

CURRENT STATUS OF AFLAJ IN THE AL AIN AREA UNITED ARAB EMIRATES

February 2006



هيئة البيئة - أبو ظبي
Environment Agency - ABU DHABI

أبحاث • تنمية • حماية
RESEARCH • DEVELOPMENT • PROTECTION

DOCUMENT ISSUE SHEET			
Project Number:	03-33-0001		
Project Title:	Water Resources Management Plan for Abu Dhabi Emirate		
	Name	Signature	Date
Prepared by:	Mike Brook Huda Al Houqani		18.02.06
Submitted by:	Mike Brook		18.02.06
Approved by:	Mohamed Dawoud		
Authorized for Issue by:	Abdulnasser Al Shamsi		
Issue Status:	final		
Recommended Circulation:	Internal and external		
File Reference Number:	03-33-0001-06-001		
Team Members	Mike Brook, Huda Al Houqani		

Front Cover Photo : Al Mutared Falaj Source Channel (25/1/06)

EXECUTIVE SUMMARY

Over the last 20-25 years the aflaj of the Al Ain area have been placed under increasing stress from declining groundwater levels in the source or mother well areas, whilst the water table in the vicinity of the aflaj shari'a itself has steadily risen in recent years due to artificial recharge of groundwater from TSE and desalinated irrigation water which is now widely used to keep the garden city of Al Ain green.

Today, only two of the seven operating aflaj have natural flow and all aflaj are supported by varying mixtures of pumped groundwater from wells, imported desalinated water from Qidfa desalination plant, Al Fujairah and , more recently, from Treated Sewage Effluent, the latter supply generally being small and unreliable. Today the aflaj are used for irrigation of the six main oasis areas which occupy an area of 350ha, or about 5% of the total green area of the city.

Given the various sources of water input to the aflaj, means that falaj water quality is never consistent, only in the case where the falaj are supported primarily from one source e.g. Al Qattara only from groundwater. The TDS of aflaj water sampled as part of this study ranged from 380 mg/l (Al Aini – largely supported by Desalinated water) to 2820 mg/l (Al Mutarid – supported by groundwater wells and TSE).

A total of 96 groundwater wells presently provide support directly to the aflaj as well as about 1,6 million imperial gallons per day desalinated water and a small, un-quantified amount of treated effluent (TSE).

The following recommendations are provided as a means of understanding the aflaj systems better and providing for assistance in their long term management:

- 1) A monitoring system for aflaj flows and water quality.
- 2) An aflaj and support well inventory (to be conducted by EAD during 2006)
- 3) Mapping of the aflaj channels and mother-wells
- 4) Measurement of the different source types of water entering the aflaj
- 5) A study for the requirement for new observation wells for the aflaj.
- 6) Provision of all collected data to EAD on a regular basis for inclusion in the new EAD Water Resources database.

TABLE OF CONTENTS

1. INTRODUCTION	4
2. HISTORY OF WATER RESOURCES DEVELOPMENT	4
3. GENERAL WATER SITUATION	9
4. CURRENT STATUS OF AFLAJ	13
4.1 FALAJ AL AINI (AL SAROOJ)	15
4.2 FALAJ AL DAOUDI	15
4.3 FALAJ AL MUTARED	15
4.4 FALAJ AL QATTARA	15
4.5 FALAJ AL JIMI	15
4.6 FALAJ AL HILI	16
4.7 FALAJ AL MUWAIJEI	16
4.8 FALAJ AL JAHILI	16
4.9 OTHER AFLAJ	16
5. CONCLUSIONS	18
6. RECOMMENDATIONS	19
7. ACKNOWLEDGEMENTS	20
8. REFERENCES	20
9 APPENDICES	21
A- DETAILS OF AFLAJ SUPPORT WELLS	21
B- AFLAJ PHOTO GALLERY	23

1. Introduction

This report provides an update of the current situation of the Aflaj (singular: Falaj) in the Al Ain area of Abu Dhabi Emirate, United Arab Emirates. Aflaj are traditional man made channels, found both above and below ground, used to collect groundwater, spring water and surface water and transport it, by gravity, to a demand area. Historically, they provided the main source of drinking and irrigation water to oasis settlements, but nowadays, they supply only irrigation water to selected oases in and around the garden city of Al Ain. The locations of the existing Oases, and other “green areas” in Al Ain, is shown in Figure 1. Oases are traditional centres of both habitation and agriculture, originally fed by naturally flowing aflaj. It is estimated that combined, they consume about 10 Mm³/yr of irrigation water for around 375,000 date palm trees and occupy an area of 350ha (Branke, 2005). The largest Oasis area, Al Ain, occupies 130ha. The present day Oasis areas have now shrunk. In early Islamic times, the combined oasis area, called Tuwwâm, was much larger and was one of the regions most important social and cultural centres.

However, none of the Al Ain Aflaj are currently working fully under natural flow conditions, rather they are now largely supplemented from pumped groundwater from support wells and piped desalinated water from the relatively new Qidfa desalination plant in Al Fujairah.

Active falaj systems, however, are still found in other parts of the U.A.E. 33 Aflaj have been studied in the Eastern Region of the U.A.E (Rizk, 1998) and their natural flows in 1996 varied from 0.08 l/s to 89.7 l/s with an average flow of 17 l/s and average Total Dissolved solids (TDS) of 697 mg/l.

The last detailed technical report on the status of the Al Ain Aflaj was provided by the National Drilling Company (NDC) in 1994 (NDC, 1994) and so an updated account is very much required. A current update of all the Al Ain Aflaj is provided along with recommendations for further investigation and monitoring.

2. History of Water Resources Development

Water resources development within the Emirate can be traced right back to the stone age, commencing 3000 BP, through the iron age, Islamic period and pre-oil times to present day. Shallow hand dug wells (only a few meters deep) and aflaj systems (aflaj) provided permanent water sources used for sustainable agriculture and drinking water supply. The shallow hand dug wells were constructed both onshore and on offshore islands. Examples of late Stone age (c. 5,000 BC to 4,000 BC) and early Islamic period (620 AD to 1800 AD) dug wells are found at the present site of Abu Dhabi International Airport and also on Marawah Island respectively. In areas of shallow water tables in the surficial, alluvial and sand aquifers, hand dug wells and open pits for water abstraction are still constructed today.

The history of aflaj development within Abu Dhabi, and the UAE as a whole, has been well documented by Al Tikriti (2002) and an overview of aflaj and oases is provided by Al Ain Municipality and Agriculture (2004). Aflaj can be traced back to the Bronze Age, although the majority of sites date back to the Islamic period. Three types of aflaj are known (Figure 2), namely:

Aini (originate from springs and are perennial in nature)	}	al qanat al jawfiya
Dawoodi (formed from sub-surface channels. Either lined or open)		
Ghaili (Surface water or base - flow diversions)	}	al qanat al mahfura

Aini Aflaj water sources are invariably springs which develop due to impervious bedrock exposures. Dawoodi aflaj are subterranean and are constructed channels which are accessed via vertical shafts known as thaqba. Their source is a mother hand dug well which feeds the main channel by gravity. The Ghaili falaj is a channel which is fed by bunding and diversion of a surface water supply, most often an active wadi bed or a spring.

Many Islamic period aflaj irrigation systems continued in use until pre-modern times and were regularly cleaned. The Iron Age aflaj have, however, long since fallen out of use and are now covered and blocked.

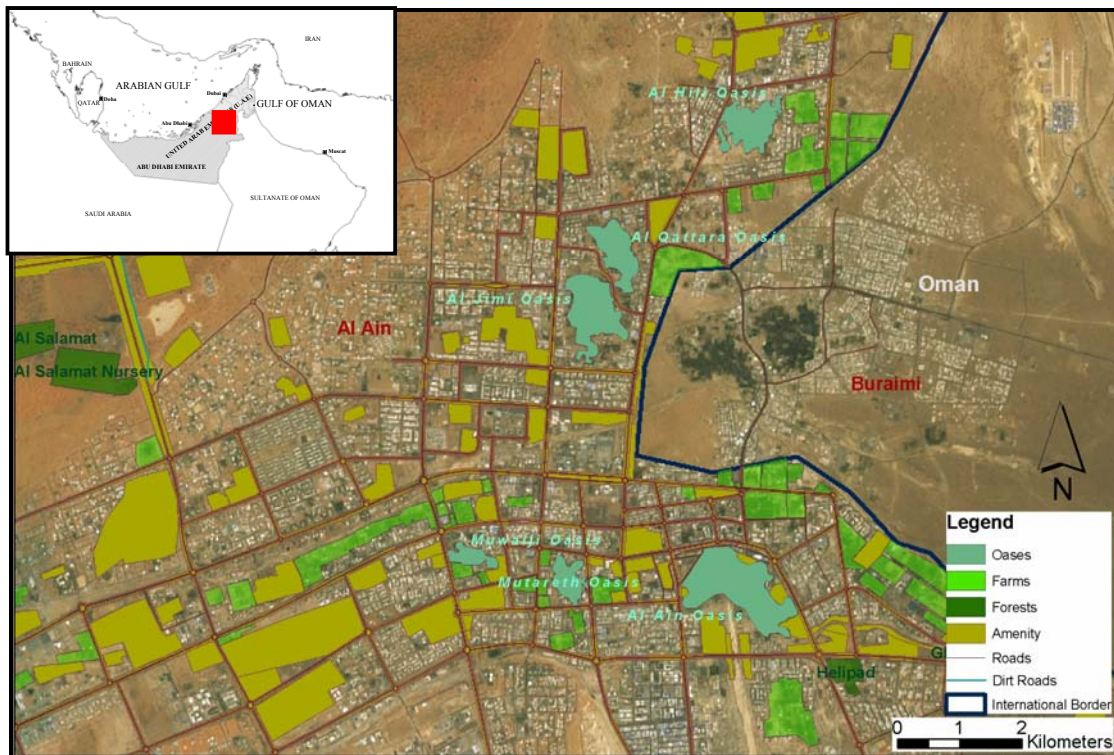
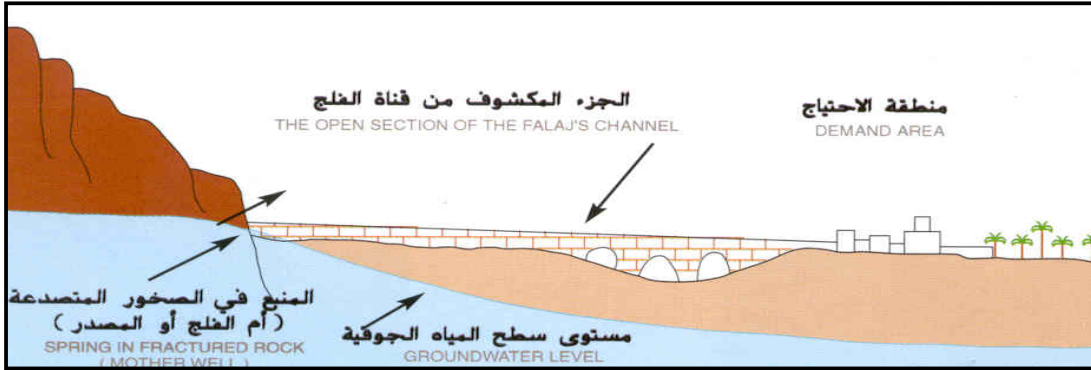
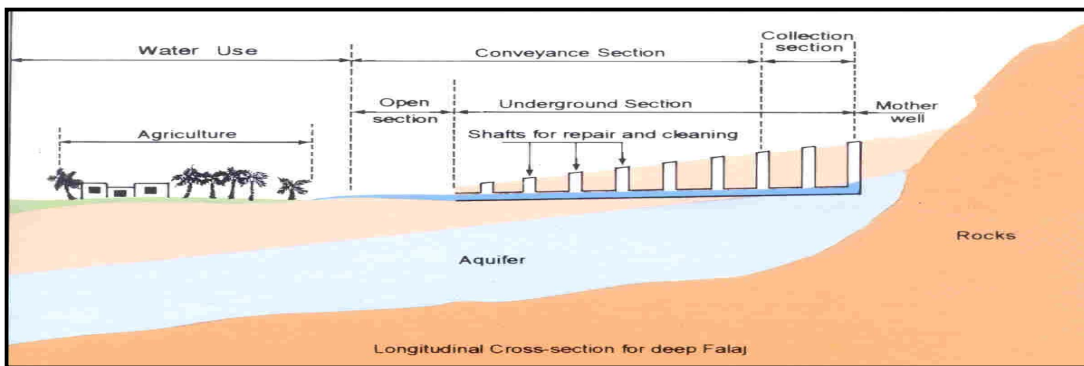


Figure 1 Present day Oases in Al Ain City (Branke, 2005)

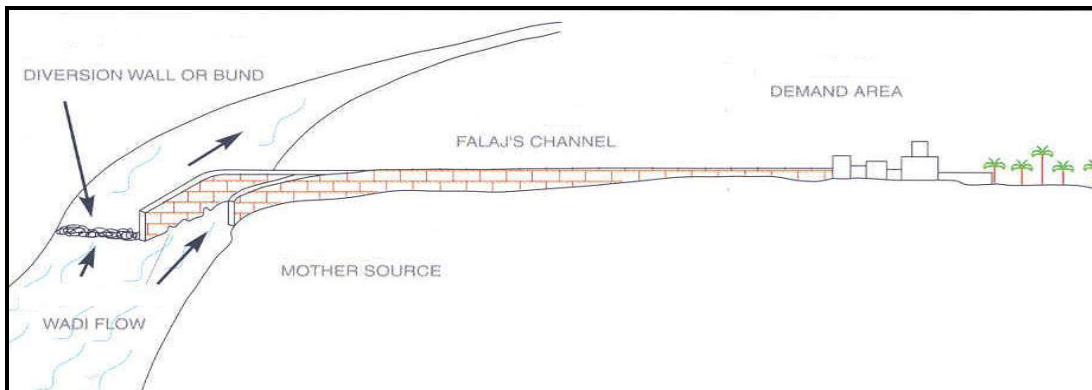
Jorgensen and Al Tikriti (1995 and 2002), from a hydrologic and archaeological study of climate change in the Hili area of Al Ain, have shown that trends of increased well depths and declining water levels for the past 4,500 years correlate with an increase in aridity of climate. Figure 3 shows a 4,500 year hydrograph with a slow groundwater



Aini Falaj



Dawoodi Falaj



Ghaili Falaj

Figure 2 The Three Types of Aflaj Systems (MRMEWR, 2001)

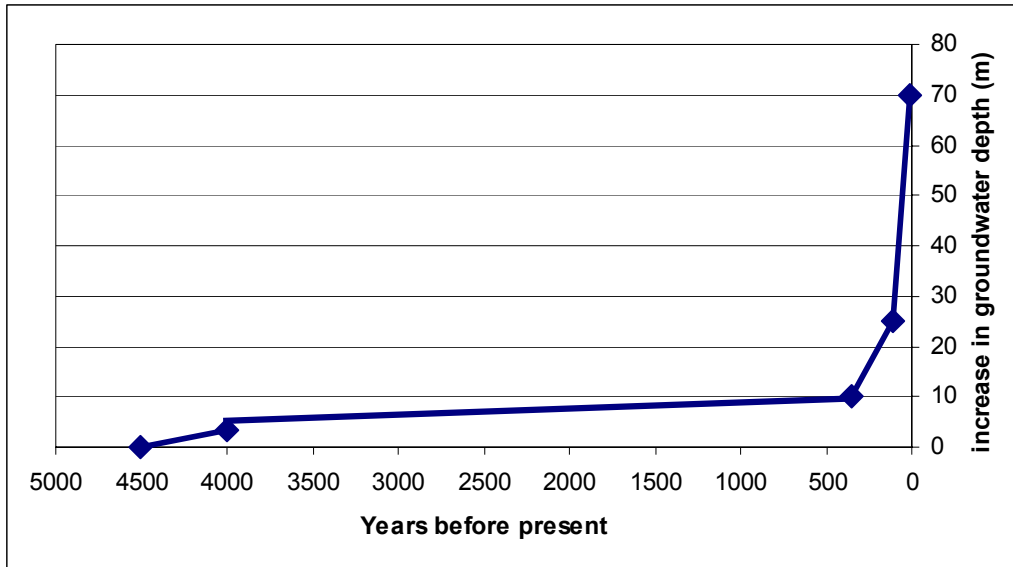
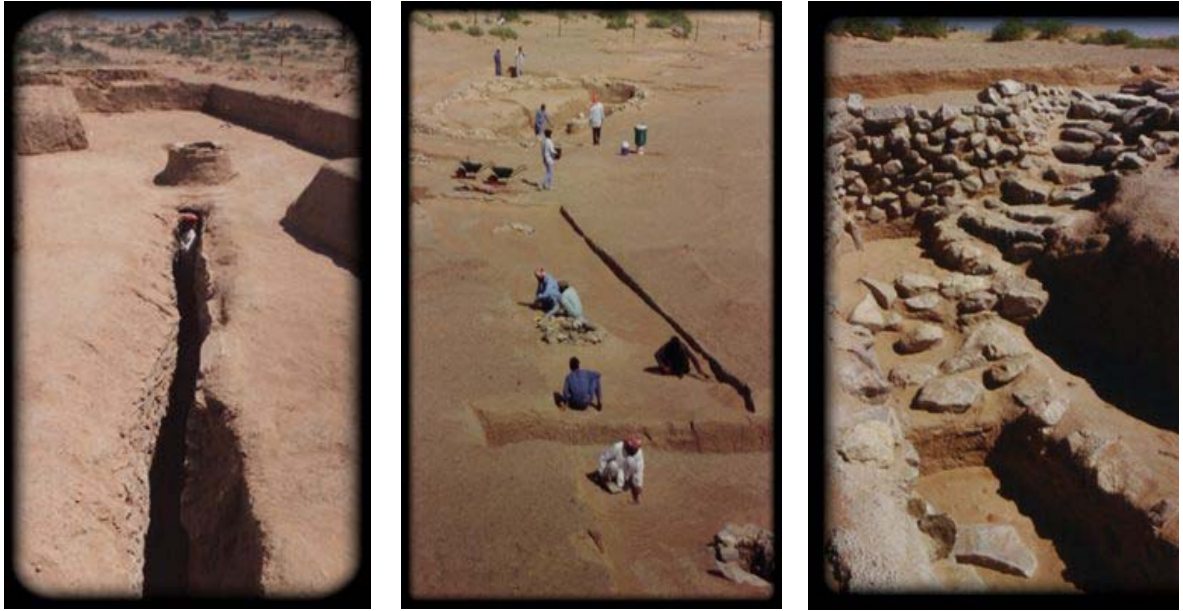


Figure 3 Changes in groundwater levels at Al Ain over the last 4,500 years
Adapted from Jorgensen & Al Tikriti (2002)

decline from 2,500 BC to ca. AD 1650, an increased rate of decline then to around AD 1900, after which there is a very rapid decline that is largely anthropogenic. The increase in aridity experienced in Abu Dhabi Emirate represents a trend which existed over all or most of the Middle East, eastern Mediterranean and northern Africa which had an immense impact on civilizations. In the Al Ain area, non-irrigation farming could not successfully be sustained at the end of the Bronze Age. This hindered economic development until the aflaj system was introduced in the Iron Age. Whilst all flowing aflaj in the Emirate are now supplemented with boreholes, there are approximately 30 working aflaj in the Northern Emirates, mostly Aini type, originating from springs in the Ophiolite Complexes e.g. Masafi, Hatta etc. A review of these aflaj has been provided by Rizk (1998).

In 2005, Archaeologists found an ancient falaj underneath the courtyard of a house in the northern part of the Hili Archaeological Park, Al Ain, a few hundred metres to the east of dig site “Hili 17” and runs just to the north of dig site “Hili 14” and believe it was built some 3,000 years ago (Figure 4). It was discovered and excavated by the Department of Antiquities, Al Ain. Open channels, a sharia, a cut and cover section and a single shaft hole were uncovered. The large collection of pottery found associated with the open channels and the sharia belong to the Iron Age Period.

Another ancient falaj has been discovered west of Bida bint Saud (Figure 4). Several shaft holes and a subterranean tunnel were excavated at different spots. The most important was the discovery of the sharia, which, according to the local pottery found, is of Iron Age. An approximate date of 1000 BC was given to this falaj as well as to a near-by structure.



(a)

(b)

(c)

Figure 4. Archaeological digs at Aflaj in Al Ain Area (courtesy of Al Ain National Museum)

(a) Hili (b) Bida bint Saud Falaj (c) steps down to Shari'a at Bida bint Saud Falaj

By contrast, in neighbouring Sultanate of Oman, there are a total of 4112 aflaj registered in the national aflaj inventory (MRWEWR, 2001), of which 3108 flow under natural conditions. The aflaj there still supply one third of the countries total water demand. Within a 50km radius of Al Ain, there are 14 operating Aflaj within Oman. The two of the eight Dawoodi aflaj are supported by wells (Falj Al Buraimi and Saara from Zaroub wellfield. All of the six Ghaili aflaj work under natural conditions. Figure 5 shows the Ghaili falaj at Al Khatwa, 50km east of Al Ain.

3. General Water Situation

The modern period in Abu Dhabi Emirate commenced with the discovery of oil in Abu Dhabi Emirate in 1958 and with its first export in 1962. The last half century has witnessed incredible economic development and massive year on year increases in water use, largely sourced from abstractions from groundwater. Furthermore, the introduction of the more efficient electric submersible pump in the early 1980's, as a replacement for lower yielding diesel engine turbine shafted pumps, in the agriculture and forestry sector in particular, has accelerated groundwater productivity, but at the expense of aquifer sustainability. In the absence of sound, groundwater management policies, abstractions have continued unregulated with severe consequences of declining groundwater levels and substantial increases in groundwater salinity in some areas and also widespread groundwater pollution associated with agricultural practices.

Aflaj have suffered from the general lowering of the water table in the catchments source areas of Al Jaww plain to the East of Al Ain. According to NDC (NDC, 1994) the combined discharge of all aflaj has declined from 160,000 m³/yr in 1964 to 100,000 m³/yr in 1993. Augmentation of the significantly reduced natural discharge with groundwater pumped from on-site wells commenced in 1983.

The irony of the water situation is that in the immediate vicinity of the aflaj, and generally within the town centre of Al Ain, groundwater levels have risen for the last 5-10 years (Figure 6) as both desalinated water and treated effluent has been used for irrigation of the green areas and has recharged the shallow groundwater table.

Table 1 provides a summary of the green areas which have been mapped within Al Ain City. Over 600 wells are operated by the parks and gardens Department; however, no new wells have been drilled in the last 2 years.

Table 1 Summary of Al Ain City Green Areas (Branke, 2005)

	Number	Area [ha]	Assumed water demand [tcmd]
Palaces	28	1466.39	258.89
Municipal Parks	31	1058.27	239.33
Other park-like Areas (e.g. Hotel Areas)	2	21.34	3.00
Public Facilities (e.g. Al Ain Zoo, University Campus)	8	468.12	49.15
Roadside Plantings & Roundabouts	11	1857.17	146.79
TOTAL		4871.29	697.17

Artificial recharge has also occurred in and around Al Ain City as a result of substantial leakage from piped distributions systems which have been badly in need of replacement for a number of years.

Observation wells GOW-35 and 36 both show a general rise in groundwater levels over the last 4-5 years, specifically 3 m and 10 m respectively as a result of the above

artificial recharge and also a reduction in crop water use on established farms. The TDS of groundwater within the falaj shari'a areas varies from 1100 – 3700 mg/l.

However, groundwater levels in the source area and original mother – well locations have declined significantly (Figure 7), thus causing the original source Mother wells to become dry and the aflaj to no longer operate with natural discharge. Observation wells GOW-55 and GOW-65 show a one meter per year decline in the groundwater table over the last 6-7 years. The location of the observation wells and Falaj Shari'a are shown in Figure 8.



Figure 5 The channel of Ghaili Aflaj (Al Khatwa, Oman)

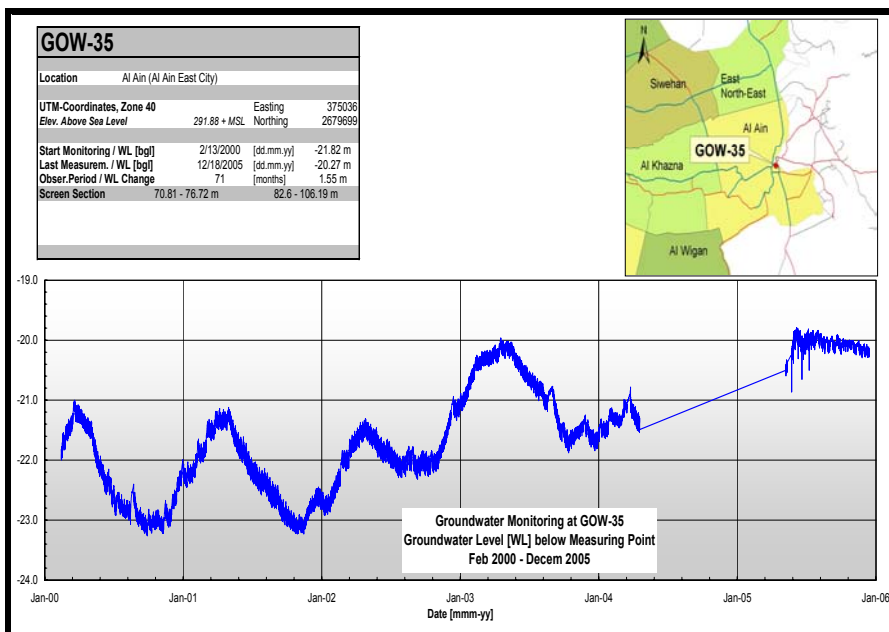
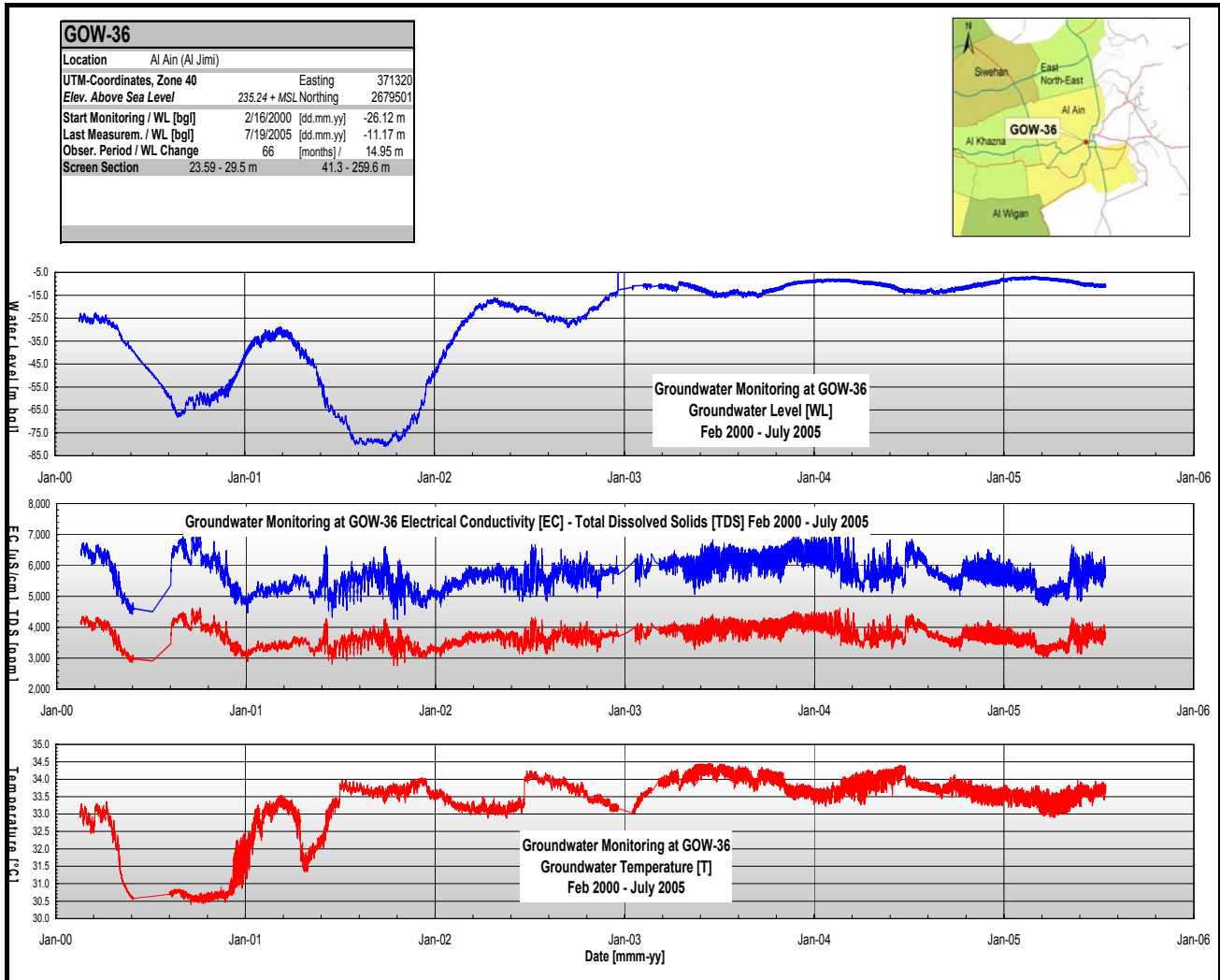


Figure 6.
Hydrographs, EC and
Temperature of observation
wells in vicinity of Falaj
Shari'a

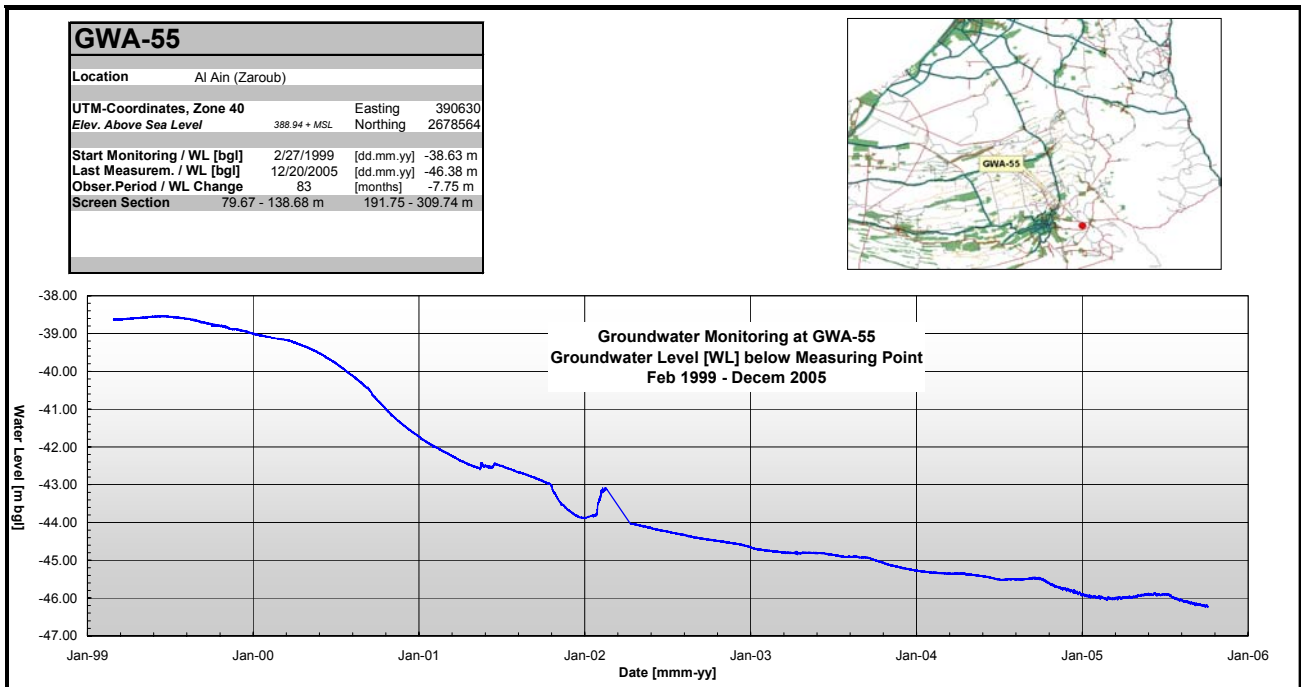
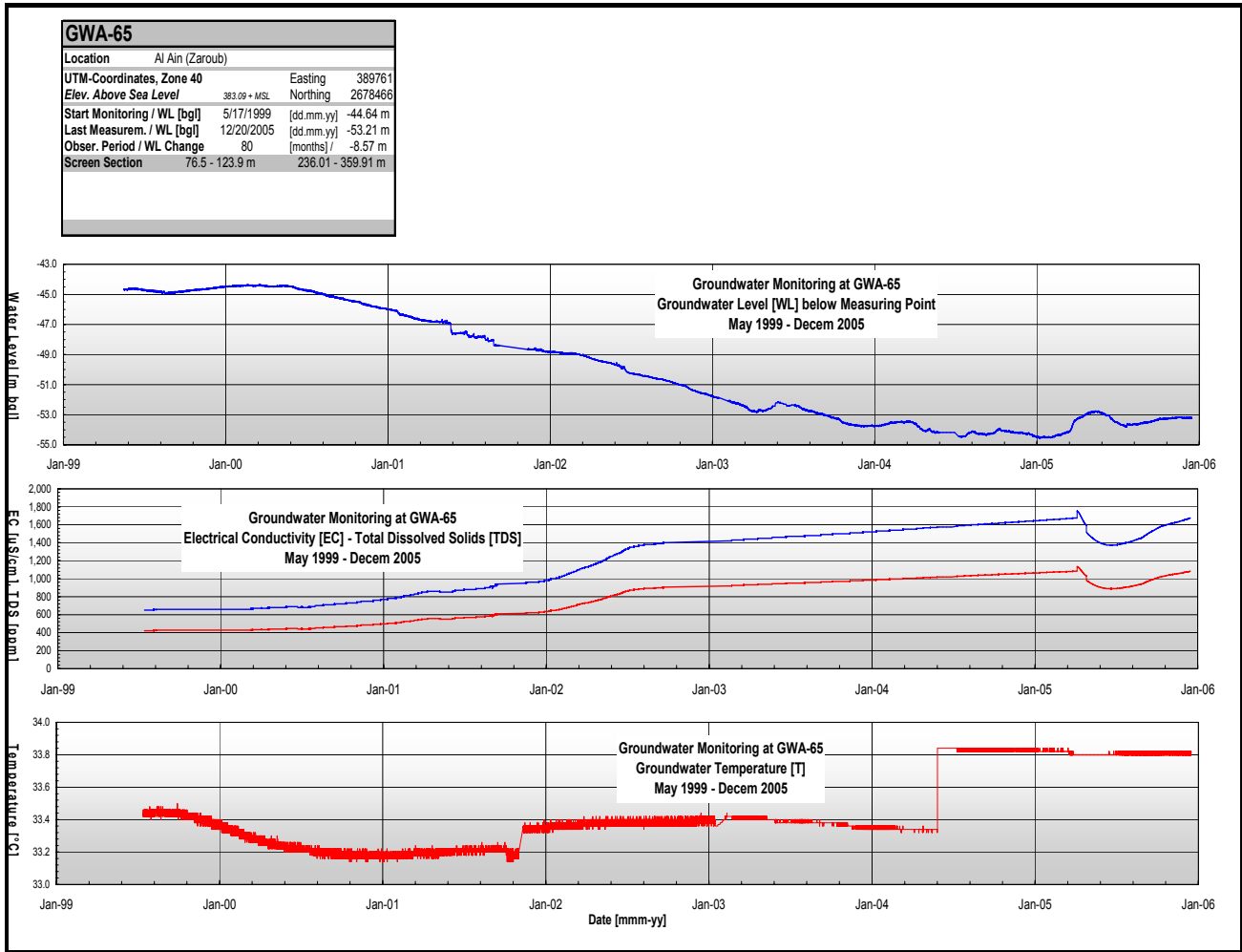


Figure 7 Hydrographs, EC and Temperature of observation wells in vicinity of Aflaj Mother wells

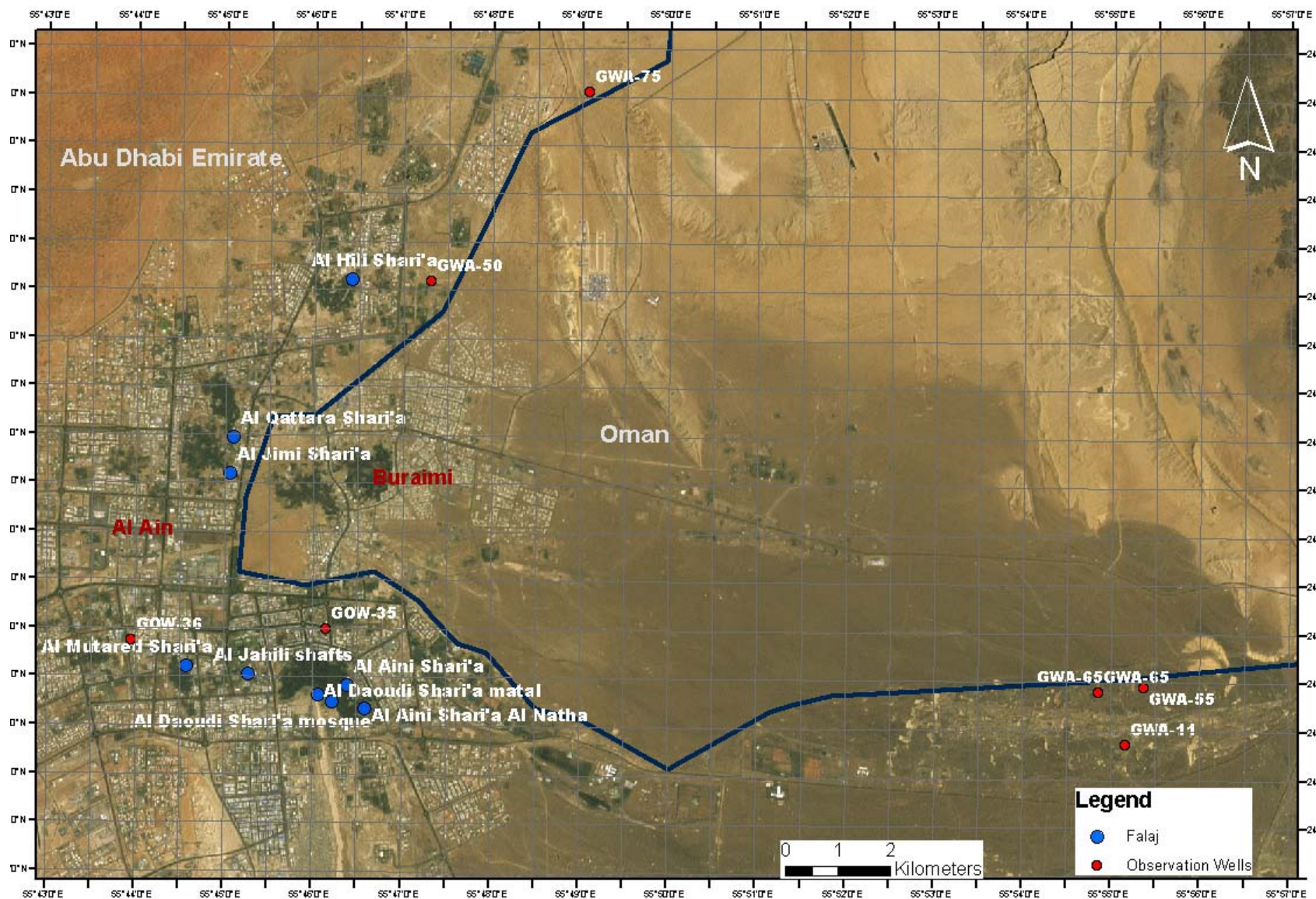


Figure 8. Locations of Aflaj Shari'a and Observation Wells

4. Current Status of Aflaj

Table 2 shows that 21 aflaj are found in the Al Ain region. Al Hili and Al Raki aflaj are the oldest and both are around 3000 years old and were constructed in the Iron Age. Of the twenty-one aflaj that have been inventoried, only nine are currently in operation. Table 2 has been compiled from information provided by the Aflaj section in the Parks and Gardens Department, Al Ain Municipality and Agriculture and also Al Tikriti's (2002) work.

Aflaj in Abu Dhabi Emirate have only been developed in the region of Al Ain City, which is fed by recharged alluvials bordering the Oman Al Hajar Mountains. Today, all nine working aflaj fall under the management of the Aflaj section of the Parks and Gardens Dept of Al Ain Municipality and Agriculture and are either partially or wholly supported by varying support from boreholes, piped desalinated water and treated effluent from the Al Zakher Sewage treatment plant. In 2004, the plant supplied a total of 21.7 Mm³/yr of tertiary treated effluent for irrigation of Al Ain's green areas, but the amount supplied to aflaj is unknown.

Figure 1 shows the location of the main Oases in Al Ain which are irrigated by seven major Aflaj, namely:

- Al Aini (or Sarooj)
- Al Daoudi
- Al Mutared
- Al Qattara
- Al Jimi
- Al Hili
- Al Muwaijei

All aflaj are of the Dawoodi type and are fed by groundwater from mother wells situated to the East of Al Ain City where groundwater levels have declined significantly in recent years.

A total of about 350 ha of Oasis exist which comprise a multitude of separate farm areas which are dedicated to producing mostly dates and alfalfa fodder for the local market needs.

The late great Sheikh Zayed bin Sultan Al Nayhan placed great importance on the preservation of these Oasis areas since they are very much part of the heritage and culture of the area and are thousands of years old. They also, along with the traditional aflaj irrigation canals, provide important places of interest for the growing tourism industry in the area.

Table 2. Summary of Recorded Aflaj in Al Ain City

Falaj Name	Site location	Mother Well Location	Depth of motherwell (m)	length (km)	to Irrigate	status
Al Aini or Al Saroj	Sahal Al jaw – Marag SE of the City		20	15 km	Al Nakhil oasis	supported by 24 wells in Aini & Daoudi
Al Daoudi	Shabaihat		20	7 km	Al Ain oasis (129.53ha)	supported by 24 wells in Aini & Daoudi 147,120 date trees
Al Mutared	N of Al Muraba tower Al Ain City Center				Al Mutareth Oasis (26.22ha)	supported by 9 wells to irrigate 40860 date tress
Al Qattara	Al Buraimi,Oman				Qattara Oasis (47.62ha)	supported by wells to irrigate 40880 date trees
Al Jimi	Al Buraimi,Oman				Al Jimi Oasis (77.27ha)	supported by wells to irrigate 70740 date trees
Al Hili	Starts from Al-Oha N&E of the City	Sahal Al-meairij	30	10 km	Hili Oasis (51.1ha)	supported by 26 wells and desalination to irrigate 54145 date trees
Al Muwaijei	City Center at Al Kuwaitat			6 km	Al Muwaijei Oasis (17.99ha)	supported by wells to irrigate 20950 date tress
Mazyad	Mazyad	Mazyad, Western Safafa	24			supported by wells
Al Jahili	Al Ain City Center				Al Jahili area	trace
Saa	Al Dhaher Area				Saah Area	abandoned
Wadi Al Hamam	Al Hili- Bidi bint Saud		6.5			abandoned
Wadi Al Jabeeb						abandoned
Al Hili Fun City						abandoned
Al Raki	NE Al Ain city					dry
Al Masoudi	Al masoudi				Al masoudi area	dry
Hazza		Al Hamala			Al towaisa in Al manaser	dry
Al Gashabi	N&E of Al-Oha				Al Hili	dry
Al Meatelej					front of al Hili	dry
Al Henryami	N of Al Ain City				S of Al Hili	dry
Al Khazami	N&E of Al Hili					dry
Um Al Mader	NE of al Hili	Um Al yadder			Al Hili	dry

4.1 Falaj Al Aini (Al Sarooj)

This is the longest falaj system at 15km and is used to irrigate the Al Nakhil Oasis. Along with Falaj Daoudi, it has the strongest natural flow (not quantified) but both aflaj presently receive 1 mgpd of desalinated water from the Qidfa, Fujairah plant. The falaj also receives groundwater from 24 wells which also support Falaj Daoudi (see Appendix A). The aflaj section believe that 50% of the total flow is natural; the other 50% is supplied by desalinated water and pumped groundwater. Measured water quality details are shown in Table 3 below, along with details for other aflaj. In 1993, the falaj was monitored with a flow of 114 l/s and a TDS of 657 mg/l (NDC, 1994).

4.2 Falaj Al Daoudi

Al Dawoodi falaj is now supported by a wellfield 24 wells (16m spacing) which it shares with Falaj Al Aini. Well water varies in TDS between 1100-1200 mg/l. The falaj receives some natural flow but also desalinated water from Qidfa since one year ago (see photo in appendix). The mother wells of the Dawoodi aflaj range in depth from 6.5 to 30m and are located some 7km away. It is estimated that one third of the total flow is still natural groundwater discharge. In 1993, the falaj was monitored with a flow of 88 l/s and TDS 400 mg/l (NDC, 1994).

4.3 Falaj Al Mutared

The falaj has no natural flow and is supplied by 9 boreholes (approx 800m³/d) and Treated Sewage Effluent (TSE) from a 4-inch delivery pipe for about 3 hours per day (equiv. only 30m³/d). The supply of TSE is inconsistent and cannot be guaranteed and forms <5% of total flow. The groundwater supplied is moderate brackish in quality. In 1982 the falaj went dry and between 1979 – 1981 recorded a yield of only 4 l/s with a TDS of 830 mg/l (NDC, 1994).

4.4 Falaj Al Qattara

This falaj was reported as being dry as early as 1979. Between 1964-1969, it averaged a flow of 31 l/s and a TDS of 473 mg/l (NDC, 1994). Today, it is the only falaj which is supplied by only pumped groundwater (25 wells supply Qattara and Al Jimi Falaj). The Qattara oasis is 47.62 ha in size and contains over 40,000 date palm trees. Groundwater quality is 1200 mg/l TDS. An example of one of the groundwater support wells is shown in Figure 9 below.

4.5 Falaj Al Jimi

This falaj is reported as going dry in 1979 (NDC, 1994). Before last drying up it had a TDS of 595 mg/l. Today, this falaj shares a 25-well wellfield supply with Falaj Al Qattara, but also receives TSE through a 6-inch pipe for 4hrs/d. TSE represents about 80% of the total daily irrigation water. The falaj irrigates over 70,000 date palm trees in the Al Jimi Oasis of 77.27 ha.

4.6 Falaj Al Hili

This falaj is reported as going dry in 1982, prior to which it had a recorded flow of 21l/s with a TDS of 370 mg/l (NDC, 1994). Today, it has only a trace of natural flow and is therefore now supported(by 26 groundwater wells and desalinated water). It receives 600,000 gpd from Qidfa with a TDS of 200 mg/l.



Figure 9. Falaj Al Qattara Support Well

4.7 Falaj Al Muwaijei

This falaj was reported as going dry in 1979, prior to which it had a discharge of around 20l/s with a TDS of 1170 mg/l (NDC, 1994). Unlike all other Aflaj described in this report, it is managed by the Private Department and is supported by wells. The falaj runs from the clock tower roundabout to the Al Mutarid area. The falaj was not visited.

4.8 Falaj Al Jahili

The falaj was more or less dry at the time of visit and has as only a trace of natural flow. The Motherwell is located in the vicinity of the Inter-continental hotel, Zaroub. The falaj shafts and channel are presently being re-furbished (Figure 10).



Figure 10. Rehabilitated Al Jahili shafts and original shaft cover

4.9 Other Aflaj

Falaj Maziyyad was not visited but is now supported entirely by wells. It is located some

20 km south of Al Ain near the Oman Border. Five other aflaj occur at Al Qabil and Hafeet, just across the border in Oman.

All the other 12 aflaj shown in Table 2 are either dry or abandoned and the Aflaj section is no longer maintaining them. Table 3 shows the aflaj water sources, locations and Field Hydrochemistry (samples taken on 25/1/06).

Table 3. Aflaj Water Sources, locations and Field Hydrochemistry

Site	E	N	pH	EC ($\mu\text{S/cm}$)	TDS (mg/l)	Source)
Al Mutarid shari'a	372375	2678988	6.5	5670	2820	G+TSE
Al Daoudi (matal)	374874	2678428				N,G,D
Al Daoudi shari'a	375156	2678289	7.2	1400	700	N,G,D
Al Aini shari'a (Maskid)	375430	2678596	Dry at	time of visit	-	N,G,D
Al Aini shari'a Al Natla	375773	2678166	7.4	770	380	N,G,D
Al Jahili shafts	373545	2678830	Dry at	time of visit		N
Al Jimi shari'a	373220	2682638	6.7	1860	920	G,TSE
Al Qattara Shari'a	373282	2683346		2600	1200	G
Al Hili shari'a	375556	2686330	7.0	3250	1660	N,G,D

WGS UTM Clarke 1984 coordinates G=Groundwater wells, D=desalinated water, N=Natural groundwater flow, TSE=Treated Sewage effluent

Outside of the responsibility of the Parks and Gardens Department is the falaj type system in place at the Bu Sukhanah spring at Ayn Al Faydah, south of Al Ain. Here an overflow of around 100-150 l/s, with a TDS of 5700 mg/l from the recreation pond, which has been excavated over and around the original spring outlet, is channelled to two surface reservoirs to provide irrigation for about 5,000 data palms in the Al Mragh area. (Figure 11)



Figure 11. Sub-surface Falaj type channel at Ayn Al Fayda

5. Conclusions

Over the last 20-25 years the aflaj of the Al Ain area have been placed under increasing stress from declining groundwater levels in the source or mother well areas, whilst the water table in the vicinity of the aflaj shari'a itself has steadily risen in recent years due to artificial recharge of groundwater from TSE and desalinated irrigation water which is now widely used to keep the garden city of Al Ain green.

For the last 3,000 years or so aflaj have provided for sustainable agriculture and civilisation in the Al Ain Region. However, today, only two of the seven operating aflaj have natural flow and all aflaj are supported by varying mixtures pumped groundwater from wells, imported desalinated water from Qidfa desalination plant, Al Fujairah and , more recently, from Treated Sewage Effluent, the latter supply generally being small and unreliable. Today the aflaj are used for irrigation of the six main oasis areas which occupy an area of 350ha, only 5% of the total green area of the city.

The Al Aini and Daoudi Aflaj have by far the strongest natural flow but around 50% of the total flow is supported. The rest of the other aflaj rely on external support for their flow. Given the various sources of water input to the aflaj, means that aflaj water quality is never consistent, only in the case where the aflaj are supported primarily from one source e.g. Al Qattara only from groundwater. The TDS of aflaj water sampled as part of this study ranged from 380 mg/l (Al Aini – largely supported by Desalinated water) to 2820 mg/l (Al Mutarid – supported by groundwater wells and TSE).

Despite the difficulties in maintaining the aflaj flows it is the strategy of Al Ain Municipality that the support to the aflaj systems shall continue indefinitely, as per decree by the late Sheikh Zayed bin Sultan Al Nahyan, and that the area of Oases which they support shall be given the highest priority for preservation. The aflaj and Oases are an integral part of the historical culture of Al Ain City, which is rich in archaeological heritage.

A total of 96 groundwater wells presently provide support directly to the aflaj as well as about 1,6 million imperial gallons per day desalinated water and a small, unquantified amount of treated effluent (TSE). It is assumed that the amount of TSE available for support to the aflaj will increase over the next 5 years since it is the strategy of the Municipality to replace all groundwater used for irrigation with TSE as part of the Al Ain Master Plan.

6. Recommendations

Hard and fast recommendations are difficult as a result of this rapid investigation, however, the following are suggested as a means of understanding the aflaj systems better and providing for assistance in their long term management:

- 7) A monitoring system for aflaj flows – currently, flows are not measured by any party. It is recommended that a representative flow monitoring site be established at each aflaj and monthly records kept of flows, suggested to be measured by current meter.
- 8) A monitoring system for aflaj water quality: varying quantities of aflaj make up water – groundwater, desalinated water and TSE, mean that the quality of water will change. It is recommended that an EC meter be used to measure water quality at an appropriate location/s in the aflaj on a monthly basis.
- 9) Whilst the total number of aflaj support wells is known, their exact position has not been accurately surveyed. The aflaj wells will be inventoried in a forthcoming national well inventory project which will be launched by the Environment Agency – Abu Dhabi (EAD) in 2006.
- 10) The aflaj channels and mother-wells have never been accurately surveyed. It is recommended that this now be conducted.
- 11) Exact quantities of the different source types of water entering the aflaj is not known. It is recommended that flow meters be placed at appropriate locations to measure the groundwater well, TSE and desalinated water inputs. By doing this, and also measuring the total aflaj flows, the natural flow contribution in each aflaj can be determined.
- 12) Once the source mother wells have been accurately mapped it is recommended that drilling of new observation wells in these areas be studied to provide valuable data on groundwater levels and quality in the source areas and to observe trends in these parameters.
- 13) It is recommended that all new monitored data for aflaj and the support wells, measured input flows etc be provided to EAD on a quarterly basis for inclusion in the new national water resources database which is currently under development at EAD.

7. Acknowledgements

The kind assistance of the Falaj section, Parks and Gardens Department, Al Ain Municipality and Agriculture, is very much acknowledged in the preparation of this report. In particular, thanks go to the following staff who provided guidance for the field visit and also invaluable data and information:

Ahmed Hilal Al Dhaheri	Head, Parks and Gardens Department
Eng Ali Salem Mohammed Al Tager	Deputy Manager, Tech Affairs
Sultan Al Shamsi	Head Falaj Section
Sultan Al Kuwaiti	Advisor to Falaj Section
Sultan Al Damaki	Deputy Head, Falaj Section
Saeed bin Fahd	Falaj Supervisor
Ali Nagi	Engineer Gardens Directorate

8. References

- Al Ain Municipality & Agriculture 2004 Aflaj and Oasis of Al Ain.
- Al Tikriti, W.Y (2002) Aflaj in the United Arab Emirates. Archaeological studies on ancient irrigation systems. Ministry of Information and Culture.
- Branke, R 2005 GIS-based Water Supply and Demand Modeling for the Eastern Region of Abu Dhabi Emirate, UAE. Submitted as part of Brandenburg University Masters Thesis to ERWDA.
- Jorgensen, D.G., and Al-Takriti, W.Y., 1995, Man, water, and climate change in UAE since the Bronze Age [abs.]: Abstract for oral presentation at Global Warming and Environmental Protection Workshop, May 2-3, Abu Dhabi, 3 p.
- Jorgensen, D.G & Al Tikriti, W.Y, 2002. A hydrologic and archeological study of climate change in Al Ain, United Arab Emirates. *Global and Planetary Change*, 35 (2002) 37-49.
- MRMEWR, 2001. Ministry of Regional Municipalities, Environment and Water Resources, Sultanate of Oman. Aflaj Inventory Project Summary Report.
- National Drilling Company (NDC) 1994. Falajes of Al Ain Area, Abu Dhabi Emirate.
- Rizk, Z.S 1998 Aflaj of United Arab Emirates: geological setting and hydrogeological characteristics. *Arabian Journal for Science and Engineering*, Volume 23, Number 1C, 3-25.

9. APPENDICES

APPENDIX A AFLAJ SUPPORT WELL DETAILS

Al jimi & Al Qattara Area

well location	no	depth (ft)	pump type and size (inches)	well production (g/hr)	Comments
behind al qattara school (1)	1	450	elec. Submersible pump 2	2000	
behind al qattara school (2)	2	650	elec. Submersible pump 2	2500	
east of al qattara historical shop	3	600	elec. Submersible pump 2	2000	
north east of al qattara police station	4	500	elec. Submersible pump 2 1/2	3000	
altawila- airport road (1)	5	800	elec. Submersible pump 2 1/2	2000	
altawila- airport road (2)	6	800	elec. Submersible pump 2 1/2	2000	
altawila- airport road (3)	7	800	elec. Submersible pump 2 1/2	2000	
altawila- airport road (4)	8	800	elec. Submersible pump 2 1/2	2000	
altawila- airport road (5)	9	800	elec. Submersible pump 2 1/2	2000	
bida bint saud- alramima(1)	10	800	elec. Submersible pump 2 1/2	3500	
bida bint saud- alramima(2)	11	800	elec. Submersible pump 2 1/2	3500	
bida bint saud- alramima(3)	12	800	elec. Submersible pump 2 1/2	3500	
bida bint saud- alramima(4)	13	800	elec. Submersible pump 2 1/2	3500	
alseena area (1)	14	500	elec. Submersible pump 2	2000	
alseena area (2)	15	500	elec. Submersible pump 2	2000	
alseena area (3)	16	800	elec. Submersible pump 2	2500	
alseena area (4)	17	800	elec. Submersible pump 2	2500	
alseena area (5)	18	800	elec. Submersible pump 2 1/2	3000	
alseena area (6)	19	800	elec. Submersible pump 2 1/2	3000	
alseena area (7)	20	600	elec. Submersible pump 2 1/2	3000	
alseena area (8)	21	600	elec. Submersible pump 2	2500	
alseena area (9)	22	800	elec. Submersible pump 2 1/2	3000	
alseena area (10)	23	800	elec. Submersible pump 2	3000	
alseena area (11)	24	800	elec. Submersible pump 2	3000	
alseena area (12)	25	800	elec. Submersible pump 2 1/2	3000	

Sarouj Area (Daoudi & Al Aini)

west of cattle souq	1	700	elec. Submersible pump 2	2500	TDS = 1145 mg/l
west of al sarouj sign(1)	2	800	elec. Submersible pump 2	1500	TDS = 1185 mg/l
west of al sarouj sign(2)	3	800	elec. Submersible pump 2	2000	TDS = 1100 mg/l
west of al sarouj sign(3)	4	500	elec. Submersible pump 2	2000	TDS = 1100mg/l
west of Hilton bridge (1)	5	400	elec. Submersible pump 2	1500	
west of Hilton bridge (2)	6	650	elec. Submersible pump 2	2000	
south west hilton bridge(3)	7	700	elec. Submersible pump 2	2000	
south west hilton roundabout	8	500	elec. Submersible pump 2	2000	uncased
alharmoudi south east alnaqafa mount(1)	9	650	elec. Submersible pump 2	2500	
alharmoudi south east alnaqafa mount(2)	10	650	elec. Submersible pump 2	2500	
alharmoudi south east alnaqafa mount(3)	11	650	elec. Submersible pump 2	2500	
alharmoudi south east alnaqafa mount(4)	12	650	elec. Submersible pump 2	2500	
alharmoudi south east alnaqafa mount(5)	13	650	elec. Submersible pump 2	2500	
alharmoudi south east alnaqafa mount(6)	14	650	elec. Submersible pump 2	2500	
almoutawa east of sanaeyia bridge (1)	15	550	elec. Submersible pump 2	2500	
almoutawa east of sanaeyia bridge (2)	16	550	elec. Submersible pump 2	2500	
almoutawa nourth of alain club (3)	17	570	elec. Submersible pump 2	2500	
almoutawa nourth of alain club (4)	18	600	elec. Submersible pump 2	2500	
almoutawa nouth of alain club (5)	19	600	elec. Submersible pump 2	2500	
south east aldefaa (1)	20	700	elec. Submersible pump 2	2500	
south east aldefaa (2)	21	450	elec. Submersible pump 2	2500	
south east aldefaa (3)	22	500	elec. Submersible pump 2	2500	
south east aldefaa school (4)	23	450	elec. Submersible pump 2	2005	
mazyad road	24	500	elec. Submersible pump 2	2500	uncased

AFALJ SUPPORT WELL DETAILS

Al Hill Area

well location	no	depth (ft)	pump type and size (inches)	well production (g/hr)	Comments
almetlaa(1)	1	650	elec. Submersible pump 2	2500	Municipality owned
almetlaa(2)	2	650	elec. Submersible pump 2	2500	Municipality owned
almetlaa(3)	3	650	elec. Submersible pump 2	2500	Municipality owned
almetlaa(4)	4	650	elec. Submersible pump 2	2500	owned by sh. Suroor
almetlaa(5)	5	650	elec. Submersible pump 2	2500	
almetlaa(6)	6	650	elec. Submersible pump 2	2500	
almetlaa(7)	7	650	elec. Submersible pump 2	2500	owned by local
almetlaa(8)	8	650	elec. Submersible pump 2	2500	
almetlaa(9)	9	650	elec. Submersible pump 2	2500	
almetlaa(10)	10	650	elec. Submersible pump 2	2500	
almetlaa(11)	11	650	elec. Submersible pump 2	2500	
almetlaa(12)	12	650	elec. Submersible pump 2	2500	
almetlaa(13)	13	650	elec. Submersible pump 2	2500	
almetlaa(14)	14	650	elec. Submersible pump 2	2500	
bida bint saud(1)	15	800	elec. Submersible pump 2 1/2	3500	
bida bint saud(2)	16	800	elec. Submersible pump 2 1/2	3500	
bida bint saud(3)	17	800	elec. Submersible pump 2 1/2	3500	
bida bint saud(4)	18	800	elec. Submersible pump 2 1/2	3500	owned by local citizen
alrimaila alhili (1)	19	500	elec. Submersible pump 2	2000	
alrimaila alhili (2)	20	500	elec. Submersible pump 2	2000	
alrimaila alhili (3)	21	500	turbine diesel pump 3	2000	
alrimaila alhili (4)	22	500	turbine diesel pump 3	2000	
alhili archaeology(1)	23	800	elec. Submersible pump 2	2000	
alhili archaeology(2)	24	800	elec. Submersible pump 2	2000	
alhili archaeology(3)	25	800	elec. Submersible pump 2	2000	
alhili pharmacy	26	450	elec. Submersible pump 2	2000	

Al Mutared & Al Muwaijei Area

north east gezlan roundabout(1)	1	450	elec. Submersible pump 2	2000	part of almutared falaj
north east gezlan roundabout(2)	2	450	elec. Submersible pump 2	2000	part of almutared falaj
north west gezlan roundabout(3)	3	450	elec. Submersible pump 2	2000	part of almutared falaj
south east gezlan roundabout (4)	4	450	elec. Submersible pump 2	2000	part of almutared falaj
north west almanaser cemetery(1)	5	800	elec. Submersible pump 2	2000	part of almutared falaj
close to almanaser cemetery (2)	6	800	elec. Submersible pump 2	3000	part of almutared falaj
east of islamic institute (1)	7	1000	elec. Submersible pump 2 1/2	3000	part of almutared falaj
east of islamic institute	8	1000	elec. Submersible pump 2 1/2	3000	part of almutared falaj
east of islamic institute-to the mosque	9	1000	elec. Submersible pump 2 1/2	3000	part of almutared falaj
west of islamic institute	10	800	elec. Submersible pump 2 1/2	3000	part of almouji falaj
south west islamic institute	11	800	elec. Submersible pump 2 1/2	3000	part of almouji falaj
east of almanaser shops (1)	12	800	elec. Submersible pump 2 1/2	3000	part of almouji falaj
north of almanaser shops(2)	13	800	elec. Submersible pump 2 1/2	3000	part of almouji falaj
north east almanaser roundabout(3)	14	500	elec. Submersible pump 2 1/2	5000	part of almouji falaj
north east almanaser roundabout(4)	15	500	elec. Submersible pump 2	2500	part of almouji falaj
north east almanaser roundabout (5)	16	500	elec. Submersible pump 2	2500	part of almouji falaj
east of bin haam mosque (6)	17	700	elec. Submersible pump 2	2500	part of almouji falaj
nourth almanaser office(1)	18	600	elec. Submersible pump 2	3000	part of almouji falaj
south west almanaser office(2)	19	800	elec. Submersible pump 2	3000	part of almouji falaj
south west almanaser office(3)	20	800	elec. Submersible pump 2	3000	part of almouji falaj
west of almanaser office	21	650	elec. Submersible pump 2	3000	inside private villa

source: Al Ain Municipality and Agriculture, Falaj Section, Department of Parks and Gardens, 2006

APPENDIX B
AFLAJ PHOTO GALLERY



Al Aini Shari'a Natha



Al Daoudi matal (Shari'a)



Al Daoudi Shari'a masked (mosque)



Al Hili Falaj Shari'a



Al Jimi Shari'a



Al Mutared Shari'a



Al Mutared source channel



Al Mutared source wells discharge



Al Muwaijei Falaj vertical shaft



Falaj Al Jahili



**Desalination support pipeline for
Al Aini and Al Daoudi Falaj**



**Desalination inlet for
Al Aini and Al Daoudi Falaj**



FIELD VISIT WITH AL AIN FALAJ SECTION (25/1/06)