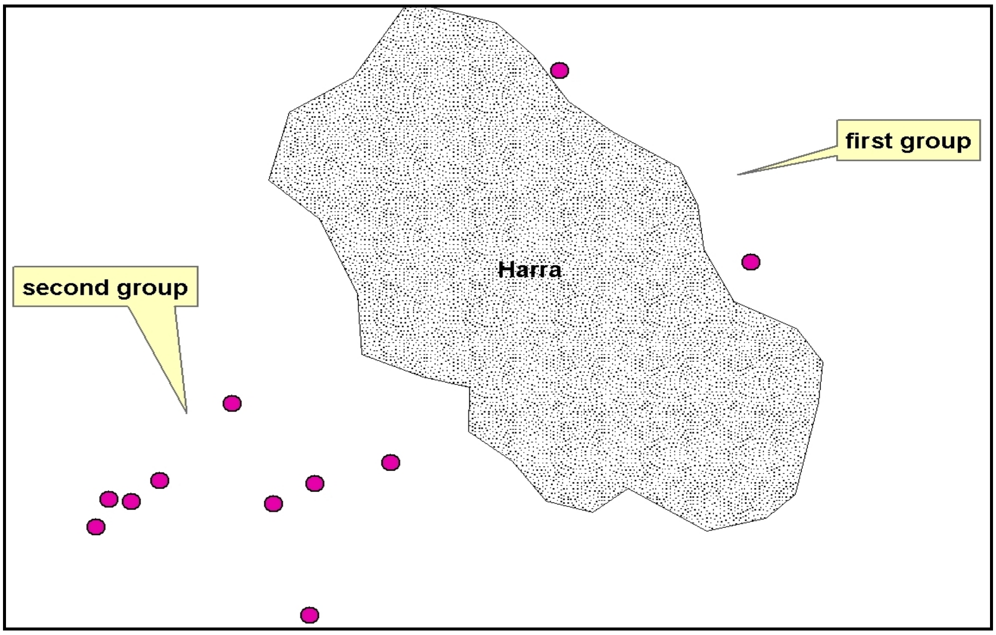

Figure 5.9: Two groups of Desert castles.

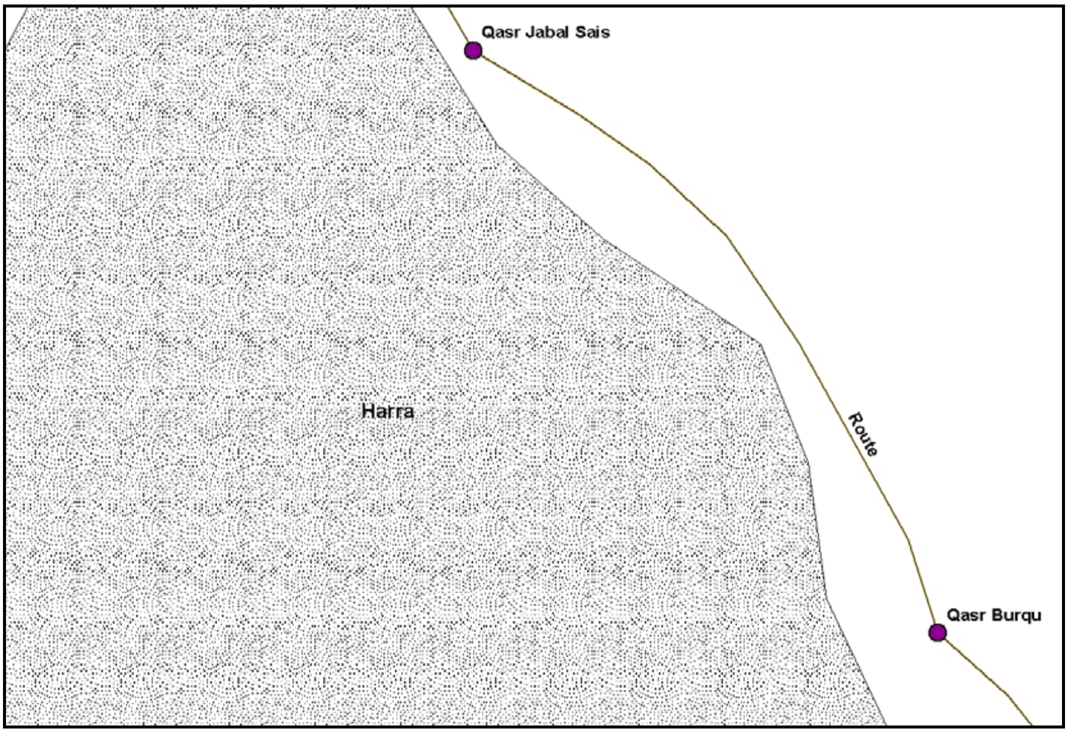

Figure 5.10: First group dotted precisely on the route.

The second group of desert castles has a different distribution pattern; figure5.12 illustrates the distribution pattern and the circle buffer zone around the qusour that located a long of the diagonal, the circle's radius was 17km.

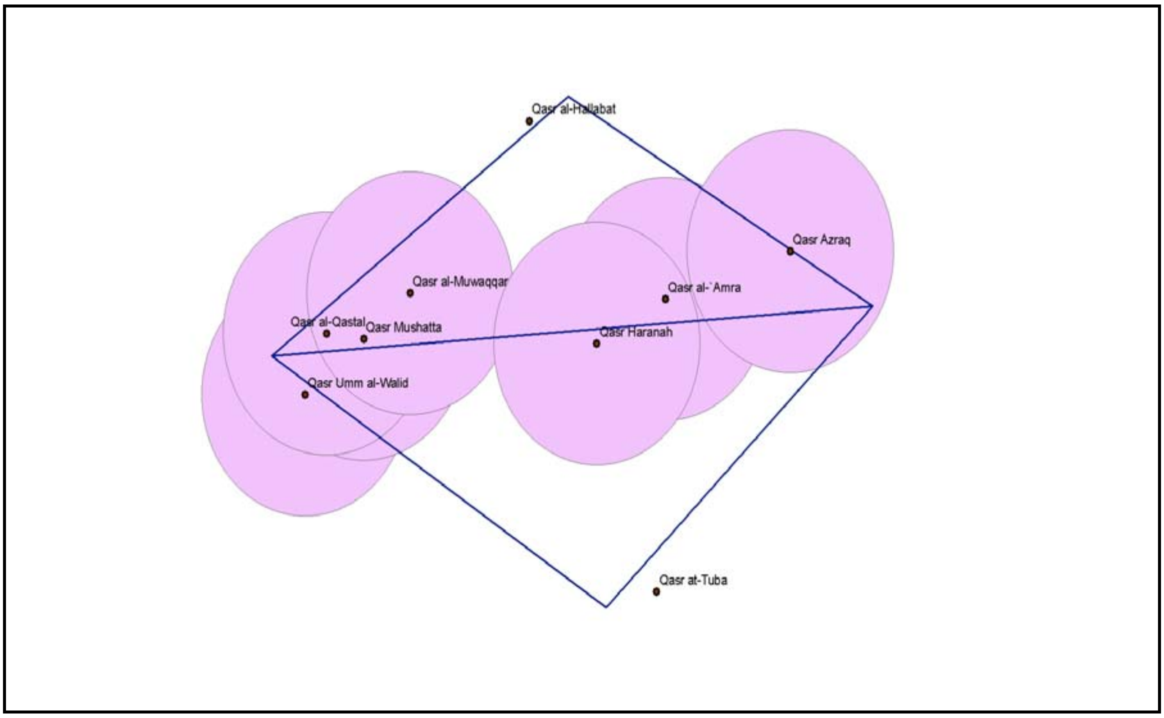


Figure 5.11: Distribution of qusour , diamond shape and buffer zones.

## 5.3 Line-of-sight communication

The researcher checked up all of terrain profiles between desert castles, then he find out that there is unobstructed line-of-sight communication between qasr Azraq and Amra, Muwaqqar and Haranah, Muwaqqar and Mushatta, Muwaqqar and Qastal, Muwaqqar and Umm al-Walid, Qastal and Umm al-Walid, Umm al-Walid and Mushatta and between Qastal and Mushatta. See figure5.12 and figures5.13.

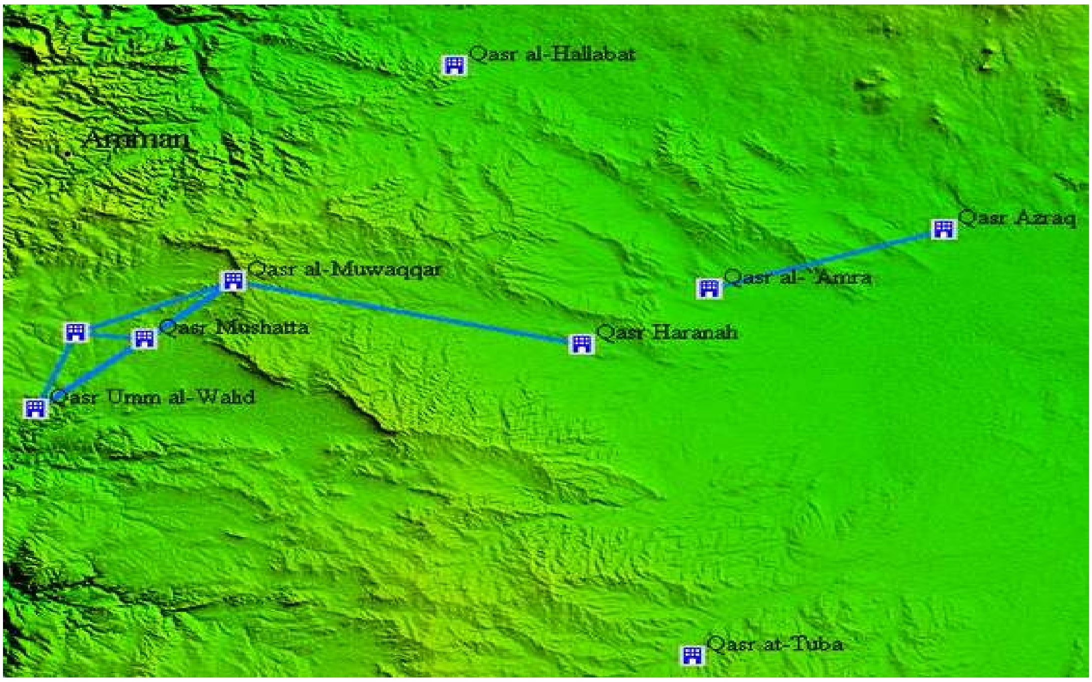


Figure 5.12: Distribution of qusour, diamond shape and buffer zones.

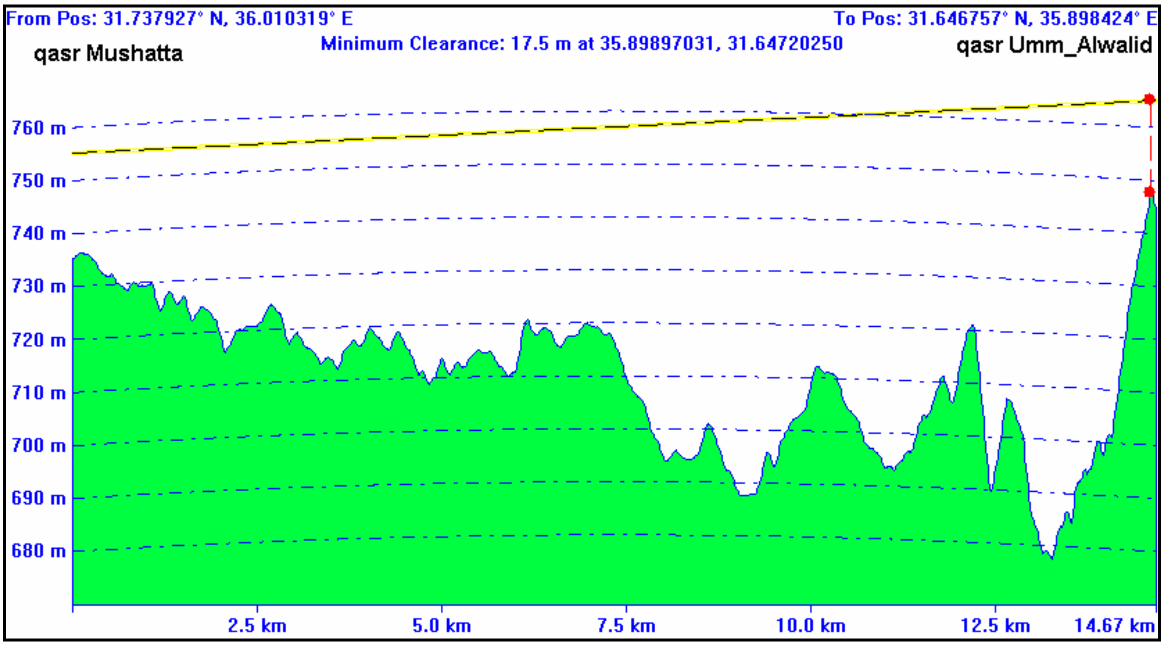


Figure 5.13.A: Terrain profiles between Umm al-Walid and Mushatta.

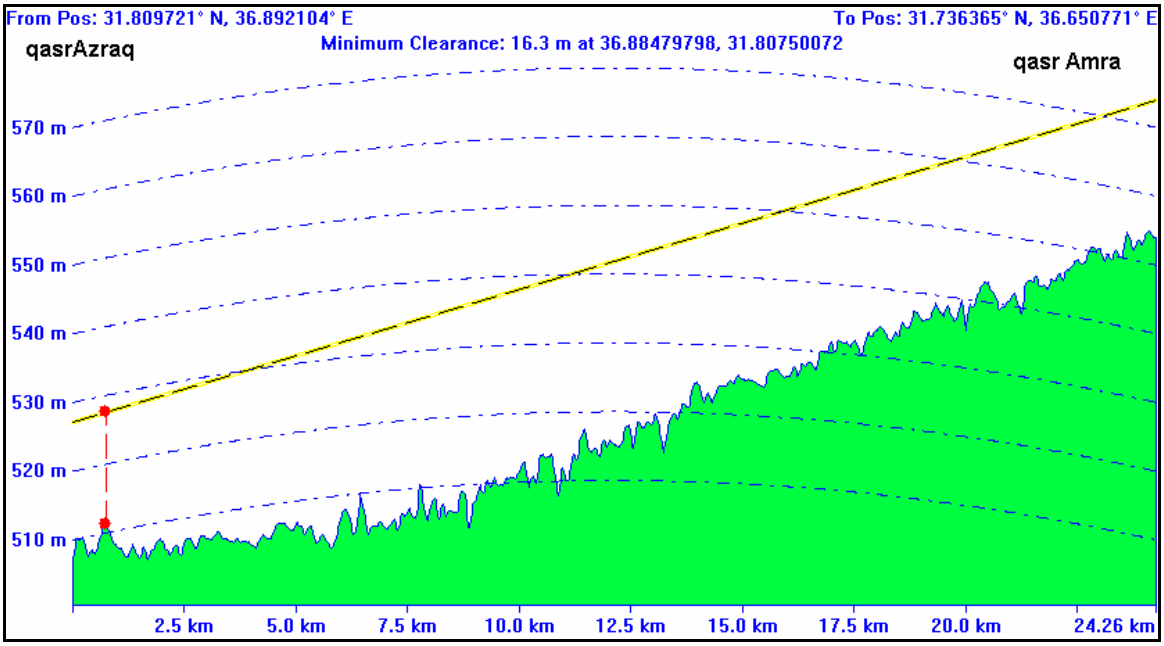

Figure 5.13.B: Terrain profiles between Azraq and Amra.

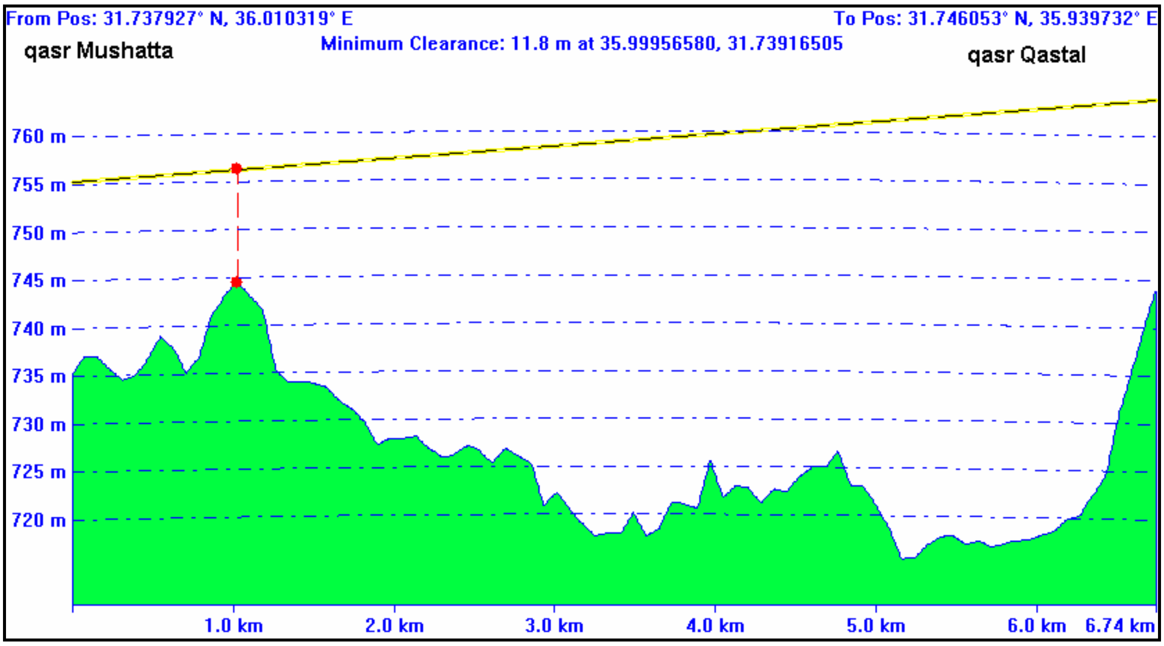

Figure 5.13.C: Terrain profiles between Qastal and Mushatta.

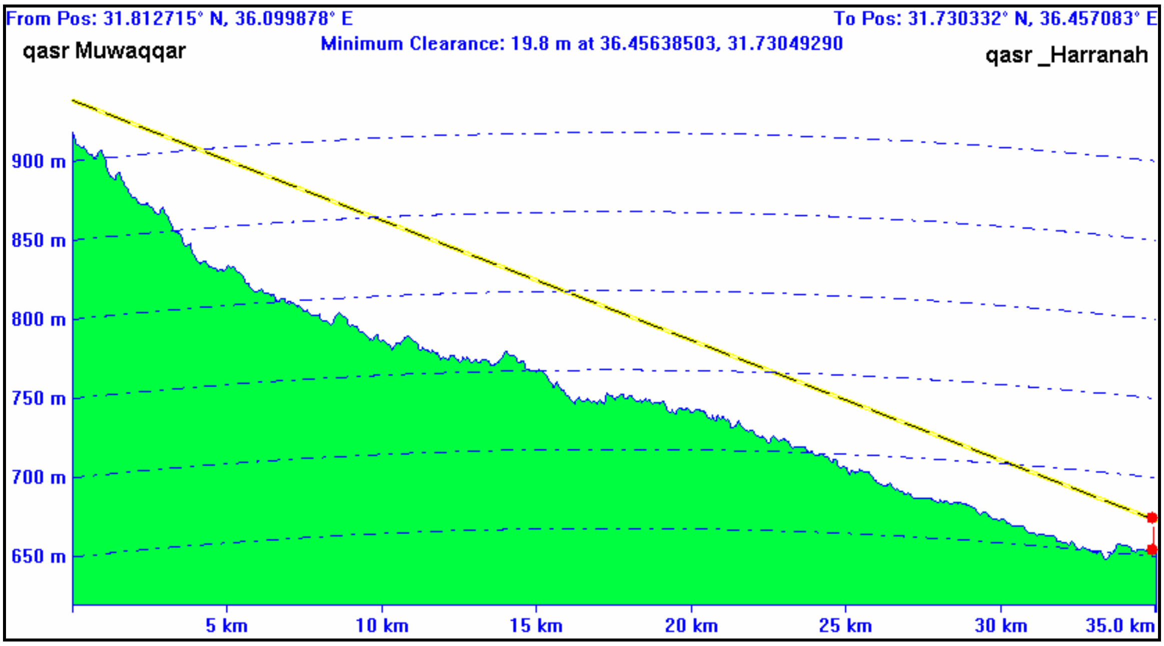

Figure 5.13.D: Terrain profiles between Muwaqqar and Haranah.

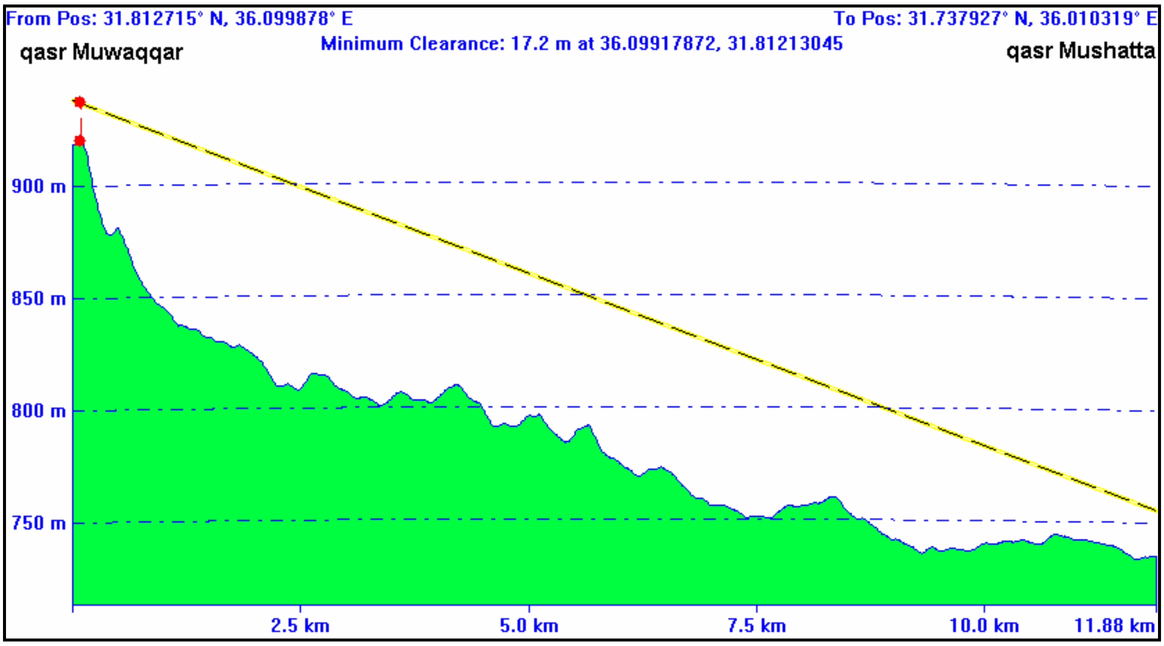

Figure 5.13.E: Terrain profiles between Muwaqqar and Mushatta.

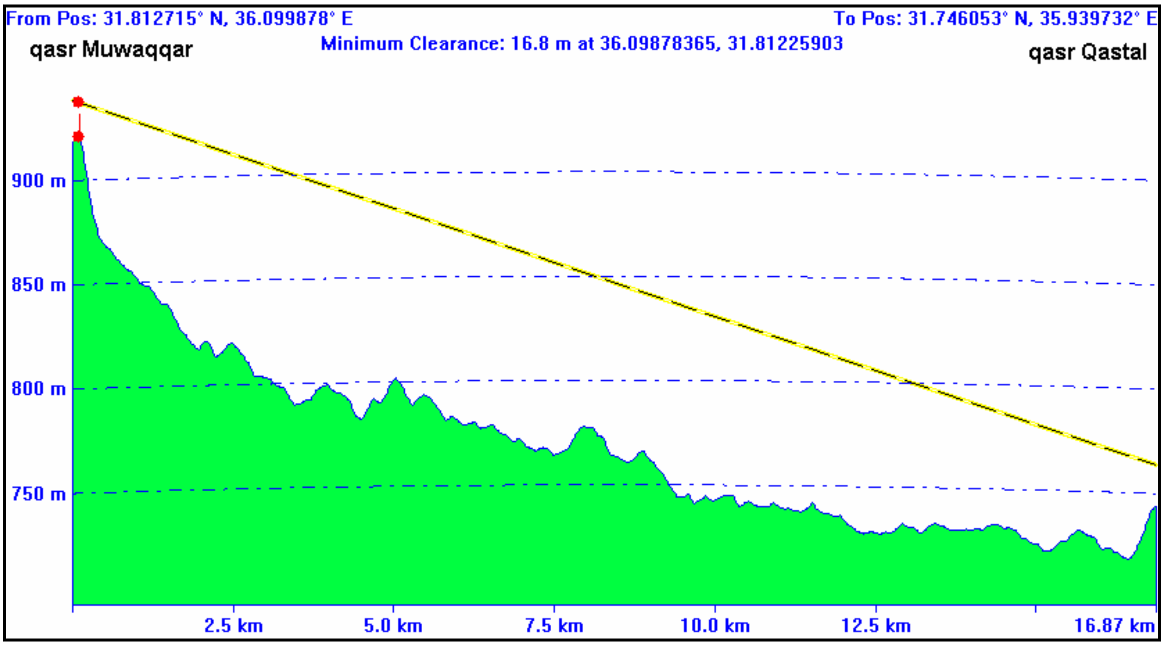

Figure 5.13.F: Terrain profiles between Muwaqqar and Qastal.

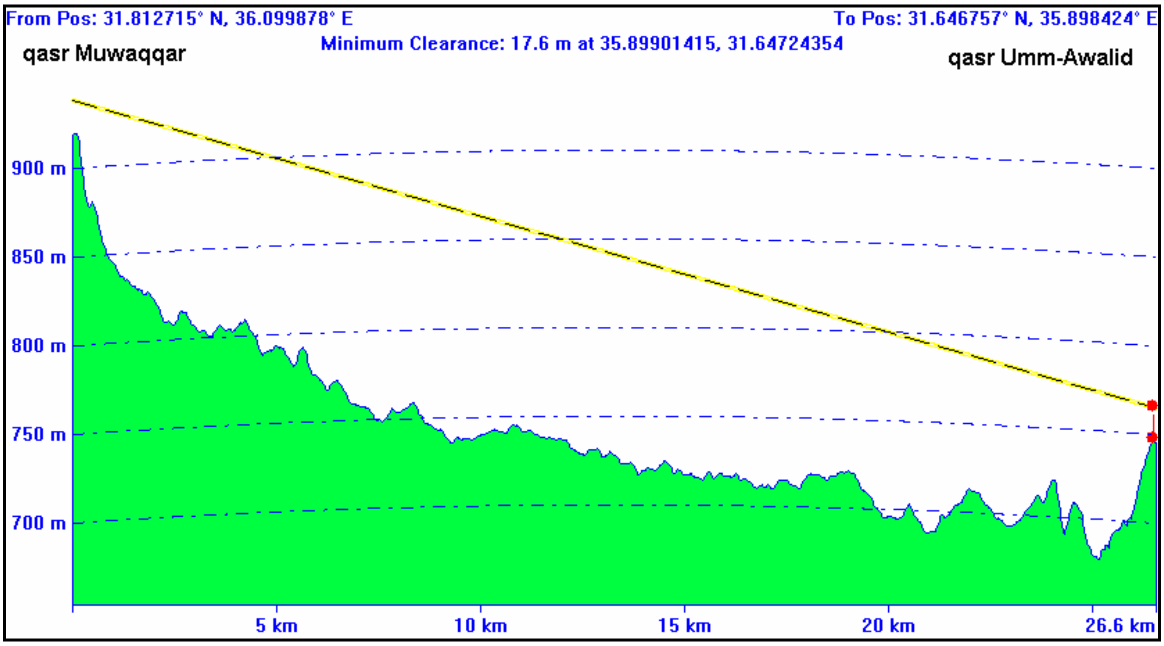

Figure 5.13.G: Terrain profiles between Muwaqqar and Umm al-Walid.

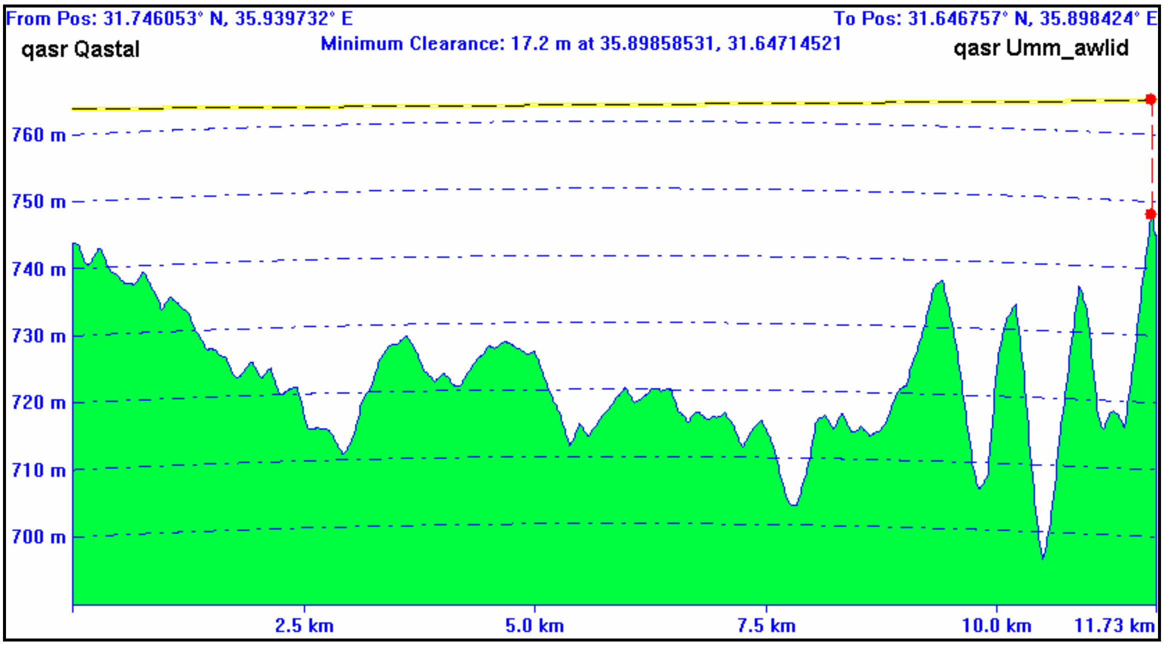

Figure 5.13.H: Terrain profiles between Qastal and Umm al-Walid.

## 5.4 Result of Quadrant Count Method

Then the result as the following:

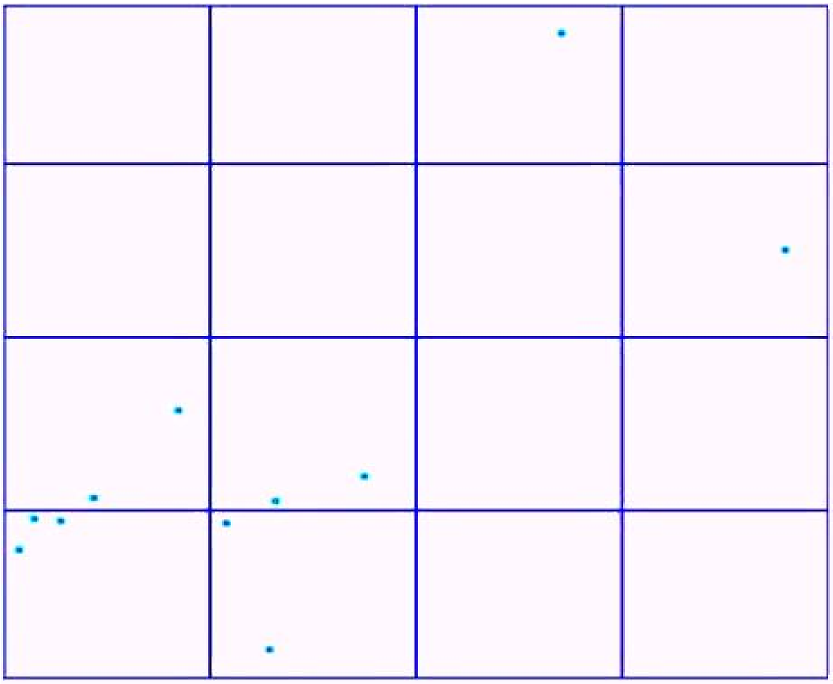
Figure 5.14: A region into 16 quadrants illustrates points' intensity.

TABLE 5.2: Results of conducting Quadrat Analysis.

| Name | results |
|---|---|
| Quadrats number | 16 |
| Quadrat length | 0.555551degree |
| Vertical step | 4 |
| Horizontal step | 4 |
| Average of points per quadrat | 0.6875 |
| Frequency | 10,2,3,1 |
| Variance | 1.40341 |
| Variance to mean ratio(VTMR) | 2.32847 |
| K-S-D statistic | 0.459951 |
| Critical value of K-s statistic with Alpha 5%: | 0.391 |

The result of quadrant cont analysis indicates the qusour pattern is clustered because the VTMR>1; VTMR =2.32847.

H0: The distribution of desert castle is not significantly different than random.

Ha: The distribution of desert castle is significantly different than random.

K-S-D > Critical value with Alpha 5%, so that we reject the null-hypothesis.

Where K-S-D=0.459951 and Critical value=0.391

# CHAPTER SIX

## 6.1 Discussion

This study uses GIS techniques to develop a geo-database and digital map for the Umayyad qusour. Historians can utilize this product in order to develop and test hypotheses about the qusour, linking features on the map with their attributes and producing reports which display information in a well-managed and comprehensible format. GIS is especially useful because it displays quantitative analysis visually. In addition viewer can conduct a variety of spatial analyses in this product, so that anyone extract information from the resulting map. One can make analysis, for example, measuring distance between features or finding point pattern, and in a variety of other ways.

The relationship between the qusour and their water sources grows out of the simple fact that desert travelers must stop at water sources. By placing the qusour close to these scarce water resources, the builders of the qusour effectively exert power over the water sources. The perennial water *sources* were not built by the Umayyads, but the extensive water infrastructure associated with the qusour maximized their potential and displayed their power over the region. Therefore the researcher used the distance between qasr Al_Hallabat and the bath complex Hammam as_Sarah, which has been demonstrated archaeologically to be associated with the construction of the qasr, as an example of a relationship between water sources and the qusour. The distance was 3,477meters. Buffers around the qusour were made with radius 3,477m.  Thus is it is possible to visualize which water sources lie outside the buffer area.  Water sources which lie inside the buffer are interpreted as having a positive association with the qasr.  If the source of water is located out of the buffer, it is interpreted to have no indicator for a positive association. Ain Soda, which "lies outside a buffer," is complex of water systems – but there is no associated qasr; therefore our assumption is unable to demonstrate whether there is a positive association or not.

To get better understanding, results of buffers were summarized in the table in Table 6.1.

TABLE 6.1: Significant location between desert castle and their water sources or water infrastructure.

| No | Name | Water_name | Distance<=3,477m | Significant |
|---|---|---|---|---|
| 1 | Umm al-Walid | dam1 Umm al-Walid | yes | yes |
| | | dam2 Umm al-Walid | yes | yes |
| 2 | qasr al-Qastal | Qastal baths | yes | yes |
| | | south reservoir - Qastal | yes | yes |
| | | east dam - Qastal | yes | yes |
| | | west dam - Qastal | yes | yes |
| | | Qastal North reservoirs | yes | yes |
| 3 | qasr Mushatta | Mushata cisterns | yes | yes |
| 4 | qasr al-Muwaqqa | Muwaqqar reservoirs | yes | yes |
| 5 | qasr al-Hallabat | Hammam as-Sarah | yes | yes |
| | | Halabat reservoir | yes | yes |
| 6 | qasr Haranah | Wadi ad-Dab`a | yes | yes |
| | | Wadi2 | yes | yes |
| 7 | qasr Tuba | Tubah Well | yes | yes |
| | | Wadi al-Ghadaf | yes | yes |
| 8 | qasr Amra | Wadi al-Butm | yes | yes |
| 9 | qasr Azraq | Azraq - `Ain Soda | No | No |
| | | Azraq oasis | yes | yes |
| 10 | qasr Jabal Sais | Jabal Sais lake1 | yes | yes |
| | | Jabal Sais lake2 | yes | yes |
| 11 | qasr Burqu` | Burqu Lake | yes | yes |

From the figure above there is one record out of 21 records located out of the buffer, i.e., 1/21=0.047619. This indicates that the water sources for Umayyad qusour tend to be located significantly close to each other more than 95%.

The desert castles are carefully situated at water sources and in the landscape to monitor important routes of transhumance, specifically access to Damascus. If some travelers come up Wadi Sirhan, they would have to go east or west around the black desert to get to Damascus, see Figure 6.2. If they go east, they have to go around the black desert and there is no water available on that route except at qasr Burqu` and Jabal Sais, which is why there are qusour there. If they go west of the Harrah they have been observed by the second group of qusour, which are clustered at the outlet of Wadi Sarhan. Azraq-Amra-Haranah-Muwaqqar-Mushatta-Qastal-Umm al-Walid provide a strong net of communications around the outlet of Wadi Sirhan. Qasr Al_Hallabat and Qasr Tubah function more as two main patrol stations (see figure 5.12).

The second group of desert castles has different functionality characteristics than the first group. For example: if some travelers come from south, they would travel the Jawf-Wadi Sarhan route or the Ma'an-Amman route on which they would face official observation from Umayyad cavalry. The southernmost patrol station, Qasr Tubah, is located exactly in the middle of these routes around 52km. Umayyad cavalry will convey the information to their stations in approximately 78 minutes, because speed of camels is approximately 40km per hour. The information could have been evaluated and then conveyed once again to the nearest qasr within 69 minutes. The nearest qasr to Qasr Tuba is

Qasr al-Harranah, part of the network of communications, so the whole qusour along the diagonal of the diamond shape would have been informed. If there were any danger the Umayyads could close of the south part of Jordan from the north part. If travelers came from north, it would have been the same procedure, except that the patrolled station would have been Qasr Al_Hallabat, and it would have taken 55 minutes for the information to reach (place).

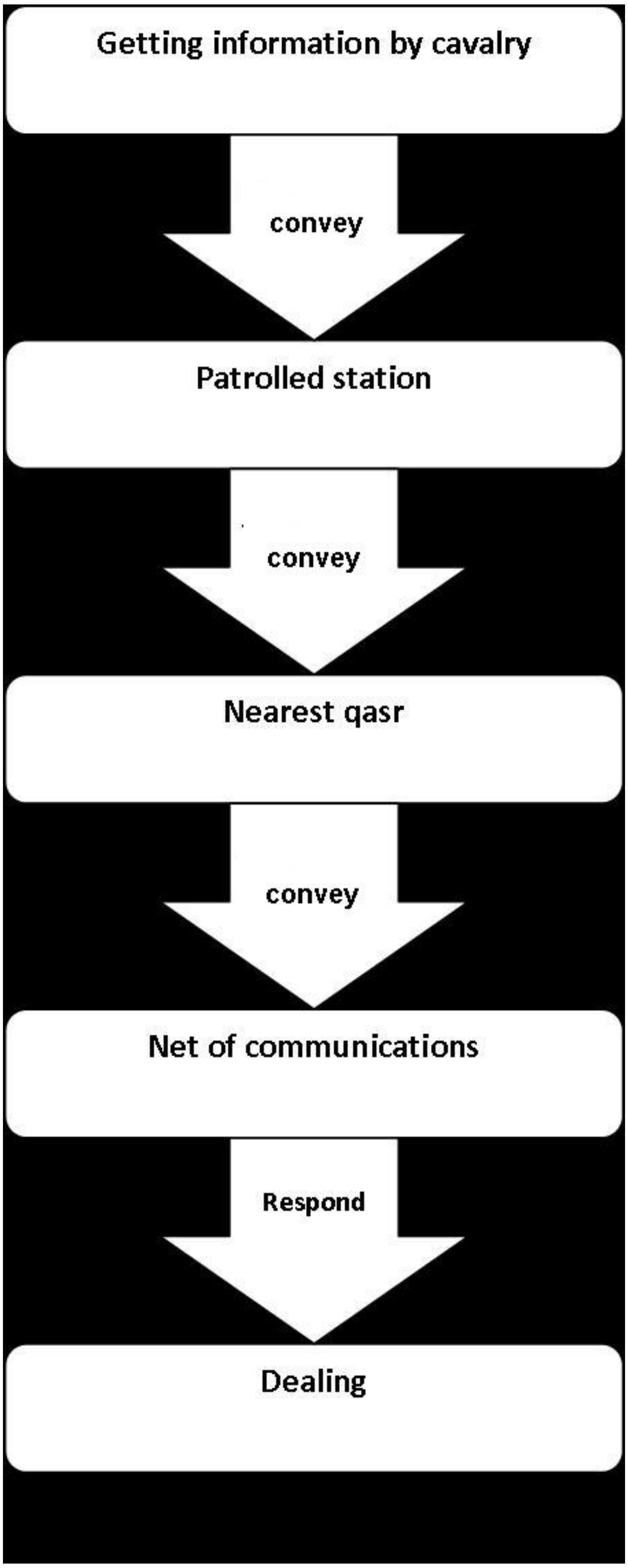


Figure 6.1: Possess of patrolling

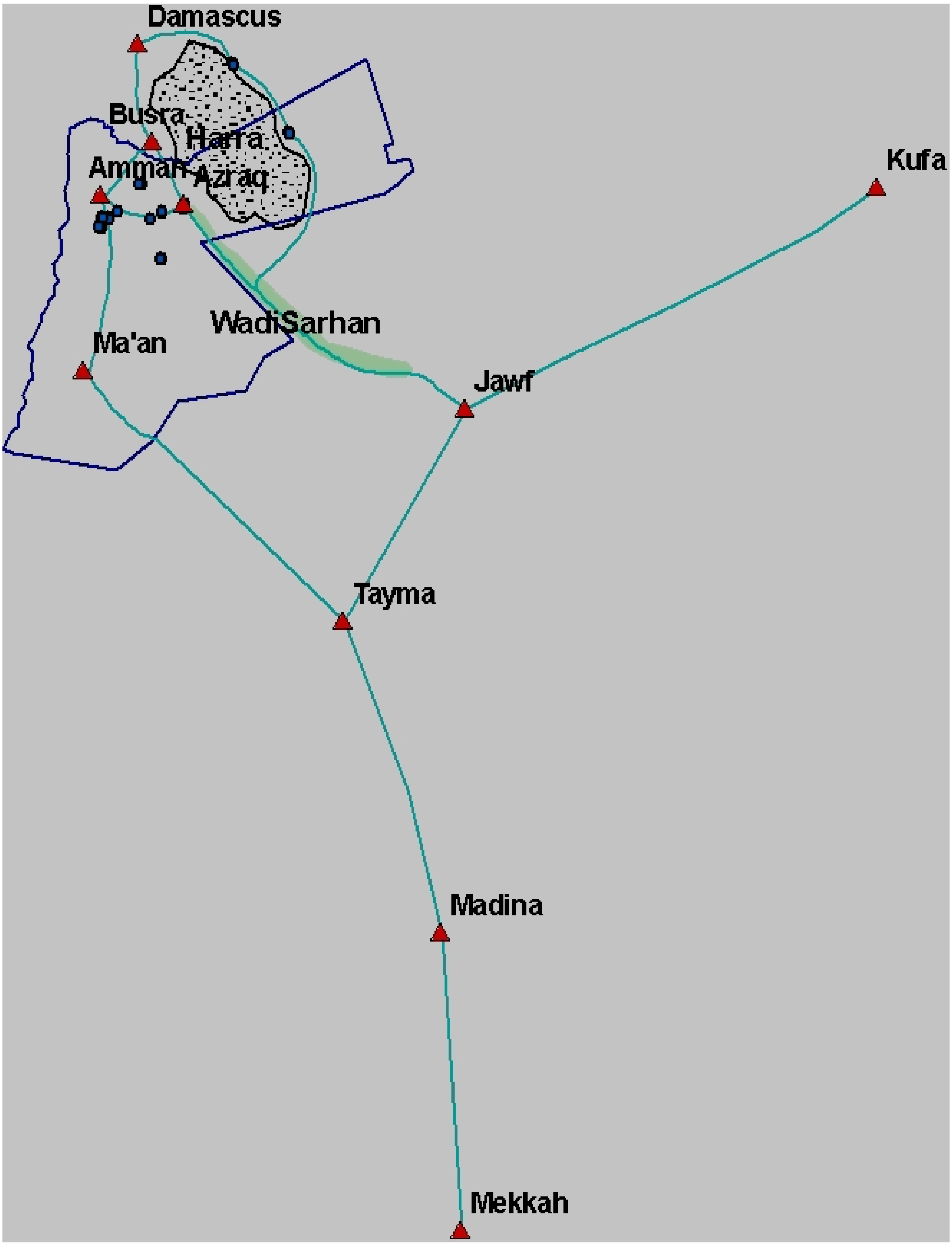


Figure 6.2: Travel routes between political centers of Kufa, Madina, Mekkah & Damascus.

We conducted quadrant analysis to examine the distribution pattern of the desert castles (qusour). The result was clustered, and this indicates that the locations of the qusour depend on something.  Consulting the information in Figure 6.2 reveals that the location of qusour are situated in this way because of the relative positions of the Harrah, the outlet of Wadi Sarhan, the positions of water sources and the resulting disposition of travel routes.

## 6.2 Conclusion

The Umayyad qusour are usually dismissed as "pleasure palaces" or "hunting lodges," even by prominent scholars (e.g., Cresswell 1969; Hilllenbrand 1982; Bisheh 1985, 1998).  Some scholars of the period are, however, beginning to argue that these prominent structures were strategic interventions in the landscape (Addison 2000, Almagro 1992, Arce 2008, King 1992.  Spatial depiction of the co-occurrence of the qusour, trade/ travel routes and perennial water sources support the notion that the Umayyad dynasty poured resources into building the qusour for highly functional purposes.

The major political centers of the time were Kufa, Madina and Damascus. Damascus was the center of the Umayyad caliphate.  Kufa and Madina were the centers of opposition to the Umayyads.  Therefore the Umayyad caliphs had good reason to monitor carefully the routes which led to Damascus from these rival political centers.

Most of relationships between the qusour and their geographical context are only hinted at in the historical sources.  The argument summarized above becomes much more powerful when these spatial relationships are represented and analyzed in GIS.

Spatial analysis draws data from archival and archaeological research and reconfigures it spatially and visually.  This reconfiguration not only makes it easier to draw and demonstrate relationships between phenomena, the attribute data has established links to maps for visual analysis. Any statistic we can think of to describe the data then automatically has geographic properties and as a result can be placed on maps for visual processing.

This argues that the Umayyad qusour were built strategically at perennial water sources in order to monitor routes of transhumance amongst the socio-political centers of the period. The objectives of the study are to construct a geo-database and digital map of the Umayyad qusour in their geographical context and to conduct a visualization and spatial analysis of the distribution of the qusour.

This study suggests that there are significant patterns in the locations of the Umayyad qusour, there is unobstructed line-of-sight communication between each qasr and its neighboring qusour among the group located west of Harrah, and there is a quantifiable relationship between the qusour, perennial water sources, and established trade routes. These patterns suggest strategic placement of the qusour.

Methods used were construction of a geo-database and digital map, a visualization, as well as proximity analysis and quadrant analysis.

The results of the analysis show that Umayyad qusour are carefully situated at routes of transhumance and the water sources. The distribution pattern of the Umayyad qusour is clustered at the out let of Wadi Sarhan, There is actually line-of-sight communication between Azraq, Amra, Haranah, Muwaqqar, Umm al wlaid, Mushatta, and Qastal, and there is a positive association between Umayyad qusour and their water sources. These results derived from GIS and spatial analyses, support the argument of Addison, Almagro, Arce and King.

## 6.3 Recommendations

GIS has typically been employed for the social sciences, environmental and engineering disciplines. Until now, historians have relied mainly on textual, architectural and art-historical analyses of the qusour in order to understand Umayyad state architecture, also most of relationships between the qusour and their geographical context are only hinted at in the historical sources. It would become much more powerful when these spatial relationships are represented and analyzed in GIS. Therefore we recommend researchers using GIS and spatial analysis in their researches problem in the humanities.

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## APPENDIXES

## DEFINITIONS

**Accuracy**: "The closeness of observations, computations or estimates to the true value as accepted as being true. Accuracy relates to the exactness of the result, and is distinguished from precision which relates to the exactness of the operation by which the result was obtained" (Gittings & Patterson, 1999).

**Bilad ash-sham:** refers to Jordan, Syria, Palestine, Iraq and Lebanon**.**

**Coordinate system -** "A reference system for the unique definition of a location of a point in n-dimensional space" (Bonham .C, 1994).

**Conceptual Model** is concerned with the real world view and understanding of data; the *logical* model is a generalized formal structure in the rules of information science; the *physical* model specifies how this will be executed in a particular DBMS instance.

**Data model -** "Collection of concepts allowing for the representation of an environment according to arbitrary requirements" (Bonham .C, 1994).

**Database design**: design the logical and physical structure of one or more databases to accommodate the information needs of the users in an organization for a defined set of applications.

**Datum** - "1. Any point, line, or surface used as a reference for a measurement of another quantity. 2. A model of the earth used for geodetic calculations" (Bonham .C, 1994).

**Digitizing** - A method of data capture that involves the conversion of data in hard copy or raster form, such as maps and aerial photographs, into a digital vector format. This is usually done by a human operator using on a digitizing tablet or sitting at a computer screen with a mouse, drawing over top of a raster image. Methods of automated digitizing and semi-automated digitizing also exist.

**Exempla**- are the plural of exemplum; an exemplum is one data-sample of something you are trying to explain.

**Feature** - "An object in a spatial data base with a distinct set of characteristics" (Bonham .C, 1994).

**Geodetic reference system** - "The true technical name for a datum. The combination of an ellipsoid, which specifies the size and shape of the earth, and a base point from which the latitude and longitude of all other points are referenced" (GIS Development, n.d.).

**Geographic database** - "A collection of spatial data and related descriptive data organized for efficient storage and retrieval by many users" (GIS Development, n.d.).

**GIS** is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.(ESRI, 1990)

**Global Positioning System** - A satellite-based navigational system allowing the determination of any point on the earth's surfacewith a high degree of accuracy given a suitable GPS receiver. The network of satellites is owned by the US Department of Defense. Error in the accuracy of GPS derived positions can be introduced through the nature of local conditions. These errors can be greatly reduced using a technique known as differential GPS.

**Haranah-** was constructed by the Sufyani Umayyads (Urice) – the brief dynasty established by Abu Sufyan (AD 661-683/ AH 41-63) which immediately preceded the caliph Marwan, who established the Umayyad dynasty (AD 683-750/ AH 64-137). The Umayyad dynasty in Syria fell in 750/ 137 to a coup by the Kufa-based `Abbasids, who launched their takeover from Humeima, a small settlement on the Hajj route. Caliph `Abd ar-Rahman I escaped (on foot!) to establish the Umayyad dynasty in Spain, where they ruled until AD 1050.

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**Map projection** - "A method of representing the earth's three-dimensional surface as a flat two-dimensional surface. This normally involves a mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface. Because the earth is three-dimensional, some method must be used to depict the map in two dimensions. Therefore such representations distort some parameter of the earth's surface, be it distance, area, shape, or direction" (Gittings & Patterson, 1999).

**Qasr**- (pl. qusour) is not directly translatable into English. These structures functioned as official reception houses, retreats, residences and centers of government administration for the first Islamic caliphate. Usually the translation is "palace," and so the Umayyad qusour are often referred to as the "desert castles" or "desert palaces."

**Raster** - "1. An element of a space that has been subdivided into regular tiles by tessellation. 2. Commonly, a data set, as for an image or DEM, composed of rasters. 3. Often used as a synonym for grid" (Bonham .C, 1994).

**Resolution** - "A measure of the ability to detect quantities. High resolution implies a high degree of discrimination but has no implication as to accuracy" (Gittings & Patterson, 1999).

**Shapefile** - "An ArcView GIS data set used to represent a set of geographic features such as streets, hospital locations, trade areas, and ZIP Code boundaries. Shapefiles can represent point, line, or area features. Each feature in a shapefile represents a single geographic feature and its attributes" (ESRI, 1998).

**Spatial data** - "Any information about the location and shape of, and relationships among, geographic features. This includes remotely sensed data as well as map data" (Gittings & Patterson, 1999).

**Tabular or Attribute Data** - A trait, quality or property describing a geographical feature. A fact describing an entity in a relational data model, equivalent to the column in a relational table.

**Vector** - "1. A quantity which has magnitude and direction. 2. Commonly, the notation used to represent spatial information" (Bonham .C, 1994).

**Water source or source of water**: The expression refers to the perennial sources of water and/or water infrastructure; the perennial sources of water could be springs, lakes, pools, or underground water. The water infrastructure makes the water from the water sources available; through channels, pipes, wells, pumps, dams, cisterns and reservoirs.