

BURAIMI: A TALE OF TWO COUNTRIES

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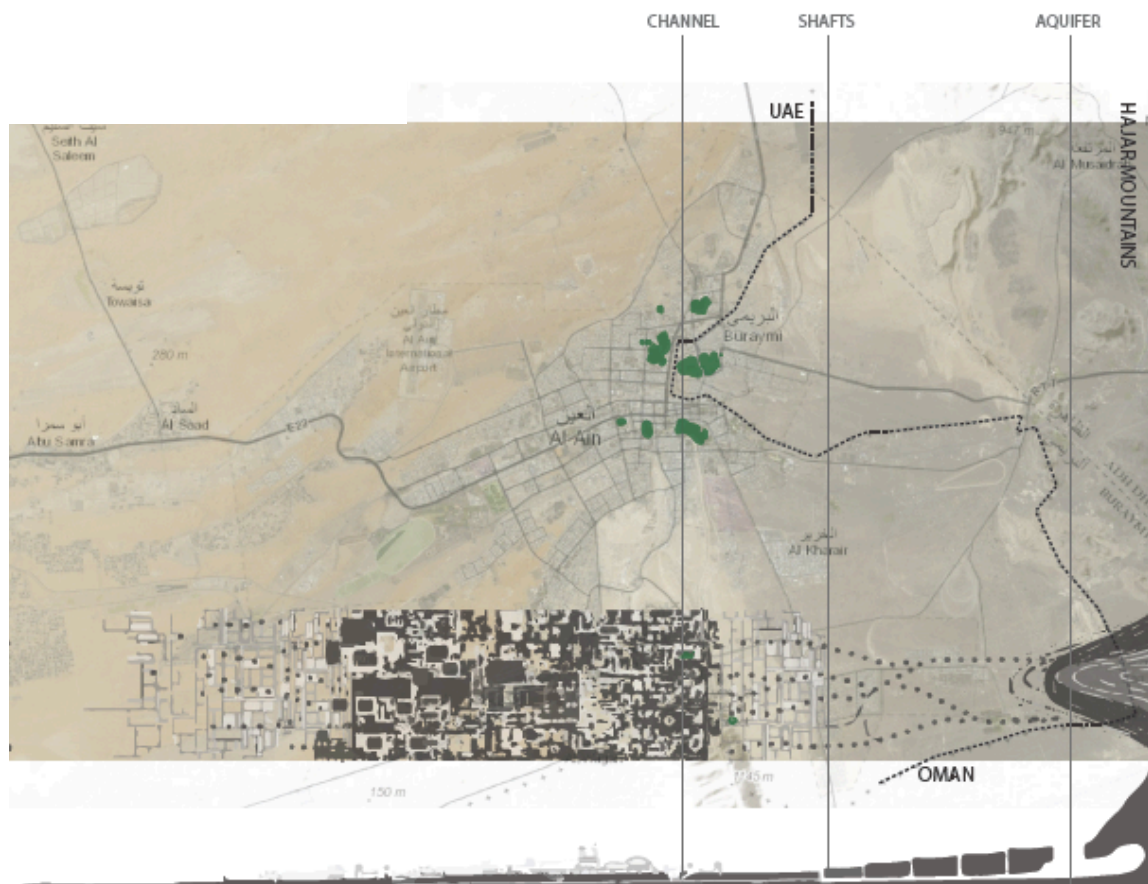
4.213 ECOLOGICAL URBANISM

BURAIMI: A TALE OF TWO COUNTRIES  
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## ABSTRACT

For thousands of years, a water management system that tapped into groundwater reserves, known as *qanat* or *aflaj* among other names, allowed the cultivation and settlement of harsh and inhospitable lands. Praised for its ecologically sustainable engineering, the relatively simple physical structure meant it was an easily transportable technology that spread across the arid belt, developing an economic, social and cultural structure to accompany it. Until the middle of the 20<sup>th</sup> century, the life of the desert dwelling Bedouins in the Arabian peninsula remained relatively unchanged, but modernization brought with it new challenges which threatened the survival of this technology and the way of life for the millions who depend on it.



**Plan of Buraimi Oases** Base map Source: ESRI, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Gattmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

At a time when Oman and UAE, like many other Arab nations, are on the brink of an imminent water crisis, where demand is far exceeding renewable resource capacity, this research seeks to explore the adaptive response of *aflaj* in the national strategy of a modern state and in mitigating the associated impacts of the past century. Through the

lens of Buraimi, due to its unique position on the border of Oman and UAE, this paper is going to focus on the different approaches taken by two nations in their *aflaj* strategies that were driven by very different circumstances. Despite being neighbouring countries, Oman and UAE have vastly different environmental, economic and social factors that have driven their responses to modern challenges. Oman has taken action to maintain the existing way of life and restore the *aflaj* system of the country. Meanwhile, UAE developed a master plan to transform the *aflaj* into agents of 'cultural heritage,' but the completion of the design coincided with the global financial crisis, and there has yet to be any implementation on ground. With more than a third of the earth's surface covered by arid land and increasing desertification, we consider the prospects for this technology where it is already implemented and for new regions by looking at two models reflecting specific national strategies.

## 1.0 AFLAJ: A WATER MANAGEMENT SYSTEM

Around 3000BCE, the Persians developed a sustainable hydraulic system that tapped into groundwater reserves providing a stable and reliable source of water. This technology was transported and allowed nomads to permanently settle the harsh arid and semi-arid regions of the Middle East and beyond. This water was able to meet drinking, domestic and agricultural needs, and it provided a point of social contact and a focus for community life.<sup>1</sup> Known as *qanat* in Persian, the system was easily adapted to a range of geographical and socio-political contexts and has a variety of vernacular names in different parts of the world (Refer to Figure 1). For the purposes of this paper, they will be referred to as *aflaj*, or *falaj* in singular, as it is called locally in the Gulf countries that comprise this study. The ease in which it was transportable made it an essential and strategic technology for empires seeking to expand their borders.

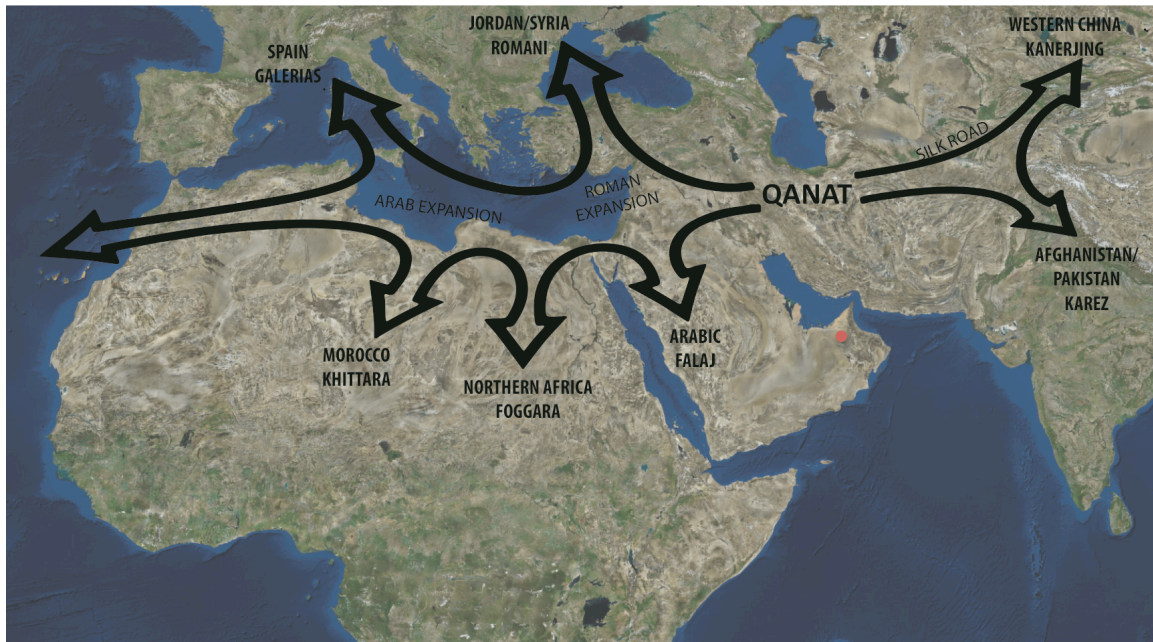


Figure 1: Spread of *qanat* with vernacular names. Base map Source: ESRI, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Gattmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

There is little that the entire region of the arid belt has in common other than its generally poor groundwater endowment (Refer to Figure 2). *Aflaj* were developed as a result of the translocation of skilled individuals capable of their construction, either through general migration or selective recruitment, so it is not unusual to find that the general pattern of building *aflaj* has followed the waxing and waning of empires.<sup>2</sup> The system is essentially a subterranean aqueduct, consisting of a network of channels that collect groundwater from a mother well sunk into an aquifer upslope from the fields and houses it services. Fuelled by gravity, it ensures that extraction can never exceed the recharge rate. *Aflaj* appear in three varieties (Refer to Figure 3) that allow them to be installed in nearly any groundwater source.<sup>3</sup>

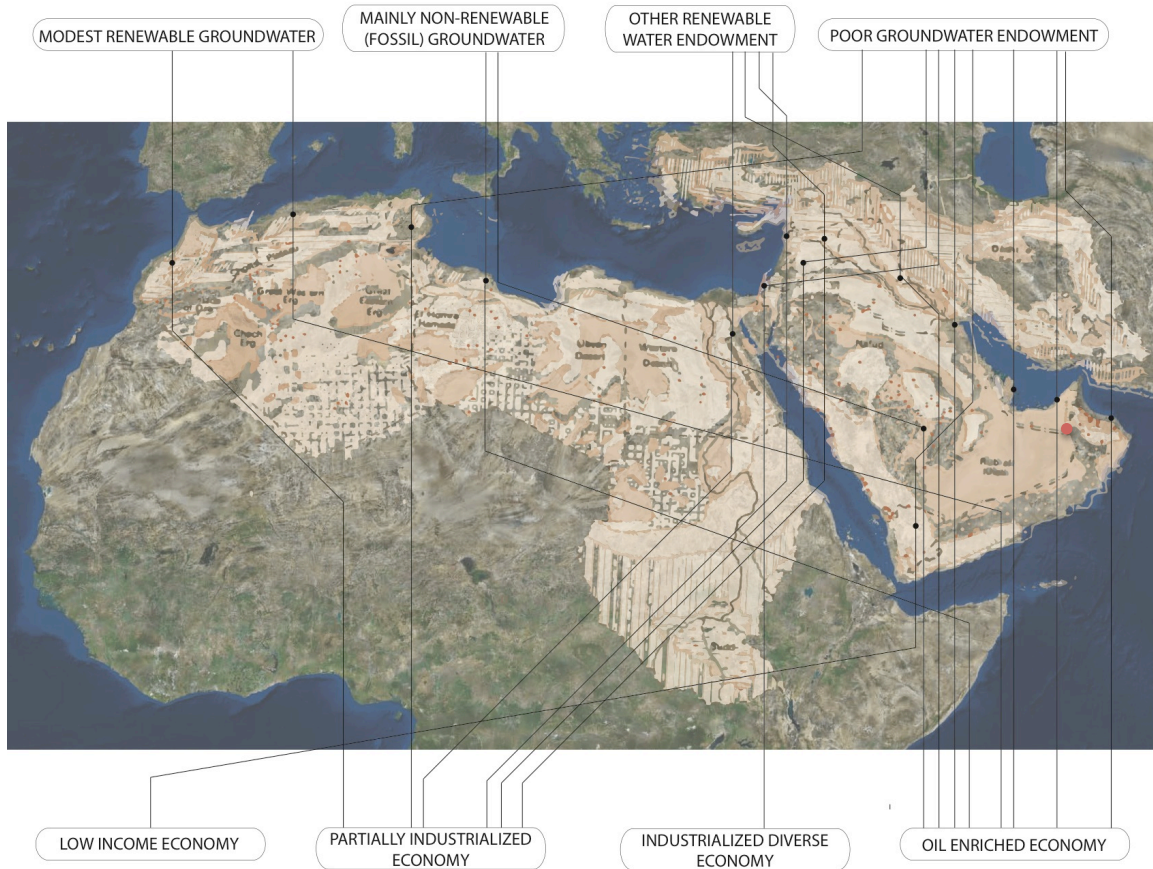


Figure 2: MENA water resources, economic conditions & *qanat* locations. Base map Source: ESRI, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Gattmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Key characteristics of the *aflaj* that contributed to its success:

1. Water is brought to surface by gravity – no energy cost
2. Subterranean network reduces loss of water from seepage and evaporation
3. Cooperative water management - a model of self funding and self help
4. Decentralised decision making and participatory processes
5. Generally reliable supply from a single source with consistent chemical quality
6. No possibility of endangering the height of the water table
7. Allows cultivation and nurturing of land for agriculture
8. Creates microclimate 5°c cooler than surrounding area
9. Model of water distribution & crop prioritisation for optimal irrigation efficiency

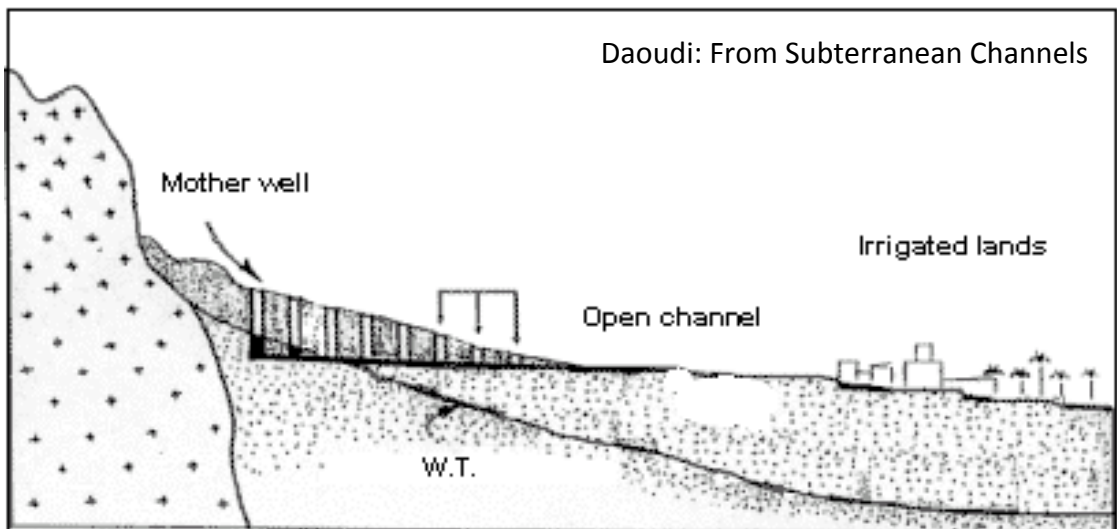
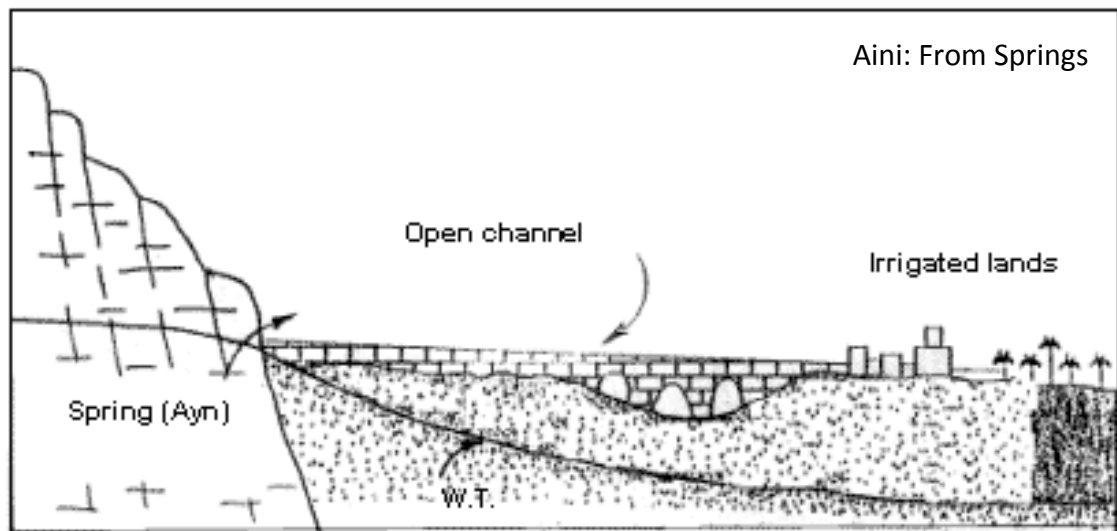
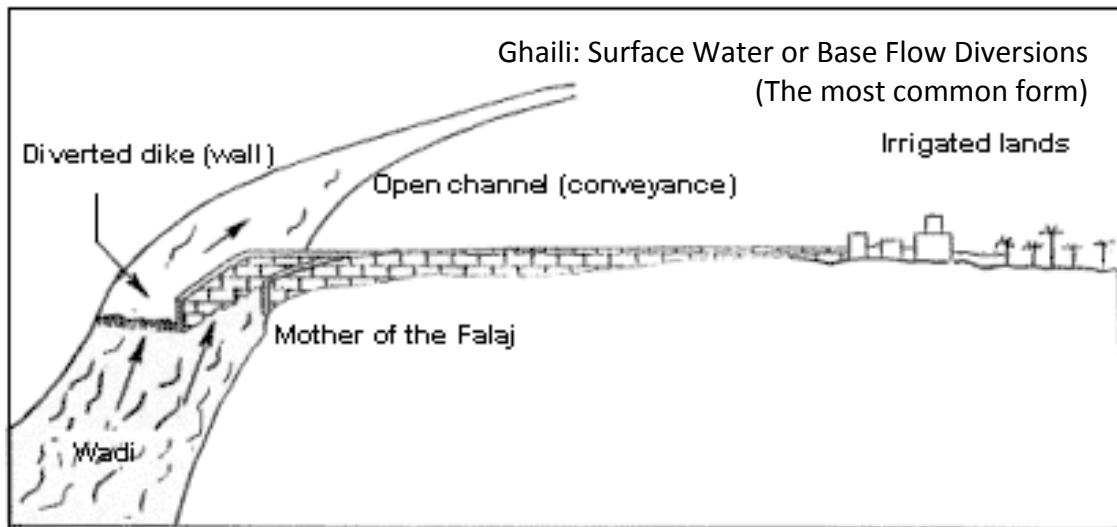


Figure 3: The varieties of *aflaj* Source: Ministry of Regional Municipalities & Water Resources, Water Resources in Oman (Oman, 2008)

In the Gulf countries of the Arabian Peninsula, the *aflaj* system operates within a complex social and economic structure that has remained largely unchanged for centuries and is often attributed as integral to the success of the system. It is based on an accurate system of water distribution with fair shares to stakeholders, as passed down through generations. Benefits include<sup>4</sup>:

1. Maintaining mutual cooperation among those individuals who use the *aflaj*
2. Providing a relatively flexible source of family income by allowing shareholders to put their water shares up for public auction or by leasing those shares for specific periods when they are not needed
3. *Aflaj* properties are auctioned every 6 months to generate funds for new construction and maintenance.
4. Providing a constant source of water for a variety of crops especially date palms
5. Generating employment by encouraging the development of traditional crafts in the towns and villages where the *aflaj* pass
6. Strengthening the sense of community and social relationships
7. Bounded by codes of social behaviour, e.g. users do not pollute the system for others
8. Establishing procedures for settling disputes relating to water shares of maintenance obligations in the form of an autonomous administration responsible for the management of each *falaj*

Distribution of water at the oasis is carried out by diverting the water flow by applying or removing sluices at the appropriate times of day for the agreed period. Before the advent of clocks, the time for each water share was determined by various methods, including the use of sundials by day and observation of the stars at night. The time needed to water all the cultivated land (the irrigation cycle commonly ranges from 7-15 day) and the order of irrigation is generally decided by a group of experienced shareholders, who take into consideration the rate of flow of the water in the *aflaj* and other factors such as the tolerance of the crops to drought and the water retention characteristics of the soil.<sup>5</sup>

An appointed *wakil* (representative or elected person) oversees the operation and management of the *aflaj*. People are free to buy/sell and even mortgage their water shares. Surplus water and water shares belonging to the *aflaj*, used to raise funds for *aflaj* maintenance, may be auctioned either every irrigation cycle or annually. Prices are generally a reflection of seasons, demand and time slot of the share.<sup>6</sup>

## 2.0 A MIDDLE EAST WATER PROBLEM:

Hydrocarbon wealth and technological advances transformed the Middle East in the 1960s at the expense of the *aflaj*. Factors which lead to the drying up of *aflaj* and challenges to future survival<sup>7</sup>:

- Absence of long-term water allocation or management plans
- Increasing population and demand on supplies
- Mechanical extraction from wells lowering groundwater levels
- Saline intrusion
- Expansion of irrigated area, which promotes overconsumption.
- High operation and maintenance costs
- Lack of skilled labour and loss of environmental literacy/traditional knowledge
- Climate change causing desertification
- Flash floods leading to collapses, damage of shafts, tunnels and channels
- Rural to urban migration
- Safety concerns in construction and maintenance
- Virtual water is economically attractive; High production costs are reflected in the high cost of crops, which cannot always compete with imported goods that have consumed water elsewhere in the production process.
- Contamination from waste and pollution

The technology has been generally accepted in rural areas where water resources are scarce. It is not suited to an urban environment primarily because it requires relatively large areas for the construction of the structures, as well as being susceptible to contamination from the densely populated urban areas. They remain undesirable due to their unpredictable water supply, and high maintenance and repair costs – eventually leading to neglect and abandonment. Due to a lack of interest from today's younger generation towards the *aflaj*, technical knowledge of the *aflaj* has had limited transmission from the older generations to sufficient youth who are to inherit the system. The endurance of the system is dependent on a communal consensus of willingness and participation.

In Oman, due to dependency on the system, damage to *aflaj* infrastructure has had especially severe consequences. Most of the farms around the *aflaj* are small-scale properties and are considered as subsistence farms where the household typically consumes a considerable part of their production. Zekri et al, estimate the costs incurred from the drying up of *aflaj*, which fall under two categories<sup>8</sup>:

- Indirect costs to the society as loss of cultural heritage, adverse environmental impact, loss of employment opportunities, loss of value related to tourism and associated economic activities.
- Direct costs to private owners in the form of capital cost, operating and management cost, energy for pumping and water transportation cost.

The ceasing or reduction of agricultural and livestock production had an adverse impact on households’ vegetables, fruits and meat consumption, where families typically consume a considerable part of their production. While houses at the periphery of the village could access domestic and drinking water through water tankers, the provisioning of water to houses amidst fields with difficult access proves too impractical and forces relocation of 16% of families.

Households that previously relied on *aflaj* for their main source of domestic and drinking water have had to locate several alternative sources of different qualities. Expenditure towards wells, water companies, tankers and bottled water resulted in an added yearly household expenditure of OR328 (USD 854) to replace water that was previously supplied freely. At a national scale the annual value of water used for drinking and domestic purposes in all dried up *aflaj* is estimated to cost OR15 million annually (USD 5.76 million). These losses are further transferred to the national economy as a loss of revenue to other industries and from the subsidization of water by the government, which conceals the real economic cost of water. Total annual losses on a national level equate to OR59 million (USD 150mill) where highest losses are incurred by the loss of agriculture and animal production for families’ consumption labelled as “household consumption losses” at 38% of total losses.

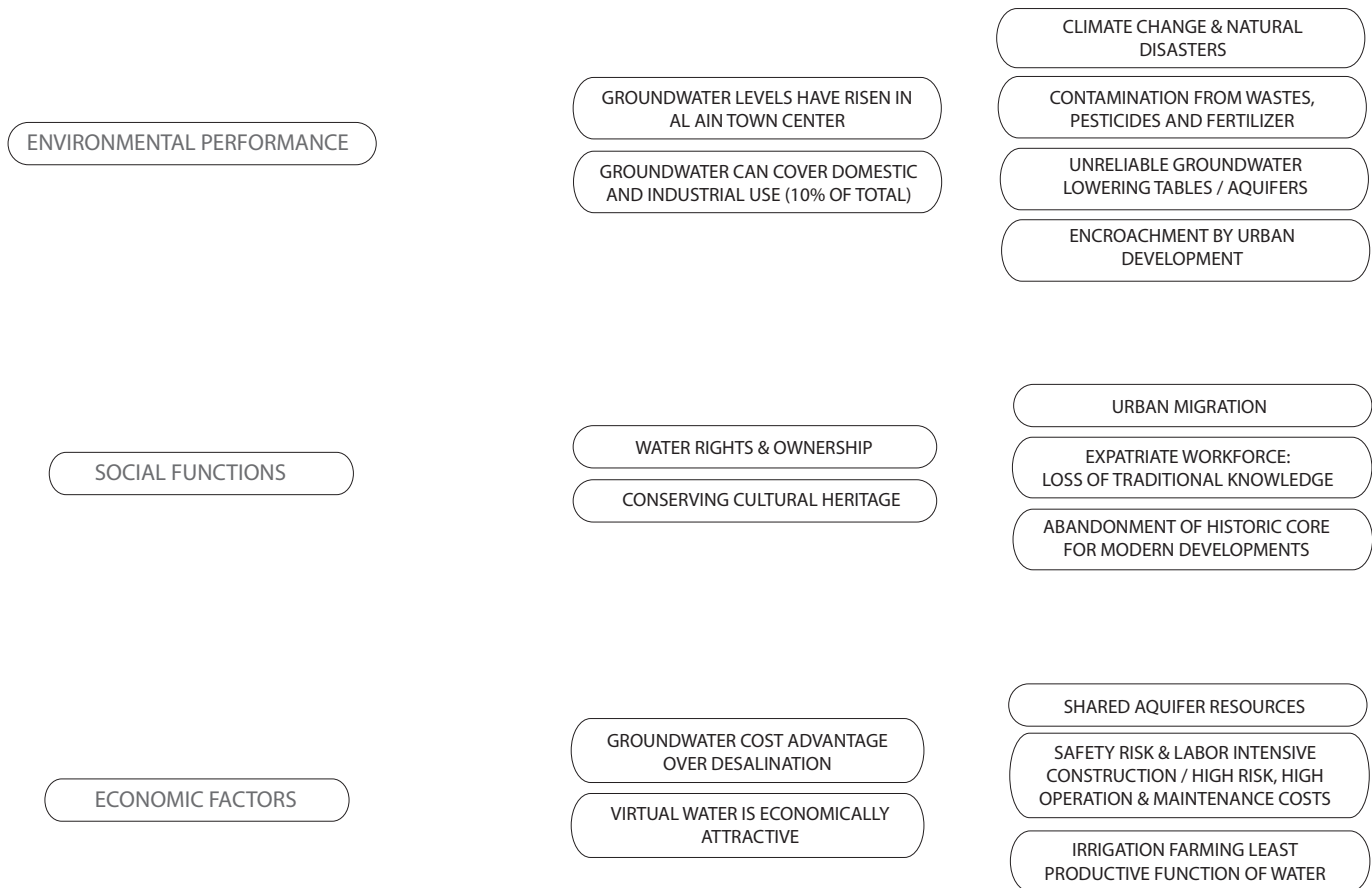


Figure 4: Matrix of Environmental, Social, Economic factors affecting *aflaj* performance

### 3.0 THE BURAIMI OASIS

The historical city of Buraimi is comprised of 7 oases within Abu Dhabi (where it is known as Al Ain) and 2 across the Omani border, and has long been one of the most important centers of agriculture in the region. 350 hectares of oases are supplied by 9 operating *aflaj*, though a total of 21 have been recorded in the area. Buraimi is located inland near the North Eastern tip of the Arabian peninsula and sits on a shared aquifer between Oman and UAE, downslope from the Hajar Mountain range where its mother well is located. Though archaeological excavations date the settlement of this site and the origins of the oasis to as far back as the Iron Age, it was only between the 16<sup>th</sup> and 18<sup>th</sup> century when date palm cultivation began to proliferate under the Ya'rubids of Oman that the majority of *aflaj* were excavated. The *aflaj* have been shown to directly influence the morphology of settlements with mosques, cemeteries and watchtowers concentrated around the points of entry to the fields and gardens. It is argued that this large scale expansion of the *aflaj* system was only made possible after the 17<sup>th</sup> century with the availability of slave labour as a result of Omani maritime expeditions.<sup>9</sup> Date production in the oasis was geared to meet more than just the subsistence needs of the population and instead was treated as a commodity for export that stimulated trade, and access to new markets and income. It is argued that there has been a decline in the number of date palms, as they were replaced with more profitable cultivars in the second half of the 20<sup>th</sup> century.<sup>10</sup>

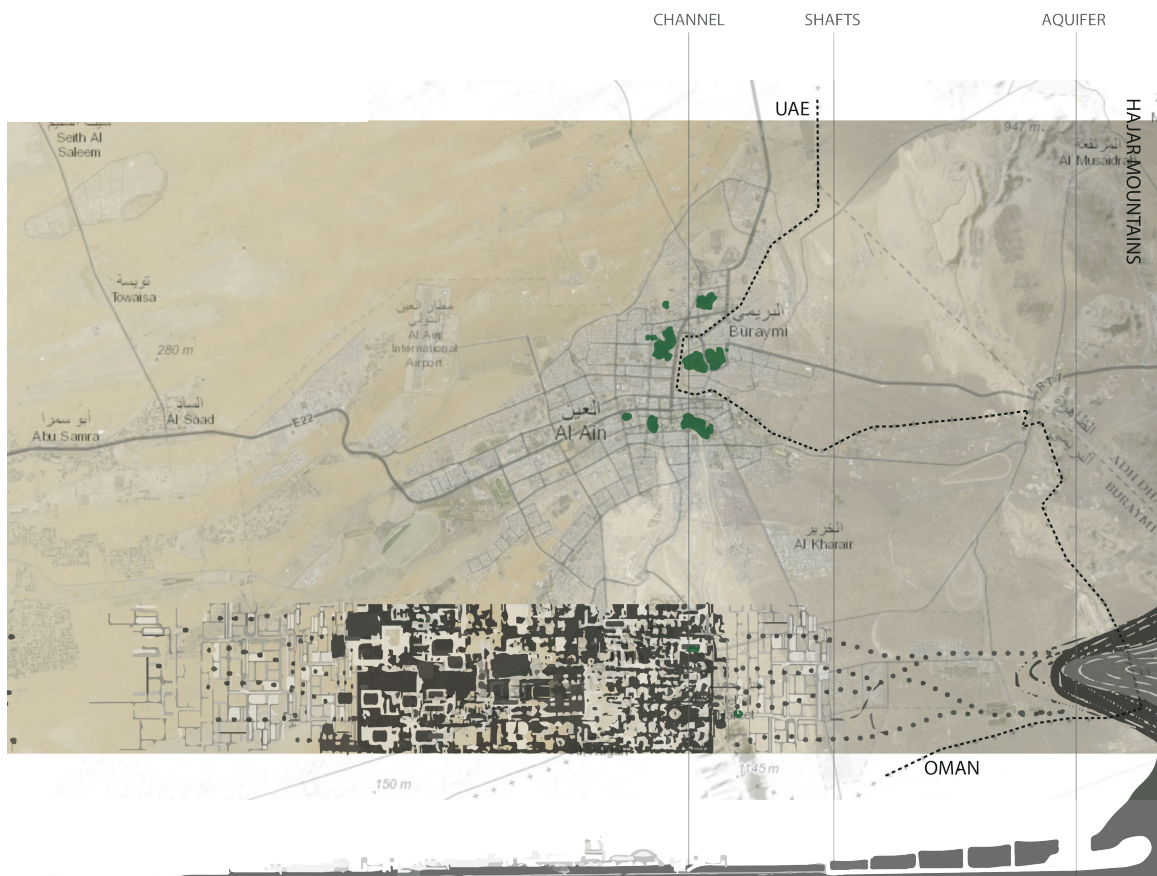


Figure 5: Plan of Buraimi Oases Base map Source: ESRI, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Gatmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

The strategic position of Buraimi has meant it has been a consistently contested territory.<sup>11</sup> Kelly observes that the contemporary joint jurisdiction of the oases is due to the undoubted historical location of Buraimi within the Sultanate of Oman and in the uninterrupted administration of the oasis by the Shaikh of Abu Dhabi since 1869.<sup>12</sup> The oases are valued as the only well watered locality in northern Oman while being in a strategic position as a shelter from the desert to the West where major routes connect to the North and Eastern edges of the Arabian peninsula.

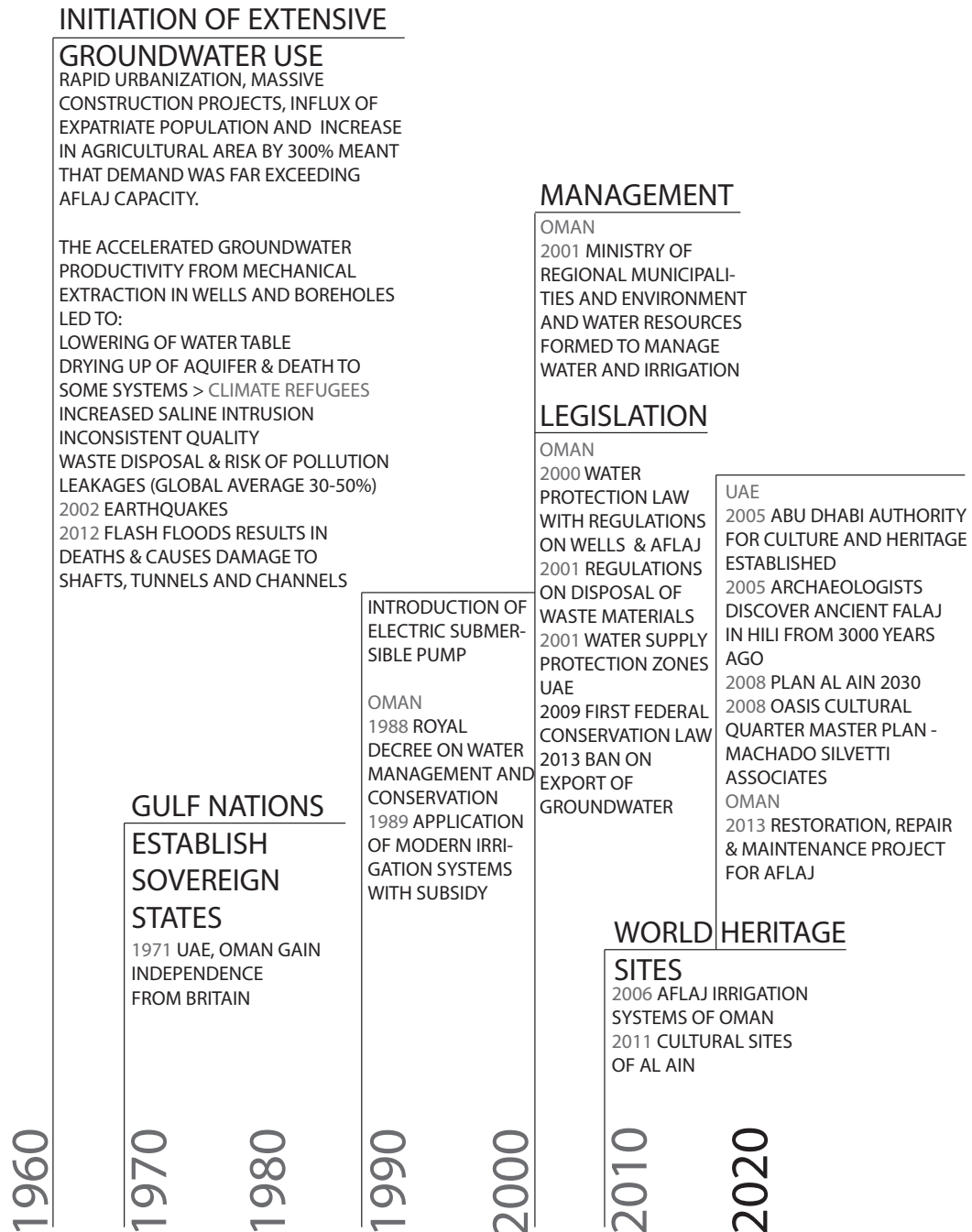


Figure 4: Buraimi water resources timeline

## 4.0 OMAN

With 73% of the population employed in the agriculture sector, and the country 75% food self sufficient, Oman had to act quickly to address the degradation to their *aflaj* infrastructure. Over 1000 *aflaj* of 4112 major arteries recorded had dried up with drastic humanitarian, environmental and financial implications. *Aflaj* supply around 410 million cubic meters of water annually representing 38% of Oman's fresh water, and are an integral source of livelihood for a large sector of the population. In response to *aflaj* deterioration, the first action was to issue a Royal Decree in 1988 on water management and conservation. The following year another decree was issued to encourage farmers to use more efficient modern irrigation techniques by subsidising costs. It was during this time the Omani government established the Ministry of Water Resources in 1989, which was charged with the restoration of *aflaj* and water supply by concentrating on the following issues<sup>13</sup>:

- Establishing protection zones and pollution control around mother wells
- Restoring *aflaj* affected by drought and over pumping, and providing support wells where necessary. By the end of 2005 they had constructed some 923 support wells, with a peak in 1991-1994 when they faced a prolonged dry period.
- Providing support, both financial and technical for repair and maintenance. By the end of 2006, the 669 maintenance projects had amounted to a total cost of OR 5.85 million (USD 14.9 million).
- Monitoring of both flow and water quality of 526 representative *aflaj* through the National Aflaj Inventory scheme.
- Augmentation of groundwater supply via recharge dams that collect flood and rainwater.

The activities of the Ministry of Water was supported by a series of Ministerial Decisions that integrated the traditional methods developed by the *aflaj* community, for the repair and maintenance of *aflaj* channels and structures with modern methods and engineering design. The use of mechanical excavation and reinforced concrete means that the works are safer, faster to carry out and last longer.<sup>14</sup>

In 2000, a renewed effort saw the issuance of a new "Water Protection Law." The following year, the Ministry of Water Resources was absorbed into the Ministry of Regional Municipalities and Environment and Water Resources (MRMEWR) where it adopted a policy to improve, conserve and protect *aflaj* in order to stabilize the rural population and retain the national heritage through the Water Resources Master Plan Vision 2000-2020. Long-term strategic goals were to<sup>15</sup>:

- Continue to support *aflaj* communities through the maintenance of systems to reduce water losses and the protection of water supply flow and quality
- Increased *aflaj* income through optimal usage of water
- Increased community self reliance and development
- Promotion of resources conservation through public awareness campaigns.

In order to do this, they established a plan of several progressive phases to be implemented, involving:

- Water allocation for each *falaj* in a catchment management plan that can achieve and sustain water balance
- Measures to balance supply and demand management
- Government subsidies to encourage increased farm productivity through conservation of water and development of improved irrigation systems
- Implementation of the principle of minimum water quota for each *falaj* sufficient enough to cover the needs of the community

The *aflaj* committees play a significant role in water management and maintenance decisions, as well as prevent sinking of new wells that might adversely impact water supply. Recognising the importance of community ownership, regulation sought to encourage conservation without too much interference. Regulations provide standards of water use to be applied equally to all villages in order to achieve strategic goals, while control of the *aflaj* remains in the hands of the *aflaj* communities, who are experienced in overcoming both technical and social problems. Schutze notes that the majority of agricultural production in Oman uses sprinkler irrigation systems, but there is small but sizable amount under floor irrigation, a few farms with bubbles, and even fewer with drip systems and so political and economic pressures are being exerted on agricultural water users to increase irrigation efficiency.<sup>16</sup>

Water resources in Oman received special attention as they represent the basis of integrated development. Significant efforts were introduced to the assessment and management of this resource such as extensive water resources assessment projects where, groundwater exploration activities are being carried out to find additional groundwater resources and non-conventional resources in order to augment the groundwater storage and cope with increasing demand. Several water resources management measures are being taken to efficiently deal with the available resources in a sustainable manner, such as groundwater protection, integrated catchment management plan and optimum use.<sup>17</sup>

## 5.0 UAE

The UAE is an unusual country, with an extremely high GDP, principally from hydrocarbon revenue. In contrast to Oman, the terrain is much more flat and arid, and therefore, UAE generally relies on groundwater resources from a shared aquifer, such as in Buraimi. The sudden wealth that flooded the country led to extreme rapid development and population explosion that pushed their demand on resources to a new high. Understanding that their natural resources are limited, the primary goal of the country, especially evident in Dubai, was to reinvest this wealth to create a tourism economy that would be able to sustain itself beyond the limits of hydrocarbon reserves. But the arrival of wealth saw a quick departure of the traditional way of life and instead ushered in a cosmopolitan urbanity that thrived on luxury and abundance. This departure brought with it a wasteful attitude and the loss of landscape literacy amongst the local population. The achievement of the tallest built structure in the world was not without towering consequences: UAE boasts one of the highest ecological footprints in the world; households alone are responsible for 57% of total water consumption, demanding a freshwater per capita use of about 650 litres per day. Approximately 40 per cent of the total supply is supported by 70 desalination plants. More than half comes from groundwater sources, but these are mainly used for irrigation as just 3 per cent can be classified as drinkable due to salt-water intrusion, while around 9 per cent is treated wastewater. The ministry predicts that at current rates the UAE's total annual water demand will double to 8.8 billion cubic metres by 2030 from 4.4 billion cubic metres in 2008. The greatest increase will be in urban centres, households, the industrial and commercial sectors, and public facilities.

In the UAE, agricultural development has been limited; Today 40 running *aflaj* supply a few scattered oases such as the Liwa group and those at Al Ain (Buraimi). 1970 statistics put the Al Ain population at 13,000, with 12.6% employed by the agriculture industry. The oases are no longer subsistence-orientated, instead, they transformed into commercially orientated assets with diversified crops.<sup>18</sup> Before, groundwater was the only source of water supply and was very scarce since there is little recharge and most of the aquifers are highly saline. It was only through seawater desalination that the growth of Abu Dhabi became possible. The plants were initially owned and operated by the government through the Water and Electricity Department, and financing was provided by the state from oil revenues. Natural groundwater recharge is estimated at about 300 million cubic meters per year. Brackish groundwater is mostly used for the irrigation of date palms, which are relatively salt-tolerant. Recharge dams have been built on wadis (valleys) in order to prevent floodwater to flow into the sea, recharging it instead to aquifers. Unplanned and uncontrolled groundwater withdrawals, especially for agriculture and forestry, total over 2,000 million cubic meters per year and have resulted in declining groundwater levels and quality. Here also, spray irrigation is the most common.

In the mid-1990s, the government decided to reorganize the water and electricity sector. The reform was inspired by the pro-private sector and pro-competition climate reigning during the 1990s, and it was implemented through foreign advisors. The reform of both sectors was based on the principles of unbundling production, transmission and distribution

- Production of electricity and desalinated water was to be the responsibility of private companies,
- Transmission of bulk water to Al Ain and Liwa oases was to be done by a public asset holding company and a private operating company,
- Distribution was to be in the hands of two public companies, one for Abu Dhabi and Liwa, and the other for Al Ain.

The sector was to be regulated by a public agency with a certain degree of autonomy from the government. The new structure was formally adopted through law No (2) concerning the regulation of the water and electricity sector passed in 1998. In 2003, Abu Dhabi piloted artificial groundwater recharge with desalinated seawater near the Liwa Oasis and was followed by the construction of large scale recharge facilities in 2008. Their objective was to create a 90-day reserve instead of the current 48-hour reserve for drinking water supply, in order to secure the country in case of a disaster that could shut down the entire water supply.

2004 and 2005 saw issuance of royal decrees to protect the oases' fabric and farming practices. In 2005 the Emirate created the Environment Department, which established a Strategic Water Master Plan published in 2009. When presenting the Master Plan, the chairman of the Environment Agency said that the future would be very challenging unless action was taken to reduce water consumption. The Plan describes the current status and the environmental and technical issues related to, projections of demand and supply, groundwater abstraction, desalination, water supply and sanitation, irrigation, wastewater treatment, and Emirati governance and institutions<sup>19</sup>. The government has run a media campaign to encourage people to save water. It has also distributed water-saving toilets and showerheads free of charge. The emirate also is in the process of expanding the use of reclaimed water. They further plan to replace all groundwater used for irrigation with TSE. Investment in both power and water production and distribution was more than US\$36 billion from 1999 to 2008. A budgetary review of Abu Dhabi's development project in 2012 saw a reassessment of the emirate's entire cultural heritage sector. The result was a merger of the Abu Dhabi Authority for Culture and Heritage and the cultural department of the Tourism Investment Development Incorporation into the Tourism Development Investment Corporation.

## 6.0 AL AIN MASTERPLAN

Although not in the same way as Dubai or Abu Dhabi, Al Ain has now entered its own process of accelerating urbanization. The oases no longer play the decisive role in the subsistence of Al Ain, having suffered loss in agricultural productivity and changes in crop regimes.<sup>20</sup> However, they have maintained a basic level of cultivation, supported by the Municipality's Aflaj department, which manages irrigation by artificially supplying water from pumped groundwater, desalinated water and Treated Sewage Effluent (TSE) into the traditional *aflaj* network. Though, the various sources have meant water quality is never consistent and can only be used for irrigation, artificial recharge has meant groundwater levels have risen in recent years.<sup>21</sup> The last detailed technical report on the status of Al Ain *aflaj* was executed in 1994 by the National Drilling Company.

In 2005, Machado & Silveti Associates were approached by one of the directors of the Abu Dhabi Tourism and Culture Authority (ADACH) to complete a master plan for the Al Ain oasis. The proposal was to transform a partially occupied site into a series of interventions that would compose a cultural landscape. Located on the edge of the oasis, it is anchored by the National Museum, and also features a center for music, souks and a boutique hotel while providing a gateway to the pedestrian walkways that filter through the oasis. Existing on the site are sheds of the livestock market which will be removed, and although there are plans to revive the old market area, the livestock market will be relocated to the site of Al Hayer, approximately 25km from Al Ain. The museum is sunken into ground to maintain visibility of the oasis canopy. The open landscape is intended to resemble sand dunes, "returning the landscape back to its natural form" intended to emulate the indigenous landscape of the surrounding desert.<sup>22</sup>

The proposal includes a visitor's center which hosts an exhibit on the evolution of the oasis, landscape, people and culture. For children up to the age of 12, there is a Water Discovery center where they can play, interact with and learn the value of water. There are other interactive exhibits such as the date palm experience. However, since all the individual oasis plots are private property, the public is not able to access the actual oasis. The walkways currently feature high walls of separation, which the plan proposes to reduce, to allow visibility into the farms and to the three-tiered agriculture.

I was able to speak with a contact at Machado & Silveti, who explained to me that when the project was initiated it was high priority and was receiving significant financing and political attention, but the recent financial crisis resulted in a standstill. Though the master plan was completed, there has been no further action of implementation yet. The plan was designed in compliance to the Plan Al Ain 2030, accompanied by aggressive tourist projections for the project. I was also informed that the idea of demonstration plots was suggested at a late stage in the design process and thus had not been included in the proposal. In another project elsewhere in the city, the

renovation of Qasr Al Muwaiji into a Fort Museum, an adaptive reuse project, we see the construction of new *aflaj* with artificial supply of TSE to irrigate the palm trees by flood irrigation.



Figure 5: Aerial photographs of Al Ain Oasis: 1968, 2002 & proposed Sources: <http://tcaabudhabi.ae/en> & <http://www.machado-silvetti.com/>

Heritage projects in the region have a highly political dimension; As native Emiratis comprise only 20% of the total UAE population, the government assumed the role of guardians of traditional culture, protecting and promoting the idea of a national cultural heritage. The leadership's use of cultural heritage to develop a national narrative and shape national identity, positions the UAE as a global brand, creating new tourist economies and resorts to exploit it. Actively safeguarding heritage has, in turn, helped to strengthen the legitimacy of the leadership. Langham & Barker, the heritage consultants on the project, describe the issue with the global heritage discourse "with its specific rules and regulatory practices can exclude indigenous populations. The global

heritage process such as those by UNESCO alter the relationship of local heritage practitioners to cultural heritage practices, since the beneficiaries of heritage are no longer just the indigenous peoples but all of humanity.”<sup>23</sup> One of the issues for the local community in Abu Dhabi is that the heritage projects are being created and shaped by expatriate workers.

## 7.0 CONCLUSIONS

Oman and UAE situate themselves in very different environmental, economic and social circumstances, which is reflected by their national priorities, and further manifested in their treatment of *aflaj* within their management of water resources. Though it can no longer satisfy the demands on water to the same extent it once did, the *aflaj* can still be considered a successful system, as it demonstrates continued resilience even in today's context and has proven adaptable to different solutions that meet national goals.

Oman relies heavily on agriculture and *aflaj* technology proliferated across huge expanses of land facilitated by local mountainous regions, therefore Buraimi constitutes little significance at a national scale. Oman's conservative approach can be looked upon as a model for other countries that could benefit from restoration and improved efficiencies. Oman's consistent incremental effort to restore the system draws many lessons as they develop improvements that make it better suited to our current environment. At the same time, Oman has taken measures to ensure autonomy of the system and keep ownership in the hands of the users. Considering of the vastness of these networks, the infrastructure and technology can be a valuable asset for those who already possess it - with a multitude of options for its adaptation to modern use. It also holds potential for incorporation into new systems of water management.

By contrast, the UAE's flat terrain was less accommodating to *aflaj*, illustrated by a handful of *aflaj* in the country, representing a mere 1% of Oman's total. Thus as hydrocarbon wealth beckoned a quick departure from the difficult rural lifestyle, Buraimi was implicated as a final remembrance of bygone days. In the UAE, the system was in greater peril, but playing a minor role in the subsistence of the population, it transforms into a tourist attraction, preserved in the name of 'cultural heritage'. The sustainability of the proposal however warrants debate, as it loses function and lacks efficiency, to condemn the traditional way of life with it. UAE's radical plan is highly tailored to its unique conditions and economy, but with implementation on hold, the government is yet to decide if the plan is still appropriate in the shadow of the recent global financial crisis.

Oman is committed to the survival of this system and the way of life that accompanies it but challenges persist. Allen warns against a "fantasy of self-sufficient food security without recognising a much more hazardous technological dependency."<sup>24</sup> It has been observed in Oman, that owners of the existing *aflaj* are not interested in participating, and have rejected the construction of *aflaj* expansion.<sup>25</sup> *Aflaj* renovation is a viable option but its long-term sustenance is only possible through communal consensus of willingness and participation. On going efforts such as the 2007 UNESCO organised: "International Training Course on Qanats" are helping to increase awareness of technical and cultural issues. *Aflaj* building skills are receiving renewed attention but there has not yet been any administrative mechanism to incentivise these skills within

mainstream development.<sup>26</sup> If they remain undesirable, how can its preservation be successfully incentivized and implemented?

In the UAE, conservation has not yet been embedded within the local lifestyle. The Al Ain master plan reveals a glaring missed opportunity to improve *aflaj* technology and infrastructure sustainably to prolong future use, as well as to allow for more interactive learning through demonstration plots. This is an unfortunate consequence of a larger strategy at a national level, which has prioritised other strategies above water conservation and education. Already maintained by expatriate workers, the plan may further encourage gentrification of the area, evacuating the indigenous and current population from the area. Though the end result becomes little more than a ploy for tourist dollars, by supplementing with artificial supply and adapting its use, it should reduce the strain on groundwater resources. Education is nevertheless lacking amongst the whole population; Farmers are unaware of the hidden cost of conventional spray irrigation, while household consumption remains dangerously high as supply and use are so disconnected.

Strong direction from leadership has pushed Oman and the UAE in different directions, reinforced by financial resources, regulation and legislation, to control damage and reflect national priorities. In meeting those aims, both can be considered successful to an extent and appropriate for their contexts, however it is still too early to fully assess the impacts and outcomes of both plans. While Oman is strides ahead in advancing ecological sustainability and technological progress of the *aflaj*, what seems to be lacking in both contexts is the presence of a research and development unit that will explore the potential of the marriage of modern technology to the *aflaj* system.<sup>27</sup> Such an approach could advance measures to reach optimum efficiency and perhaps find sustainable solutions that allow replicability and the construction of new *aflaj* with less cost, less labour intensive, and minimal risks, which could then be exported to other nations newly facing desertification to secure an additional renewable water source. While it is not a complete solution to the overarching problem, traditional knowledge can nevertheless contribute to an integrated approach for sustainable infrastructure.

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