TREND ASSESSMENT OF GROUNDWATER QUALITY IN ABU DHABI EMIRATE

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

AL DHAFRA SUMMARY REPORT
AUGUST 2020

Content

1 Introduction 01

2 Fieldwork 03

3 Interpretation of Groundwater Analyses 11

3.1 Basic Parameters 11

3.2 Nitrate 15

3.3 Trace Elements 17

3.4 Water Quality Indices 19

4 Conclusion and Way Forward 21

Abbreviations:

^{226}Ra	Radium-226
^{228}Ra	Radium-228
^{222}Rn	Radon-222
µS/cm	micro Siemens per centimeter
Alk	Alkalinity
b.d.l.	below detection limit
BOD	Biological Oxygen Demand
Bq	Becquerel
CBE	Charge Balance Error
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
Dom.	Domestic
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
GLV	Guideline value
Hex.	Hexavalent
Irr.	Irrigation
QA	Quality Assurance
QC	Quality Control
SAR	Sodium Adsorption Ratio
S_y	Specific yield
TDS	Total Dissolved Solids
Tot.	Total
WHO	World Health Organization
WQI	Water Quality Index
WTF	Water Table Fluctuation (method)

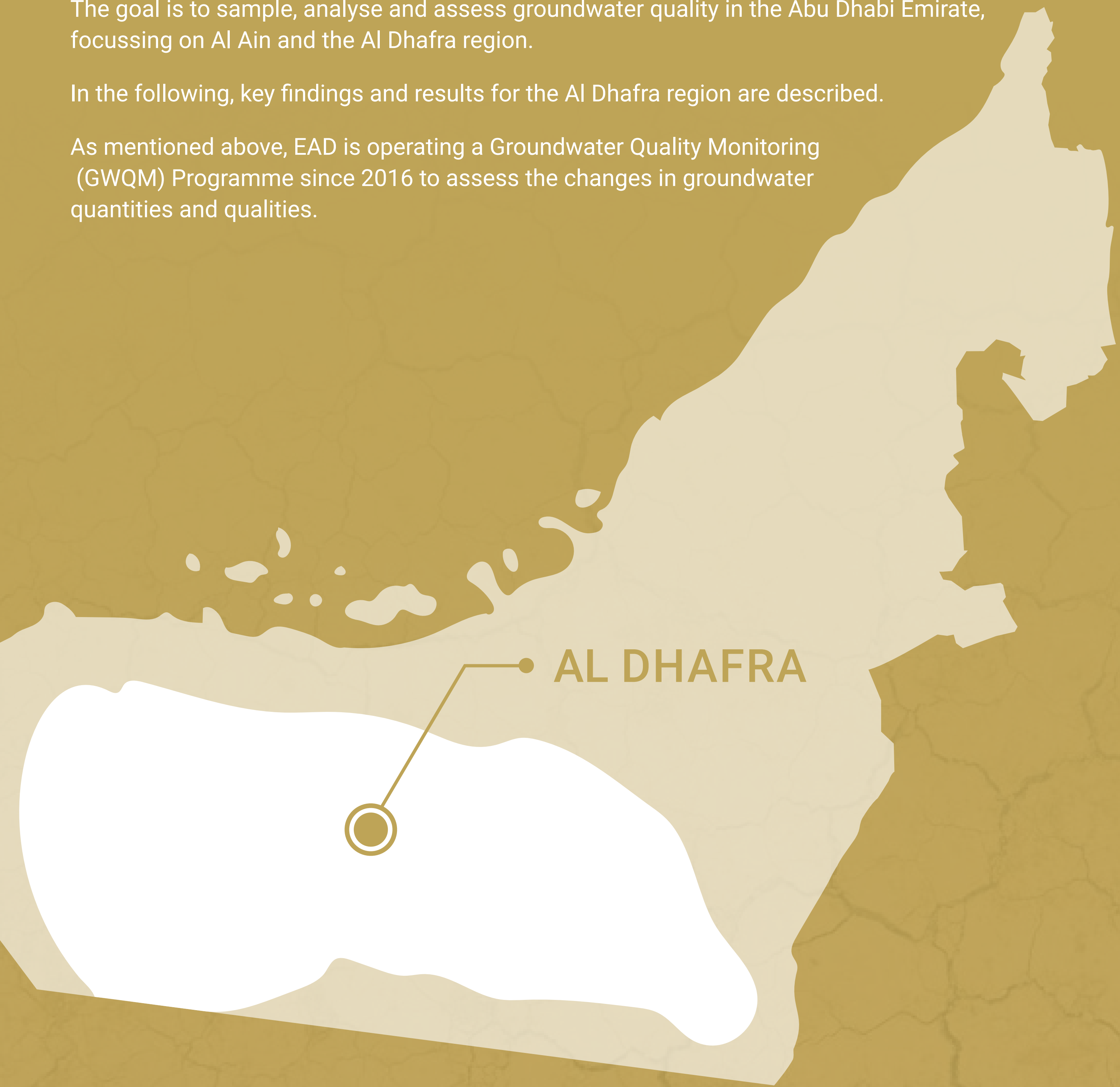
1 INTRODUCTION

Following optimisation of the groundwater monitoring programme in 2016 and the subsequent Groundwater Quality Baseline Survey project in 2018, Environment Agency - Abu Dhabi (EAD) analysed the trend of all groundwater constituents (Natural & Anthropogenic) within the frame of our latest initiative Trend Assessment of Groundwater Quality in Abu Dhabi Emirate.

The goal is to sample, analyse and assess groundwater quality in the Abu Dhabi Emirate, focussing on Al Ain and the Al Dhafra region.

In the following, key findings and results for the Al Dhafra region are described.

As mentioned above, EAD is operating a Groundwater Quality Monitoring (GWQM) Programme since 2016 to assess the changes in groundwater quantities and qualities.



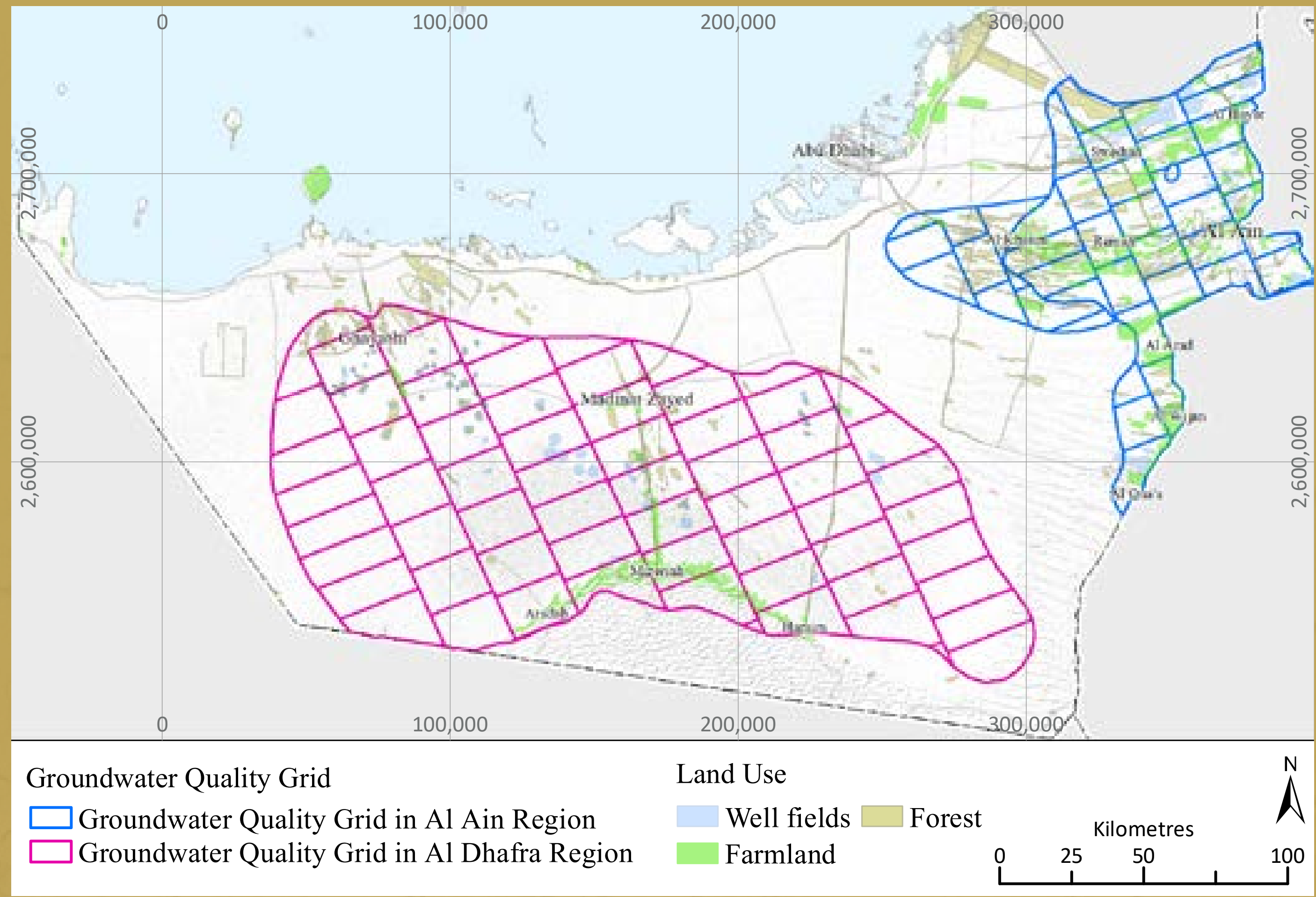
Due to increasing pressure on groundwater resources, the groundwater quality trend in the Emirate of Abu Dhabi shall be assessed, particularly, within areas with directly useable groundwater zones.

To conduct trend analysis of all groundwater constituents (Natural & Anthropogenic) and provide relevant interpretation, the groundwater quality monitoring programme comprises:

1 ASSESSMENT OF THE GROUNDWATER QUALITY

2 GROUNDWATER QUALITY MONITORING

3 ENHANCEMENT OF SALINITY MONITORING



The area of this campaign lies within the Groundwater Quality Grid of Abu Dhabi Emirate, which is designed to monitor groundwater quality of the surficial aquifer across the Emirate and of the water bearing formations underlying the surficial aquifer.

2 FIELDWORK

Groundwater samples were collected in the Al Dhafra region from the wells sampled during the Groundwater Quality Baseline Survey, in 2018 In case the pre-selected well was not accessible or suitable anymore, replacement wells were selected.

73 WELLS

SELECTED FOR AL DHAFRA REGION

7 ADDITIONAL

SAMPLES FOR QUALITY ASSURANCE

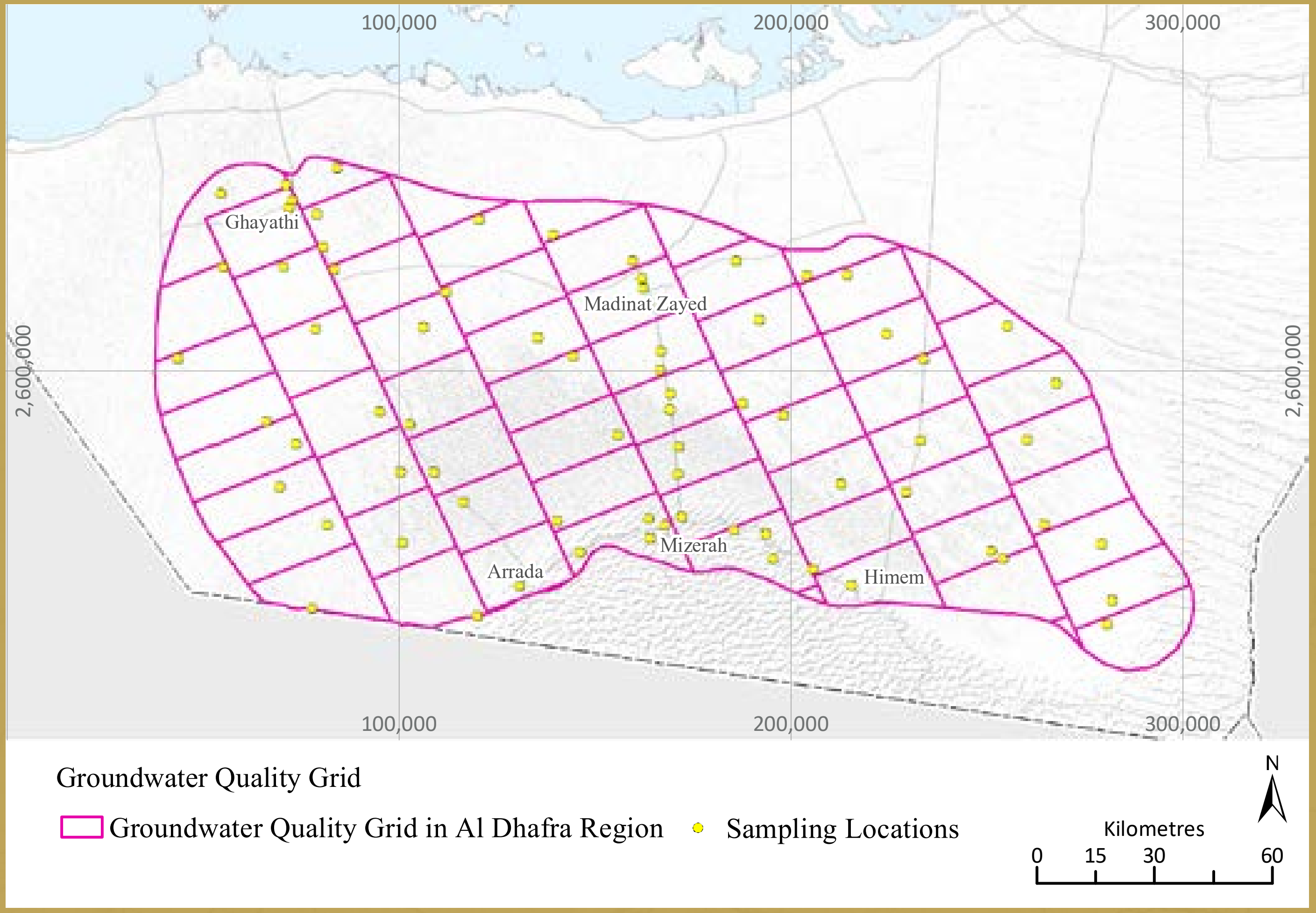
Sampling took place from January 2020 until February 2020.

Two well-trained sampling teams, guided by their team supervisor collected samples for hydrochemical analyses, *i.e.* major anions/cations, trace elements, microbiology, pesticides, pharmaceuticals and radionuclides. For the collection of samples and depending on the parameters, different sample bottle types (*e.g.* glass, HDPE, *etc.*) and sizes were used.

Throughout the sampling campaign, Standard Operating Procedures for Groundwater Sampling were closely followed.

During each site visit, various field data were recorded *e.g.* well type, dimensions, casing material as well as carrying out *in-situ* measurements such as water table, electrical conductivity, pH, dissolved oxygen, turbidity, alkalinity and hydrogen sulphide.

The required sampling approach for each well depended on the well status, *i.e.* whether the well was Operational (Type A) or Idle (Type B). In case Idle wells were encountered, the field crew installed a mobile pump.

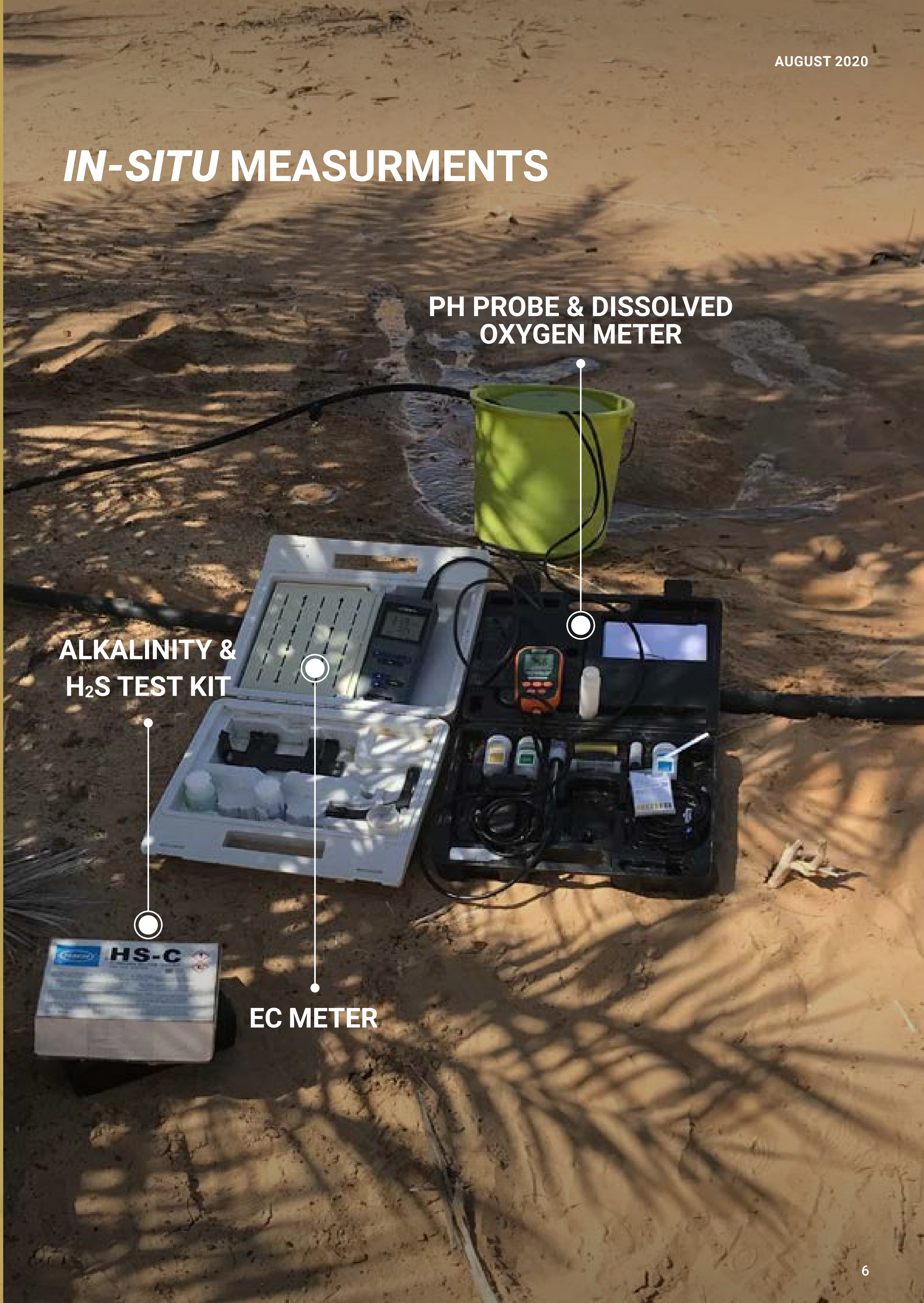


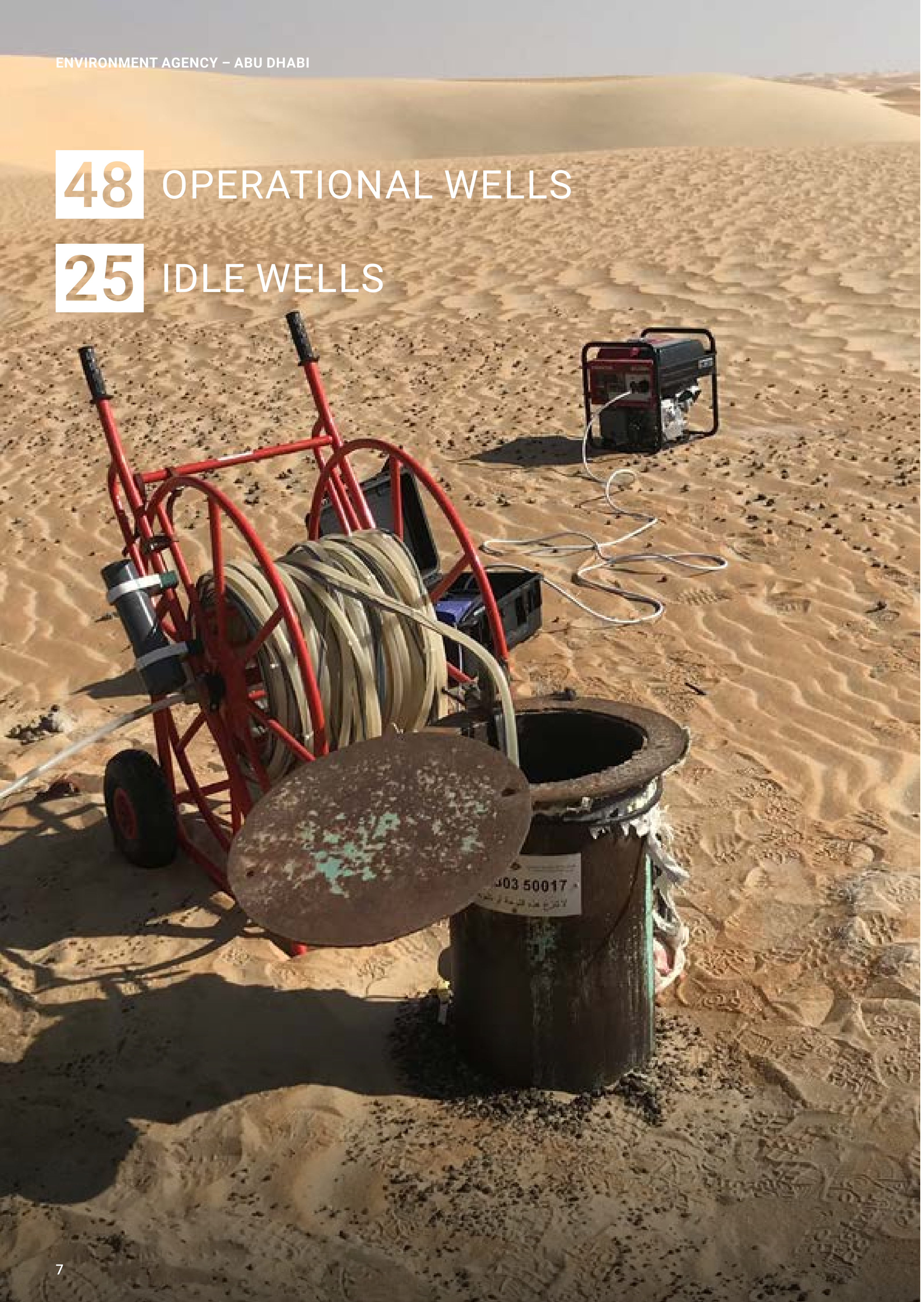
After the *in-situ* measurements were taken, groundwater sampling took place.

Once the sampling was completed at one site, the sampling equipment was decontaminated to prevent cross contamination between sampling locations and events, and to protect the health and safety of the sampling staff that may be exposed to contaminated equipment.

A chain-of-custody form was implemented for each sampling bottle and clearly marked, showing sample ID, date and time, number of bottles per samples, parameter to be analysed, on-site results, if performed and the name of technician taking the sample.

IN-SITU MEASURMENTS





48 OPERATIONAL WELLS

25 IDLE WELLS

After the sampling was completed and the samples appropriately packed (*i.e.* placed in a cooler box filled with ice packs, *etc.*), the samples were handed over to Laboratory at an agreed meeting point.

A laboratory, accredited according to DIN EN ISO / IEC 17025, certified through the Emirates National Accreditation System (ENAS) and listed with the Abu Dhabi Quality and Conformity Council (ADQCC) was selected.

Laboratory analysis were conducted from January 2010 until April 2020.

Pharmaceutical products, NDMA and wastewater indicators were analysed from the same 25 wells, as for the Groundwater Quality Baseline Survey.

Duplicates (4 samples) and Field blanks (2 samples) for bacteria were taken for quality assurance.

For Radionuclides, all wells were included in the analysis of ^{226}Ra and ^{228}Ra.

OVERVIEW OF SAMPLING PARAMETERS ANALYSED BY THE LABORATORY.

ITEM	GENERAL CONSTITUENT CATEGORY	SAMPLED CONSTITUENT(S)	QUANTITY
8		Ferrous iron	80
9		Major cations	80
10	Basic Ions	Major and minor anions	80
11		Nutrients (N and P compounds)	80
12	Trace Metals	Trace elements/metals including Chromium (total and VI)	80
13a		Total coliform, Escherichia (E . coli)	80
13b	Bacteria	Replicate sample Total coliform, Escherichia (E. coli)	4
13c		Field blank Total coliform, Escherichia (E. coli)	2
14	DOC/TOC	Dissolved/total organic carbon	80
15	Pesticides	Pesticides	80
17		Wastewater indicators	
18	Wastewater Reuse	Pharmaceutical products	25
19		N-nitrosodimethyl amine (NDMA)	
20	Radio-nuclides	Radium isotopes (^{226}Ra & ^{228}Ra)	80

FIELD BLANKS & REPLICATE SAMPLES FOR QUALITY ASSURANCE

MAJOR CATIONS

Ca^{2+} Mg^{2+} Na^{+} K^{+}

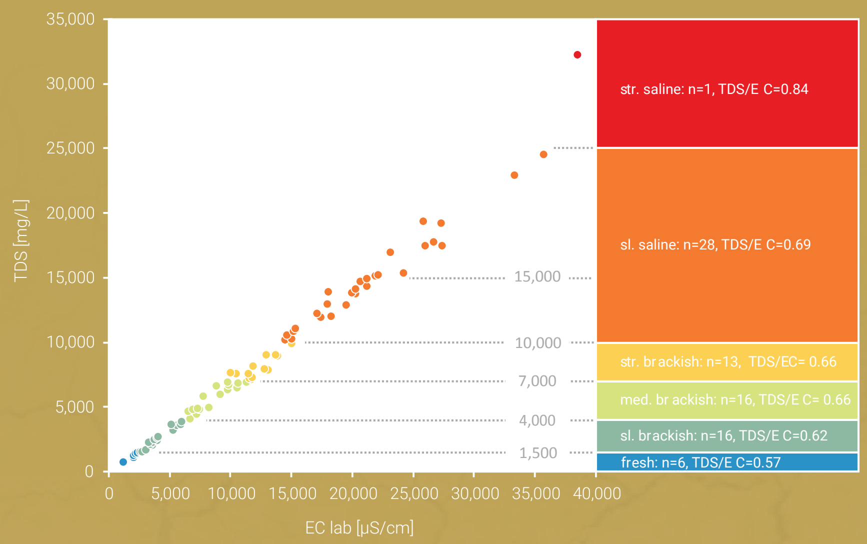
MAJOR ANIONS

Cl^{-} SO_4^{2-} HCO_3^{-}

3 INTERPRETATION OF GROUNDWATER ANALYSES

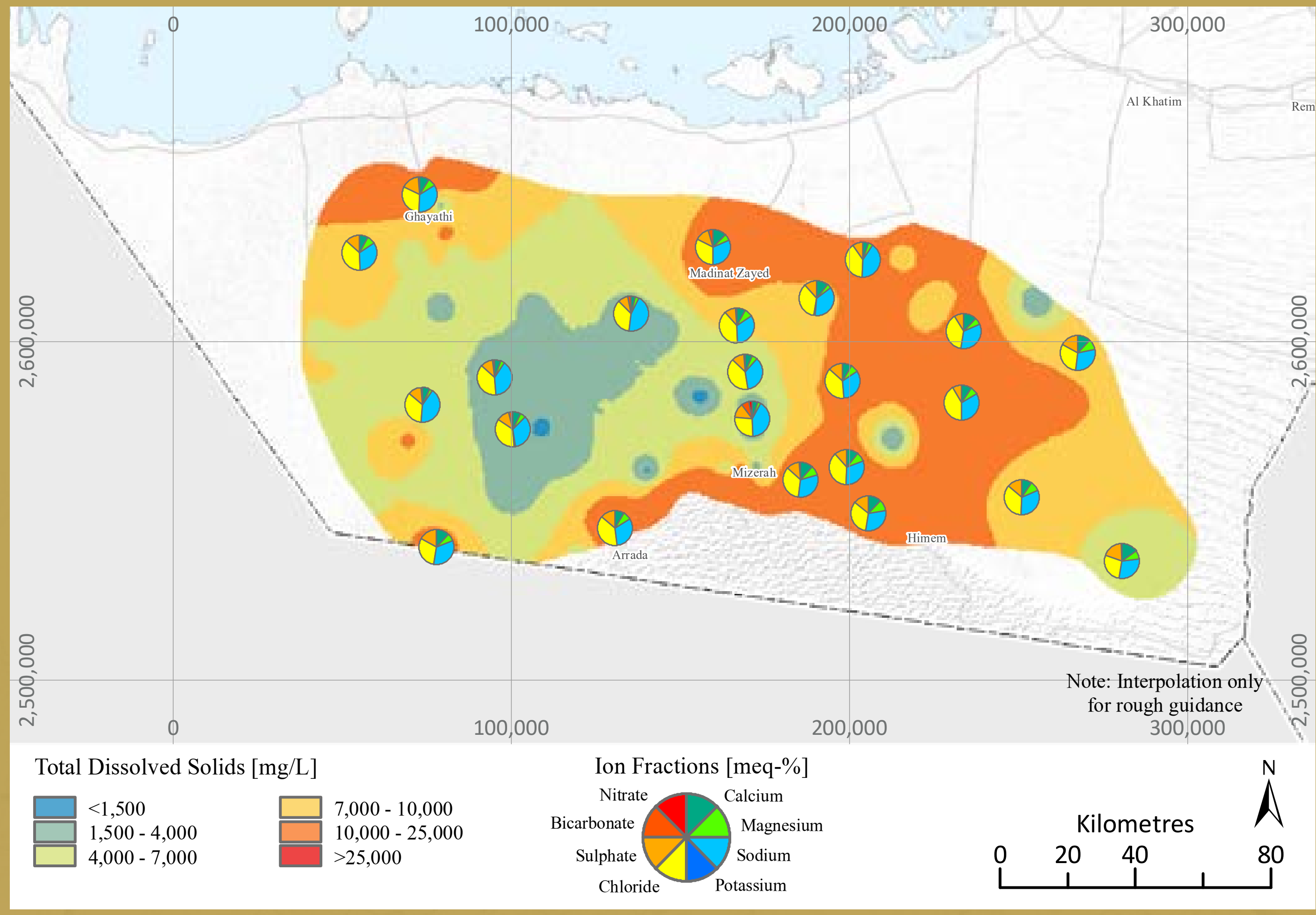
3.1 BASIC PARAMETERS

The internal QA/QC measures implemented by the lab were complemented by own plausibility checks comprising blank and duplicate analyses (**where validated**), the calculation of charge balance errors (all errors within ± 5 %), and the correlation between parameters that were measured in the field and in the laboratory (**where validated**). Moreover, related parameters were compared. An example for the latter is given in the following figure.



Apart from the excellent correlation, the chart illustrates the wide range of encountered salinities, covering the following classes of the UAE salinity scheme: fresh (6 samples), slightly brackish (16 samples), medium brackish (16 samples), strongly brackish (13 samples), slightly saline (28 samples), and strongly saline (1 sample). However, overall salinities are rather high – 72 out of 73 values exceed the EAD (2017) guideline value of 1,000 mg/L for domestic purposes.

Fresher waters prevail in the central part of the study area, mainly north and northwest of the Liwa Crescent. In the peripheral parts of the study area, *i.e.* down-gradient, the groundwater becomes more saline. This pattern has also been observed in the Groundwater Quality Baseline Survey and is thought to reflect a fresh water mound. Its formation was probably facilitated by the high infiltration capacities of the sandy dune and interdune areas favouring groundwater recharge.



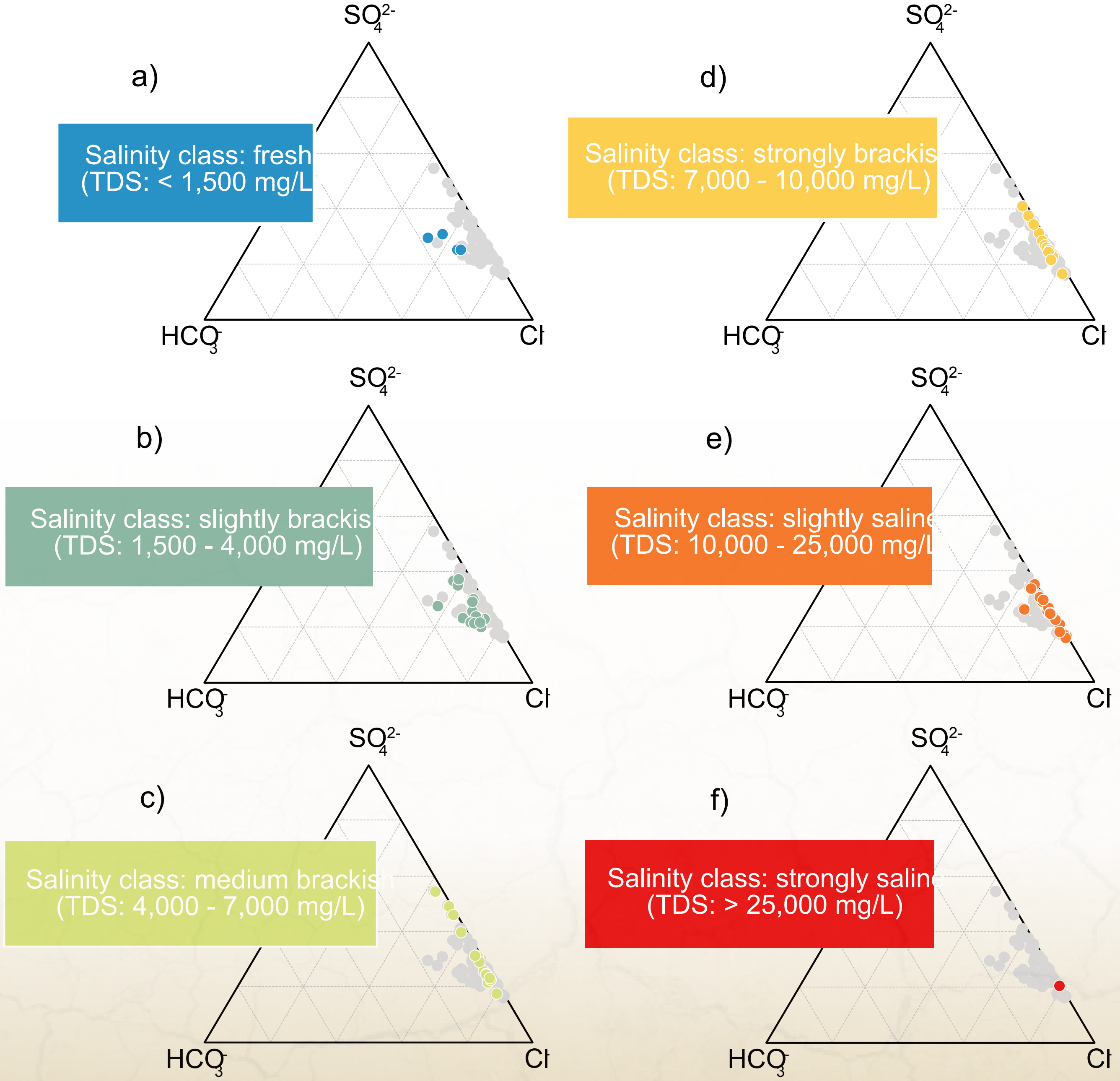
The calculation of relative changes since the last campaign yielded both increases and decreases. Since 2019 has been a particularly wet year with sustained rainfalls, these TDS decreases might be linked to recent recharge.

Among the ions contributing to the total salinity, Sodium and Chloride are overall the most dominant, but also Calcium and Sulphate often show significant contributions. Accordingly, Na-Cl-SO_4 is the most common water type (44 samples), followed by Na-Ca-Cl-SO_4 (19 samples), and Na-Cl (6 samples). The remaining water types play a subordinate role.

Which water type prevails in a given area also depends on the salinity of the water. This is illustrated above figure in which several anion ternary plots are combined. Fresh and slightly brackish waters show small but significant bicarbonate shares. With increasing salinity, however, bicarbonate becomes less important and accordingly sulphate and especially chloride play a greater role.

ONLY 1 WELL

WITH TDS > **25,000** PPM



Correlation analyses revealed that several basic parameters are inter-related, in terms of their concentrations, but partly also in terms of concentration changes.

The correlation matrix reveals strong positive correlations among the major ions Calcium, Magnesium, Sodium, Potassium, Chloride, Sulphate, and the TDS – a common phenomenon. If the total salinity is high, most major ions will be enriched as well.

Although Bicarbonate is also considered a major ion, it does not follow this trend. This is largely due to the relatively low solubilities of carbonate minerals, which imply that Bicarbonate concentrations cannot rise proportionately during salinization.

	TDS	Ca^{2+}	Mg^{2+}	Na^+	K	Cl^-	So_4^{2-}	HCO_3^-	Br^-	No_3^-
TDS										
Ca^{2+}	0.89									
Mg^{2+}	0.90	0.93								
^+Na	0.98	0.81	0.82							
K	0.84	0.76	0.74	0.80						
Cl^-	0.99	0.85	0.88	0.98	0.81					
So_4^{2-}	0.93	0.89	0.90	0.87	0.82	0.87				
HCO_3^-	0.12	0.18	0.13	0.08	0.22	0.09	0.15			
Br^-	0.18	0.19	0.21	0.11	0.36	0.16	0.23	0.10		
No_3^-	0.46	0.54	0.56	0.39	0.37	0.41	0.57	0.08	0.11	

Color Legend

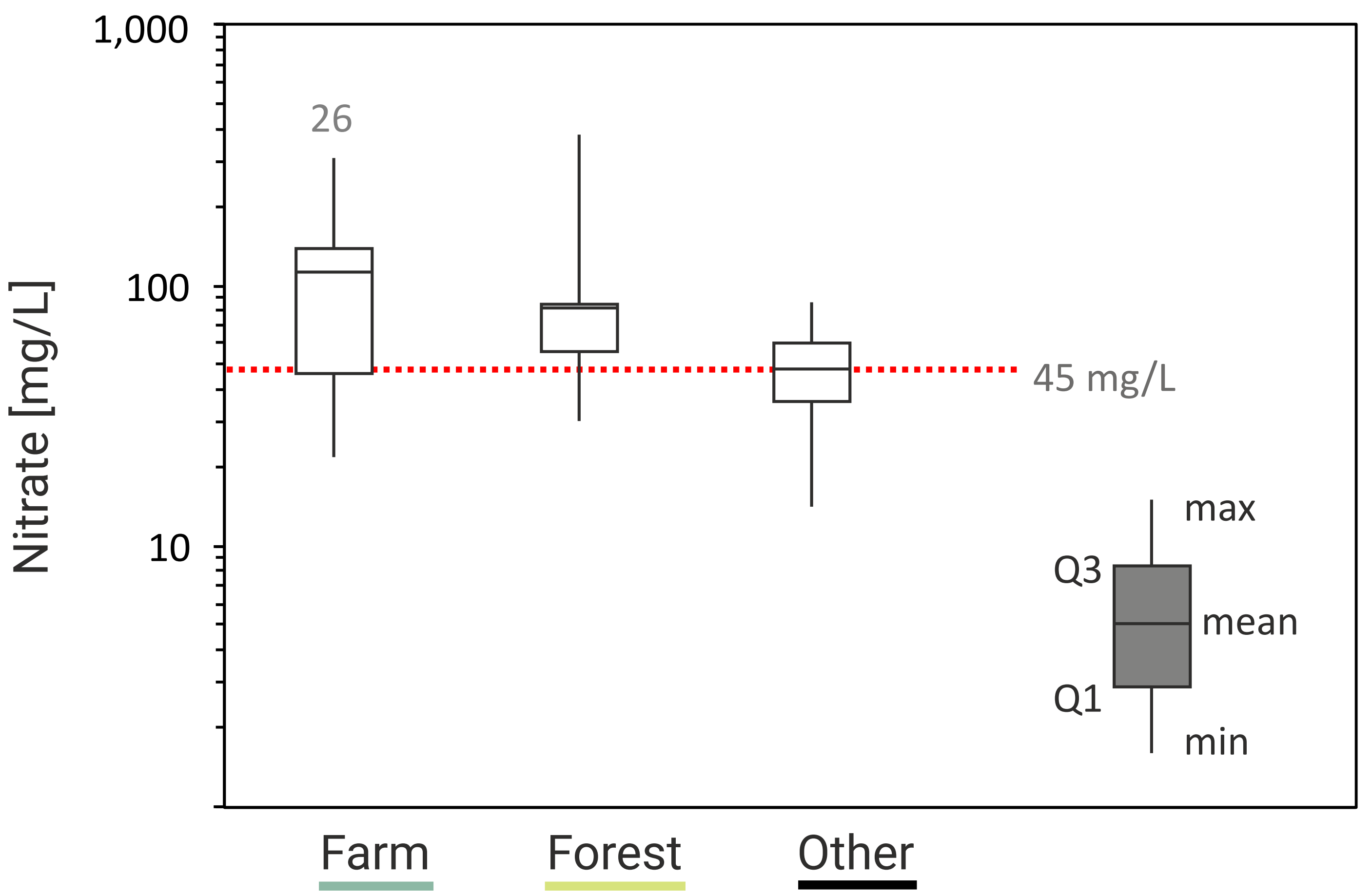
-1.0 -0.8 -0.6 -0.4 -0.2 0.2 0.4 0.6 0.8 1.0

strong... ...negative correlation weak... weak... ...positive correlation strong...

The relatively light colours in the Nitrate line, reflecting lower correlation coefficients, indicate that this anion is somewhat decoupled from the other constituents. Hence, its abundance is not necessarily a function of salinity. Instead, it is largely contamination-controlled.

3.2 NITRATE

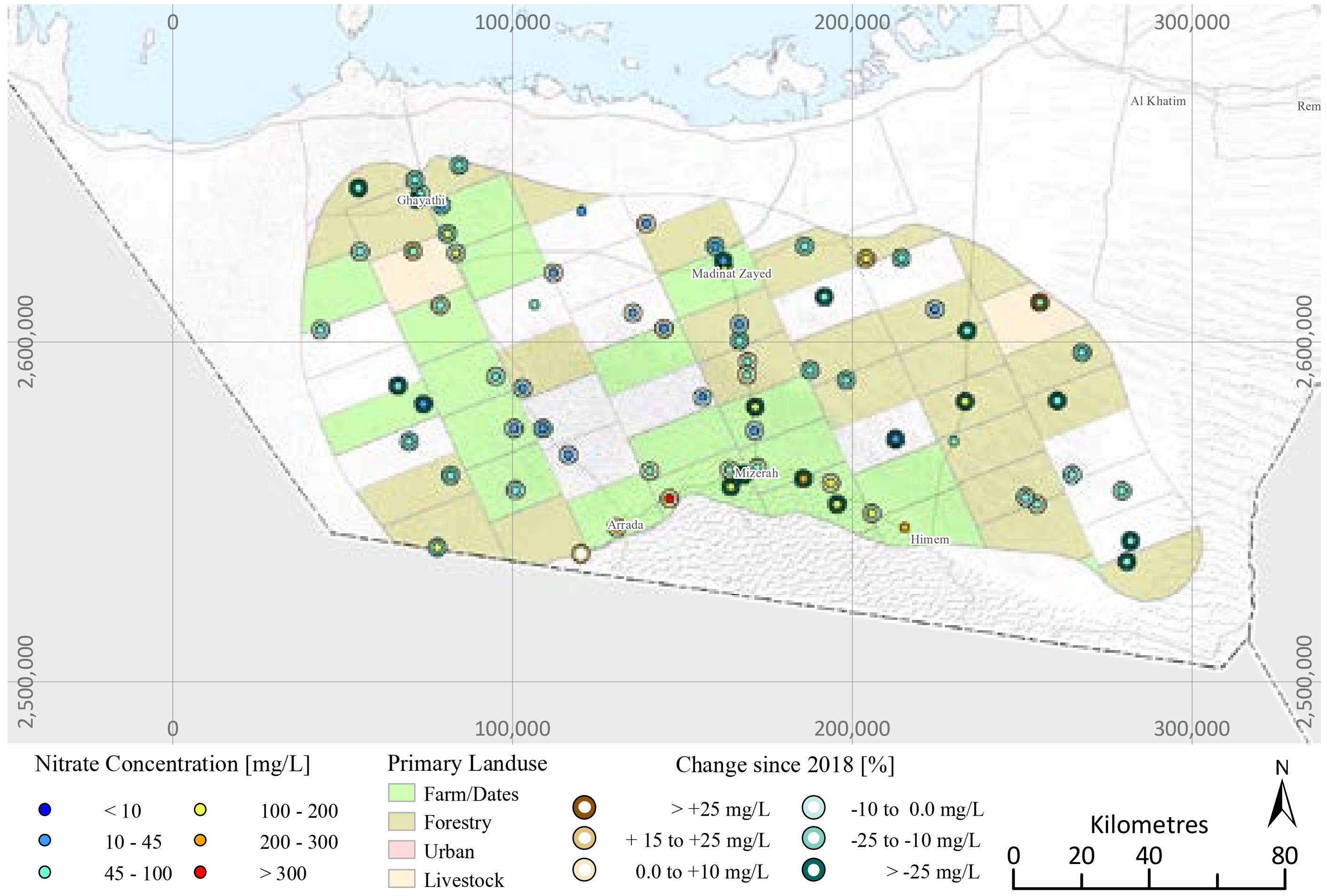
The encountered Nitrate concentrations range between 14 and 380 mg/L. The mean value amounts to 84 mg/L. Considering the EAD (2017) guideline value for domestic use of 45 mg/L, guideline violations are encountered in a total of 54 water samples.



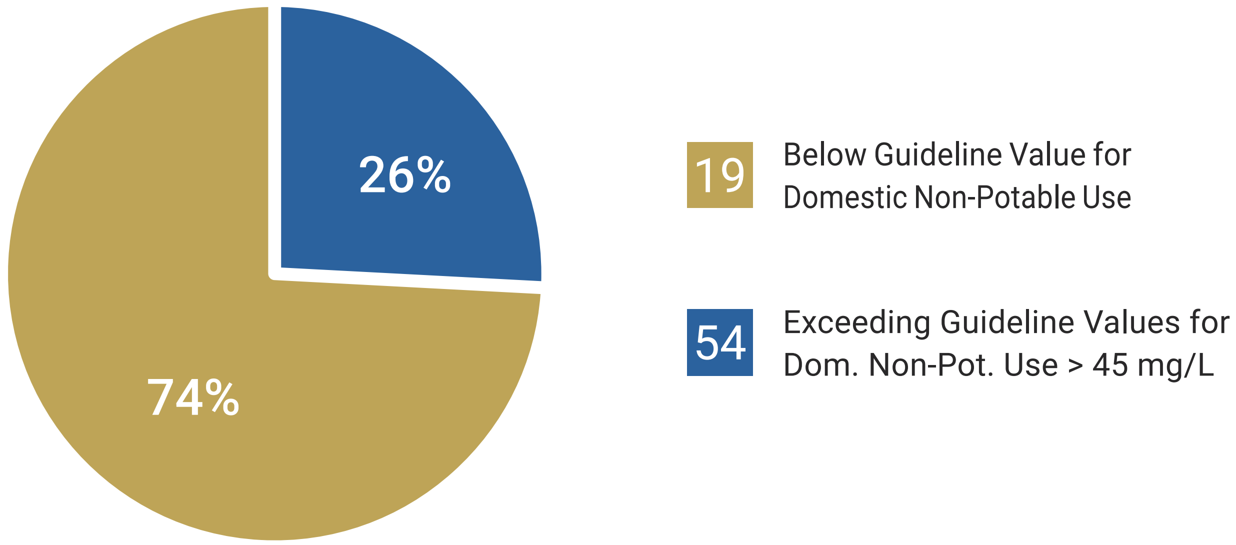
Above shown figure reveals an appreciable scatter within each land use class. Farm-dominated cells exhibit the highest average Nitrate concentration (112 mg/L). The maximum value, however, was encountered in a forestry-dominated cell (380 mg/L).

In both land use classes, the mean concentration clearly exceeds the EAD (2017) guideline value of 45 mg/L (for domestic, non-potable use). Nitrate concentrations that are associated with other land uses scatter around the threshold and the corresponding mean value (48 mg/L) falls close to the threshold.

Hence, it seems that anthropogenic impacts in agricultural and forestry settings (*e.g.* fertiliser use) play an important role in the Nitrate context.



NITRATE GUIDELINE VIOLATIONS



3.3 TRACE ELEMENTS

Most trace elements show a rather large scatter, which is in line with the distinct salinity variations and the presence of a range of water types. Only individual elements show elevated concentrations.

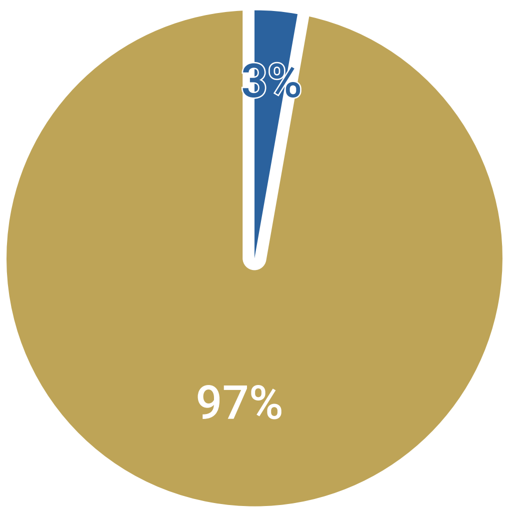
Concentrations of Arsenic for instance fall mostly below 10 µg/L, except for one, accounting for 55 µg/L, thus violating the guideline values for domestic and livestock use (18 µg/L and 25 µg/L, respectively). This contamination is not a new phenomenon – the concerned well showed a similar concentration in the previous project.

In contrast to Arsenic, Boron and Chromium are common contaminants in the study area. Boron concentrations average around 3,453 µg/L, whereas the mean Chromium concentration amounts to 184 µg/L.

Elevated Boron concentrations are often harnessed as wastewater indicators and are sometimes present in fertilisers. Additionally, Boron can be associated with desalination units. In the present case, however, a natural source is more likely. The number of guideline violations is strongly dependent on which guideline value is considered. Thresholds for the different uses differ strongly. They range between 500 µg/L (irrigation) and 5,000 µg/L (livestock watering).

As for Chromium, the concentrations range from 11 to 443 µg/L. A total of 71 samples exceed the guidelines values of 50 µg/L for domestic, non-potable use.

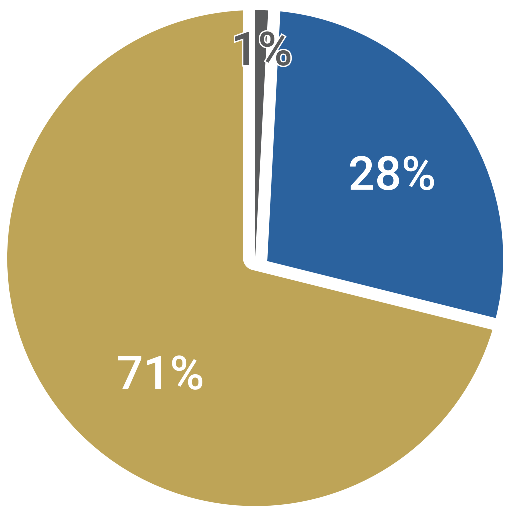
CHROMIUM



2 Below Guideline Value for Domestic Non-Potable Use

71 Exceeding Guideline Values for Dom. Non-Pot. Use > 50 µg/L

BORON



1 Below Guideline Value for Agricultural Irrigation [<0.5 mg/L]

20 Below Guideline Value for Domestic Non-Potable Use but exceeding the Guideline Value for Agricultural Irrigation (>0.5 mg/L to 2.4 mg/L)

52 Exceeding both Guideline Values (> 2.4 mg/L)

Since much of what has been mentioned has also been observed in the previous project, it can be summarized that the overall water character largely remained the same. Nevertheless, some parameters showed significant changes in some wells and the following potential processes may play a role in the study area.

- Recent (natural) groundwater recharge: Usually this will have a dilution effect, but also the opposite is, in principle, possible (flushing of accumulated salts from the unsaturated zone),
- Effects caused by irrigation practices (intentional salt flushing, unintentional irrigation return flow),
- Contamination through the (uncovered) well itself (*e.g.* drifting sand),
- Collapsed sections or blown-in sand possibly isolating previously contributing zones,
- Upconing of salty water,
- Well maintenance/rehabilitation,
- New pump/modified discharge,
- Changed pump position.

While the exact underlying process cannot be identified for each case, some changes can be attributed with reasonable confidence to certain phenomena.

Two wells that now showed microbiological contaminations with E. coli, an indicator for faecal contamination, are a good example. Since both were shallow dug wells that were not or insufficiently covered, these cases illustrate a certain vulnerability of this well type towards (anthropogenic) contamination.

Although human activities can cause water quality deterioration, also natural contaminations were found. Examples comprise several trace elements (*e.g.* Boron, Chromium, Molybdenum, Selenium; various wells), but also the radionuclide Radium-228 (only one well). While the corresponding concentrations were elevated and showed some fluctuations, the phenomenon was known from the Groundwater Quality Baseline Survey.

By contrast, the pesticide and pharmaceuticals analyses were inconspicuous.

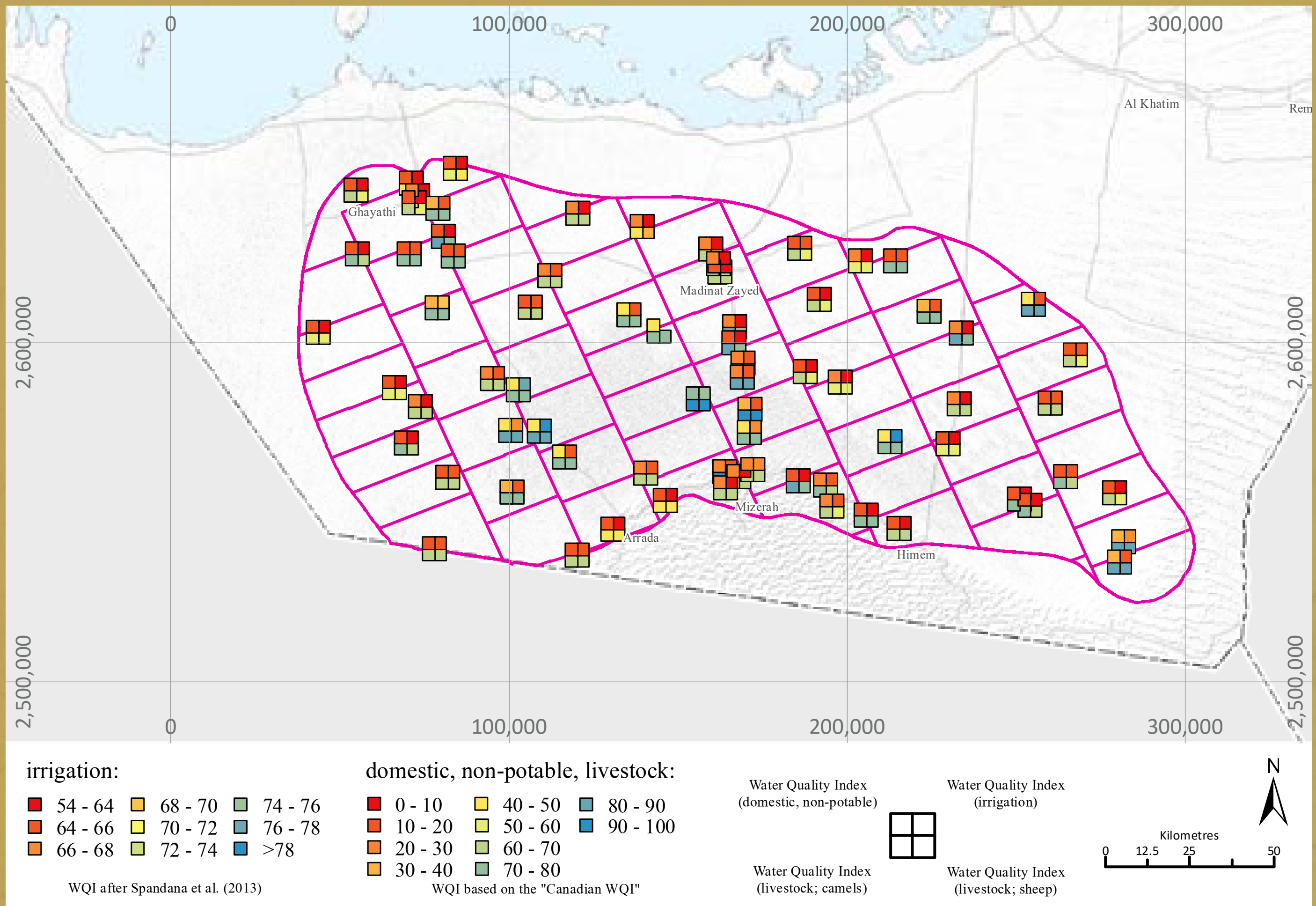
3.4 WATER QUALITY INDICES

In addition to the evaluation of single parameters and their EAD (2017) guideline value violations, water quality was also assessed in an integral way. To this end, several key parameters were combined to calculate so-called water quality indices (WQI). Like in the previous project, WQI values are calculated with respect to the following potential uses:

DOMESTIC (non-potable) use

IRRIGATION PURPOSES

LIVESTOCK WATERING



The WQI values for domestic use showed a large range (12 to 72; mean: 24) and reflect the greatly varying water qualities encountered in this study. Not surprisingly, the highest scores were found for the freshest waters, prevailing in the centre of the study area. Towards the peripheral areas, the scores decrease. Hence, the overall spatial pattern did not change and also the mean WQI remained rather stable (slight decrease from 25 to 24 %). The number of wells with a positive and a negative development are balanced.

With respect to irrigation, the groundwater use is rather restricted due to elevated salinities and the associated Sodium dominance. The elevated Boron values (see above) represent a further restriction. The WQI values, combining several relevant parameters, range between 56 and 79 % (mean: 65 %). Better waters occur in the centre. While individual wells did show some change, the overall statistical metrics (minimum, maximum, and mean WQI) remained the same, *i.e.* overall, individual hydrochemical shifts balanced each other out.

In terms of livestock, two cases were considered – camels and sheep. The WQI values for camel watering range from 43 to 100 % and average at 71 %. As in the above-mentioned cases, better waters prevail in the central area. A comparison with previous values reveals that the minimum WQI has increased (from 36 to 43 %), but on average the quality largely remained the same (slight change from 70 to 71 %).

The overall pattern is largely the same for sheep watering. Here, the WQI values scatter between 40 and 100 % and the mean accounts for 67 %. In comparison with the Groundwater Quality Baseline Survey, the average water quality remained rather stable (slight increase from 66 to 67 %).

GREATLY VARYING WATER QUALITY INDICES

4 CONCLUSION & WAY FORWARD

GENERAL DECREASE OF TDS

0 PESTICIDES DETECTED

CONTINUED MONITORING

Although some parameters and wells did show changes since the last sampling campaign, the overall picture remained the same. The groundwater in the study area is generally salty and several water constituents appear in concentrations that constitute violations of the EAD (2017) guideline values. Prominent examples comprise Boron and Chromium. Pesticides and Pharmaceuticals, by contrast, were inconspicuous.

New E. coli contaminations were associated with shallow dug wells that were not or not sufficiently covered, highlighting a certain aquifer vulnerability.

Yet, contaminations do not only reach the groundwater through wells, but possibly also through the unsaturated zone, via groundwater recharge. That such replenishment does take place, even under the generally arid climate, is suggested by a number of wells that showed a decrease in TDS.

The outlined observations call for a number of additional steps:

FUTURE MONITORING

TRACE ELEMENT PROJECT

GROUNDWATER RECHARGE ESTIMATIONS

UPDATE OF GROUNDWATER CONTOUR MAPS

PRECIPITATION MONITORING

نحافظ على تراثنا الطبيعي . ضماناً لمستقبلنا

PRESRVING OUR HERITAGE · PROTECTING OUR FUTURE

CONTACT US

+971 2 445 4777

customerhappiness@ead.gov.ae

Environment Agency - Abu Dhabi

EnvironmentAbuDhabi

www.ead.gov.ae

@EADTweets

Environment Agency - Abu Dhabi

PO Box 45553 - Abu Dhabi - United Arab Emirates

ص ب ٤٥٥٥٣ – أبو ظبي – الإمارات العربية المتحدة