KUWAIT

Desert Bloom

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Kuwait Oil Company (KOC)
Kuwait Instiutue For Scientific Research (KISR)

Samira Omar Asem
Waleed Yousef Roy

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His Highness, The Amir of Kuwait,

Sheikh Nawaf Al-Ahmad Al-Jaber Al-Sabah

His Highness, The Crown Prince,

Sheikh Mishal Al-Ahmad Al-Jaber Al-Sabah

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Other photos in the book without acronym belong to KOC archives.

Map of the State of Kuwait and its suburbs

Table of Contents

Foreword

Ever since the discovery of oil in 1938, the Oil & Gas industry has played a major role in the prosperity of Kuwait's national economy. Oil production and processing has long been the mainstay of Kuwait's national revenue and has been the major catalyst of its socio-economic development. Kuwait has one of the highest hydrocarbon reserves in the world; they account for approximately 90% of the country's income.
KOC assumes a wide range of activities not limited to oil and gas exploration and production; encompassing onshore and offshore surveys, drilling test wells, and developing producing fields. The great importance that KOC assigns to HSSE standards, allows it to conduct its activities with a focus on minimizing risks of environmental damage to other natural resources and to the ecosystem in general.
Environmental protection and welfare are crucial for Kuwait's oil sector. Over the last three decades, the pressing state of the environment has become all too evident, and the damage to the environment was a result of many factors, not least of which was the Iraqi invasion of 1990 that resulted in the largest recorded environmental disaster in modern history, when about 700 oil wells were set ablaze by the retreating Iraqi forces.
After the liberation of Kuwait in 1991, this environmental disaster demanded immediate action. The consolidated efforts of the Kuwaiti government, represented by the oil sector, and international partners, succeeded in the enormous task of extinguishing the oil well fires in 240 days.
The extensive damage that was inflicted on the oil sector and the environment alike continues to have a profound effect, and it is still the focus of environmental restoration and remediation efforts to this day. Nevertheless, the knowledge gained and the lessons learned from the invasion helped to establish a culture of environmental preservation and sustainability in Kuwait in general and in the oil sector in particular. Thus, the government of Kuwait, institutions and KOC have taken initiatives to tackle various challenges through the Kuwait Environment Remediation Program (KERP). KOC managed to rehabilitate large areas of contaminated soil, and by collaboration with the Kuwait Institute for Scientific Research (KISR) and the Kuwait National Focal Point (KNFP) it aims to implement the latest technologies that would lead to the preservation of the environment and making its sustainability a top priority on its agenda. KOC's endeavors aimed to restore the environment to its previous state and enable the desert to bloom again. It is essential to clarify that every step taken was thoroughly studied and scientifically-based, with the aim of ensuring that the measures to remediate the environment and processing the contaminated soil will not cause further damage.

The remediation and restoration programs developed by KOC are exceptional in that they convert damaged lands into productive lands for natural recovery. When the damaged areas are treated and remediated, they are set up as oases and protected areas for the conservation of natural resources and for biodiversity.
Simultaneously, KOC managed to develop its workforce and expertise in Health, Safety, Security, and the Environment. KOC has won prestigious regional and international awards in this regard. It has also excelled in reducing gas flaring in its operations and has become at the forefront of the Global Gas Flaring Reduction Partnership, under the supervision of the World Bank.
With each successful initiative implemented and project pursued, KOC is steadily getting closer to achieving Kuwait's vision of protecting, preserving, and remediating the country's natural assets and further improving the environment for future generations. While developing and implementing new policies, goals, and initiatives related to the environment and ecosystems, the company is well aware of and is committed to the United Nations Sustainable Development Goals (SDGs), as it places much value and utmost importance upon environmental conservation and protection of natural resources.
This book brings to the reader a story that should be recounted to generations to come about KOC's endeavors in the remediation and restoration programs. Furthermore, it represents documentary evidence of the environmental damages that have been tackled in the company's areas of operation. It also highlights KOC's perspective in sustainable development and the achievements made so far to reach the (SDG) goals and the vision of "New Kuwait - 2035".

Ahmad Jaber Al-Eidan
Chief Executive Officer
Kuwait Oil Company

Acknowledgments

We greatly acknowledge the vision of KOC to remediate and restore the damaged natural resources of Kuwait and to conduct a multi-million-dollar remediation program for UNCC. The Program was implemented successfully through KOC in collaboration with local and internationally reputed professional contractors.

A large team from KOC and various technical team members joined in the Kuwait Environmental Remediation Project implementation with one specific goal that is to remediate the contaminated soils of Kuwait within the KOC premises. We acknowledge the technical team and the Public Relations team of KOC who aided in providing information, maps, and images and supported us in responding to our questions and enquiries. This book would never have been produced had it not been for the efforts of this team. Thanks are due to the following Information team members: Mr. Mohammed Al-Basry, Ms. Bedoor Sayed Omar and Dr. Fajer Al-Husaini. Our appreciation is expressed to the following technical team members and dedicated staff of KOC: Ms. Aisha Al-Baroud, Mr. Khaled Al-Rewaih, Mr. Mathuew, Mr. Matt Harus, Mr. Krishna Vangala, Mr. Mishari Al-Harbi, Mr. Mishari Al-Bader, Ms Reem Al-Othman, Mr. Ahmad Al-Maqseed, Mr. Muthanna AlMu'min. We appreciate the efforts of the team and their support in arranging interviews and site visits to the contaminated areas of KOC. Many thanks also go to Bader Naome for his intensive work in compiling data and information from different sources.

We are honored to have Eng. Ahmad Jaber Al-Eidan/ Chief Executive Officer, KOC. Our thanks are extended to KOC management for their guidance and approval of the publication of this book and to KISR management for their kind support in the preparation of this book.

Samira Omar Asem
Waleed Yousef Roy

Acronyms and Abbreviations

°C	Degrees Centigrade or celsius
AU	Animal Unit
B bpd	Billion Barrel Per Day
b/cd	barrels per calendar day
BAC	Battle Area Clearance
BAU	Business-as-usual
bbl/d	billion barrel per day
BCM	Billion Cubic Meters
bft^3	Billion Cubic Foot
bm^3	Billion Cubic Meter
BP	British Petroleum & Gulf Oil Cooperation
bpd	Barrels Per Day
CEO	Chief Executive Officer
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
COP26	Conference of Parties 26th
CSM	Conceptual Site Model
DG	Director General
DGM	Digital Geographical Mapping
DOL	Dry Oil Lake
eMISK	Environmental Monitoring Information System of Kuwait
EOD	Explosive Ordnance Disposal
EQUATE	Equate petrochemical company
F4	Decision of Governing Council UNCC Category F and sub-category F4, the Fourth installment claims.
Ft^3	Cubic foot
ft^3pd	Cubic Foot Per Day
GC-MS	Gas Chromatography-Mass Spectrometry
GDP	Gross Domestic Product
Gg	Gigagrams (i.e., one billion grams)
GGFR	Global Gas Flaring Reduction

GHG	Greenhouse Gas
GIS	Geographic Information Systems
Ha	hectare
HCs	Petroleum Hydrocarbons
HFC	Hydrofluorocarbons
HSSE	Health, Safety, Security and Environment.
IEA	International Energy Agency
IMAS	International Mine Action Standards
IPCC	Intergovernmental Panel on Climate Change
IPIECA	International Petroleum Industry Environmental Conservation Association
KAFCO	Kuwait Aviation Fueling Company
KEC	Kuwait Export Crude
KEPA	Kuwait Environment Public Authority
KERP	Kuwait Environmental Remediation Program
KFAS	Kuwait Foundation for the Advancement of Sciences
Kg	kilogram
KGOC	Kuwait Gulf Oil Company
KIPRC	Kuwait International Petroleum Research Center
KISR	Kuwait Institute for Scientific Research
Km	Kilometer
Km^2	Square Kilometer
KNDP	Kuwait National Development Plan
KNFP	Kuwait National Focal Point
KOC	Kuwait Oil Company
KOTC	Kuwait Oil Tanker Company
KPC	Kuwait Petroleum Corporation
KU	Kuwait University
KUFPEC	Kuwait Foreign Petroleum Exploration Company
LPG	Liquid Petroleum Gas
m	Meters
M bpd	Million Barrel per Day
M	Million

M&A	Monitoring and Assessment
MCM/d	Million Cubic Meter per day
m^3pd	Cubic Meter Per Day
MEW	Ministry of Electricity and Water
Mft^3	Million Cubic Foot
Mm^3	Million Cubic Meters
Mm^3pd	Million Cubic Meter Per Day
MMRP	Military Munitions Response Program
MOD	Ministry of Defense (U.S.A)
MRA	Master Research Agreement
MSF	Multi Stage Flash
N_2O	Nitrous Oxide
ng g^{-1}	Nanogram per gram
NGO	Non-governmental Organization
NK	North Kuwait
NKETR	North Kuwait Excavation, Transportation and Remediation
NOx	Nitrogen Oxides
O_3	Ground-level Ozone
ODC	Oil Development Company
OEFC	Organization Engaging Field Contractor
OPC	Oil Contaminated Piles
OPEC	Organization of Petroleum Exporting Countries
OSSC	Oil Sector Services Company
PAAC	Public Authority for the Assessment of Compensation resulting from the Iraqi Aggression
PAAET	Public Authority for Applied Education and Training
PAAF R	Public Authority for Agriculture and Fish Resources
PAH	Polycyclic Aromatic Hydrocarbons
PIC	Petrochemicals Industries Company
PM10	Particulate Matter less than 10 microns in diameter
PMC	Program Management Consultant
PTC	Petroleum Training Centre
PV	Photovoltaic (solar)

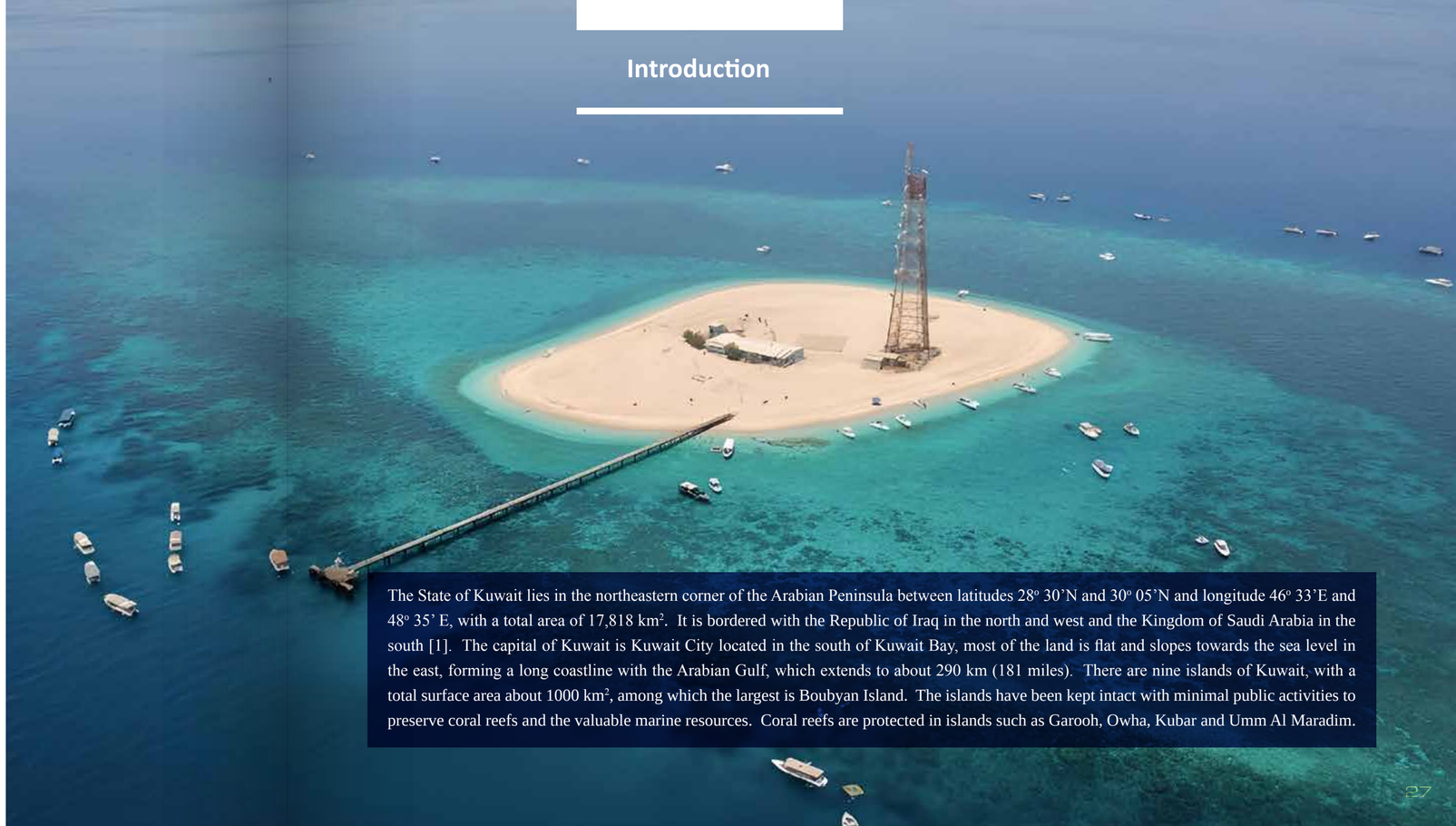
R&D	Research & Development
RBA	Risk Based Approach
RTC	Remediation Target Criteria
SDG	Sustainable Development Goal
SEK	Southeast Kuwait
SETI	Science, Energy, Technology, and Innovation
SK	South Kuwait
SKETR	South Kuwait Excavation, Transportation and Remediation.
STI	Science Technology and Innovation
SO_2	Sulfur Dioxide
SRG	Soil Remediation Group
SSC	Site Soil Characterization
STI	Science, Technology and Innovation
TDS	Total Dissolved Solids
TM	Technology Management
TOR	Terms of Reference
TPH	Total Petroleum Hydrocarbon
TRS	Total Remediation Strategy
TT	Treatment Technology
UNCC	United Nations Compensation Commission
UNFCCC	United Nations Framework Convention on Climate Change
UNMAS	United Nations Mine Action Service
USACE	United States Army Corp of Engineer
USDA	United States Department of Agriculture
UXO	Unexploded ordnance
VWC	Volunteer Work Center (Kuwait)
WJO	Wafrah Joint Operation
WOL	Wet Oil Lake
ZOR	Al-Zour Refinery Project

Sunset
In Kuwait

Sheep and goats grazing during sunset in Kuwait (S).

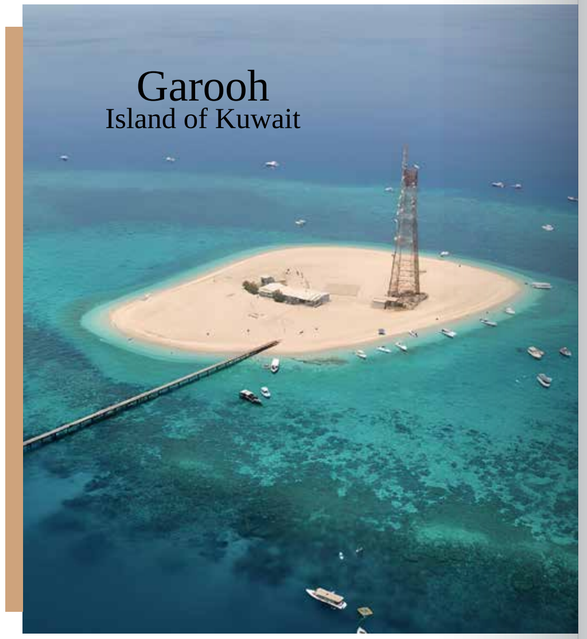
Introduction

Introduction



The State of Kuwait lies in the northeastern corner of the Arabian Peninsula between latitudes 28° 30'N and 30° 05'N and longitude 46° 33'E and 48° 35' E, with a total area of 17,818 km^2. It is bordered with the Republic of Iraq in the north and west and the Kingdom of Saudi Arabia in the south [1]. The capital of Kuwait is Kuwait City located in the south of Kuwait Bay, most of the land is flat and slopes towards the sea level in the east, forming a long coastline with the Arabian Gulf, which extends to about 290 km (181 miles). There are nine islands of Kuwait, with a total surface area about 1000 km^2, among which the largest is Boubyan Island. The islands have been kept intact with minimal public activities to preserve coral reefs and the valuable marine resources. Coral reefs are protected in islands such as Garooh, Owha, Kubar and Umm Al Maradim.

The landscape slopes gently from about 280 m above sea level near AL-Salmi in the extreme south-western corner of the country towards Khur Al-Subiyah in the north-east. The southern part of the country drops across a series of low, discontinuous scarps, separated by wide plateau and plains towards the Arabian Gulf coast in the east (Figure 1). The western and northern parts of Kuwait lie within a large old alluvial fan which extends from near Hafr al-Batin in Saudi Arabia to as far as Khur al-Hammar in Iraq and the northern shore of Kuwait Bay (Figures 2 and 3) [2]. To the north and northwest of Kuwait, there is the Mesopotamian plain with Euphrates and Tigris River deltas at the head of the Arabian Gulf. To the south and southwest, there is a sequence of sedimentary rocks of the Arabian platform overlying the Arabian Shield. The average gradient of the north-eastward slope is about 2 m/km^2. Perhaps an old course of the Tigris-Euphrates River introduced the large alluvial fan to the northeastern parts of the Arabian Peninsula (Figure 4). These alluvial fans are locally referred to as the Kuwait Group, comprising mainly gravels and sands. A striking feather in the north of Kuwait Bay is Jal AL-Zuor escarpment (Figure 5), perhaps the remains of an old alluvial fan channel, marks the north-westerly limit of transgression in the Kuwait Bay area. It is some 80 km long and up to 145 m high. Several alluvial fans are developed at the foot of the escarpment, and they terminate in playa and sabkha sediments towards Dawhat Kazmah Bay.



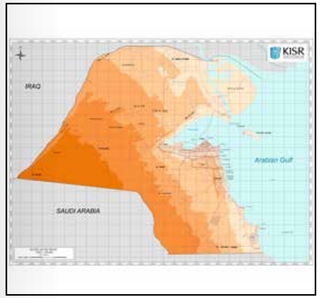


Figure 1. Location of the State of Kuwait and Main Roads [1].

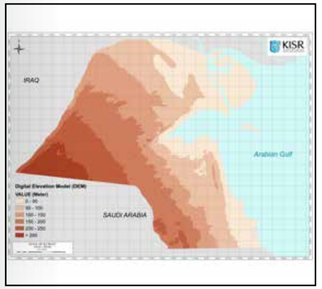


Figure 2. Elevation map of Kuwait [2].

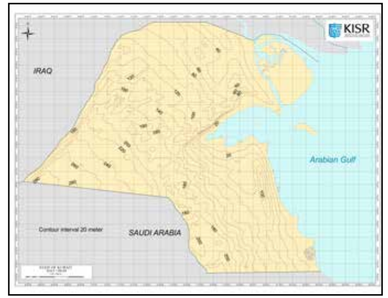


Figure 3. Contour map of Kuwait [2].

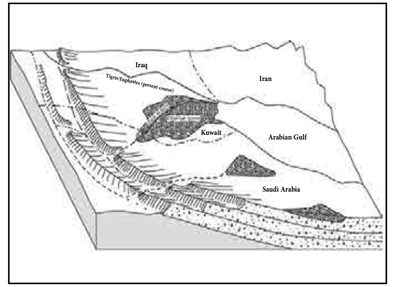


Figure 4. Courses of the Tigris Euphrates in the Arabian Peninsula.

Figure 5. Jal AL-Zour Escarpment in the north of Kuwait Bay (S).

The areas in the north and south of Kuwait have been managed by Kuwait Oil Company (KOC) for oil production. Nearly all of Kuwait's current crude oil production comes from onshore fields and mainly from the Greater Burgan oil field in the south, which is about 1000 km^2 in size. Other oil fields are in the north comprising the Ratqa, Rawdatain, Sabriya and Bahra. The southern Greater Burgan Field is the world's largest sandstone oil field, and the second largest overall, after Al-Ghawar in Dhahran, Kingdom of Saudi Arabia. The Burgan Field is made up of three main subsurface structures known as the Magwa, Ahmadi, and Burgan formation. Oil production was reported at 2,468,000 bpd in September 2021 (Figure 6).

About half of the domestic consumption of refined products of oil goes to power plants and seawater desalination units, while the rest is consumed mainly by the oil industry itself, followed by the transport sector [3] [4].

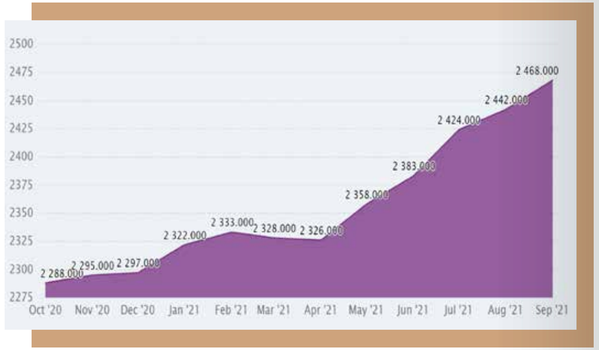


Figure 6. Oil production in Kuwait from Oct. 2020 to September 2021 [4].

The petroleum industry is the largest industry in Kuwait owned by the government, accounting nearly for half of the county's GDP.

The main companies and their responsibilities are shown below:

Name : Kuwait Petroleum Corporation (KPC)

Responsibility: Holding group responsible for international marketing and "umbrella" national oil company

Name : Kuwait Oil Company (KOC)

Responsibility: Crude oil exploration and development company.

Name : Kuwait National Petroleum Company (KNPC)

Responsibility: Runs oil refineries across Kuwait.

Name : Petrochemicals Industries Company (PIC)

Responsibility: Petrochemical and fertilizer manufacturer.

Name : Kuwait Petroleum International (KPI, also known as- Q8)

Responsibility: Runs refining and marketing business overseas.

Name : Kuwait Foreign Petroleum Exploration Company (KUFPEC)

Responsibility: International oil exploration company.

Name : Kuwait Oil Tanker Company (KOTC)

Responsibility: Crude oil shipping

Responsibility: Aircraft fuel

Name : Kuwait Gulf Oil Company (KGOC)

Responsibility: Oil and gas exploration and production in the Saudi-Kuwaiti neutral zone; joint venture with Saudi Arabia.

Responsibility: Handles all construction projects, maintenance, security, firefighting and medical services to all oil sector employees and their families.

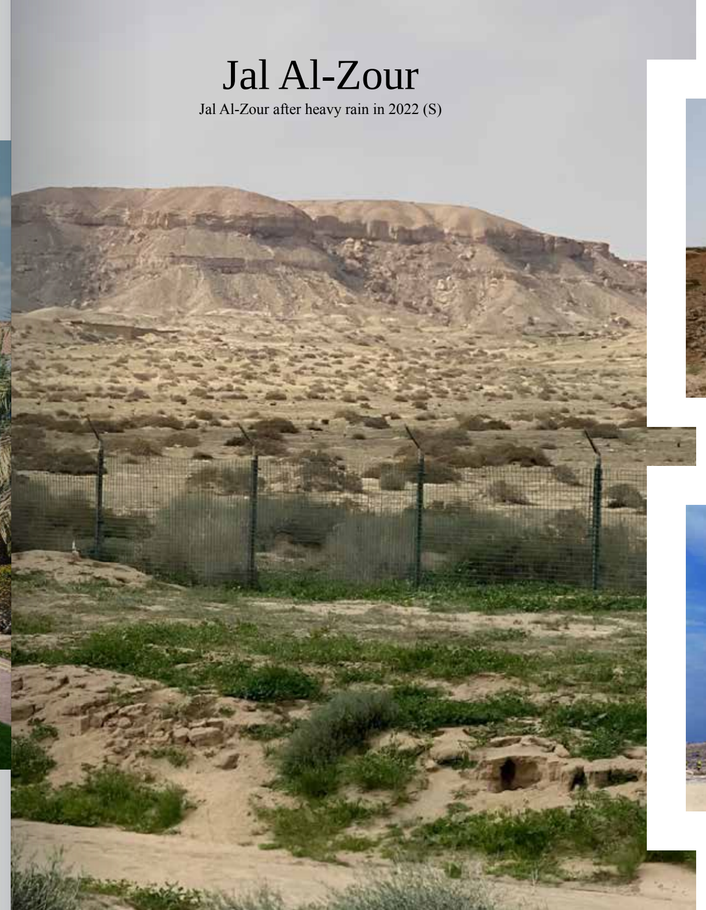
Land degradation has been a problem due to overgrazing and off-road use by vehicles, which increase sandstorms. With growing population, expansion in urban areas and increase in industrial and social activities, more natural habitats are degrading with losses in biological diversity. This environmental degradation was further manifested by the invasion of Kuwait in 1990, where 798 oil wells were ignited, causing the largest environmental and ecological disasters in world history. This is further aggravated by the current climatic changes that the globe has opted to adapt to and mitigate by committing to net zero emissions by 2050. An action plan is needed to strategically cut global emissions by 45% by 2030.

Climate change impact and air pollution in Kuwait have been of concern to the government, particularly KPC. Greenhouse gasses (GHG), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) were estimated in 2016 at about 86,336 ((Gg) CO_2-equivalent (Gg=gigagram= 10^9 g) including land mostly from the energy, industry, waste,

Kuwait Oil Company (KOC) Main Office Ahmadi.

Jal Al-Zour

Jal Al-Zour after heavy rain in 2022 (S)



Warah Hill in Burgan oil production area in Kuwait (2014) (S)

and agriculture (in the USA an average passenger vehicle on the road releases 650g of CO_2/km). This amount showed an increase in emissions including land of 139% from 36,211 Gg CO_2-equivalent in 1994 to 86,336 Gg CO_2-equivalent in 2016 [3]. Energy related GHG emissions growth continues to represent most of Kuwait's emissions.

KOC manages crude oil and natural gas production. Whilst control and sustainable oil production operations have been considered in their strategic planning, the government is also planning Green Kuwait in its National Development Plan (KNDP), which was initiated in 2021. This plan will increase the green areas and reduce pollution and temperature rise as alternative measures to combating desertification and climate change phenomena. In addition, Kuwait is reducing its carbon footprint by promoting clean energy initiatives, introducing new low-carbon technologies, and developing long-term partnerships to exploit sustainable energy opportunities. By 2035, Kuwait will have a total annual emissions reduction of about 5,600 Gg with a cumulative emission reduction of nearly 60,000 Gg of CO_2 - equivalent [3].

Burgan Oil Production oil fields in 2014 (S)

Gathering Point at Burgan oil production area.

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[2] Kuwait Institute for Scientific Research (KISR). 1999. Soil Survey for the State of Kuwait-Volume II. Reconnaissance Survey. AACM International Adelaide. Kuwait Institute for Scientific Research (KISR) and Public Authority for Agriculture and Fish Resources (PAAFR).

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Chapter 1
Kuwait Oil Company

Chapter 1

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1.1 Introduction

Chapter 1 covers in-depth information regarding KOC, its history, resources, and policies. Geological and oilfields descriptions, photographs, and history are explored, giving a clear and thorough understanding and overview to the reader. By the end of Chapter 1, the reader should have a clear image of KOC that includes insight to assets, policies, and legacy. Oil fields are detailed, described, and their images provided. Additionally, Health, Safety, Security and Environment (HSSE) policies are outlined and explored to give a clear understanding of KOC's inner workings, as well as their commitment to health, safety, security, and environment.

KOC's strategic plan for biofuel and sustainable development is presented with emphasis on its role in the Kuwait National Development Plan (KNDP) and Sustainable Development Goals (SDGs). KOC's contribution to reducing electricity consumption for oil production is presented as per its plans for developing renewable energy parks. In addition, the interest of the company in research and development (R&D), allying with research institutions such as KISR, is elaborated on with examples of collaborative research projects.

1.2 Background

KOC was established in 1934 by the Anglo-Persian Oil Company, which is known today as BP/Chevron. Four years later, oil was discovered at Burgan Field and the first crude oil shipment was inaugurated in 1946 by H. H. Sheikh Ahmad Al-Jaber Al-Sabah, the former Emir of the State of Kuwait (Figures 1 and 2). Shortly after, new fields were discovered and developed for commercial exportation. In 2006, gas was discovered in the deep Jurassic reservoirs at Rahiya, Mutriba, Um Niga and other fields throughout Kuwait. These discoveries fulfilled a long-standing Kuwaiti dream of becoming self-sufficient in gas that can be used for power generation. Currently, two main oil fields in Kuwait are in north Al-Sabriah and Al-Raudhatain and in the southeast at the Greater Burgan, which produces about 1.7 Mbpd and comprises the three smaller fields of Burgan, Magwa and Ahmadi. It also has the first installed oil well in 1938. It is the oldest and largest oil field known as the Greater Burgan field (Figures 3,4 and 5). Al -Wafrah oil field in the south is owned by Chevron Cooperation and is known as Wafrah Joint Operation (WJO), discovered in 1984 by KOC.

Figure 1. The oldest oil well at Greater Burgan installed in 1938 (numbered BG-1 IM) [1]

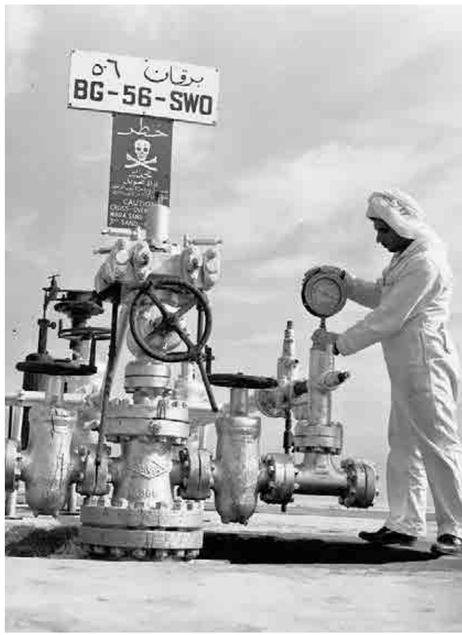

Figure 2. KOC at Burgan oil field in 1959 and oil exportation operations in the Arabian Gulf [2]

Warah Hill
in the fifties

Figure 3. Hill at Greater Burgan in early fifties. A significant natural feature in Greater Burgan area.

Figure 4. Kuwait Oil Fields showing the largest oil field at Greater Burgan in SEK. [3], [4]

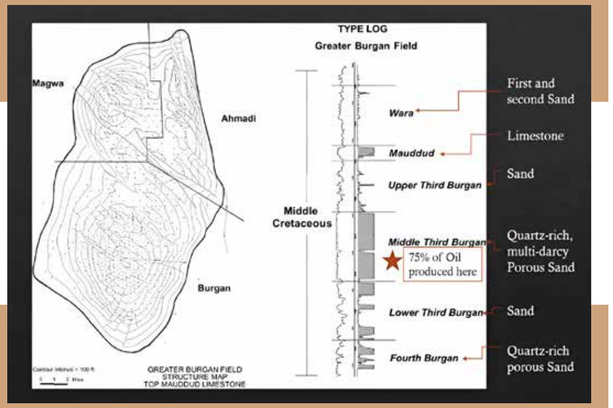

Figure 5. Geology of Burgan Oil fields. [5]

1.3 Management and Production of Oil and Gas

Under Kuwait Petroleum Corporation (KPC), the Ministry of Oil and Supreme Petroleum Council, KOC is responsible for managing oil and gas production and exportation. Kuwait is a member of the Organization of the Petroleum Exporting Countries (OPEC), which provided data on oil and gas production in Kuwait (Table 1) [6].

The country's proven oil reserves were estimated by the Ministry of Oil at 101.5 billion barrels, just over 7% of the world's total. KOC estimated Burgan's production capacity at 1.7 Mbpd in 2005. It was the fifth most productive oilfield worldwide in 2013 [7].

The International Energy Agency (IEA) then predicted an output of 1,530,000 billion barrels per day (Bbpd) in 2030. In 2005, KOC estimated a remaining life of 30 to 40 years for Burgan, at a production rate of about 1.7 Mbpd [8]. In 2018 Kuwait's crude oil production capacity was about 3.15 Mbpd, whereas in 2016 the gross crude oil production reached about 2.883 Mbpd. In January 2018, KPC officials disclosed plans for the company to spend over $500 billion to boost its crude production capacity to 4.75 M bpd by 2040. Nearly $114 billion of this amount was allocated over the five years (2018-2022).

Table 1. General information about Kuwait (2019) [6]

Population	4.42 inhabitants
GDP per capita ($)	30,280
Proven crude oil reserves (million barrels)	101,500
Proven natural gas reserves (billion cu.m,)	1,784
Crude oil production (1,000 b/d)	2,677.7
Marketed production of natural gas (million cu.m.)	13,952
Refinery capacity (1,000 b/cd)	736.0
Output of petroleum products (1,000 b/d)	886.3
Oil demand (1,000 b/d)	460.4
Crude oil exports (1,000 b/d)	1,986.3
Exports of petroleum products (1,000 b/d)	637.1

Half of the oil and gas production is consumed locally in the power plants and seawater desalination plants, while the rest is consumed mainly by the oil industry and the transport sector. Al-Zour Refinery Project (ZOR), (Figure 6). a petrochemical plant located 90 kilometers (km) south of Kuwait, processes nearly 615,000 bpd of light Kuwait Export Crude (KEC), a high-quality oil which is of a lighter density than heavy oil and contains low Sulphur [9]. Natural gas has been consumed in power stations and petrochemical industries above the production capacity, which led to importing natural gas to about 4.3 bm^3 in 2016, nearly 11.8 Mm^3pd. [KNPC data (Figure 7)].

Figure 6. Al-Zour Refinery project (ZOR) is a refinery complex located approximately 90km south of Kuwait [9]

Figure 7. KNPC Shuaiba developed refinery facility (2021)

1.4 Health, Safety, Security and Environment (HSSE)

The oil production industry requires a HSSE management system, which includes identification and analysis of workplace hazards, the development of group-wide guidelines and minimum requirements, training, and education of personnel. Regular audits oversee the collection of HSSE statistics, fire protection, noise protection, medical precautions, health & safety measures, environmental protection measures, and much more. Incidents or accidents are regularly documented for evaluation and investigation.

KOC coordinates with the Kuwait Environment Public Authority (KEPA) to develop standards and regulate environmental issues in its operations. This is essential to protect the environment and prevent environmental pollution and crude oil spills from oil wells or pipes. Measures also include energy efficiency, as well as the reduction of emissions and management of water and waste resources. Intensive awareness campaigns, training, and refining employees on HSSE are conducted by KOC since the establishment of the HSSE system in 1995. HSSE achievements include the development of Marine Colony near Kubar Island in collaboration with Kuwait Institute for Scientific Research (KISR), and the development of oases and nature reserves such as the "Spirit of the Desert in the south and north, Kuwait Oasis, Al-Qurain Hill Nature Reserve, and Al-Abdaliya Nature Reserve". These oases and nature reserves will be further discussed in Chapter 6.

1.5 KOC's Strategic Plan

The vision of KOC is to achieve a leading global position in upstream oil and gas as an integrated and value enterprise. KOC developed a strategic plan for the year 2040 to achieve this vision with focus on eight key goals [10], [11], [12]. These goals help KOC to focus its efforts on specific targets to improve business, creativity, innovation, and sustainability. These goals are shown in Figure 8.

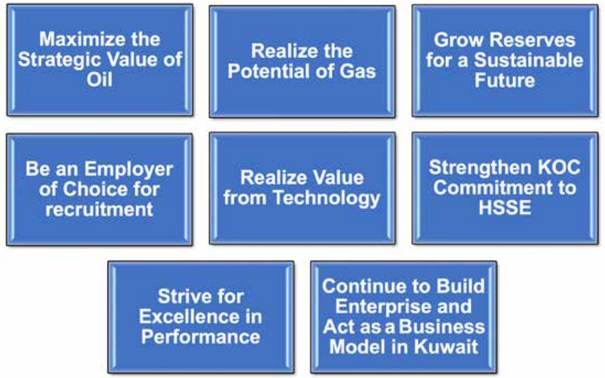

Figure 8. The eight strategic goals of KOC 2040.

1.6 Kuwait National Development Plan (KNDP) and Sustainable Development Goals (SDGs)

The vision of the late Amir, His Highness Sheikh Sabah Al-Ahmad Al-Jaber Al-Sabah

"(To) transform Kuwait into a financial and business hub, attracting investments, and – where the private sector leads the economy – creating competition and promoting production efficiency, under the umbrella of enabling government institutions. This transformation as a whole shall accentuate our values, safeguard, and enhance our social identity, and help us achieve greater, more balanced human capital and resource development, providing adequate infrastructure, advanced legislation, and an inspiring business environment".

1.6.1 Kuwait National Development Plan, New Kuwait.

The KNDP was developed in 2010. The plan was based on the vision of the late Amir of Kuwait, Sheikh Sabah Al-Ahmad Al-Jaber Al-Sabah, to transform Kuwait into a financial, cultural, and institutional leader in the region by 2035. The vision aims to attract investors, thus creating a competitive economy led by the private sector and promoting production efficiency. The Kuwait National Development Plan sets the nation's long-term development priorities (Figures 9, 10, 11). It is organized around five themes, or desired outcomes, and seven pillars, or areas of focus for investment and improvement. Each pillar has several strategic programs that are designed to impact achieving the vision of a "New Kuwait", and some projects have a direct relation to mitigation of GHG emissions of the business-as-usual scenario and adaptation to the negative impact of climate change. Kuwait also seeks to develop and modernize the national infrastructure to improve the quality of life for all citizens [13], [14], [15], [16], [17].

There are three main projects that were integrated in Al-Zour Refinery project to develop a prosperous and diversified economy aimed at reducing the country's dependence on oil revenues: the Bio-fuel project, the Olefins III, and Aromatics II [9].

Figure 9. The Seven Pillars of New Kuwait.

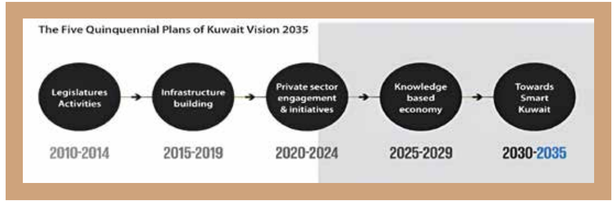

Figure 10. The five quinquennial plans of Kuwait 2035.

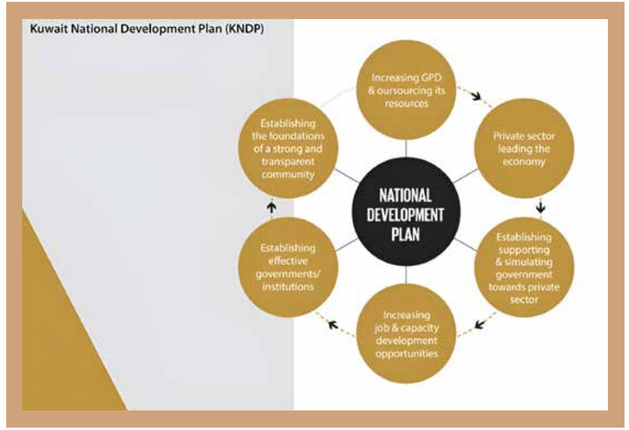

Figure 11. Kuwait National Development Plan (KNDP).

1.6.2 Sustainable Development Goals

Seventeen United Nations (UN) SDGs were adopted in 2015, with the target of reaching them in 2030. These goals are shared worldwide in a global partnership to recognize that ending poverty and other deprivations must go hand-in hand with strategies that improve health and education, reduce inequality, and spur economic growth while tackling climate change and working to preserve oceans and forests. The 17 SDGs are as follows [18]:

1. No Poverty.
2. Zero Hunger.
3. Good Health and Well-Being.
4. Quality Education.
5. Gender Equality.
6. Clean Water and Sanitation.
7. Affordable and Clean Energy.
8. Decent Work and Economic Growth.
9. Industry, Innovation, and Infrastructure.
10. Reduced Inequalities.
11. Sustainable Cities and Communities.
12. Responsible Consumption and Production.
13. Climate Action.
14. Life Below Water.
15. Life on Land.
16. Peace, Justice, and Strong Institutions.
17. Partnerships for the Goals.

The Government of Kuwait developed its Voluntary National Report Review in 2019, which shows status and progress of the SDGs. Percent Achievements of the 17 SDGs are summarized in Table 2.

Table 2. Percent Achievements of the 17 SDGs for the State of Kuwait [19]

	Achievements %
SDG1	100
SDG2	65.2
SDG3	84.8
SDG4	74.7
SDG5	55.8
SDG6	50
SDG7	86.6
SDG8	77.6
SDG9	45.7
SDG10	Integrated in other SDGs
SDG11	44.6
SDG12	28.9
SDG13	43.8
SDG14	37.4
SDG15	55
SDG16	73.9
SDG17	52.9

1.7 Research and Development (R&D)

Undoubtedly, the petroleum sector is undergoing unprecedented stress and change. Competition from other gas and petroleum producers, growth in alternative energy, greater efficiency in vehicles, and the reality of global climate-change, altogether conjoin to lower and fluctuating global oil prices. For Kuwait, this has created budgetary pressures and uncertainty in the future of the country's economy. R&D of new technology, however, holds the potential for positive change within the sector that can maintain the value of Kuwait's hydrocarbon assets, while responding creatively to the environmental challenges posed by the sector.

For the oil sector, KPC is involved with several activities promoting the science, energy, technology, and innovation (SETI) ecosystem. For the upstream, KOC has a mature technology management function responsible to scout, pilot and implement key and emerging technologies. KOC is also responsible for R&D to develop new solutions for the upstream. Currently, this research is conducted in collaboration with leading local and international R&D organizations.

Key Science, Technology, and Innovation (STI) activities at KOC include:

1. Kuwait International Petroleum Research Centre (KIPRC) (Figure 12)

The center will cater for 21 R&D/Technology Management (TM) programs under seven platforms. The center will not only kick-start the in-house R&D for the upstream but will also bring together all the other elements of the R&D/TM ecosystem including collaboration and capability development.

2. Research and Technology Management through Collaboration

KOC identified local and external collaborators through master research agreements (MRA).

A total of 11 external universities and research centers, nine service companies, and several local universities and institutes including KU, KISR, and PAAET were identified as strategic partners.

3. Post Graduate Program

There is an essential need to satisfy KIPRC work force requirements with high-level research professionals (i.e., Ph.D./M.Sc. Degrees across various disciplines). KOC has worked on identifying proper paths to secure these high-level employees. Several initiatives are currently with KU under Petroleum Eng., Chemical Eng., and Geology, as well as with PAAET to help in operating KIPRC.

Figure 12. Kuwait International Petroleum Research Center.

Lightning on Kuwait City in
Winter 2021 (O).

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Chapter 2
The Environmental Setting of Kuwait

Chapter 2

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2.1 Introduction

Chapter 2 covers Kuwait's environmental setting, giving a clear descriptive overview of Kuwait's geographical features. Climate Change and Greenhouse Gas (GHG) emissions are presented for different sectors in Kuwait. Vegetation cover and plant communities that once dominated Kuwait's desert are presented, emphasizing how environmental protection is important for biodiversity conservation and restoration. Updated images are shown for land degradation and soil erosion. By the end of this chapter, the reader will understand what Kuwait's environment is and how it is changing, if at all, over time.

2.2 Desert Ecosystem

High temperatures that exceed 50 °C in summer, high speed dry winds, high evaporation rates, low organic matter in soil and low soil moisture contents are Kuwait's desert characteristics that make it difficult for plants to grow naturally. Annual average precipitation during winter ranges between 75-150 mm. Despite the harsh climatic conditions and the soil characteristics, records on Kuwait's desert showed some distinct plant communities (Figure 1). These are: *Rhanterium epapposum; Hamada salicornica; Cyperus conglomeratus; Stipagrostis plumosa;* and some salt dwelling species. However, these plant communities are hard to be observed today except in areas that have been protected from human activities such as the *Rhanterium epapposum* community, which remains confined to Sulaybia/Kabd protected area in the middle south of Kuwait. The desert ecosystem includes salt marshes and sabkha in the coastal plain with sand dunes and terraces, desert plain, alluvial fan, escarpment, ridges, and hills, wadis and depressions, and Barchan dunes and sand sheets [1] (Figures 2, 3, 4, 5, and 6).

Figure 1. Spring flowering annuals near Warah Hill at Greater Burgan area in the south Kuwait (S)

Figure 2. Wadi Umm Al-Rimam in the north of Kuwait representing wadis and depression ecosystem (S)

Figure 3. Jal Al-Zour in the North of Kuwait, escarpments, ridges, and hills ecosystem (S)

Figure 4. *Hamada salicornica* in the desert plain ecosystem in the northern borders of Kuwait (S)

Figure 5. Mobile Sand and Sand Dunes in the Desert of Kuwait, Barchan Dunes and Sand Sheets (S)

Figure 6. Measures to Control Moving Sand

SEVERE DUST STORMS

Figure 7. Severe dust storms are natural phenomena manifested by land degradation (2015) (S)

2.3 Land Degradation and Soil Erosion

The desert landscape of Kuwait has been intensively used for urban developments. Most of the open desert areas have been overgrazed by livestock and used for spring camping. Agricultural areas are confined to the north, center, and south areas. Other areas are used for oil and groundwater production. The desertification problem has been manifested due to demographic and natural processes that altered the stabilized soils and made them more vulnerable to wind erosion. Dust storms are natural phenomena in Kuwait and are increasing over time due to land degradation and climate change. The military activities during the Iraqi invasion and the subsequent Gulf War added more pressure on land and the vegetation was severely damaged. The main plant communities that once dominated the desert landscapes such as *Hamada salicornica* and *Rhanterium epapposum* are no longer existing in the open deserts. Plant communities reduce sand mobility and control their movement if kept intact. Therefore, it is necessary to maintain and manage vegetation to reduce dust storms.

Soil is vulnerable to wind erosion especially during hot and dry summers. The small particles can be easily carried out by speedy wind, and they accumulate near any obstacle, such as plants, roads or buildings

Figure 8. Mobile sand accumulation on depressions, fences, and roads (S)

that can drift wind speed and direction leading to dropping its load and deposition of sand. This process is usually seen in areas of the open desert that are highly degraded due to anthropogonic factors, especially overgrazing [2], [3], [4]. Compound fences are used to reduce mobile sand movement and stabilize soil for natural plant recovery.

Figure 9. Camel grazing in a barren land in Kuwait (S)

2.4 Climate

Maximum daily temperatures in Kuwait can exceed 50°C during the long and dry summer. The summer season occurs over a roughly 5-month period, from 21 May to 4 November, and is characterized by a significant increase in both humidity and heat levels, with daily maximum temperatures ranging between 43- 48°C. The highest-ever recorded temperature was at Mutriba in the northwest of Kuwait scoring 54 °C on July 21, 2016. During winter, the weather improves making it more livable, with the lowest temperature recorded at -4°C in January 1964. Low temperatures, clouds, rain, and a cold northwesterly wind called “Shamal” characterize this short season that does not exceed two months (December-February). The spring season is a three-month period from 16 February to 20 May and is characterized by moderate temperatures, rain, cloudy conditions, and hot southerly winds. The autumn season occurs over a single month - from November to December - and is characterized by moderate temperatures, greater cloud cover, more frequent rain showers, and increasingly cold nights.

2.5 Climate Change

Climate change is a long-term global shift in temperatures and weather patterns due to both natural and human-induced factors. In 2021, the UN pledged to save and restore forests (COP26 Summit, 2021) and to reduce GHG to net zero by 2050. In Kuwait, oil and gas fuels contributed to 8% of CO_2 emissions [5]. The World Bank records on climate change (Climate Change Knowledge Portal) (Figures 10-11) showed an increasing warming trend by 4.19 ^{o}C per century since the 1950s and a decreasing linear trend in precipitation by 0.88 mm/month per century for the period 1951-2000.

The GHG emissions were more than 60 Mt on carbon dioxide equivalent (CO_2e) based on the electricity and heat sector (Figure 12).

The contribution of the energy sector, including electricity & water, was 57% of total CO_2 emissions and continued to increase for several decades (Figure 13). CH_4 emissions had the second largest share of GHG emissions estimated 95.336 Gg or about 2.3% of Kuwait’s total emissions on CO_2e base. Solid waste and fugitive emissions were highest

contributor to the CH_4 emissions (Figure 14). N_2O emissions were very small compared to other GHGs. For decades the agriculture sector was the highest contributor to N_2O emissions. Other fuel combustion and wastes also contributed to N_2O emissions in Kuwait (Figure 15).

It is anticipated that all land areas of Kuwait will become warmer in the future. Under the Business As Usual scenario (BAU) known as "RCP 8.5", which refers to comparatively high GHG that does not include any specific climate mitigation target, the temperature will rise between 4.3- 4.5^{o}C by the 2071-2100 period [5]. RCP 8.5 is also known as the worst-case scenario (low future concentrations are referred to as "RCP 2.6" [5].

The impact of climate change on biodiversity is a serious issue due to the increase in the intensity and frequency of dust storms, drought, sea-water rise, and seawater temperature increase that will affect the spawning period of fish and shrimp, and would cause fish migration to other more suitable areas. A strategic plan for climate change mitigation and adaptation is needed for the State of Kuwait [6].

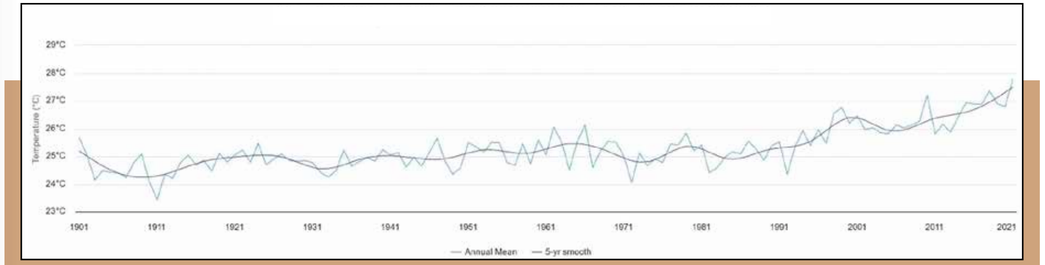


Figure 10. Average annual mean temperature in Kuwait (1901-2020) (Source: World Bank 2020)

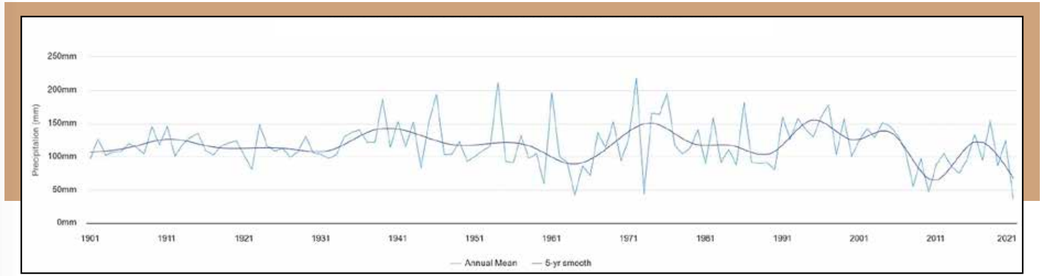


Figure 11. Average annual precipitation in Kuwait (1901-2020) (Source: World Bank 2020)

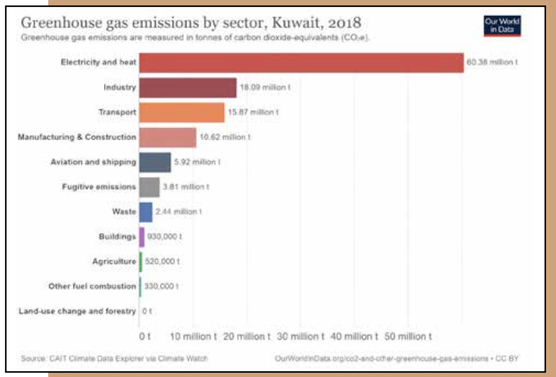
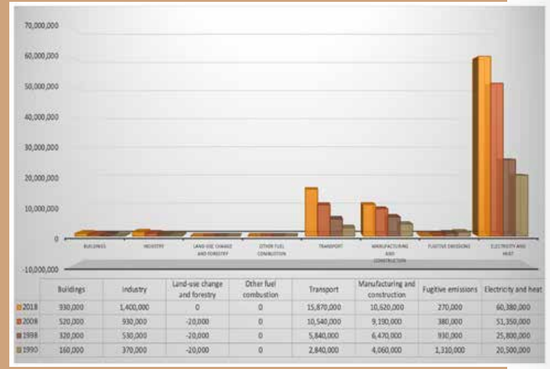
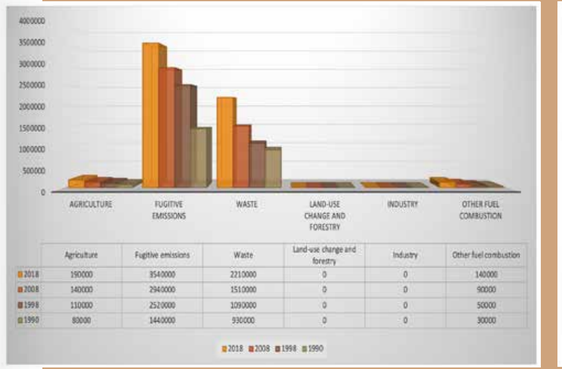


Figure 12. GHG emissions in Kuwait by sectors in 2018. (Source: Our World in Data 2022)



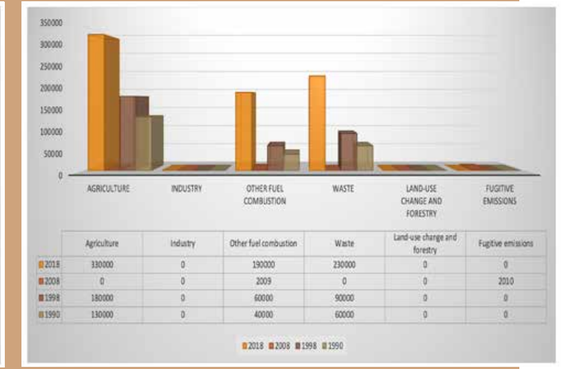
	Buildings	Industry	Land-use change and forestry	Other fuel combustion	Transport	Manufacturing and construction	Fugitive emissions	Electricity and heat
2018	930,000	1,400,000	0	0	15,870,000	10,620,000	270,000	60,380,000
2008	520,000	930,000	-20,000	0	10,540,000	9,190,000	380,000	51,350,000
1998	320,000	530,000	-20,000	0	5,840,000	6,470,000	930,000	25,800,000
1990	160,000	370,000	-20,000	0	2,840,000	4,060,000	1,310,000	20,500,000

Figure 13. Co2 emissions in tons (t) by sector in four years, Kuwait (Source: Our World in Data 2022)



	Agriculture	Fugitive emissions	Waste	Land-use change and forestry	Industry	Other fuel combustion
2018	190000	3540000	2210000	0	0	140000
2008	140000	2940000	1510000	0	0	90000
1998	110000	2520000	1090000	0	0	50000
1990	80000	1440000	930000	0	0	30000

Figure 14. CH_4 emission in tons (t) by sector in four years, Kuwait (Source: Our World in Data 2022)



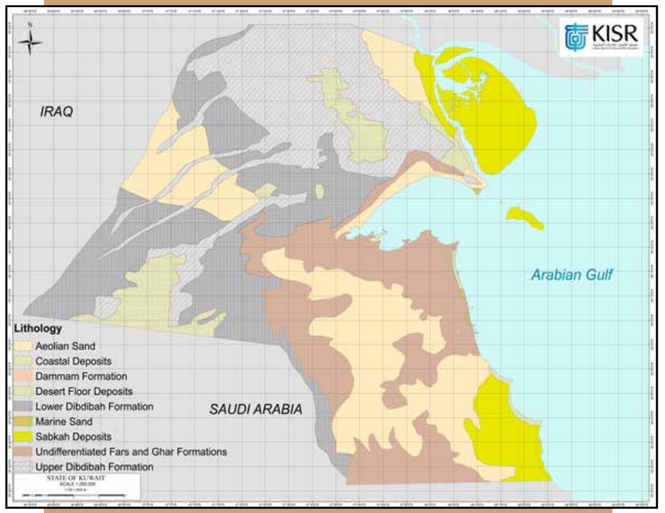
	Agriculture	Industry	Other fuel combustion	Waste	Land-use change and forestry	Fugitive emissions
2018	330000	0	190000	230000	0	0
2008	0	0	2009	0	0	2010
1998	180000	0	60000	90000	0	0
1990	130000	0	40000	60000	0	0

Figure 15. N_2O emission in tons (t) by sector in four years, Kuwait (Source: Our World in Data 2022)

2.6 Geology and Soils

Kuwait lies between the Arabian Shield and the Zagris fold belt, at the periphery of the Arabian platform. The oldest exposed rocks are limestones of the Dammam Formation (Eocene). A small outcrop of this formation occurs south of Al-Ahmadi. However, almost all surface and near-surface formations are of Neogene (Miocene-Pliocene) or Quaternary age. The Neogene sediments consist of clastic deposits with subordinate carbonates and evaporites, locally known as the Kuwait Group. The Kuwait Group comprises units of the Ghar, and Fars Formations (Miocene-Pliocene) overlain by the Dibdibah Formation (Pliocene-Pleistocene). The Kuwait Group sediments are overlain by Holocene sediments and underlain by the Eocene Dammam Formation. The Dibdibah Formation underlies the northern half of the country. The upper member of this formation is composed of sandy gravel and/or gravelly sand with a high percentage of scattered pebbles, cobbles, and boulders. Calcrete and gypcrete are common in Kuwait. Late Pleistocene and Holocene sediments of southern Kuwait reflect the major sea level fluctuations in the Arabian Gulf over the last 8,000 years. Holocene sediments occur as a veneer, usually less than 1m thick practically covering the older rocks [7].

The soils of Kuwait were classified in 1999 by KISR in collaboration with AACM International (Australia). The soil maps were prepared based on two surveys: a reconnaissance soil survey at scale 1:100,000, and a detailed soil survey at scale 1:25,000 for 200,000 identified in the reconnaissance survey as most suitable areas for irrigated agriculture. Soil names and descriptions were provided, and maps were developed. Soils were described according to the USDA Soil Survey guidelines and classified according to the Keys to Soil Taxonomy, 1994. Soil taxonomy is based on soil properties observed or inferred during field surveys and confirmed by laboratory assessments of soil samples. Soil taxonomy considers the soil's morphology, physical and chemical characteristics, soil temperature and soil moisture status. Almost all the soils in Kuwait are calcareous to some extent in the first meter from the surface. The extent of the carbonate accumulation and the degree of its association with accumulations of gypsum, salts and clay determines the subgroup.



Geology of Kuwait [8]

Kuwait's soils are generally poorly developed, mainly sandy, low in organic matter and water retention capacity. Aridsols (70.8%) and Entisols (29.2%) are the main soil orders [7, 8] (Figure16). According to the USDA soil classification methods the soils of Kuwait are identified and characterized into eight great soil groups: Petrogypsids; Terripsamments; Petrocalcids; Haplocalcids; Aquisalids; Calcigypsids; Haplogypsids; and Torriorthents [8]. Of these, Petrogypsids and Torripsamments are most common (Figure 17). The Petrogypsids occur on level to gently sloping plain formed on the sand and gravel deposits of the Dibdibah Formation. The Torripsamments, on the other hand, normally occur on extensive sand sheets in the central and southeast directions. While Calcigypsids and haplogypsids soil types are found in the northern part of Kuwait, Haplicalcids occur in the north, south and center. Aquisalids are found in the coastal areas and in Boubyan and Failaka islands [9].

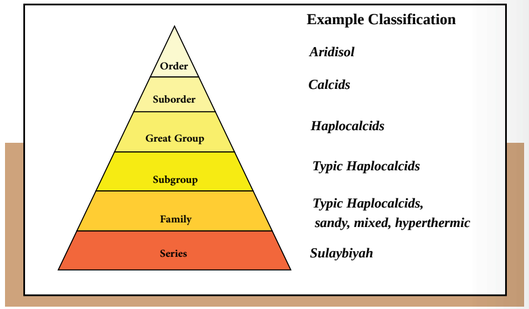


Figure 16. Hierarchy used in soil taxonomy

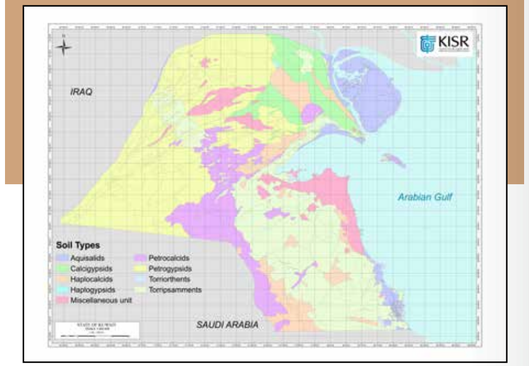


Figure 17. The soils of Kuwait (KISR 1999).

2.7 Water Resources

Natural fresh water sources are lacking in Kuwait. There are no rivers or surface water due to low annual precipitation, a high evaporation rate and high soil infiltration rate. Any streams or runoff water can only last a few hours after rain. Groundwater is available for drinking, which flows naturally from Saudi Arabia through lateral underflow towards the sea level in the east. Most of the fresh groundwater can be found in the fields of Raudhatain and Umm Al-Eish. Saline groundwater has high salinity of around 20 g/L, and brackish groundwater contains high amounts of soluble salts up to 7 g/L. The brackish water is used for domestic and agriculture irrigation , which is continuously on high demand. The quality of the groundwater is deteriorating due to excessive withdrawal, reaching 164.7 MCM in 2006. Water management and preservation is enforced by the Ministry of Electricity & Water (MEW) with emphasis to efficiently produce desalinated water by multi-stage flash (MSF) evaporation process. There are eight desalination plants with total capacity of 3.11 MCM/d. In 2004, a municipal wastewater treatment plant was established in Sulaibiya by using RO and has the capacity of 375,000 m^3/d influent.

The plans are now to continue reclaiming municipal wastewater for landscaping and greenery projects [10]

2.8 Vegetation

Due to the harsh climatic conditions of the State of Kuwait, especially during the summer, the vegetation is sparsely dominated by woody shrubs that are less than 2 m in height and confined to specific areas with favorable conditions. The understory of annual species usually grows during winter and spring with dynamic structure and density depending on the amount of rainfall, landform, and biotic factors such as grazing. Vegetation communities in Kuwait are described by Omar et al., 2007 [11] with main communities such as *Hamada salicornica, Rhanterium epapposum, Cyperus conglomeratus, and Tetraena qatarensis.* However, these communities are almost completely stripped except in those areas that have restricted access; such as the petroleum industry, KOC oasis and reserves. The first rains in early winter trigger the germination of the seeds of annual plants and stimulates the sprouting of perennials. On the other hand, heavy grazing and land misuse prevent plant communities from completing their life cycles, thereby depleting the seed bank, and further reducing regrowth in subsequent seasons.

For long-term maintenance of the vegetation cover, it is important that annual species germinate, grow, and produce enough seeds on a yearly basis.

Figure 18. (*Hamada salicornica)* community type in Kuwait (S)

Therefore, these species face the challenge of germinating at the correct time and place to capture sufficient moisture and avail favorable conditions (temperature, light and moisture) to be able to complete their life cycle [11]. After seeds germinate, proper establishment is very critical for subsequent growth and seed production. The tolerance of seedlings to drought, which varies between species, determines the final floristic composition in a community [12-15]. Proper distribution of rainfall following germination is needed to accelerate population growth, flowering, and seed production [16, 17].

Under Kuwait's environment, Brown [18] showed that 4 mm rainfall was sufficient to stimulate germination in species such as *Plantago boissieri;* however, others required at least 25 mm rainfall, but survival until maturity under these conditions was very high. The total amount of rainfall was not critical for species composition or frequency in a particular year, but it affected biomass production. In the absence of vegetation cover, a large soil surface becomes exposed and splashing of raindrops may cause surface sealing, which could result in poorer soil structure, reduced permeability, increased surface run-off, and accelerated soil erosion [19].

Figure 19. *(Rhanterium epapposum)* community (S)

2.9 Desert Land Use and Land Cover

Rangeland (75.12%), which is mainly used for grazing and recreational activities such as camping, is the dominant desert land use [1,7]. Oilfields and military activities occupy 7 and 4% of the total land areas, respectively. Grazing of native vegetation has historically been a mainstay of the nomadic people of Arabia. Over the years, traditional nomadic grazing has given way to sedentary forms of livestock raising, with steady increase in demands for available natural resources [20-22]. Overgrazing not only reduces productivity, but also affects species richness and relative abundance [26, 28]. The open grazing policy in Kuwait is one of the main causes for degradation of rangeland. Stocking rates in Kuwait (2 – 8 ha/AU; 1 AU = mature female camel, or 5 sheep or 6 goats) are nearly 7 times more than the land can safely carry [10]. More recent records show that stocking rates in the rangelands in Al -Bahra, Al-Mutla and Sulaibiya were 2.15, 1.83 and 1.4 ha/AU, respectively [23]. Stocking densities in arid rangelands recommended were between 17.5 ha/AU to 55 ha/AU with an average of 33 ha/AU [24].

Studies conducted at KISR showed that the grazed areas contained 53% less plant cover and 3.3 times higher bare grounds than protected areas. Consequently, herbage production is substantially lower in the open-grazed areas [25]. Plant species like *Rhanterium*, which are more palatable, are heavily used up to 90% [26, 27], giving way to predominance of less palatable species like *Cyperus conglomeratus*. Similarly, some of the perennial grasses have dramatically declined in the Kuwaiti desert due to grazing. In addition to the direct effects of grazing, large herds of livestock, particularly the sheep, trample the soil surface leading to severe soil compaction, reduction in infiltration rate and loss of surface soil through wind erosion. Heavy grazing also drastically affects plant development and seed production.

Growing awareness of climate change has propelled national and international governments, companies, and NGOs to take action to tackle the problem of GHG. The Kyoto Protocol on reducing the GHG has been ratified by 163 governments. Under this protocol, targets for GHG reduction have been fixed. The member countries and participants can meet their targets through a range of activities including afforestation, grazing management, revegetation, all of which are thought to sequester carbon in biomass and thereby offset emissions from the use of fossil fuels and other sources. The basic premise of biocarbon is to combine climate mitigation and biodiversity conservation in one activity, for example restoration of degraded habitat through assisted natural restoration using native species. Because of the many possibilities for conserving biodiversity and sustainably using biological resources through investing in carbon mitigation or offsets, this holds good promise for Kuwait. The options to use carbon finance in biodiversity conservation increases the area under greenery utilizing the native species and adopting biodiversity-friendly agriculture such as organic and ecological farming. However, the major challenge would be the strengthened links between biodiversity performance indicators and carbon matrix standards [28].

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Chapter 3
Biodiversity and Protected Areas in Kuwait

Chapter 3

Biodiversity and Protected Areas in Kuwait

3.1 Introduction

This chapter covers Kuwait's biodiversity and protected areas, providing information and high-resolution images of plant and animal life in Kuwait. It also gives a descriptive overview of Kuwait's protected areas that include information and images. The chapter serves to showcase the positive impact Kuwait's environment has experienced through the implementation of key protected areas. Desert habitats are photographed and described showing the dominant plant species and soil types with geological descriptions. Important land features are described with maps showing their locations. Water drainage and water catchment areas (Khobrat) are photographed during rainy seasons. Wetlands in Boubyan Island are mapped with photographs of migratory birds landing areas. Field visits to hot spots were carried out to photograph and document species diversity.

By the end of this chapter, the reader would understand Kuwait's biological life, types of communities, important land features, wetlands, and protected areas in Kuwait. The reader will also be able to realize the importance of protecting Kuwait's biodiversity by establishing protected areas.

3.2 Plant Communities

The flora of Kuwait is dominated by some annual species that flourish during the mild seasons. There are 256 annuals identified as indigenous species in Kuwait. Perennial shrubs and bushes grow all the year long, but some are deciduous and shed their leaves during hot summers. There are 83 herbaceous perennials, 34 under shrubs and one tree identified.

The dominating plant communities are described as follows:

Hamada salicornica community also known as *Haloxyletum*. This community, although extending from Iraq in the northeast down to the northern edge of the Rub' al Khali in Saudi Arabia, can be only seen today in Kuwait within areas protected from grazing and human activities. It is usually associated by *Astragalus spinosus* and *Chrozophora* spp. The common annual type seen in this community is *Stipa capensis.*

Rhanterium epapposum community, commonly known as *Rhanterietum.* This community has been intensively used for fuel and grazing. The plant is rarely seen in open lands for grazing. Some common associated species are *Moltkiopsis ciliata*, *Helianthemum lippi*, and *Stipagrostis plumosa.*

Cyperus conglomeratus community known as *Cyperetum*: A very widespread plant in the Arabian Peninsula. It spreads on vulnerable sandy soils particularly when *Rhanterium epapposum* is removed.

Figure 1. Annual species like *Senecio glaucus* dominate during spring in Kuwait

Figure 2. *Cyperus conglomeratus* growing on sandy soil in Burgan oilfield, KOC (S)

3.3 Geomorphological Features

Kuwait has generally low relief, with elevations ranging from 284 m above sea level at the westernmost corner to a few meters above sea level in the eastern part around the shoreline of the Arabian Gulf (Figure 3).

The elevation of the northeastern region ranges between 120 m above sea level at its southern fringes to zero level and below at its northeastern corner (Figure 4). The eastern and southern fringes of the study area are low-lying and generally flat, where large tidal flats and sabkha formations exist. These flats are bounded by coastal sand accumulations around shrubs (known as “nabkhas”), terraces and coastal ridge. Geomorphologically, the northeastern part of Kuwait is classified into the following units:

• Coastal plain (beach, intertidal zone, coastal aeolian landforms and (“sabkhas”)
• Hilly terrain and ridges (Jal Al-Zour, Al-Rukham and Liyah)
• Hydrographic basins (wadis and depressions)
• Aeolian landforms (depositional and erosional)

The most predominant topographic feature in the northeastern part of Kuwait is Jal Al-Zour, a 65-kilometer-long escarpment located North of Kuwait Bay. Local relief reaches about 125 m at Al-Khuwaisat near the southwest end of Kuwait Bay. This escarpment, which exposes a sequence of different rock formations, is between one and thirty-five million years old (Holocene to Miocene in age). To the west and northwest of the escarpment the surface slopes gently away from the edge into a broad, shallow depression. Several alluvial fan formations spread from the foot of Jal Al-Zour escarpment toward the coastal plain, where successive old marine terraces and a former coastline exist (Figure 5) [1], [2], [3], [4].

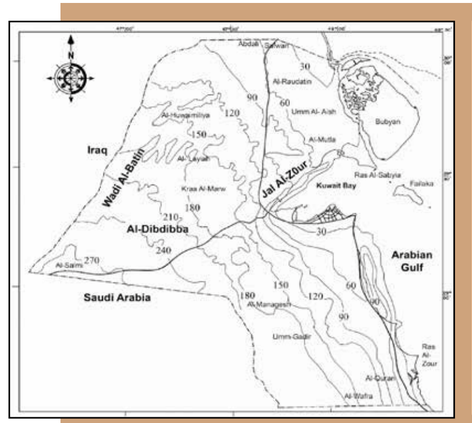

Figure 3. Main land features and contour lines of Kuwait.

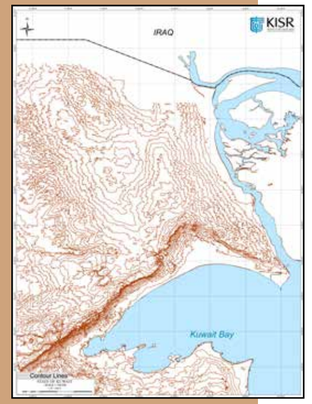

Figure 4. Detailed Contour lines of the Northeastern area of the State of Kuwait.

Umm Ar-Rimam depression (Figure 6) is located about four kilometers to the west of Jal Al-Zour escarpment. It forms two main connected depressions with depths of up to 15 m, partially covered with fine sediments. Recently the southern depression is used as a reservoir for treated sewage water. The main landforms of Umm Ar-Rimam depression are shown in (Figures 4 and 6). Most of the area shown in (Figure 4) has been protected since 2004.

Another interesting feature is the fallen rocks at the Jal Al-Zour foot (Figures 7 and 8). One significant feature is the Madeira rock, located at the southeastern coastal area of Sabah Al-Ahmad Nature Reserve. This rock is three-meters high split into two parts due to weathering processes, and ended resting on the ground at the base. The rock used to be frequently visited by local visitors and campers. Some grafting on the rock shows the names of some visitors and the year of visit, which goes back to 1956.

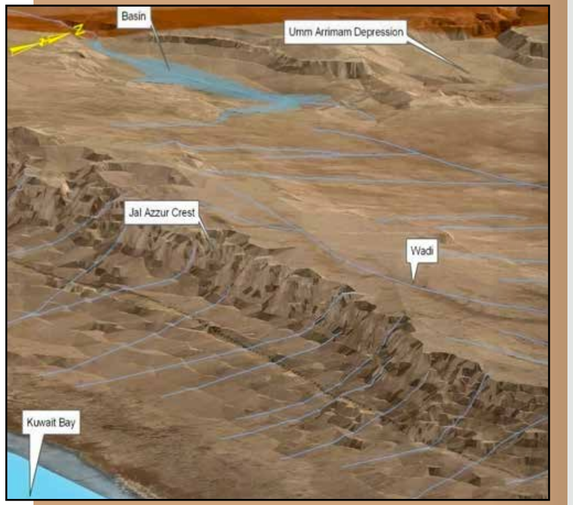

Figure 5. A 3D model for a part of Jal Al-Zour hilly terrain showing main land features: crest, wadi and Umm Ar-Rimam Depression [1]

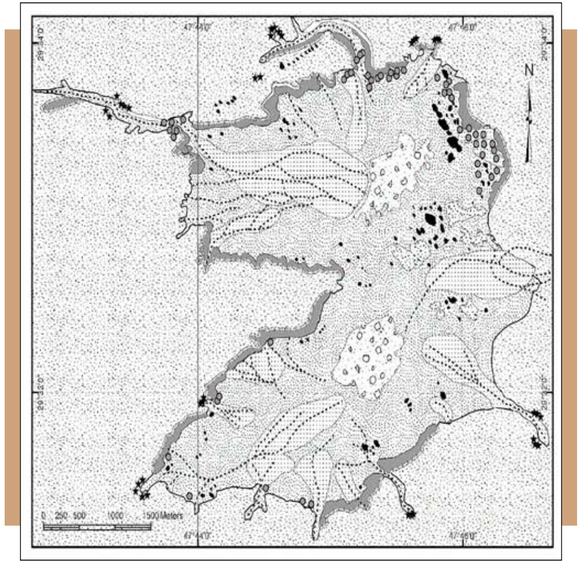

Figure 6. Geomorphological map of the Umm Ar-Rimam depressions: (1) erosional platform; (2) floor of the depression; (3) piedmont slopes; (4) alluvial fans; (5) playa bottom; (6) falling dunes; (7) single yardangs; (8) Lycium shawii nabkhas; (9) Haloxylon salicornicum nabkhas; (10) cliff; (11) main water channels and gullies. [2]

Figure 7. Jal Al-Zour escarpment in the Sabah Al-Ahmad Nature Reserve (S).

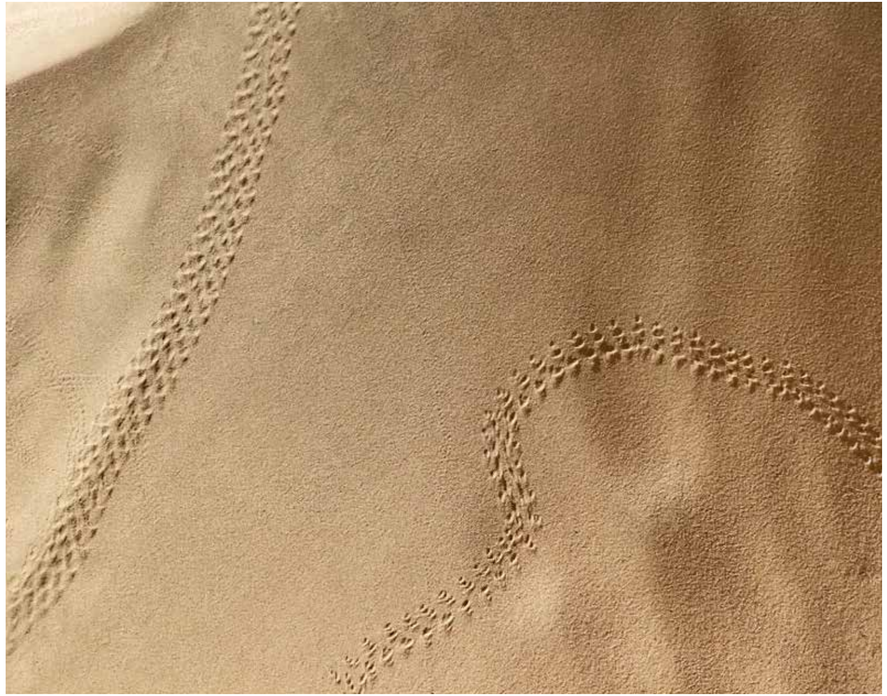

Figure 8. Animal tracks on Jal Al-Zour sand dunes (S).

3.4 Habitats and Bird Migration

Kuwait has a coastline exceeding 500 km in length including the islands coastal line. In terms of numbers of birds supported, this coastal region is very important. The very gentle slope of the land into and under the sea ensures that the tidal fall from high to low water levels exposes an intertidal zone of enormous area. A second significant factor is Kuwait's position at the head of the Gulf and adjacent to the great inflow from the Tigris and Euphrates rivers, which carry huge quantities of nutrients into the Arabian Gulf waters (Figures 9 and 10).

These waters provide an abundance of crabs, isopod crustaceans, mollusks, worms, and mudskippers, which provide sustenance for numerous birds. In the Sulaibikhat Bay subsystem alone in the southwest of Kuwait Bay, the shallow waters and more than 2250 hectares of intertidal mud flats provide support for thousands of seabirds and waders of more than 60 species.

Kuwait Bay itself is a shallow and well-sheltered body of water that provides an important habitat for overwintering, surface-feeding duck species, grebes, and coots. From December to March, it is common to see thousands of Wigeon, Teal, Shoveler, Pintail and Gadwall, along with Coot. Kuwait's northern waters are also host to the European Cormorant during the winter months; mid-winter counts indicate that the population is around 2000. The Greater Flamingo is also common in Kuwait Bay during the winter period, when around 1000 birds may be present.

Figure 9. Tigris and Euphrates rivers in Iraq (https://www.pinterest.com/pin/258394097350797830/)

Figure 10. Kuwait Bay and Islands of Kuwait [3]

Water birds, such as rails and crakes, winter over or occur on passage in marshland habitats. Little Crake, Baillon's Crake and Spotted Crake, along with the very secretive Water Rail, are common in spring and fall. Herons and egrets are also common passage migrants in spring and fall, and Purple Heron, Little Egret, Cattle Egret, Squacco Heron, Night Heron and Little Bittern have been recorded regularly (Figure 11).

City greenery parks and cultivated areas in Al-Abdaly at the northern border, in the central area of Al-Sulaibiyah and in the south at Al-Wafrah are usually surrounded by windbreaks of tall *Tamarix* trees that may reach 10 m or more in height, attracting a wide variety of birds (Figure 12). Several resident species are commonly associated with these areas, the most common being: the House Sparrow, which is adapted to building its nest in trees or in buildings; the Laughing Dove; and the Collared Dove. The White-cheeked Bulbul is also common in cultivated areas, urban parks and gardens.

Figure 11. Grey Heron (*Andrea cinerea*) in Kuwait (E)

Figure 12. *Tamarix aphyla* tree in Kuwait (S), important for bird nesting.

The most impressive of Arabia's desert plain habitats covered with shrubs is the Asian houbara (*Chlamydotis macqueenii*) (Figure 13), which used to be a regular winter visitor and breeding migrant. It used to be a favorite game bird for falconers, but the advent of four-wheel drive vehicles over plants and automatic shotguns led to the virtual elimination of this species in Kuwait.

The conservation efforts of KISR saved few numbers of this species in captivity at Kabd research station. The Stone Curlew and the Cream-colored Courser show similar behavior to the Houbara, in that they will often run away from danger rather than take flight; both are also hunted by falconers. They are now very scarce, but the Cream-colored Courser may breed in the far west of Kuwait in favorable years. The Sand grouse are also birds of open arid areas and two species, the Black-bellied Sand grouse and the Pin-tailed Sand grouse, are irregular winter visitors to Kuwait.

The Eagle Owl breeds in rocky gullies on the south side of Wadi AI-Batin. One or two pairs of Kestrels may occasionally nest on inaccessible ledges on Jal Al-Zour and a few pairs of Little Owls are still thought to breed in holes in the cliff faces (Figure 14). Small colonies of House Sparrows also breed high up in suitable holes and crevices in this area. In the extreme west of Kuwait, the most common nesting species is the Desert Lark, which builds its nest on the gently sloping sides of rocky or stony gullies.The islands of Boubyan and Warba provide breeding sites for a variety of seabirds. Boubyan and Warba Islands are not only important for Kuwait but are regionally and internationally recognized because they provide intertidal wetland foraging and nesting habitats for many threatened migratory waterfowl species.

Figure 13. Asian houbara (*Chlamydotis macqueenii*) in 2021, Kabd KISR (E)

Figure 14. Nesting owls in Jal Al-Zour cliffs (O)

Two other sites, Ras Al-Qayd and Ras Al-Barshah were selected as important habitats based on high densities of birds feeding within those areas. The other important habitat is the northern lagoons that attract many species of birds and fish. These lagoons were preserved by establishing Mubarak Al-Kabeer Nature Reserve in north Boubyan Island [5].

In addition, the coral islands of Kuwait's southern waters provide nesting areas for sea terns that arrive for the summer from the Indian Ocean. Umm Al-Maradim Island has small numbers of nesting terns, but Kubbar Island supports impressive colonies of four other species. In recent years, the White-cheeked Tern has become the most numerous, over 850 pairs nested on Kubbar alone. The colony size of Bridled Terns (Figure 15) has fallen from previous years to about 700 pairs, possibly because fires destroyed the vegetation under which this species nests.

A smaller colony of Lesser Crested Terns exploits an area of bare, hardened sand and may be as large as 240 pairs in some years (Figure 16). The least common is the large Swift Tern, which nests on the fringe of the colony of Lesser Crested Terns and usually numbers not more than 14 pairs on Kubbar Island.

Protected areas in Kuwait include both coastal and desert regions. Coastal protected areas, such as Sulaibikhat Bay and Al-Jahra Pond, were established to protect migratory birds. Desert protected areas, such as the Sabah Al-Ahmad Nature Reserve (330 km^2) and Al-Sulaibiyah Research Station at Kabd (40 km^2), are important for the protection of plants. Wildlife species, primarily reptiles, birds and a few mammals, benefit from the protected habitats in all areas.

Figure 15. Bridled Tern (O)

Figure 16. Breeding migratory Lesser Crested Tern at Kubbar Island, Kuwait (O)

3.5 Wildlife
3.5.1 Mammals

The Arabian Peninsula represents a bridge between Eurasia and Africa, allowing faunal interchange to occur. Subsequently, the fauna of the Arabian Peninsula shows a close affinity with both those regions. During the past two decades, studies of wildlife species in the Gulf region have increased. More areas were designated for the protection of endangered species, such as the Asian houbara (*Chlamydotis macqueenii*). The reintroduction of Arabian mammals, such as the gazelle (e.g., the "reem" *gazelle-Gazellasubuturosa*) (Figure 17) and Arabian onyx (*Oryx leucoryx*) are also part of this protection program. Common species are the Ethiopian Hedgehog (*Paraechinus aethiopicus*) and Red Fox (*Vulpes vulpes*) [6].

Other common species include rodents such as Indian gerbil (*Tatera indica*), Libyan jird (*Meriones libycus*), Euphrates jerboa (*Allactaga euphratica*), and Lesser jerboa (*Jaculus jaculus*) [6].

Figure 17. Reem gazelle at the Sabah Al-Ahmad Nature Reserve in 2009 (S)

Figure 18. Ethiopian Hedgehog (*Paraechinus aethiopicus*)

Figure 19. The Red fox, (*Vulpes vulpes*) (E)

Figure 20. The Red fox, (*Vulpes vulpes*) (O)

3.5.2 Insects

Kuwait has 578 species of insects, belonging to 414 genera and 22 orders. There are three species of apterygota, 113 species of exopterygota and 462 species of endopterygota [7]. More species were identified reaching 684 species in 2011 [8].

The largest order is that of beetles (*Coleoptera*) with 230 known species, then butterflies and moths (*Lepidoptera*) with 76 recorded species, followed by bees, wasps, and ants (*Hymenoptera*) with 71 species, and finally the locusts (*Orthoptera*) with 34 known species [7].

One of the most common insects in Kuwait is the ground beetle (Family: Tenebrionidae) . The most famous species is probably (*Trachyderma hespida*). This black beetle is omnipresent in houses and in the desert. Active during daytime, this beetle burrows the larvae and pupae beneath soil cover (Figure 21).

Insect collectors have focused on the locust. This is due to the ability of the locust to destroy living bushes and any available green grass, causing sheep to die by the hundreds. Locusts originate in Africa and migrate from Ethiopia to Yemen. From there, the swarms select one of two routes: either to Baluchistan and India via the southern Arabian Sea, or up to Hijaz Plateau and Najd Peneplain, along a northeastern tract to Kuwait.

Figure 21. The black beetle in the desert of Kuwait (S)

Two main types of locusts are recorded: the red-colored variety (*Anacridium aegypticum*) known locally as “yakhakha” and the common desert-yellow variety with brown markings (*Schistocerca gregaria*) known locally as “jarad”.

In addition to the locusts are the roller beetles, known locally as “Abu-Ja’al,” which appear after a good rain.

There are two ant species in Kuwait: the small, yellowish house ants (*Monomorium pharonis*) and the large, black ants (*Catayglyphis*), known locally as “abou”. There are several apiaries in Kuwait where honey is produced. Bees acquire nectar from caphor in the spring, siddr in the summer, and acacia in the winter [9].

There are two kinds of termites or “arda” (*Isoptera*) present in Kuwait: the small house termite (*Psammotermes hybostoma*) and the desert termite (*Anacanthotermes vagans*). Termites are social insects like ants and bees. Their community consists of a king, a queen, workers, and soldiers. The workers build the nest and the tunnels from soil and saliva to avoid heat and light.

Other recorded species include wolf spider *(Lycosidae spp.*) and Arabian scorpions (*Androctonus crassicauda*) (Figures 22 and 23). Bees are commonly found in gardens and parks (Figure 24).

Figure 22. Wolf spider (*Lycosidae spp.*)

Figure 23. Arabian scorpions (*Androctonus crassicauda*)

Butterflies vary with the time of year. During the winter, southern European species predominate, while in the summer, Indian and other Asian varieties move in. The most common variety is the painted lady (*Vanessa cardui*) (Figure 25), which is a regular migrant to Kuwait and is more abundant during the cooler months of the year (March and September). This butterfly is a strong flier and, even if settled on the ground, is difficult to approach. The adult is orange in color with black and white markings. Larvae are dark brown with short hairs, and feed on many kinds of vegetation. The pupa is initially green, later changing to a golden color. It hangs from the twigs of the host plant. Another butterfly, which is common in Kuwait, is the swallowtail (*Papilio demoleus*). This bluish butterfly has white markings and blue-white-red spots on the hind wing. It is found on citrus trees that the green larvae feed on. Their green pupae hang from the lower surfaces of leaves. This butterfly has a wide distribution from the Gulf eastward to China and southward to Australia.

Figure 24. Bee with pollen at Al-Dubaiyah (S).

Figure 25. Painted Lady (*Vanessa cardui*) (S)

3.5.3 Reptiles

Reptiles are common in the desert of Kuwait [10]. They dwell in shrubby areas or open deserts. Some common species are: Zarudny's Worm Lizard (*Diplometopon zarudnyi*); Mesopotamian Spiny-tailed Lizard (Saara loricata); Spiny-tailed lizard, Dhub (*Uromastyx aegyptius*); Arabian Toad-head Agama (*Phrynocephalus arabicus*); (Figure 27), Blanford's Short-nosed Desert Lizard (*Mesalina brevirostris*); Ocellated Bronze Skink (*Chalcides ocellatus*); Horny-scaled Agama (*Trapelus ruderatus*), and Arabian Toad-head Agama (*Phrynocephalus arabicus*); The Dhub is the largest reptile that is vulnerable due to hunting and degradation of habitats (Figure 26).

Snakes are found in irrigated farms and under desert shrubs. Some identified species are: the Arabian horned viper (*Cerastes gasperettii*); Arabian Sand Boa (*Eryx jayakari*); and Moila snake *(Mapolon moilensis*). Desert Monitor (*Varanus griseus*) which resembles the Dhub and snake together is usually seen in shrubby area where rodents such as the Jerboa burrow underground. The desert monitors are carnivores that feed on Jerboas, although the latter can run up to 24 km/h.

Figure 26. Spiny-tailed lizard (*Uromastyx aegyptius*)

Figure 27. Toad-head Agamid relaxing over (*Rhanterium epapposum shrub*) (S)

3.5.4 Birds

Passage migrants: During fall in the Palearctic region, many millions of birds migrate from their breeding grounds in Europe and Asia to Africa, Pakistan, and Indo-Malaysia. Most birds tend to fly at relatively high altitudes. Many species probably make uninterrupted flights across Arabia. However, unfavorable winds and poor weather conditions sometimes delay birds, which then stop and rest for a day or two before continuing.

Some migrants, especially birds of prey, rely mainly on soaring and gliding in thermals (rising currents of warm air). On occasion, up to 500 large raptors have been observed above Jal Al-Zour. In fall, the birds head for Hafr Al-Batin in Saudi Arabia. All observations along the Kuwait side of Wadi Al-Batin indicate that the larger birds of prey fly to the southern end of Wadi Al-Batin on their route to the Bab Al-Mendab strait, which separates the Arabian Peninsula from the Horn of Africa, crossing into Africa.

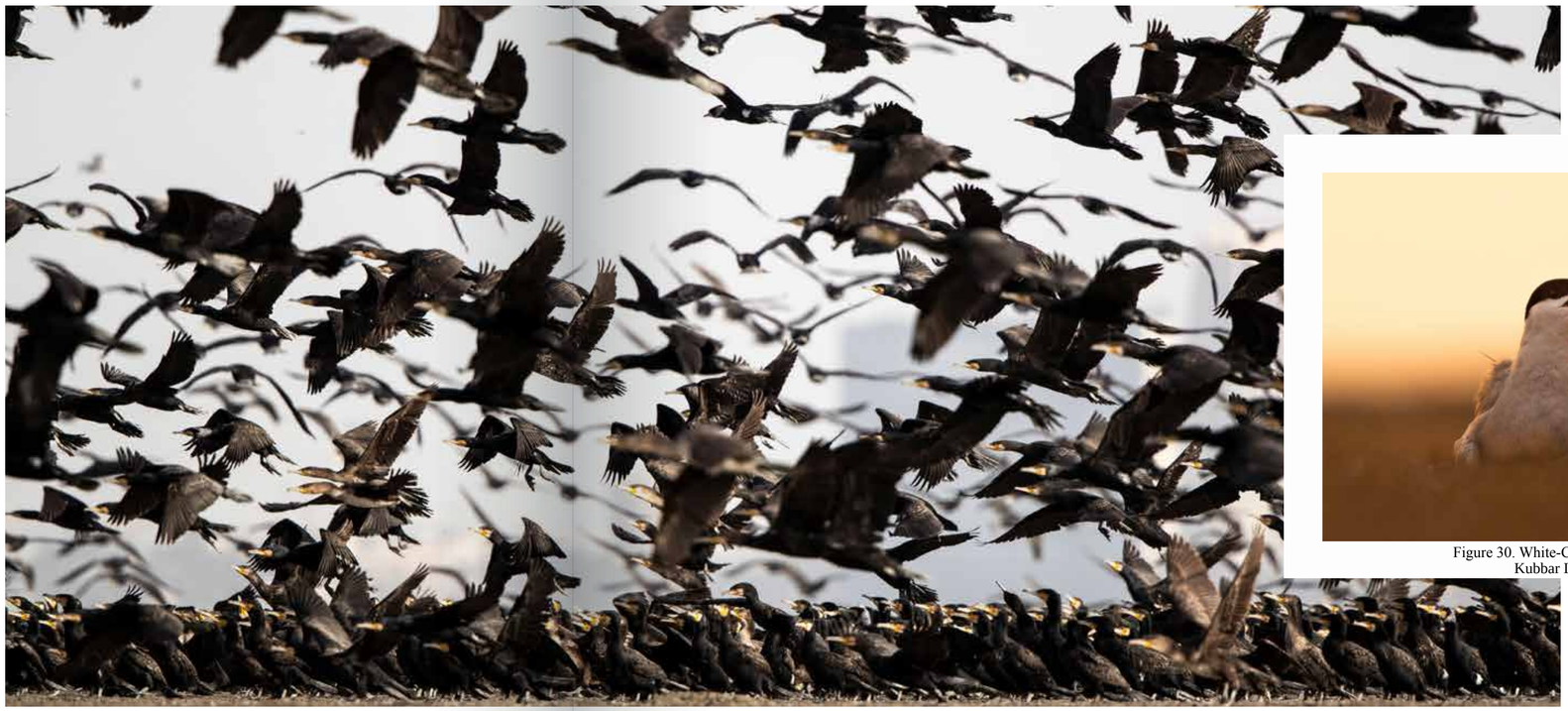

Figure 29. Great Cormorant flock (*Phalacrocorax carbo*) (O)

Figure 30. White-Cheeked Tern on its nest and pellets in Kubbar Island (*Sterna repressa*) (O)

Other species also clearly illustrate the migratory movement through Kuwait. In springtime, for example, it is possible to drive north from Al-Jahra to Al-Abdaly and become part of a continuous movement of hirundinids, such as Swallow and Sand Martin travelling northward parallel to the road. At Messilah, it is possible to watch thousands of Yellow Wagtails arriving at dusk from south and dropping into roost in the scattered vegetation along the coastal strip.

Winter visitors: During the northern winter months some species move southward to spend the entire winter in Kuwait's relatively mild climate. The most abundant of the wintering birds are those of the marine and coastal habitats, including grebes, herons, ducks, raptors, rails, waders, gulls, and terns [11]. The Great Cormorant (*Phalacrocorax carbo*) flocks in hundreds in the coastal southern shores feeding on small fish (Figure 28). However, owls, bee-eaters, larks, pipits, chats, thrushes, warblers, starlings, and buntings are also to be found during winter.

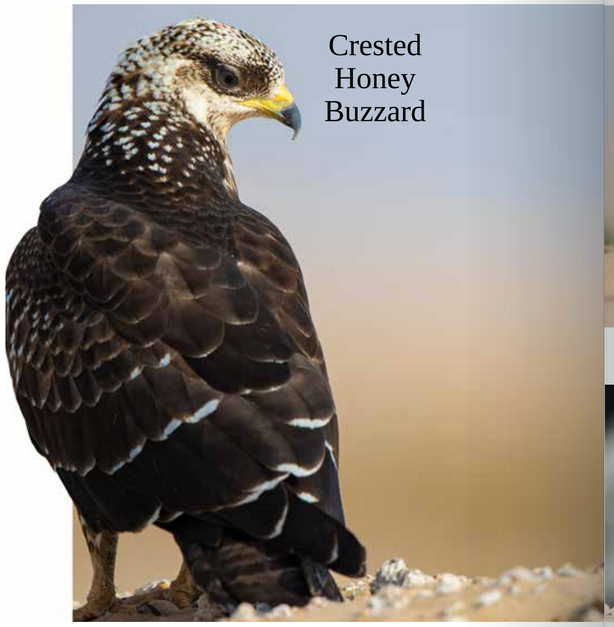

Figure 31. Crested Honey Buzzard (*Pernis ptilorhynchus*) (O)

Figure 32. Scarce and endangered passage migrant Egyptian Vulture (*Neophron percnopterus*) (O)

Figure 33. House sparrow - (*Passer domesticus*) (E)

Figure 34. Isabelline Wheatear - (*Oenanthe isabelline*) (E)

Figure 35. Northern Wheatear - (*Oenanthe oenanthe)* (E)

Figure 36. Great Grey Shrike - *(Lanius excubitor)*

Figure 37. Steppe Eagle (*Aquila nipalensis*) (O)

Figure 38. Pied Kingfisher (*Ceryle rudis*) (O)

Figure 39. Short-toed Eagle - (*Circaetus gallicus*) (E)

Figure 40. Greater Spotted Eagle (*Clanga clanga*) (O)

Figure 41. Western Reef Heron (*Egretta gularis*) (E)

Summer visitors: Despite the extreme heat and aridity of the summer, four species of sea terns remain in Kuwait: Bridled Tern, White-cheeked Tern, Lesser Crested Tern and Swift Tern, all of which arrive in Kuwait's waters from the Indian Ocean in April and May and depart in early September. There is only one perching species, the Rufous Bush-chat, which is regularly recorded as a summer visitor.

Residents: Of the 380 or so species, fewer than six percent are present all year. Only 10 species, Moorhen, Kentish plover, Collared Dove, Laughing Dove (Palm Dove), Eagle Owl, White cheeked Bulbul, Red-vented Bulbul, Graceful Warbler, Common Mynah and House Sparrow, appear to qualify as breeding resident.

Nomads: Several species comprising the avifauna of Kuwait are adapted to arid and semi-arid biotopes and some of these have traditionally been regarded as resident. Species that are noticeable by their periodic absences are the ground nesting species, Desert Lark, Hoopoe Lark, Bimaculated Lark, Crested Lark, Temminck's Homed Lark, and the Cream-colored Courser. Their absences usually stretch from the end of winter, through spring and summer, to late autumn.

Figure 42. Eurasian Sparrowhawk (*Accipiter nisus*) (O)

Figure 43. European Bee-eater (*Merops apiaster*) (O)

Figure 44. Whinchat (*Saxicola rubetra*)

Figure 46. Isabelline wheatear (*Oenanthe isabelline*)

Figure 45. European turtle dove (*Streptopelia turtur*)

Figure 47. Red backed shrike (*Lanius collurio*)

Figure 49. White-Throated Robin (*Irania gutturalis*) (O)

Figure 48. Common Myna (*Acridotheres tristis*) (E)

3.6 Desert Wildflowers

During spring, plants bloom abundantly, but only when protected from grazing with good rainfall during winter. Seeing abundant desert bloom is a sight that will never be forgotten. The once barren and dry soil becomes covered with a colorful patchwork of white, purple, red, yellow, and white flowers. Most spring wildflowers are annuals, meaning they live their brief lives in only a matter of weeks or months. They grow from sown seeds anew each year, and depending on last year season's conditions. Seeds of desert annuals are particular in their requirements. If the soil is moist, but the winter is too cold or too warm, they will not germinate. If the soil is too dry because not enough rain has fallen, they also will not germinate. Seeds need the right moisture and right temperature to germinate properly. They may remain dormant for years until the combination of moisture and temperature is just right to germinate for certain wildflowers but not for others. This strict requirement for desert seed germination ensures the seed of the right conditions to survive to maturity. Like spring campers, desert annuals leave the desert as soon as the weather turns hot during summer.

Figure 50. (*Echium rauwolfii*) showing anthers and stigma for pollination (S)

Figure 51. (*Moltkiopsis ciliata*) (S)

Figure 52. (*Lycium shawii)* (S)

Figure 53. (*Echium rauwolfii*) (S)

Figure 54. (*Tamarix aucheriana)* (S)

Figure 55. (*Mathiola longipetala)* (S)

Figure 56. (*Ochradenus baccatus)* (S)

Figure 57. (*Nitraria retusa)* (S)

Figure 58. (*Cyperus conglomeratus)* (S)

Figure 59. (*Lasiurus scindicus)* (S)

Figure 60. (*Senecio glaucus*) (S)

Figure 61. (*Gynandriris sisyrinchium)* (S)

Figure 62. (*Calligonum comosum)* (S)

Figure 64. (*Silene villosa)* (S)

Figure 63. (*Cenchrus ciliaris*) (S)

Figure 65. (*Farsetia aegyptia*) (S)

Figure 66. (*Cenchrus divisus*) (S)

Figure 67. (*Calligonum comosum*) (S)

Figure 68. (*Citrullus colocynthus*) (S)

Figure 69. (*Gagea reticulata)* (S)

Figure 71. *(Rumex vesicarius)* (S)

Figure 70. (*Anthemis desertii*) (S)

Figure 72. (*Ochradenus baccatus*) (S)

Figure 73. (*Calligonum comosum*) (S)

Figure 74. (*Cistanche tubulosa*) (S)

Figure 75. (*Lasiurus scindicus*) (S)

Figure 76. (*Ephedra alata*) (S)

The main purpose of flowers is to attract insects and other visitors that pollinate the flowers by transferring pollen from the anthers of one flower to the stigma of another. Most plants prefer cross-pollination by moving pollens between plants. Self-pollination is possible in the desert when pollinators are scarce. These pollinators are bees, wasps, ants, flies, beetles, butterflies, and moths.

Scientific names of plants are Latin or Greek names given to plants based on their descriptions. They have three parts. The first part, the genus name, corresponds roughly to a family name. The second part, the species name, corresponds to first name. The third part of every plant name is the authority or the surname of the botanist who first described the plant as a new species. Often the surnames are abbreviated. The scientific names used in this book incorporate the most recent nomenclature of plants without the authentications. Readers are recommended to refer to textbooks like the “Flora of Kuwait” or “Vegetation of Kuwait” for a complete nomenclature of plants [1] and [12].

Figure 77. (*Horwoodia dicksoniae flowers*)

Figure 78. (*Horwoodia dicksoniae*)

Figure 79. (*Convolvulus oxyphyllus*) (S)

3.7 Protected Areas in Kuwait

In the Fourth Master Plan of Kuwait, Kuwait Municipality designated restricted areas for the conservation of biodiversity. These areas are shown in green in (Figure 80). The Long border strip with Iraq shows the buffer zone in Wadi Al-Batin nature reserve with two adjacent protected areas: Al-Dibdibah (Wadi Al-Batin) in the southwest and Al-Huwaimiliah (Khabari Al-Awazem) in the northwest.

Other protected areas are Al-Liyah and Sabah Al-Ahmad Nature reserve in the north of Kuwait Bay. The northern section of Boubyan Island is designated for Mubarak Al-Kabeer nature reserve. In the south, along the border with Saudi Arabia, is Um-Gudair nature reserve. There are coastal and marine reserves in Jahra, Al-Khwaisat and Sulaibikhat Bay. These protected areas are designated to provide a sanctuary for wildlife species and plant communities to flourish naturally. They are usually fenced to exclude livestock grazing.

Most of the reserves have been established, however few remain to be initiated by PAAFR. These are: Khabari Al-Awazem (Al-Huwaimiliah) (Figure 81), Um-Gudair (Figure 82), and Wadi Al-Batin (Figure 83).

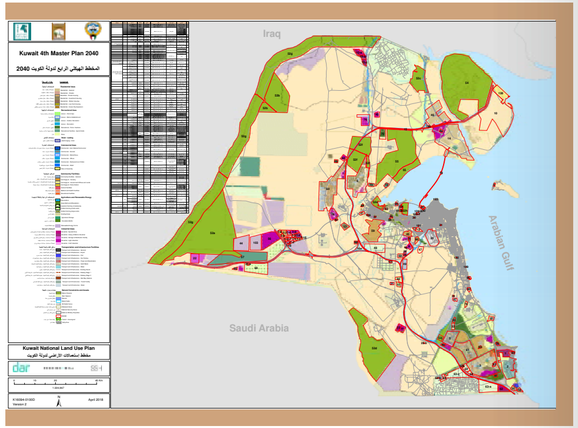

Figure 80. The Fourth Master Plan of the State of Kuwait.

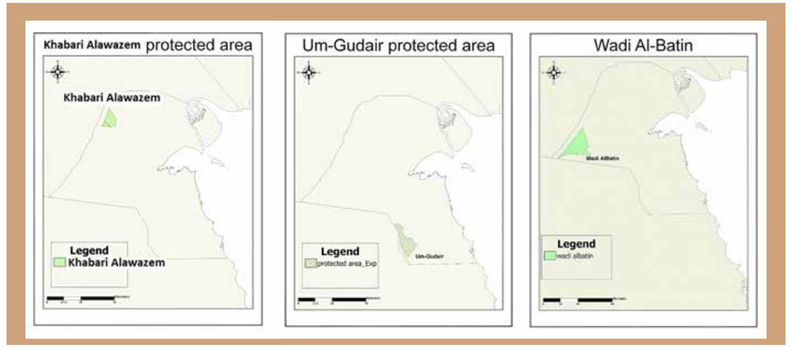

Figure 81. Khabari Al-Awazem (Al-Huwaimiliah) protected area

Figure 82. Um-Gudair protected area

Figure 83. Wadi Al-Batin protected area

Sabah Al-Ahmad Nature Reserve: This reserve is located in the north of Kuwait Bay (Figure 84). It is bordered in the south by Kuwait Bay, in the northeast by Al-Aujah, and in the northwest by Umm Al-Aish. The total area is 331.41 km^2. A chain fence that is 2 m high and 117 km long protects the reserve. The whole area is divided into two sections intercepted by the Al-Subbiyah road. The road links Jahra City, Al-Subbiyah and Boubyan Island. Along each side of the road, the reserve fence extends with two main gates allocated on each side, facing each other (like a mirror reflection). The two gates are considered the main entrances to the northern (desert) section and southern (coastal) section of the reserve area. There are also six other gates located at each side of the fence in the east, northeast, north, west, and southwest parts of the fence. The area of the desert section is 280 km^2, the coastal section area is 51.06 km^2. The fence along Al-Subbiyah road extends for 15.9 km and the shoreline extends for 14.4 km. The two main entrance gates are located adjacent to each other on Al-Subbiyah road.

Al-Liyah: Al-Liyah area is about 200 km^2 and located to the north of Al-Jahra City. This area is severely degraded as a direct result of gravel quarrying and associated activities during the last decades. Surface deformation, hydrologic disruption, soil losses, degradation of vegetation cover and deterioration of biological diversity are the main forms of land degradation in the mentioned area. Geomorphologically, Liyah area consists of three main landforms: undulated desert pavement; Liyah ridge; and hydrographic basins. The ground elevation of Liyah area ranges between 88 – 130 m above sea level.

Figure 84. Sabah Al-Ahmad Nature Reserve in Kuwait.

During the period of 2002-2008, a rehabilitation program was designed and implemented by KISR in cooperation with the Follow-up Security Decisions Committee of the Council of Ministers. The rehabilitation program started with ground levelling and refilling of excavations followed by fencing of the area. Plantation activity started at a later stage. Currently, at least 20% of the area has ecologically and environmentally recovered or on its way for good recovery.

Buffer Zone. The Buffer Zone (Demilitarized Zone) between Kuwait and Iraq was established by the UN in 1993-1994. It extends between Al-Salmi (southwest) and Umm Qaser (northeast). It has about 212 km length and average width of about 5km (total 1060 km^2).

Geographically, the Buffer zone is classified into several sectors, from southwest to northeast. These are:

- Al-Salmi-Abraq
- Abraq Al-Huwaimiliyah
-Al-Huwaimiliyah Abdaly
- Abdaly-Umm Qaser

A security system was established in 1995 by Kuwait after the Gulf War in 1991. This system consists of border trench, electric fence, and another trench (about 5km to the east of the border trench). Field observations conducted during 2008-2011 indicated the following:

During rainy seasons, e.g., November-December 2009, January 2011 surface runoff was blocked against bund walls. The trenches act as artificial water collectors for runoff water.

In certain segments, e.g., Al-Huwaimiliyah, parts of the border trench are severely encroached by sands.

Mubarak Al-Kabeer Nature Reserve: Boubyan Island covers an area

of about 1,200 km² (about 7% of Kuwait). The Island (Figure 85) is separated from the mainland (to its west) by Khor Al-Subbiyah (maximum 3 km width). It is bordered with Khor Boubyan (1.5-2 km width) from north and with Khor Abdullah from east (3 km width in Kuwaiti territorial waters). The southern fringes of Boubyan Island overlook the Arabian Gulf. Muddy beaches (about 2 km width) are developed at the eastern and southern coasts of the island. In the north part is Mubarak Al-Kabeer Nature Reserve, where many lagoons form attractive wetlands for migratory birds and rearing of important fish.

During summer, aeolian processes, which are represented by deflation prevail at the central and southern parts of the island as a direct result of the following factors:

- The drop of the shallow groundwater table, which results in the dryness of the top-soil (silt and clay of high potential erodibility).
- Prevailing of strong northwesterly winds.
- The surface sediments of Boubyan Island are composed of distinctly laminated and thinly bedded layers of aeolian silts and sandy to silty cohesive clay. The upper part is dominated by gypsum precipitation.

Figure 85. The Master Plan Development for Boubyan Island [5]

Figure 86. Artificial pods in Burgan area, KOC

Figure 87. Annuals during spring 2020. (S)

Figure 88. The national flower of Kuwait (*Rhanterium epapposum)* (S)

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Chapter 4

The Oil Fires and Kuwait Environmental Remediation Program (KERP)

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The Oil Fires and Kuwait Environmental Remediation Program (KERP)

4.1 Introduction

On August 2nd 1990, Iraqi troops invaded the State of Kuwait and remained until the country was finally liberated on February 26th, 1991. After the Gulf War, 798 oil wells in Kuwait were ignited, causing the largest environmental and ecological disaster in history [1]. Chapter 4 describes the impact of the Iraqi Invasion on the oil production sector during 1990-1991, and the detonation of the oil wells in the north and south of Kuwait. The environmental damage is presented with data and maps to show the extent of pollution on land. The reader will become aware of KERP and UNCC awards and decisions. In addition, the roles of the Kuwait National Focal Point For Environmental Projects (KNFP) remediation and KOC in the supervision and implementation plan of the largest environmental remediation program in the world are presented to demonstrate their responsibilities and contributions.

4.2 Background Information

The invasion of Kuwait in 1990-1991 caused severe damages to the environment. In some areas, the damage was irreversible if no action had been taken by Kuwait to alleviate, remediate or mitigate it. The world at large witnessed those damages when the dark skies caused by oil fire plumes covered the whole region. It took almost nine months before the last fire well was extinguished by the Government of Kuwait in collaboration with international expertise. KOC suffered great losses from the destruction of facilities, roads, and oil wells. The oil production facility, which is the main source of income for the country, was demolished. Oil pollution spread on land and sea. About 20-25 million barrels of ignited crude oil were extinguished using twelve billion gallons of seawater collected in artificial ponds to control the fire [2]. Crude oil spilled from the damaged oilwells across the land surface created “oil lakes” in depressions. The damage was beyond the capacity of the Kuwaiti Government to manage without the support of the international community [3].

Figure 1. Dark sky and plumes of oilwell fire in Burgan and extinguishing the well fires in collaboration with specialized companies.

The Kuwaiti Government approached the UNCC to compensate Kuwait for the implementation of the largest remediation and restoration program in the world. This resulted in compensating the State of Kuwait about USD$ 3 billion to remediate and restore damaged ecosystems in the marine and terrestrial environments [4] [5]. The approved remediation methods included application of technologies (e.g., bioremediation) and restoration (e.g., re-vegetation with native plants) that were already established by research institutions such as KISR. The knowledge and experience of KISR scientists helped in developing Kuwait Environmental Remediation Program (KERP) in collaboration with Kuwait National Focal Point (KNFP) and Public Authority for the Assessment of Compensation resulting from the Iraqi Aggression (PAAC). The role of KISR focused on assessing the direct impact of the Iraqi invasion on the environment of Kuwait and supervising the implementation of KERP [6].

Figure 2. Use of seawater to extinguish an oil well in 1991. Smoke, soot and tarcrete spread over the area for miles.

Figure 3. When the oil wellfires were extinguished, the environment was devastated. Damage on facilities caused more challenges to KOC to rebuild and alter the damage.

The Monitoring & Assessment (M&A) program implemented by KISR from 2001 to 2006 provided scientific evidence for the direct impact of military activities and environmental aggression (i.e., detonation of about eight hundred oil wells in 1990 -1991) [6]. KISR also worked with KNFP and the stakeholders (KOC and PAAFR) to develop projects and phase plans to UNCC in the period from 2011-2014 [7]. The outcome of these projects provided political assurances to UNCC to compensate the State of Kuwait fully for the implementation of KERP.

KERP is unique in the region and has been initiated by experts from local and international organizations and entrepreneurs. The establishment of entities (PAAC) and liaison body (KNFP) with the involvement of the stakeholders (KOC, PAAFR, MEW) and the contribution of scientific institutions (KISR and KU) all provided a unique governance for the implementation of this complex program under the supervision of the UNCC.

Figure 4. Kuwait KOC fire fighters who extinguished oilwell fires in 1991.

Figure 5. The late Crown Prince Sheikh Saad and on his left side H.H. Sheikh Nawaf Al-Sabah (the Current Emir of Kuwait) with members from the Government visited the site to observe extinguishing oil fires on 6th November 1991.

4.3 Oil Contamination Features

The damaged oilwells spilled crude oil across the land surface, creating distinctive features recognized as: wet contamination areas; dry contamination areas; oil-contaminated piles; and tarcrete material [8]. The "oil lakes" affected about 114 km^2 of Kuwaiti land in the northern (NK) and southern (SK) Kuwait oil fields [9]. The aerial deposition of crude oil that settled and accumulated on the land surface formed a solidified material of varying thickness, which resembles asphalt/tar on the surface creating what is known as "tarmat" or "tarcrete" (Figure 6).

Contaminated soil piles were generated during the recovery phase to stop the spread of crude oil over land. The oil pollution caused long-term and short-term impacts on soil, vegetation and wildlife and threatened groundwater resources and public health.

Figure 6. Dry oil lake and tarcrete mat in Greater Burgan area.

By 2004 [8], the contaminated soil volume was estimated in Greater Burgan at 24.4 Mm^3 and in Sabriyah/ Rawdhatain at 6.89 Mm^3. The extent of the contamination is shown on a map at scale 1:50,000 that was further reduced in Figure 7 showing 37,115 ha (66% of the total area) in Greater Burgan was contaminated by crude oil. In Sabriyah and Rawdhatain, it was 16,859 ha (54% of the total area) (Figure 8). The contaminated areas in both locations were divided into four map units (oil lake, dry oil lake, tarmat, and soot).

Upon closer inspection of the volume calculations, the dominant type of contaminated soil layer is 'oily soil'. In the Greater Burgan survey area, it formed 80.8% of the total contaminated soil volume (with 22.1% occurring in the "oil lake" map unit and 58.7% occurring in the dry oil lake unit), totaling 20.48 Mm^3. In the Sabriyah and Rawdhatain survey areas, it formed 83.7% of the total contaminated soil volume (17.7% in the oil lake map unit and 66.0% in the dry oil lake unit), totaling 5.56 Mm^3.

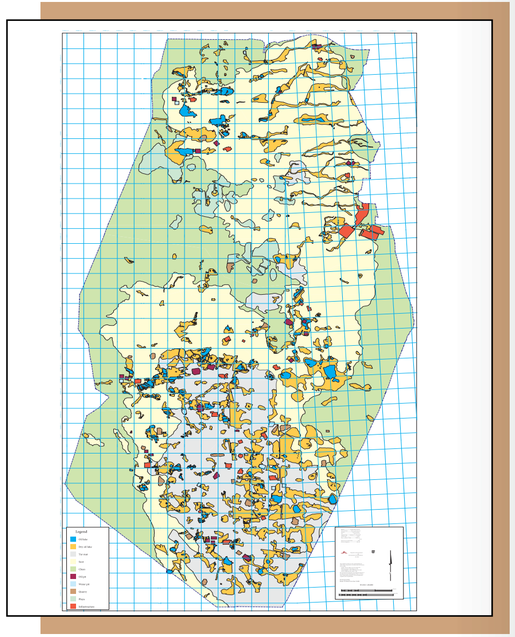

Figure 7. Contamination distribution map in Greater Burgan area (a reduced copy of 1:25,000 scale map) [8]

The other contaminated soil layer type in Greater Burgan was liquid oil, forming 6.0% of the total contaminated soil volume, then tarmat (tarcrete) 7.7% and soot 2.5%. In Sabriyah and Rawdhatain, it was liquid oil, forming 9.5% of the total contaminated soil volume, then tarmat 6.3% and soot 3.5% [8].

If remediation is an option, then the bulk of the contaminated soil to be dealt with has oily soil layer characteristics. In some areas, the oily soil is below a liquid oil layer that would also need to be ameliorated. Any method for remediation of the tarmat and soot would need to consider that they occur over an extensive area and form a thin layer (<1 cm) at the soil surface. More studies were developed several years later and showed specific features that are characterized in more details in Chapter 5.

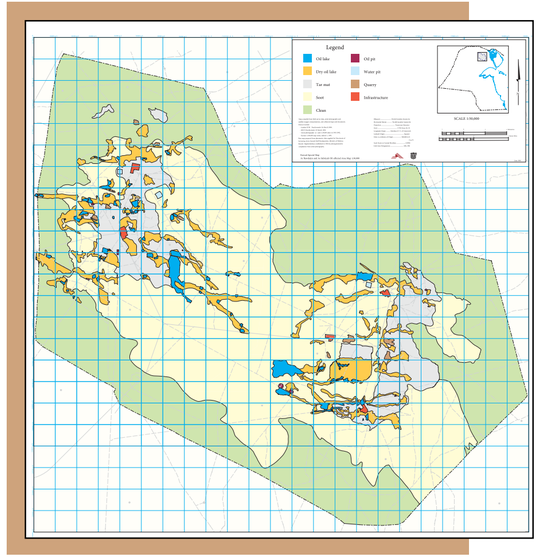

Figure 8. Contamination distribution map in Rawdhatain area, north of Kuwait (a reduced copy of the 1:25,000 scale map) [8]

4.3.1 Effects of Oil Contamination on Wildlife

Wildlife species in Kuwait such as monitor lizard, spin-tailed lizards (*Uromastyx* spp.) and many other reptiles, rodents (e.g., Desert Hedgehog) and mammals (e.g., Red Fox) live and monitor the desert as well as many bird species. Some of these animals were trapped and eventually doomed in the oil lakes while moving within or flying over the contaminated areas. Some of the wildlife species observed during the surveys of the oil lakes were reported as follows [8]:

"At the time of the survey (19th November, 2001), most of the oil lakes at Burgan Oil Field were drying up. Recent deaths of wild animals caught in oil lakes were observed on 22nd October, 2002, and on 23rd October, 2002. A Hooded Malpolon, (Malpolon moilensis) was observed trapped in an oil lake … and the next day, a Hen Harrier, (Circus cyaneus) was observed floating dead in an oil lake. This juvenile raptor was observed the previous day during the line transect exercise …. One important observation was of a Houbara bustard (Chlamydotis undulata) …. Other interesting observations were a short-nosed lizard (Mesalina brevirostris) and a darkling beetle (Blaps spp) observed predating on ants; also, a short-nosed lizard was observed eating a moth". Further studies on the impact of crude oil on wildlife is presented in Chapter 5.

Figure 9. Corpses of birds in a dry oil lake in Kuwait

4.4 Unexploded Ordnance (UXO)

4.4.1 Introduction

Oil pollution was not the only significant risk to KOC operations; the presence of millions of ammunitions, mines, and UXO (Unexploded Ordnance) spread over the country posed even more threats to humans, animals, and remediation efforts [9]. UXOs are major hazards which include ordnance items that have been fired, projected, dropped, or purposely armed and placed in such a way to go off. UXO posed the risk of injury or death to all personnel and contractors working in KOC premises.

The Kuwaiti Ministry of Defense (MOD), which is responsible for detection and disposal of UXOs, conducted an intensive assessment and survey for such ordnance in Kuwait. KOC contributed to developing a public awareness campaign on risks and threats of UXO. Posters were issued about the diverse types of mines and ordnances that could be encountered in the oil fields and distributed to field operational areas to alert all employees and contractors who worked in the oil field sites. Remnants of UXO beneath or within oil lakes remained a great threat to the remediation efforts of KERP [10, 11]. KOC's role in the remediation program required clearance of UXO and to develop UXO strategic plan as a basis for conducting the required UXO geophysical surveys, investigations, reacquisition of targeted subsurface anomalies, intrusive investigations, and the minimization of risk through removal of any threat of UXO prior to conducting KERP project soil remediation work [11].

4.4.2 Protocol for UXO Operations in KERP

The MOD maintained efficient Explosives & Ordnance Demolition (EOD) team capable of dealing with routine detection of UXO and mines at the country level [12]. KOC was aware that UXO and mines must be cleared prior to any intrusive remedial work in KERP for the protection of KOC workers and infrastructures. EOD and demining operations followed the guidelines in the International Mine Action Standards (IMAS), developed by the United Nation Mine Action Service (UNMAS). These guidelines included recommended procedures for demining and EOD. KNFP produced documents to provide all international guidance, protocols, and procedures for the performance of commercial explosive ordnance survey and disposal contracts for work conducted under KERP [13]. To remediate oil lakes in the NK and SK oil production areas, KOC had to develop a plan and a strict protocol to secure the safety of its workers and contractors. This required survey, mapping, and clearance of UXO in the hazardous areas to be remediated particularly the oil lakes, which was a big challenge.

4.4.3 Soil Remediation from UXO

KOC – Soil Remediation Group (SRG) was established in 2012 by KOC's Higher Management responsible for planning, design, and execution of remediation and restoration projects in KOC oilfield areas. Moreover, to accomplish the future agenda of KERP and SRG, it was important to ensure UXO clearance before remediation of the contaminated features. However, the presence of UXO remained a significant threat to personnel and property inside the oilfields.

Over the period starting 2012, UXO specialists detected and cleared a considerable number of several types of ordnances, which were dispersed in KOC oilfields in collaboration with MOD [14]. The UXO Program consisted of:

- Digital Geographical Mapping (DGM) and Battle area Clearance (BAC) survey of oil lake features, within the KOC properties in north and south Kuwait.
- UXO 100% coverage DGM survey and clearance and BAC of the source material areas for the initial remediation projects in the Rawdhatain and Greater Burgan oilfields.

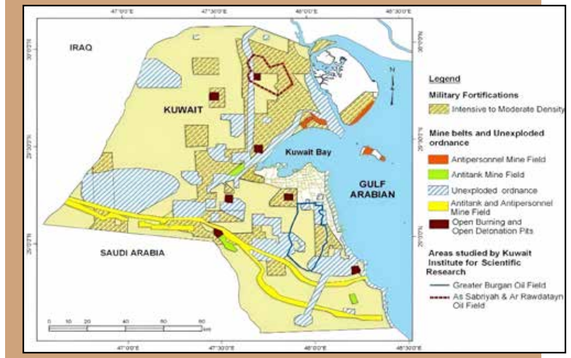

Figure 10. Distribution of Mines in Kuwait 1991.

The UXO Program activities supported the UNCC Decision 258, as it was related to the soil remediation requirements covered within UNCC Claim No. 454 (1) - Remediation of areas damaged by oil lakes, oil-contaminated piles, oil trenches and oil spills [15].

KOC supported by the Project Management Consultant (PMC) appointed a pre-qualified organization engaging field contractor (OEFC) to conduct UXO operation. The UXO program operation conducted by KOC was in accordance with KNFP/UNCC, Kuwait MOD, International Mine action Standards (IMAS), United State Army Corp of Engineer (USACE), Military Munitions Response Program (MMRP), internationally recognized DGM, and Kuwait Governmental Organization, protocols and procedures.

Figure 11. Mines and ammunitions left in the desert of Kuwait after liberation in 1991 [15]

Figure 12. Detection and clearance of UXO in oil contaminated areas prior to soil remediation operations at KOC premises.

4.5 Contributions of KOC to KERP

Under KERP, KOC is fully responsible for the planning and execution of the remediation and restoration projects in KOC oil fields. These areas are in the NK including the Ratqa, Rawdhatain, Sabriyah, and Bahra oil fields; and the SK including Greater Burgan, Managuish, and Umm Qudair oil fields. The Greater Burgan oil field comprised three district oil fields, namely, Al-Ahmadi, Burgan and Magwa.

To efficiently remediate the contaminated soil, a Total Remediation Strategy (TRS) was developed as a more environmentally friendly approach to replace the initial strategy by UNCC Decision, which required constructing a massive number of landfills. The TRS ensured remediation through more sustainable means and therefore reduced the number of landfills [16]. The TRS comprised alternative remedial solutions and relied on treating certain ranges of total petroleum hydrocarbon (TPH) contaminations with the most appropriate remediation techniques and evaluating and promoting remediation in areas where natural remediation is existing after several decades of the oil spill [17, 18].

The TRS utilized soil remediation technologies together with a reduced scope for soil remediation through the use of the risk-based approach (RBA) [2]. The RBA guidelines followed the International Petroleum Industry Environmental Conservation Association (IPIECA), which supports decision-making with management of impacts to soil and groundwater addressing potential exposure and risks, investigation techniques and readily available technologies from a site-specific assessment and/or corrective action plan. The remedial solutions that make up the TRS comprised the following four key elements:

1. Enhanced bioremediation.
2. Remediation treatment technologies.
3. Sludge disposal via beneficial re-use.
4. Engineered landfills.

The advantage of the TRS was that it was successful in meeting stakeholder objectives, remained compliant with the intent of the UNCC directives, and provided a flexible solution that was not reliant on the success of one element but the interaction of all the TRS elements. The TRS allowed KOC for a greater efficiency in the management of materials to prioritize elevated risk materials and limited unnecessary disposal of soil and high double handling cost.

Figure 13. Representatives from UNCC, KISR, KNFP, KOC and MOD discussing project plans for implementation of KERP at KNFP building in Kuwait (S).

Figure 14. Kuwait delegate at UNCC Geneva in 2005, represented by the Public Authority for the Assessment of Compensation resulting from the Iraqi Aggression (PAAC), the official entity responsible for the environmental remediation program chaired by Dr. Adel Omar Asem/Director General (DG) of PAAC, seated in the first row with Dr. Sabikah Al-Abdulrazaq/Deputy DG/PAAC.

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Chapter 5

Environmental Damages and Remediation Initiatives

Chapter 5

Environmental Damages and Remediation Initiatives

5.1 Introduction

After visually showcasing and exploring the environmental damages caused by the Iraqi invasion to Kuwait in Chapter 4, efforts taken to remediate and restore the environment are explored and presented in this chapter to allow the reader to understand the large efforts taken by KOC to return Kuwait's environment to its former state. Impact of oil pollution on soil, groundwater, vegetation, and wildlife species are shown in pictures and presented by data analysis. The remediation efforts of KOC in compliance with UNCC Decisions 258 are described and shown in photographs. Images before and after remediated sites are compared to document the remediation efforts. Successful stories are presented to show KOC efforts in the remediation of contaminated soils particularly the oil lakes and the restoration efforts to rehabilitate vegetation and wildlife species. Descriptions covering all stages from planning to implementation are presented to broaden the awareness of the readers on the magnitude of work conducted by KOC to remediate the oil damaged areas and contaminated soils. The monitoring plan for evaluation of ecosystem functioning and restoration measures are addressed with some data and images.

5.2 Oil Contamination Surveys

After the liberation of Kuwait on February 26th, 1991, the government set up an immediate action plan to extinguish the oil fires that spread in north and south Kuwait, causing massive destruction of the oil sector and pollution in land, air, and sea. KOC spent millions of dollars to rebuild its facilities. When the last fires were extinguished on the 6th of November, 1991, KOC started to assess soil contamination that spread over land. Several studies were conducted and reported as part of KERP that was submitted to UNCC for the environmental remediation awards. The oil contaminated areas were estimated at about 114 km^2 as shown earlier in Chapter 4. Estimates on the total volume of contaminated soil was about 26 Mm^3. This amount was further categorized based on the type of contamination as shown in (Figure 1) identifying six types of contaminations:

1. Contaminated Piles,
2. Dry Oil Lakes,
3. Wet Oil Lakes,
4. Tarmat/Tarcrete,
5. Wellhead Pits, and
6. Coastal Oil Trench.

In 2003, an analytical sampling survey in NK and SK was conducted by KISR using high-resolution satellite imagery (IKONOS) to produce preliminary maps (See Figures 7 and 8 in Chapter 4).

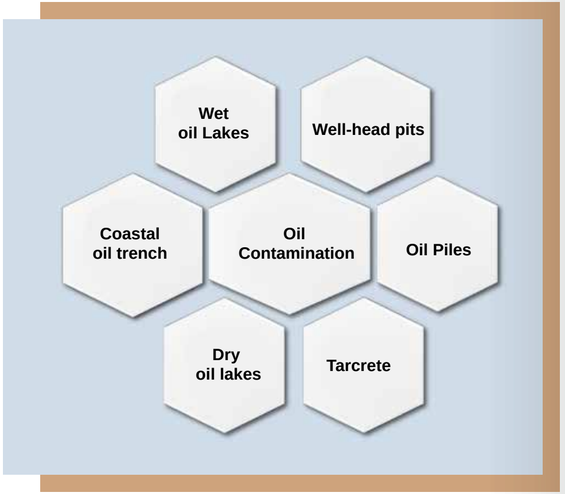

Figure 1. Types of Oil Contamination in oil production areas in Kuwait.

KOC conducted a sampling survey which involved collecting soil samples from nearly 1,300 sites at three depths/layers (layer 1, contaminated surface; layer 2, subsurface contaminated layer; and layer 3, the layer below all visible contamination). The mean total petroleum hydrocarbon (TPH) mg/kg concentration was measured using KEPA method 9071 in each type of layer for all categories of oil contamination. This preliminary investigation provided valuable information for understanding the extent of pollution in soil layers to prepare a remediation plan for submission to UNCC.

(Figure 2) presents the relative volume of each type of contamination showing a large volume of contaminated piles about 12.22 Mm3 followed by dry oil lakes (8.92 Mm^3). This damage altered desert soil properties and ecological landscape, which caused losses in native plants and wildlife in their damaged habitats. It was deemed necessary by KOC to characterize soil in the contaminated areas and to suggest remediation processes (e.g., landfill disposal, soil sludge treatment, and/or bioremediation).

5.2.1 Characteristics of Soil Contamination.

All contaminated features varied in type, area, volume, and depth of oil penetration. The following section shows soil characteristics of oil lakes and dry contamination areas [1, 2, 3, 4, 5, 6].

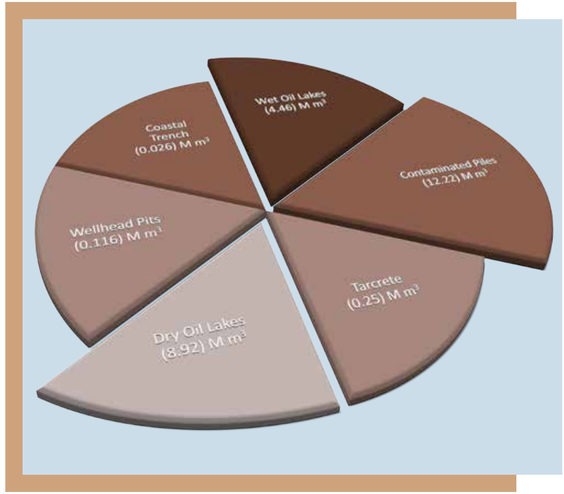

Figure 2. Quantitative estimate of contaminated soil for each feature in KOC premises.

5.2.1.1 Wet Contamination Areas

Wet oil lakes are areas covered with black liquid/sludge (highly weathered oil), sometimes covered by a thin hardened crust, and semi-solid oil saturated material resulting from oil flow damaged oil wells. Wet oil lakes occur in areas where large liquid oil accumulated because of local topography and micro relief (Figure 3). Oil lakes cover a surface area of over 7.18 km^2. Previous investigations revealed that the average depth of oil contamination in the wet contaminated areas is approximately 0.65 m below surface grades with an approximated volume of about 4.5 Mm^3. Sludge material has been found to contain mean TPH concentrations of more than 19%. The underlying contaminated soil is found to contain a mean TPH concentration of 3.4%.

5.2.1.2 Dry Oil Lakes Contamination

Dry oil lakes are areas covered with thin and moderately hard dry black tar layer. Dry oil lakes are generally found in shallow depressions and/or flat areas. They are without wet oily layers or oil sludge. Dry contamination areas cover almost 98 km^2 of the desert, with an average mean depth of approximately 0.27 m below surface grades. The surface tar material in areas of dry soil contamination is found to contain mean TPH concentrations of about 7.3%. Underlying contaminated soil is found to contain a mean TPH concentration of 2.5%.

5.2.1.3 Oil-Contaminated Piles

Contaminated piles are oil-contaminated soil collected as mounds. The soil piles were made to stop the spread of oil flows caused by the destruction of the oil wells or clear areas with heavy oil contamination during firefighting. Height of piles range from 0.45 m to 7.0 m and the estimated land coverage is about 8.6 Km^2 (Figure 4). Oil-contaminated pile surface materials are found to contain mean TPH concentrations of about 4.0%. The underlying contaminated soil is found to contain a mean TPH concentration of 4.6%.

5.2.1.4 Coastal Oil Deposits

The coastal oil deposit is an area with visible surface oil contamination and located in the supra-tidal zone north of Kuwait Bay. The oil filled trench is a man-made trench filled with crude oil and is approximately 1.4 km long with associated oil spills in the supra-tidal zone north of Kuwait Bay (Figure 5).

5.2.1.5 Wellhead Pits

Wellhead pits were constructed to store seawater used for fighting the oil well fires. Oil sludge and/or contaminated soil have accumulated at these pits from firefighting activities.

5.2.1.6 Tarcrete

Figure 3. Wet Oil Lake (S)

Figure 4. Contaminated oil piles in Burgan area (S)

Tarcrete is a solidified material which reassembles asphalt, and is a result of air borne pollution from the crude oil well fires that settled and accumulated on the desert surface. The tarcrete forms a crust of varying thickness across large areas of the desert and covers over 270 Km^2 of the desert (Figure 6).

Figure 5. Coastal oil trench in Al-Subbiyah, Kuwait

Figure 6. Tarcrete feature at Burgan (S)

5.2.2 Geotechnical Properties of contaminated soil

A research study was conducted in 2011 to assess the geotechnical properties of the oil lakes to find an alternative solution for their use. The study indicated that the impact of contamination is decreasing in time due to the evaporation of oil volatile compounds. Thus, the strength of the soil is increasing, and the compression decreasing over time. Hence, the contaminated soil showed some improvement in its geotechnical properties due to the aging effects and it is possible to use the contaminated soil for engineering purposes, road construction or building material [4].

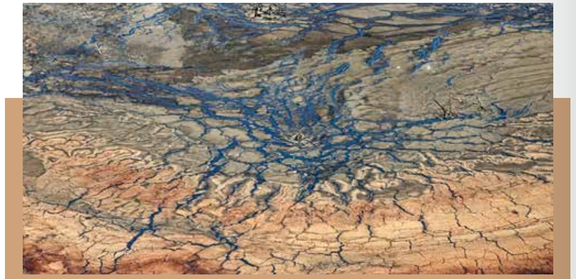

Figure 7. Upper view of an oil lake showing sludge and weathered layer affecting soil properties in time [4]

Figure 8. Dry Oil Lake at Burgan with physical and chemical characteristics of soil affected by the presence of oil [4]

5.2.3 Site Survey on wildlife

The impact of oil spills on wildlife species in Greater Burgan area is presented based on a detailed field study conducted on sand lizard (*Acanthodactylus scutellatus*) and its prey of local ants during 2002-2003. These were selected as an indicator species to monitor the effects of oil pollution and are found in abundance. Polluted sites with apparently different degrees of contamination (namely tarmat/tarcrete, soot, and clear sites) located at Greater Burgan oil field were compared with control areas outside this region in a study conducted in 2002 [7]. The authors mentioned that "*Five Acanthodactylus scutellatus* lizards from each study and control site were humanely killed and stored in a freezer at −20°C until analyzed. Ants from the same sites were also collected and treated in a similar manner. Lizard and ant whole body tissues were subjected to Gas Chromatography-Mass Spectrophotometry (GC-MS) to determine concentrations of HCs [hydrocarbons]". The study concentrated on sixteen PAHs, which are EPA priority pollutants used as indicators of petrogenic HC contamination. There were significantly different concentrations of total PAHs in lizards and ants among all four study sites. Of the 16 PAHs, phenanthrene, fluoranthene, and benzo[a]anthracene were present in both lizard and ant samples irrespective of the apparent degree of pollution, but were undetectable in materials from the control sites. The range of total PAHs in lizards was 26.5–301 ng g^{-1} and it was 6.7–82.1 ng g^{-1} in ants. Concentrations increased progressively along an expected contamination gradient. Total PAHs were detected in biota even in an area (clear site) that did not appear, virtually, to contain petroleum soil pollution which supports the value of indicator biota species. For all three sites where PAHs were found in biota, the ratio of total PAHs in ants to lizards was consistently 3.3–3.4. These authors concluded that, "*although 12 years have passed since the Kuwait oil spill catastrophe, all sites are still contaminated with PAHs. Use of lizard and ant materials in monitoring such desert locations seems to be an effective strategy* " [7].

Furthermore, in a second publication of the same authors [8] they mentioned that ten lizards (5 of either 6) on each polluted and each control site were observed in the field at a time of the year when they were highly active. Air, substrate, and burrow temperatures were recorded, and lizards were monitored for their morning emergence times, as well as their basking and foraging activities. The study confirmed that the morning emergence times and the basking behavior varied in sand lizards among the different pollution site categories. Physical changes in the tarmat sites caused the substrate temperatures in these locations to rise more quickly in the morning in response to solar gain than was the case in the other sites. This gives lizards in these locations the opportunity to emerge earlier and start eating more quickly, giving them an energetic advantage (perhaps, in turn, influencing their rates of growth and fecundity). The clear sites had the next earliest emergence and were the next hottest, but it is difficult to account for this in terms of the physical characteristics of this site.

The study concluded that: " *The basking times were clearly shorter on the dark soot and tarmat sites that appeared to have higher solar gain than control or clear sites. There did not appear to be any obvious differences in foraging activity of lizards in the different locations. It appears that some aspects of simple behavior in these lizards provides reliable, noninvasive indices for assessing oil pollution in desert locations. The precise impact of these changes in these reptiles on their long-term viability needs to be evaluated* " [8].

5.3 A Strategy for Remediation

KOC in collaboration with KISR, KU and PAAC provided scientific evidence on the damage to oil wells and the massive land pollution due to the oil fires. The UNCC agreed to compensate the State of Kuwait for the environmental damages and to remediate about 26 Mm^3 of soil by using available and well proven technologies, such as bioremediation, which was proven successful by KISR at a pilot scale after the liberation of Kuwait in 1992. The UNCC, KNFP and KOC cooperated in joint projects to remediate the oil contaminated soils in different categories/features. KOC was responsible for executing the soil remediation projects to address the UNCC environmental Claims numbered 5000259, 5000450, and 5000454, as described below::

Claim 5000259- Remediation of Marine & Coastal Resources - deals with all cleanup related to coastal and marine resources. Remediation and restoration were through excavation, transportation and landfilling of oily contaminated material from coastal oil deposits, coastal oil trenches and weathered oil layers.

The coastal oil deposits are in the supratidal zone north of Kuwait Bay. The coastal oil deposits surround an oil pumping station and portions of an oil pipeline which was the source of discharge of crude oil to coastal soils. The deposit encompasses an area of approximately 88,884 sq. m with contaminated soils.

Claim 5000450 - Remediation of Damaged Terrestrial Ecosystems (element 2-WHP, and element 3 Tarcrete) deals specifically with all remediation of areas in and around Wellhead Pits and Tarcrete. A total of 163 (65 in NK and 98 in SEK) geographically stretched across Rawdhatain, Sabriya, Burgan and Magwa oil fields needed to be cleared from contaminated soil.

Claim 5000454 - Remediation of areas damaged by Oil Lakes, Oil Piles and Oil Trenches 5000454 is designated for remediation of areas damaged by Oil Lakes, Oil-Contaminated Piles, Oil Trenches and Oil Spills, and Revegetation. Claim 454 -1; focuses on the remediation of areas damaged by crude oil spills of KOC's oilfields in the form of wet oil lake (WOL): crude oil flow from damaged oil wells and pipelines accumulated in shallow topographical depressions and drainage channels resulting in what is referred to as wet oil lakes.

Dry Oil Lake (DOL): areas covered with a thin and moderately hard dry black tar layer overlaying hydrocarbon contaminated soil. Oil Contaminated Piles (OCP): man-made mounds of soil that are contaminated with crude oil, these piles were made by firefighting teams in an effort to stop the spread of oil flows caused by the destruction of oil wells.

Claim 454-2 addresses the re-vegetation of features that are remediated under Claim 454-1; i.e. WOLs, DOLs, and OCPs.The re-vegetation scope restored plant cover, ecosystem, and provided sustainable environment to local wildlife, equivalent to 1990 status. Native species were used in the revegetation of the cleared areas.

In 2012, KOC established the Soil Remediation Group (SRG) to plan, design and execute remediation and restoration projects in KOC areas (Figure 9). UXO specialists were assigned to clear various types of ordnances dispersed in KOC oil fields. A more sustainable remediation strategy was developed by KOC's PMC known as TRS (See Chapter 4). This strategy aimed to minimize the need to construct 17 landfills initially planned to reduce the overall landfill capacity from 26 Mm^3 to 5.3 Mm^3. The Total Remediation Strategy (TRS) relied on treating certain ranges of TPH contamination with the most appropriate technique.

Figure 9. Soil Remediation Group (SRG) of KOC with UNCC representatives (2012)

The PMC (AMEC) with KOC planned the following five-steps strategy (Figure 10) that is based on understanding contamination concentrations, toxicology, potential migration and exposure pathways and modeling this for receptor groups to minimize unnecessary remediation [9]:

1. Risk Based Approach (RBA) to be conducted by sampling and assessing marginal TPH contamination utilizing internationally recognized assessment models. Acceptable TPH concentrations for human health and environmental receptors shall be determined.
2. Active/enhanced bioremediation– soil contaminated with 'low end' TPH concentrations shall be addressed with enhanced active bioremediation. This remedial solution is a robust, well proven, and cost-effective approach to address high volumes of oil contaminated soil, demonstrated in the past to be effective in desert environments.
3. Remediation treatment technologies – used to treat more challenging TPH concentrations, to address potentially 20% of the total volume of contaminated soils. Sustainability is one criterion for selection of treatment methods.

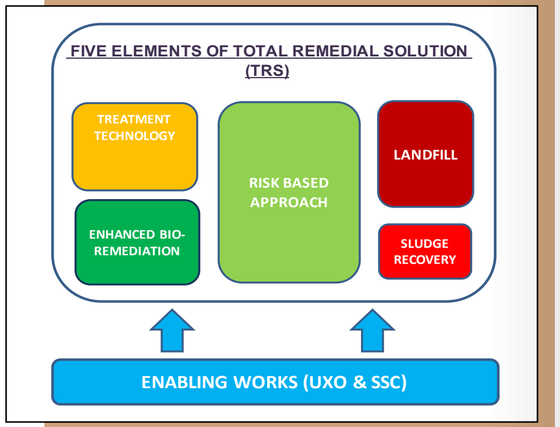

Figure 10. The five steps in the strategy to remediate contaminated soil [9]

4. Sludge disposal through beneficial recycling or re-use – oil sludge is the most challenging source contaminant to be addressed and it represents potentially 20% of the total volume. Treatment is highly energy intensive and comes at high cost and low through-put. The approach for sludge includes identifying a disposal outlet through a re-use/recycle option. This will rely on separation from wet-oil lakes and temporary storage without mixing. Market assessment and construction of temporary storage forms are part of this solution.
5. Containment in engineered landfills – this is the default position that matches UNCC existing strategy but for the most challenging TPH contamination concentrations only. Any material that requires consignment to landfill will have measures put in place to minimize volumes requiring disposal.

These steps in the strategy were supported by parallel activities that include SSC through data acquisition and clearance of UXO. The most important aspect is to ensure that large areas are cleared of UXO to provide the volumes required.

Figure 11. Looking ahead for the strategy to remediate contaminated soil (S)

5.4 Execution of the Remediation Strategy

The revised KERP strategy entitled TRS was implemented in 2014. The strategy gets revisited each year as more information becomes available to continually streamline the KERP program. (Figure 12) shows the estimated cumulative volume of remediated soil over time. So far (2022) the following have been completed.

- Construction of two (2) engineered landfills (capacities -1.7 Mm^3 and 575,000 m^3).
- Excavation, transportation, and filling of contaminated materials into the two landfills.
- UXO Phase 1 survey for 114 km^2 & clearance on priority areas was performed by implementing appropriate and proven digital geophysical mapping (DGM) technologies.
- Bioremediation of SEK 1 to treat about 300,000 m^3 of contaminated soil.
- SSC Project: to acquire up-to-date information on the site wide soil characteristics for NK and SEK oilfields. Soils and groundwater samples were collected with soil descriptions, elevations, and photographs from each location to provide data for re-evaluation of contamination source feature volumes; for future remediation design; and for risk assessment as part of the overall RBA. The data collected is a critical path activity which underpins future KERP projects.
- RBA: Development of a contaminated land risk-based approach utilizing internationally recognized risk assessment models to derive acceptable risk criteria for human health and environmental receptors.
- Remediation of NK will be addressed to the entire remaining portion of contaminated features i.e. approximately 4 Mm^3. The remediation treatment consisted of bioremediation, treatment technologies and engineered landfill.
- Remediation of SK, consisting of UXO, Excavation & Transport, Bioremediation, Treatment technologies and Landfills.

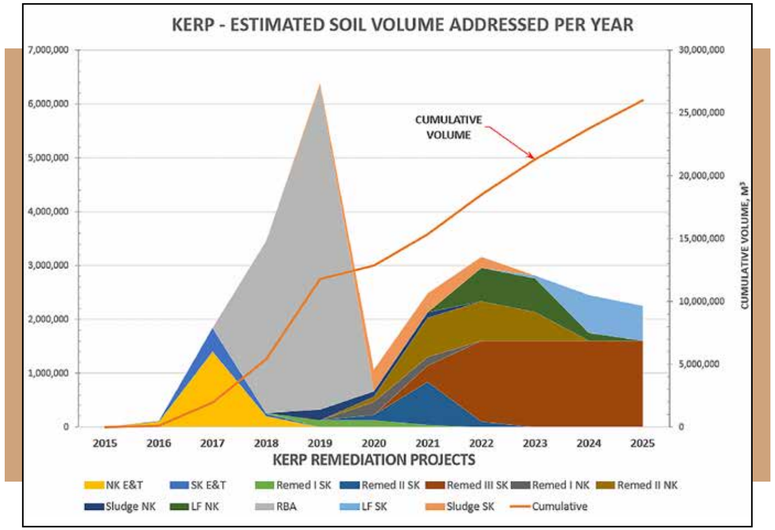

Figure 12. Project plan over a decade for the remediation of contaminated soil by KOC (2015)

5.4.1 Construction of landfill facilities for hydrocarbon contaminated soil (2014-2018)

Two engineered landfills were constructed, one in NK, with a capacity of 1.7 Mm^3 and another in SK, with a capacity of 0.6 Mm^3. About 1,700,000 m^3 of contaminated soil was transported and contained into the NK landfill and about 580,000 m^3 of contaminated soil was transported and contained into the SK landfill. The objective of these early projects is to remove oil contaminated soil from the recharging aquifer areas in Um-Al-Aish oil field in NK and in certain areas in SK, which are considered as a priority for future KOC developments. In the future, it may be required to construct a limited number of landfills to host non-treatable or non-reusable soils. Major components of the landfills include single composite liner over an artificially established geological barrier, leachate collection system, closure, or capping system (geo-membrane liner, soil, gatch, and gravel), leachate management comprising collection system with perforated pipes, sumps and submersible pumps, and gas venting system as shown in (Figures 13-18).

5.4.1.1 Amount of contaminated soil transferred to the landfill for each feature:

The following table shows the amount of excavated soil transported to the landfill based on the type of feature.

Type of Feature	Amount of transferred soil to the land fill in m^3
Wellhead Pits	223,313
Oil Contaminated Piles	235,277
Wet Oil Lake	988,537
Dry Oil Lake	809,781
Coastal Trench	6,626
Coastal Deposit	32,800
Total	**2,296,334**

Figure 13. Lining base of Land Fill in the SK Oil production areas.

Figure 14. Early stages of landfill construction and filling in the North area of Kuwait (S)

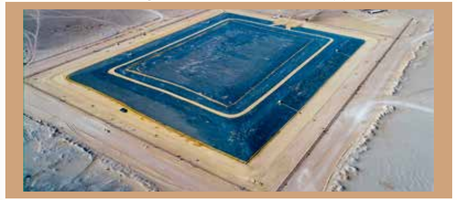

Figure 15. Capped landfill in the south east of Kuwait in 2021

Figure 16. Filling oil sludge after lining SK.

Figure 17. Construction of landfill in SK.

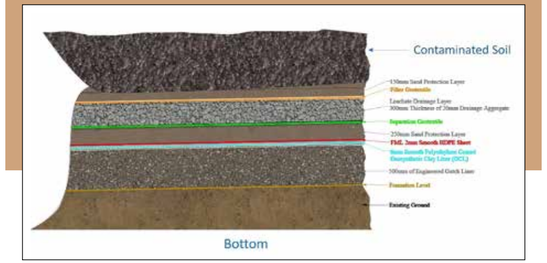

Figure 18. Cross section of landfill base lining system (KOC).

5.4.2 UXO Management

The process of surveying and clearance involved multiple steps and quality control checks that were important, yet time and labor consuming. It was clear that the remediation project works could not be started prior to the completion of the UXO clearance activities and once the proper clearance certificates were issued by the concerned authority. This has taken considerable time for the implementation of the projects. A special safety protocol and techniques were developed by experts in the remediation team. Thus, prior to project commencement, a UXO protocol was developed and applied in KERP in accordance with International Standards, enabling safe implementation of UXO clearance and remediation activities.

The UXO were removed and detonated by specialized experts in collaboration with the Ministry of Defence staff. Once the sites were declared clean from mines and munitions, then the remediation team would start safely.

This resulted in full safety of the remediation team and no injuries or casualities occurred.

Within the oil-contaminated area, clearance of UXOs was initially limited to dry areas, and because of difficulty of access, there were no clearance certificates for the wet oil lake features. Due to the non-clearance of wet oil lakes and the depth of excavation in oil contaminated dry-areas and sand shifting, all areas were subjected to further UXO surveying and clearance to ensure the safest possible conditions for operations and employees.

UXO has been one of the main challenges in KERP Projects. About 517 UXO items and 34,830 small arms ammunition and pyrotechnics were found, identified, and disposed of under KERP.

Figure 19. Detection and Clearance of UXO with experts at the contaminated sites.

5.4.3 Selection of Proven Technologies

The approved TRS designated treatment bands across the contamination spectrum and the selection of the proven technologies were to be optimized according to those TPH bands. This required sustainable technologies of the highest caliber that were fit to meet project schedule and remediation approach (Figure 20). Example of Remediation Target Criteria (RTC) approaches depending on level of soil contamination (%TPH) and RTC are listed as follows [10], [11].

- Remediation of contaminated soil with 1-5% TPH level to achieve 1% RTC (10,000 mg/kg) by bioremediation.
- 1-2% passive bioremediation by enhanced natural attenuation via backfilling of abandoned gatch pits with contaminated soil TPH (1-2%) and addition of nutrients plus bulking agents and water (15%) to enhance and accelerate natural biodegradation processes. No RTC to be achieved.
- Bioremediation or TTs for soil with 5-7% TPH level to achieve 1% RTC (10,000 mg/kg).
- TT for contaminated soil greater than 7% TPH by utilization of different remediation/treatment technologies or a train of different methodologies except thermal. RTC to be achieved is 1% (10,000 mg/kg).
- Oil sludge recovery for contaminated soil with TPH greater than 15% from deep wet oil lake with no RTC to achieve using a combination of extraction system followed by a recovery unit to enhance the characteristics of the oil to be reused in gathering centers processes (Figures 21-23).

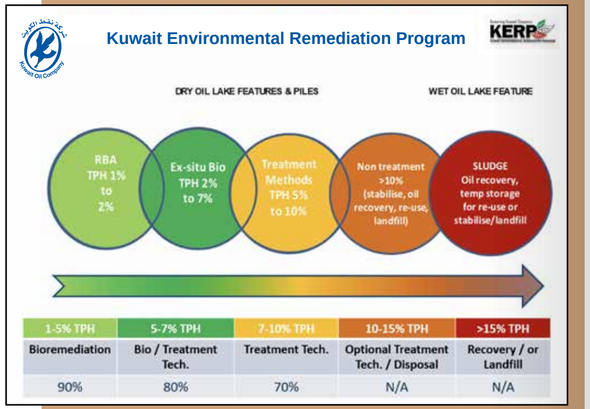

Figure 20. KOC approach in remediation of contaminated soil.

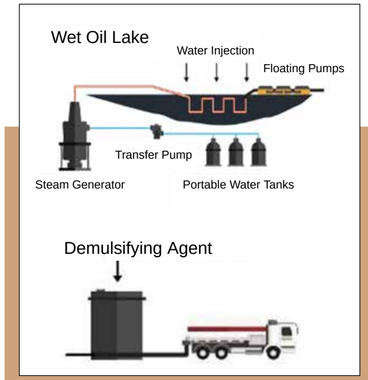

Figure 21. Oil sludge extraction method.

Figure 22. Recovered oil in storage tank.

Figure 23. Technologies for remediation of contaminated soil with crude oil [12]

5.4.4 Remediation achievements

The KERP award for claim 5000450 was achieved successfully using proven technologies and landfill methods. Up to early 2020, KOC executed the following projects, which were completed in Dec. 2018 [10] (Figures 24-35).

NK Excavation & Transportation Project (1.7 Mm^3 of contaminated soil removed and total cleared area 5 Mm^3).

- SEK Excavation & Transportation project (0.5 Mm^3 of contaminated soil removed and total cleared area 1.2 Mm^3).
- NK Landfill project (capacity -1.7 Mm^3).
- SEK Landfill project (Capacity -0.5 Mm^3).

In addition to the above projects, under the implementation of UXO clearance projects in NK and SK oil fields, KOC plans to remediate about 20 Mm^3 of contaminated soil.

- NKETR project with a volume of 4 Mm^3.
- SKETR project with a volume of 9 Mm^3.
- SKETR II project with a volume of about 0.5 to 7 Mm^3.

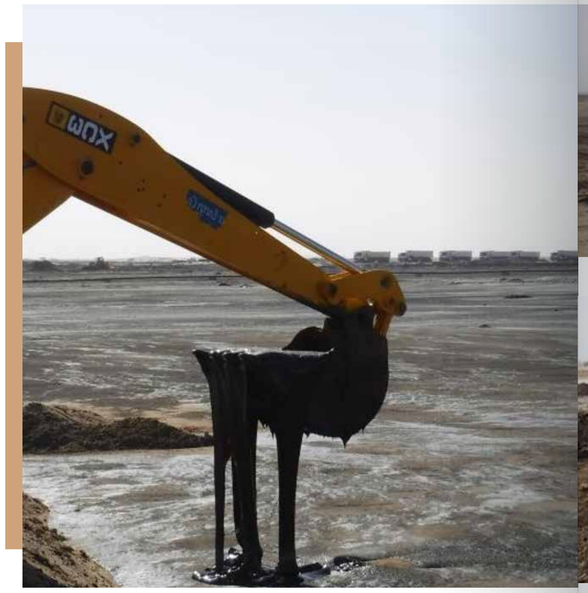

Figure 24. Wet oil lake before remediation (2016)

Figure 25. The same oil lake after remediation by KOC in (2020).

Figure 26. Dry oil lake contaminated area before remediation.

Figure 27. Dry oil lake after remediation by KOC.

Figure 28. Oil contaminated pile before remediation.

Figure 29. Oil contaminated pile after remediation.

Figure 30. Coastal oil deposit before treatment.

Figure 32. Wellhead pit before remediation

Figure 34. Excavation of oil contaminated soil

Figure 31. Coastal oil deposit after treatment.

Figure 33. Wellhead pit after remediation.

Figure 35. Oil Lake before remediation showing Tell Wara in the back.

5.5 Long-Term Monitoring

Monitoring is an essential part of any remediation/restoration program. It provides critical information to evaluate the extent of the success of the remediation and restoration efforts. It also provides the opportunity and flexibility to modify interventions undertaken to ensure a more effective return to the pre-disturbance structure and function of the ecosystem. Subsequently, the monitoring plan aims to achieve this through carrying out well-designed monitoring protocols and considering various indicators for the ecosystem structure and functions.

The UNCC Decision 258 required a long-term monitoring plan that collects relevant data before, during and after remediation or restoration activities to be carefully integrated into the remediation project. During remediation, activities should be adapted in response to data and analysis developed through such a monitoring program. This provides opportunities to identify and address negative impacts of remediation activities if any arise. It also assists in identifying successful remediation or restoration approaches. The criteria for the evaluation of the remediation or restoration project were specified before the completion of the monitoring program. The planning team had to consider carefully how data is collected by the monitoring program, how it is used to evaluate and, where appropriate, alter remediation decisions. For quantitative indicators of ecological conditions, an advanced and appropriate sampling approach was used on the basis of the statistical comparisons method.

5.5.1 Monitoring Approach

Two types of monitoring activities are carried out as part of this monitoring plan. These are compliance monitoring and surveillance monitoring.

Compliance Monitoring. The target of compliance monitoring is to ensure that the quality and/or quantity of the environmental component, within the specified level or acceptable limit/endpoints, following the remediation measures. For example, in the case of 5000454 claims, compliance monitoring has been made during excavation, technology treatment, and landfill activities. Monitoring carried out by the field contractors who will oversee the remediation activities. However, KNFP/KISR are conducting independent monitoring for verification purposes to ensure compliance with F4 requirements, in terms of the effectiveness of the remediation and acceptable environmental impacts.

A detailed compliance plan and related TOR, for the compliance monitoring of remediation/restoration projects. was developed to guide the contractors on the monitoring requirements, considering pertaining UNCC guidelines and the relevant national environmental regulations enforced by KEPA.

Surveillance (Long-term) Monitoring. Surveillance (long-term) monitoring is used for characterizing the ecological functioning of the terrestrial ecosystem, and for the chemical characterization of groundwater aquifer to assess the restoration of the aquifer system because of the remediation measures.

A multi-perspective approach was applied and integrated to achieve effective monitoring and assessment of the targeted ecosystems under restoration.

This approach includes the use of remote sensing and interpretation of satellite images, as well as ground surveys, following an ecosystem-based approach that incorporates multiple essential components of the system (groundwater quality, hydrology, sediment dynamics and quality, atmospheric deposition, terrestrial, biological, chemical and physical indicators). Selected monitoring indicators are measurable, appropriate to the spatial and temporal scale of disturbance/contamination, standardized, and diagnostic with respect to the potential cause. A list of the relevant indicators is given and described in the relevant monitoring component of the plan.

Surveillance monitoring was carried out at three stages: before; during; and after restoration activities. The first-year surveys to collect baseline data was carried out to provide ambient or historical environmental conditions against which subsequent monitoring data would be compared. Subsequent monitoring surveys were made in the following years based on the remediation/restoration projects implementation status/progress and results obtained from the baseline/first year survey. Reference ecosystem (sites) that would serve as a model for planning and implementing the monitoring activities were included in these surveys. The identification of these reference sites for Ecosystem Functional Monitoring is considered based on several factors including, among others:

- Soil properties: The soil characteristics will be the primary criteria. Soil types like contaminated surfaces to be rehabilitated will be identified for the reference site.
- Geomorphic setting: The oil lakes and contaminated surfaces have often occupied the topographic lows. It is recommended that the reference sites should be in the same geomorphic unit as the contaminated surface, i.e. if the contaminated surface is within a paleo-channel, the reference site should also be within the similar geomorphic unit. The reason is that it will have similar porosity, permeability, infiltration and, most probably, similar soil moisture content.
- Geological formation: The geologic formation is not a very important factor, but consideration of lithostratigraphic units will give an idea if there are gatch layers and impervious surfaces.
- Depth to water level/table: Reference sites should have a similar depth to the water table as the contaminated surfaces.
- Proximity to the contaminated surface: Proximity to the contaminated site will assure that the monitoring and the contaminated sites have been in the same environmental milieu. The dust phenomena, precipitation, and soil moisture will be comparable.

Several reference sites were provisionally identified and will be further verified on the ground during the initial data collection survey activity of the relevant claims.

5.5.2 Groundwater Monitoring

Many studies were conducted to assess TPH levels in areas contaminated with oil lakes particularly in the Northern region where freshwater aquifers are commercially produced (in Rawdhatain and Umm Al-Aish). One of the studies used advanced data analysis and visualization software (EVS-Pro) for groundwater contamination assessment analytes: TPH and TDS. This method was used to reduce the number of samples needed (saving time and money) and provides a superior assessment of the analyte's distribution [11]. Long-term monitoring of the landfill in the north and south of Kuwait by KOC is being carried out to make sure that the landfill has no negative impact on the groundwater. Another study used Conceptual Site Model (CSM) to assess impact of tarcrete on groundwater, which is a presentation of chemical and biological conditions and the processes that control the transport, migration, and potential/actual impacts of groundwater contamination on human health and/or the environment by evaluating the linkage between a release of a chemical from a source, a transport or exposure pathway and the exposure to uptake of the chemical contaminants by the receptor [13]. This is illustrated in the (Figure 36). Results of the modeling determined that the potential risks to the fresh groundwater resources from tarcrete deposits are interpreted to be very low due to various factors; such as significant unsaturated zone thickness, low mobility of the hydrocarbons constituents within the subsurface material and further attenuation provided by surface dilution. Subsequently, tarcrete impacted material do not pose risks to fresh groundwater resources and remedial action to remove and remediate the tarcrete from this area is not warranted.

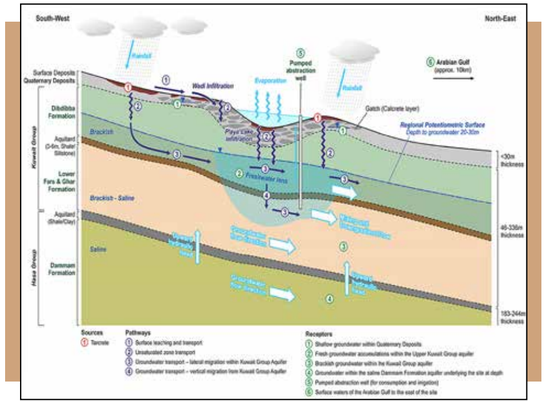

Figure 36. Source-pathway-receptor Conceptual Site Model (CSM) for groundwater monitoring [9]

5.5.3 Landfill Monitoring Components & Benefits

Regular monitoring of the various components of the physical environment of landfills is conducted to provide an early warning of potential liabilities, reduce operational costs and retention of records (Figures 37 and 38). The PMC carries out quarterly inspections for the following:

1.SITE INFRASTRUCTURE

- Inspect and maintain the integrity and effectiveness of final cover - repairs to the cover, correct settlement, erosion, prevent run-off and damages, maintain and clean drainage system, slopes, ditches, roads, etc.
- Inspections and maintenance of the fence, gates, windsocks, solar panels and electrical systems, batteries, generators, lighting, and other equipment.
- Inspect and perform required maintenance/replacement of fire extinguishers.

2.ENVIRONMENTAL WORKS

- Maintain leachate collection system and leachate monitoring to demonstrate that leachates (if any) do not pose a threat to human health and the environment.
- Inspections Groundwater Monitoring to:
  - Demonstrate groundwater quality is not impaired.
  - Minimize threat to sensitive receptors (i.e., drinking water aquifers, ecological receptors).
  - Maintain the gas control system (passive) & perform a gas monitoring program to mitigate off-site gas migration that potentially poses HSE hazards (explosions/ fires).

Figure 37. Ground water monitoring in the landfill area.

Figure 38. Leachate Inspection Pipe in the landfill.

5.5.4 Ecological Monitoring

Restoration projects were implemented after the remediation of contaminated areas in NK and SEK oil fields in accordance with UNCC Environmental Claims. They ascertained the need to apply modern remediation/re-vegetation approaches to accelerate the recovery of native vegetation and resort the ecological functioning of the oil affected areas to pre-invasion levels. Thus, it was essential to reintroduce native plants and create favorable conditions for their establishment and growth as part of the revegetation project. KOC plans to revegetate 24 km^2 of remediated area under the KERP project. This will be executed with phased manner in collaboration with KISR and PAAF [8].

5.6 References

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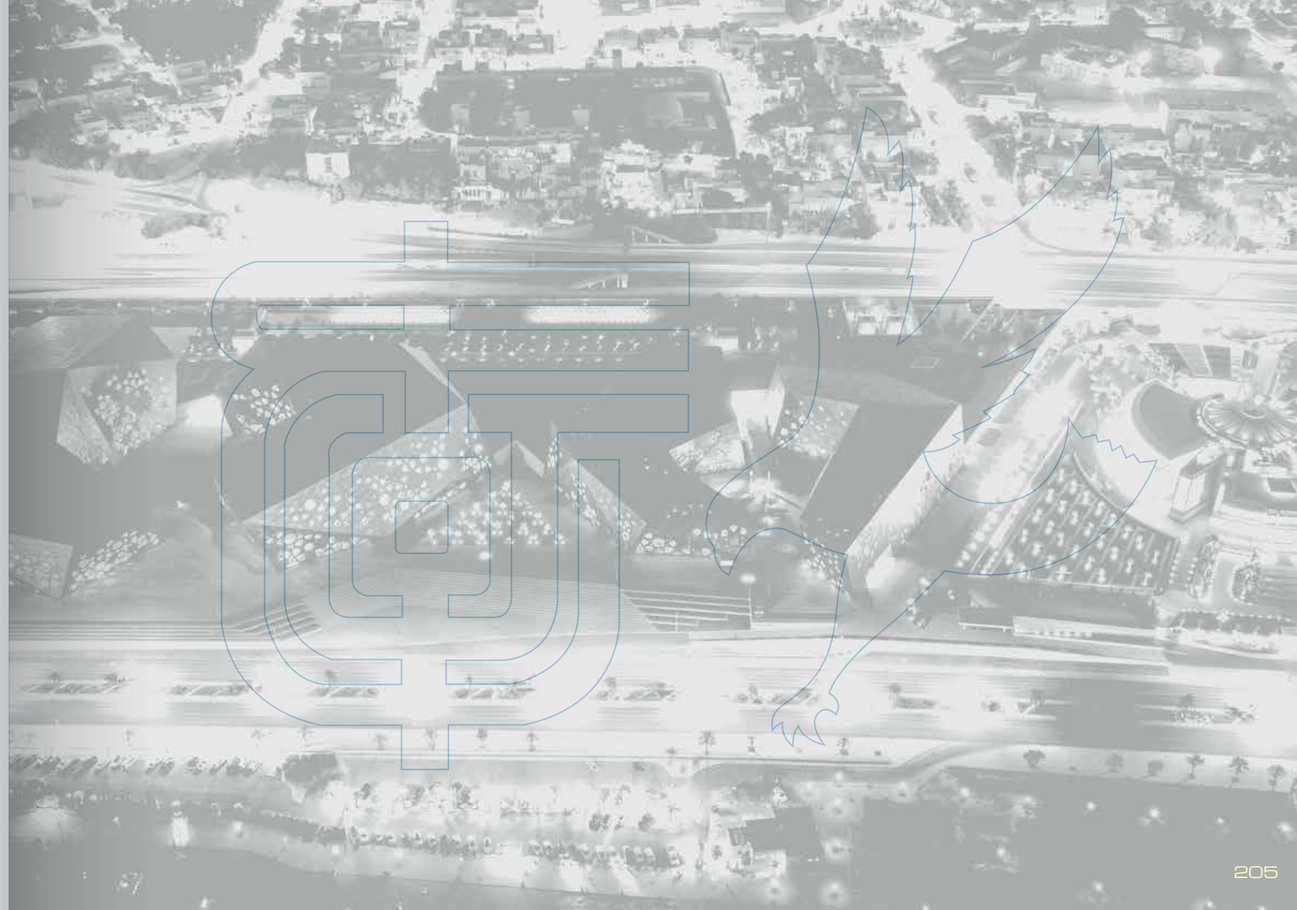
Chapter 6
Restoring Damaged Ecosystems



Chapter 6

Restoring Damaged Ecosystems

6.1 Introduction

Opportunities that have been pursued for remediating damaged ecosystems are further detailed in this chapter. Additional opportunities for future restoration efforts and projects are presented with suggested courses of future action to remediate the environment. This chapter will show the reader how KOC exerted efforts protecting biodiversity within its premises and how KOC contributed to preserving renewable natural resources for future generations. Efforts are made to document the recovery of the desert after several decades of protection and conservation. KOC management and protection measures are discussed in addition to highlighting the need for monitoring and assessment of ecological restoration in protected areas.

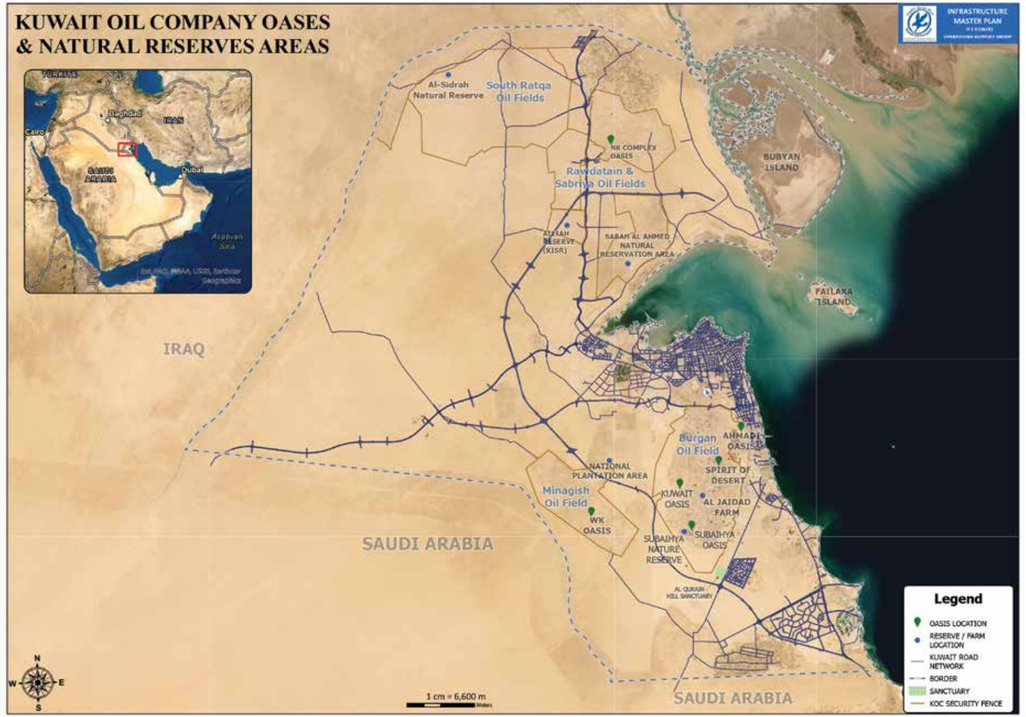
6.1 Restoration Measures

The established nature reserves by KOC provide benefits to the environment, especially due to their extreme damage from the oil-well fires. KOC rehabilitated these areas and turned them into oases that enhanced the growth of native plants and provided shelter and refuge to wildlife species. In other words, these areas gained life after doom. One would ask why these areas have been selected and not others? The answer is simple: it is because the company accepted this big challenge to restoring devasted habitats due to the invasion and indeed, they succeeded. Local and international standards and procedures were adopted in the restoration program with support from HSSE team at KOC.

The oases include re-vegetated areas, roads, and buildings, that are used for meetings, as well as displayed areas for demonstration of the restoration efforts. In these oases many institutions conducted meetings and events every year. That was because oases provide visitors with many services and facilities, which serve the image of the company and Kuwait.

6.2 KOC Desert Oases

There are seven oases presented in this chapter: the Spirit of the desert at Burgan, Kuwait Oasis in Burgan, Al-Qurain Hill Nature Reserve, Abdaliya Nature Reserve, Subaihiyah Oasis in Burgan, Ahmadi Oasis, and finally the Spirit of the Desert in the North (Al-Rawdhatain) oilfields.



6.2.1 The Spirit of the Desert, Burgan

The vision of the “Spirit of the Desert” began with one goal in mind: to restore damaged sites at KOC in the South & East fields. The aim was to restore the land to even better than its pristine condition so that it would brim over with the sound of migrating birds, desert plants and animals once again.

The site was a dumping area dotted with minor water bodies showing oil contamination, which was indicated by the prevalence of environmental degradation. The southern rim was drained by water erosion caused by gullies and rills, the desert was eroded by wind creating loose fine sediments, the soil was compacted and sealed, and the banks of the lake had collapsed.

The “Spirit of the Desert” Oasis, naturally like the shape of Kuwait’s map, is located at about 4 km from the main security gate of Burgan Oil Field on Al-Ahmadi-Burgan main road. From the north, the site is limited by open desert area dotted with several dumping sites. More than 240,000 sq. m (over 24 hectares) of land including 67,614 sq. m (about 6.75 hectares) of water shed have been managed and rehabilitated since November 2004. The area of the lake’s banks constitutes a primary section and two secondary sections of 1405 m of length. There are no buildings inside the oasis, while only workers are employed there for maintenance activities.

Surface: 1.5 km^2.

Figure 1. Inauguration of the Spirit of the Desert Oasis in Burgan, KOC , November 2004.

Inauguration: November 2004

The location where Spirit of the Desert exists was once used as a dump and waste site. Today, however, the entire area has been rehabilitated and is thriving with new life. Wild foxes and migratory birds come from the desert, while fish, ducks, geese, and pigeons are re-introduced. These types of animals were selected because they could live in any atmosphere and in any water or lake, while the plants were selected because they bear extreme heat.

Figure 2. The lake of the Spirit of the Desert Oasis in Burgan Area, KOC

6.2.2 Kuwait Oasis

This landmark project encompasses artificial lakes and state-of-the-art office facilities. It is an artificial island that is home to 1,837 different types of trees. The oasis itself is comprised of three oases that thrive on the banks of the water lakes in the oilfield area of Burgan. The first is located on Burgan Road, while the second is located in North Kuwait near Gathering Center (GC-2). The third is located near the offices on Al-Managuish Road.

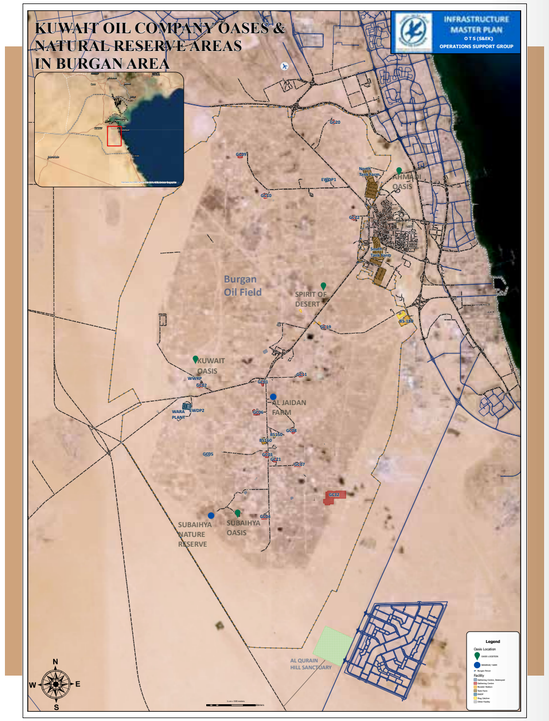
When you observe Kuwait Oasis, it is easy to imagine that you are on an island with water on all sides. The oasis is the most wonderful site inside Burgan.

The idea of the oasis is all about using unused materials. The waters surrounding the island were drawn to the lake from the old waters a half-kilometer away, which were used in GC-2. The material used in setting up the oasis consisted of 100 tonnes of remediated waste.

Surface area: 1.1 km^2

Inauguration: November, 2004.

It is recognized to have the shape of Kuwait Map [1].



Kuwait Oasis

Figure 3. Kuwait oasis at Burgan area.

6.2.3 Al-Qurain Hill Nature Reserve

Al-Qurain Hill is in the south, near Al-Wafrah agricultural area and 127 m above sea level. The hill is a rounded elevation of limited extent rising above the surrounding land with a local relief of less than 300 m. The Qurain Hill Nature Reserve has been created in collaboration with Kuwait Voluntary Work Center (KVWC). Kuwait has allocated 12% of its entire area for the establishment of nature reserves. This sets KOC to become the first of its kind at world levels when comparing total area and population. The project is aimed at preserving the region and getting it back to its pristine state.

The reserve's current location was an abundant resource frequented by sheep herds in the past. Heavy grazing and human activities caused pressure on natural life and, in turn, doomed many trees. This initiative by KOC seeks to reduce gas emissions and reflects the desire of the late Amir to care for and preserve Kuwait's environment, and to produce renewable energy. A solar energy pilot project was established in the reserve while preserving the area for recovery of wildlife species.

Figure 4. Opening ceremony of Al-Gurain Hill Nature Reserve, KOC.

6.2.4 The Abdaliya Nature Reserve, West Kuwait Oasis.

The reserve is another ambitious project to grow hundreds of trees, as part of KOC efforts geared toward preserving and rehabilitating desert areas. The officials for this project made great efforts and succeeded in creating better conditions for restoring the natural life cycle.

The project is in Abdaliya area, about 50 km from Kuwait City and was implemented in two phases. The first phase, which covered an area of approximately one million square meters, was carried out between January and April 2011, while the second phase, which includes an area of about two million square meters, was implemented between September 2011 and February 2012.

As part of the company's ambitious effort toward environmental rehabilitation, the Abdaliya Nature Reserve is a project that seeks to grow hundreds of new trees in the desert.

This reserve is home to many types of desert plantations, and includes 5,650 trees and shrubs of seven species as follows:

Table 1. Planted trees and shrubs in KOC Oases.

Plant type	**Scientific name**	**Number of plants**
Trees	*Rhamnus lycioides*	2,450
	Acacia tortilis	1,000
	*Lawsonia inermis (*Henna tree)	100
	Acacia sp.	1,000
Shrubs	*Rhanterium epapposum*	100
	Farsetia aegyptia	500
	Atriplex halimus	500

Figure 5. (*Lawsonia inermis)* (Henna tree) (S).

Regarding animals living in the reserve, there are 27 different types as follows:

Table 3. Observed animal species in KOC reserves.

Animal type	Species
Birds	Steppe Buzzard
	Steppe Eagle
	Lesser Kestrel
	Greater Spotted Eagle
	Pallid Harrier
	Red-tailed Wheatear
	Glossy ibis
	European Bee Eater
	European Turtle Dove
	Yellow Wagtail
	Spotted Flycatcher
	Red backed Shrike
	Northern Wheatear
	European Stonechat
	Bulbul
	Woodchat Shrike
	Ringed Plover
	Toed Lark
	European Roller
	Steppe Gray Shrike
	Little Egret
	Grey necked-bunting
	Isabelline Shrike
Reptiles	Gerbilles
	Agama blandfordi
	Uromastyx aegyptia
Rodents	*Vulpes rueppellii*

Figure 6. Abdaliya Nature Reserve.

Abdaliya Oasis

Figure 7. Abdaliya Oasis in 2012 (S)

6.2.5 The Subaihiyah Oasis, Burgan

KOC has established the Subaihiyah Oasis on a historic location in South Kuwait, with the stated goal of preserving the environment and protecting wildlife in the area. It embraces an exhibition displaying KOC history and the history of the Subaihiyah area.

The environment has been enhanced with thick plant coverage to foster the presence of migratory wildlife species. In addition, an artificial lake was created that supports fish life. 300 tons of steel and 250 square meters of concrete from recycling materials were used in building facilities inside the oasis. Seventy per cent of the materials used in all the facilities, buildings, and concrete structures in both Kuwait and Subaihiyah oases come from recycling of Gathering Centers that were destroyed in the Iraqi invasion.

Surface area: 2.5 km^2.

Inauguration: May 5th, 2015.

Figure 8. Al-Subaihiyah Oasis in Burgan area.

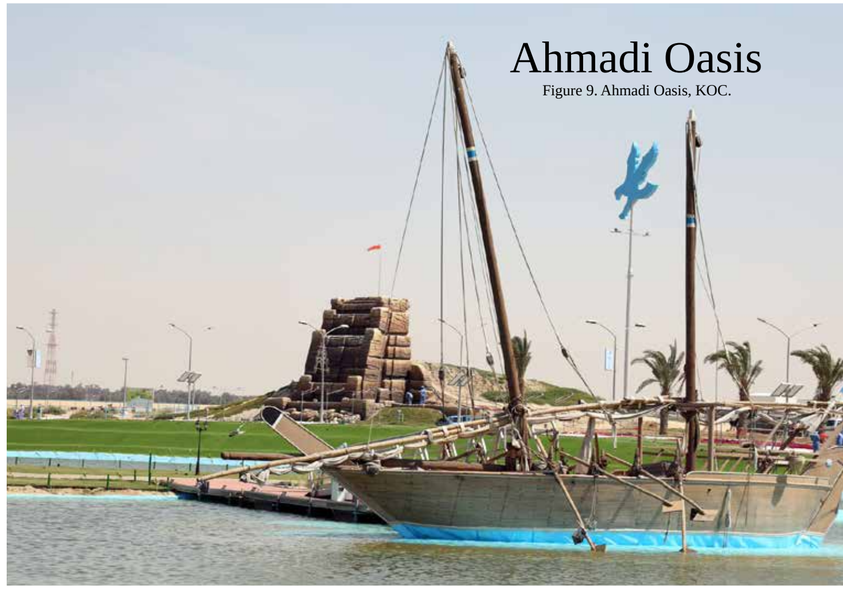
6.2.6 Ahmadi Oasis

KOC has developed an eco-friendly project near its head office for the betterment of the local communities utilizing the potential of the available natural resources. This vibrant Oasis was converted from a dumping area in the desert and was designed with in-house resources.

The oasis includes the following facilities: Kuwait ecology map; waterfall; walk / bike track of 800 m length; LCD screen; greenhouse of 3000 sq. m; solar plant; glass hall; fishing area; dancing fountain; windmill; enhancement area (4500 sq. m); children play zone; sports area (football, tennis and basketball); and a swan lake. The glass hall inside the oasis is the perfect setup for both formal and informal gatherings with infrastructure and facilities. The green house (3,000 sq. m) is a one-stop place for all nature lovers. Varieties of flowers and fruits are grown there, and it can be used to host meetings. The beautiful entrance, which can also be used as a water tank, has been constructed by recycling and redesigning vessel tanks. KOC directorates and groups could also potentially plant trees inside the oasis as a contribution to the environment. Many chalets have been built inside the oasis with attached private lawns to serve as the best option for camping with families during spring. It could also be used as booths during events. An ancient Kuwaiti home has also been built and modeled on the golden era of Kuwait. There is a wall which represents H. H. the Amir Sheikh Sabah Al-Ahmad Al-Jaber Al-Sabah and the victims of the Iraqi invasion. It is built from around 3000 recycled soda bottles, and it lights up at night with the colors of Kuwait flag. Of the total surface area, the green areas represent 75% (114,000 sq. m), while Waterscape represents 22% (34,000 sq. m) and buildings only 1% (2,500 sq. m).

Surface area: 152,000 sq. m.

Inauguration: April 7th, 2016.



Ahmadi Oasis

Figure 9. Ahmadi Oasis, KOC.

6.2.7 Spirit of the Desert Oasis, North Kuwait Complex.

Although this area is small relative to other oases, its location in the northern oilfields of KOC has a significant importance, especially for migratory animals that move from north to south. Few trees and grass plants have been introduced to enhance the greenery in the area after severe damage from the oil fires. The area is currently under expansion to re-vegetate with native plants and remediate contaminated soils.

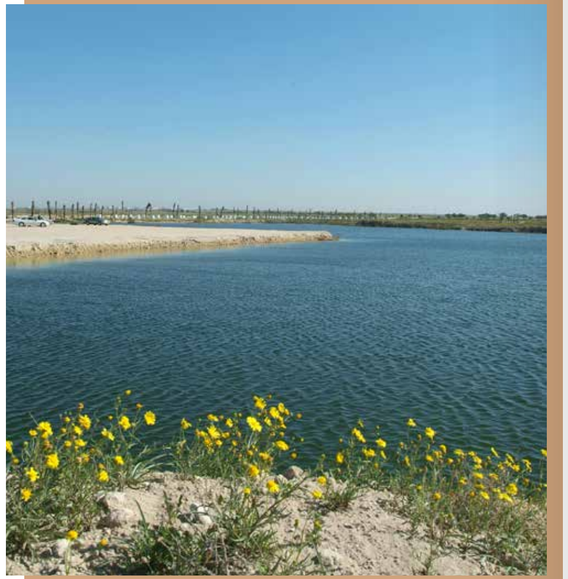


Figure 10. Spirit of the Desert Oasis in the north oilfield, KOC (S)

6.3 Al-Ahmadi Japanese Garden

The Japanese Garden, officially named the “Bioremediated soil park”, is a public park owned and maintained by KOC, and is a collaborative project established by KOC, KISR, and the Japan Petroleum Energy Center. The garden was established in Ahmadi in 2007 to demonstrate potential of bioremediated soil in greenery projects. A diversity of trees, shrubs, ground cover and lawn with flowering plants are planted both in the remediated and original soils. The garden attracts many residents who enjoy their leisure time in a healthy environment. The garden was designed with rocks, shades, benches, slopes, and paths with high safety standards for children’s playgrounds. Another way in which it is unique is that it is pet-friendly, unlike many green spaces in Kuwait. It aims to promote family and leisure activities in the neighborhood, to develop social interactions. KOC has been generously hosting events for external bodies in this garden, for which they have expressed gratitude. The Zen philosophy of gardens here has caught the attention of gardeners worldwide, as they are not only beautiful, but also relaxing to the body and the mind.

Built by KOC as a gift to the community, the company once again takes initiative, for more similar gardens to be built throughout Kuwait. KOC hopes more people will learn to appreciate this garden and pay it a visit.

Ahmadi
Japanese Garden

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Chapter 7
Perspectives and Lessons Learnt

Chapter 7

Perspectives and Lessons Learnt

7.1 Introduction

This chapter provides information and images regarding KOC initiatives and achievements over the years as well as those pursued in the future. This chapter provides a thorough overview of KOC's environmental responsibility and efforts to produce clean energy, protect the environment, remediate contaminated soil (Figures 1 and 2), and contribute to society by providing services and enhancing awareness.

Figure 1 An aerial view of a remediated site at KOC area in the south oilfields of Kuwait

Figure 2 KOC remediation team near a large pile of contaminated soil at Burgan Oilfield

7.2 Major KOC Achievements
7.2.1 Reduction of Gas Flaring/Clean Energy

Gas flaring is the burning of natural gas associated with oil extraction. It is a process that has been used for over 160 years and takes place due to market and economic constraints, as well as political regulations. Flaring is a waste of a valuable natural resource that should be used for generating power or reserved for future use. It is also a source of pollution and contributes to gas emission and climate change. It requires economically viable markets for companies to make the investments necessary to capture, transport, process, and sell gas sustainably.

KOC has flared gas since oil was discovered in Kuwait, in order to reduce pressures during crude oil extraction for safety reasons. These flares were numerous and could be easily seen from the air when flying over the country. However, KOC realized that many of these gas flares at oil production sites are a great waste and cause of air pollution. The methane emissions resulting from the flare combustion contribute significantly to global warming [1], which contradicts the Kyoto Protocol under UNFCCC that was adopted at the Earth Summit in Rio de Janeiro in 1992 and ratified by Kuwait on 11 March, 2005, before entering into force in 9 June, 2005 .

In this convention three gases were agreed to be reduced worldwide: CO_2, CH_4 and N_2O. The outlook of the total GHG emissions was estimated to 103.4 Mt of CO_2-eq in 2035 [2]. Moreover, since 2008, Kuwait has been a net importer of natural gas, consuming more than it produces and struggling to keep up with growing domestic demand for electricity. Therefore, KOC developed a comprehensive strategy to maximize domestic gas utilization. A key component of that strategy has been capturing associated gas, instead of wastefully releasing and flaring it during oil production.

KOC received a commendation from the World Bank for its efforts in reducing gas flaring within the company's scope of operations. KOC officials maintained that this new recognition reflects KOC's international standing as a socially responsible company that upholds the valuable contributions of its employees to environmental responsibility. The 2021 article released by the World Bank on its website entitled "Gas Utilization in Kuwait Reaps Economic and Environmental Benefits" praised KOC's success in using nearly 99% of associated gas from production.

KOC, which represents the country in the World Bank-led Global Gas Flaring Reduction Partnership (GGFR), knew that effective gas management was a key objective for the company to optimize the utilization of a valuable resource and reduce its environmental impact. The mission is to reduce gas flaring to less than 1% of total production, which the company has succeeded in doing. To achieve this target, KOC conducted thorough, periodic reviews of the gas value chain from producing wells to end users to identify all sources of waste or potential optimization.

KOC's successful gas flaring reduction is a result of several key factors: a solid commitment from all levels of the company to make flare reduction a priority; significant financial investments in state-of-the-art facilities and operations; close cooperation within KOC departments and with downstream companies and customers in order to adapt to any unforeseen situations and limit the duration of flaring; and a close, productive partnership with GGFR and other organizations to achieve the stated targets.

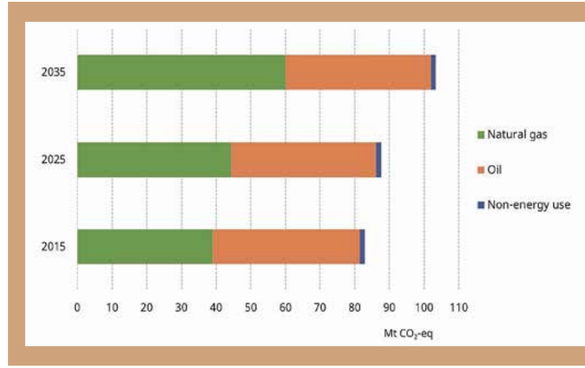


Figure 3. CO2-Equivalent emissions by fuel in Kuwait [2]

7.2.2 New Ahmadi Hospital

It was in 1947 when KOC established the first KOC hospital in Kuwait City, a small and humble health service building used for medical treatment and hospitalization with a total capacity of 80 patients (Figure 4). In order to serve patients coming from different KOC locations, the hospital was expanded in 1948 and transferred from Kuwait City to Magwa, managing a reasonably-sized building that provided 130 beds divided into four main wards equipped with modern equipment and highly qualified staff. In time, KOC established more services and clinics in the fields of Wara, Mina Al-Ahmadi and Al-Ahmadi City. In 1960, with the increase of KOC staff and operations in Al-Ahmadi City, the Ahmadi Hospital was opened for KOC employees and their families, which was later extended to all oil sector employees and their families [3].

In recent years, KOC decided to construct a new and modern hospital complex featuring state-of-the-art facilities for advanced medical services, which was inaugurated on 26th April, 2017 under the patronage and presence of H. H. the Amir, Sheikh Sabah Al-Ahmad Al-Jaber Al-Sabah. In March 2018, the hospital was in full operation to serve the KOC and Ahmadi community. The 80,000 square meters (19.77 Acres) hospital provides 300-400 beds with full medical services. LWI, in association with Gulf Consult (GC), developed the design of the hospital. The site consists of five buildings, which are 10,000 square meters each on two levels incorporating 254 studio apartments with parking lots for resident doctors and nurses. The distinctive Islamic geometric make-up of the design plays a key role in the function of the hospital. The design is based on Islamic principles, considering local tradition and reflection of Kuwait environmental condition (Figure 5). Not only does it aid in the overall spatial organization, but it also creates trouble-free orientation for the visitors to the facility, with an unambiguous separation between the patient rooms and the diagnostic treatment areas. State-of-the-art building system allows full control of environmental systems and provides essential health services [4].

Figure 4. KOC Clinic in the late forties

Figure 5. The new Ahmadi Hospital catering for KOC oil sector families and Ahmadi city residents [4]

7.2.3 Ahmad Al-Jaber Oil & Gas Exhibition

Ahmad Al-Jaber Oil & Gas Exhibition demonstrates the oil history in Kuwait from its early stage of formation to its discovery and production [5]. The exhibition provides modern technology that presents to the public the topics of oil origin, drilling, transportation, and exportation in an extremely attractive way. The exhibition is named after Kuwait's 10th ruler, who served as Amir from 1921 to 1950, and it was during his reign that the birth of the oil industry began. The exhibition serves as a national museum of oil and gas that creates a learning experience for visitors based on the story of oil, while raising awareness about the enormous role it plays in the economy of the State of Kuwait. It is also a platform for networking in the form of hosting international conferences and exhibitions, as well as providing an entertaining and unforgettable learning experience (Figures 6 -11).

Figure 6. The authors during a visit to Ahmad Al-Jaber Oil & Gas Exhibition in 2021.

Figure 7. Part of Ahmad Al-Jaber Oil & Gas Exhibition showing oil discovery in Kuwait.

Figure 8. The main enterance of the exhibition at Ahmadi.

Figure 9. the foyer of the exhibition.

Figure 10. Roof view of Ahmadi City.

Figure 11. Ahmad Al-Jaber Oil & Gas Exhibition.

7.2.4 Solar Initiatives

In contribution to KNDP, KOC pledged to generate 15% of energy from renewable sources by 2030, and deployed a pioneering project to cut down CO_2 emissions and save 500,000 barrels of oil over 20 years. This project is named Sidrah 500, after a local tree known as Sidrah (*Ziziphus spina-Christi*), and is located at *Umm Gudair* field in West Kuwait, generating 10 MW of electricity from photovoltaic solar panels [6]. The project is a practical translation of KPC's vision of "realizing value from technology and contributing to enterprise and state", and was inaugurated on October 26th, 2016, by KPC CEO, Mr. Nizar Al-Adsani, and KOC CEO Mr. Jamal Jaafar. Sidrah 500 is the first large-scale photovoltaic solar energy project implemented by the company. "It is the first KOC project registered with the 'Clean Development Mechanism' under the UNFCCC," he said.

Facts about the Sidrah 500 project:

- 10 MW peak, 5 MW minimum during summer months from 10AM – 2PM.
- Location: Umm Gudair, West Kuwait.
- 5 km away from F-193 substation, which is connected to MEW Managuish-B substation.
- Feeds 29 Electric Submersible Pumps (ESP).
- Located on a plot of land (360,000 square meters = 36 hectares).
- The plant uses crystalline silicon panels at a 16.2% rate of efficiency.
- Panels on single-axis trackers to maximize output of the solar plant.
- First utility-scale solar plant in Kuwait.
- First solar plant in the world to power ESPs.
- First KOC project to register with the U.N.

Figure 12. KOC team visiting the solar park in Kuwait.

7.2.5 Wastewater Treatment

As stated in the previous chapters, Kuwait is extremely hot and arid particularly during summer, which extends from May to September. Freshwater is negligible and groundwater is scanty. Only two relatively small areas in the country are being tapped for their groundwater supplies. Rainfall in the country on average varies between 75-200 mm per year. However, rainfall in Kuwait is extremely unpredictable – a small amount may be measured one year, while the next may be significantly higher with an average of 113 mm.

Due to extremely high evaporation rates and low soil moisture, recharge of aquifers is very slow and almost negligible. There are three categories of groundwater grouped based on their salinity level. The first is fresh groundwater, with a content of soluble salt of less than 1,000 mg/l. This water, which is found in the North of Kuwait at *Rawdhatain* and *Umm Al-Aish* fields, is a strategic freshwater reservoir for drinking water. The second is brackish groundwater, with a soluble salt content ranging from 1,000 to 7,000 mg/l. This water is produced from the Al-Shigaya, *Umm Gudair*, Sulaibiya, Wafra and Abdali fields, and used mostly for agriculture and domestic purposes and as drinking water for livestock. The last category of Kuwait's groundwater supply is high salinity water (brackish), with a soluble salt content of between 7,000 to 20,000 mg/l. This water is not appropriate for agricultural or domestic use.

To reduce the negative impact of associated water on oil production operations, KOC conducted several studies to use some low-saline wastewater for industrial purposes and daily operations. Some studies include but are not limited to:

• Applications of smart valves to wells in North and West Kuwait, where the production of associated water has been reduced to a minimum, in parallel with an economic increase in oil production.

• Work to isolate bacteria in systems and networks of distribution and associated water injection, and classify these bacteria and determine the type responsible for increasing corrosion rates in pipes and devices exposed to such water. This study would enable the company to apply successful methods to reduce bacterial growth, in turn avoiding or reducing corrosion in transport equipment and pipes, ultimately reducing the use of chemicals that inhibit bacterial growth.

• Treating associated water with the aim of producing brackish water suitable for use in industrial applications (firefighting water, brackish water for salt separators, water suitable for enhanced oil production applications).

• Reuse of wastewater from KNPC's refineries for industrial purposes within the

fields of KOC. The results of this study had a significant impact on protecting the marine environment and finding a permanent alternative to the drained and saline water from Abdaliya field.

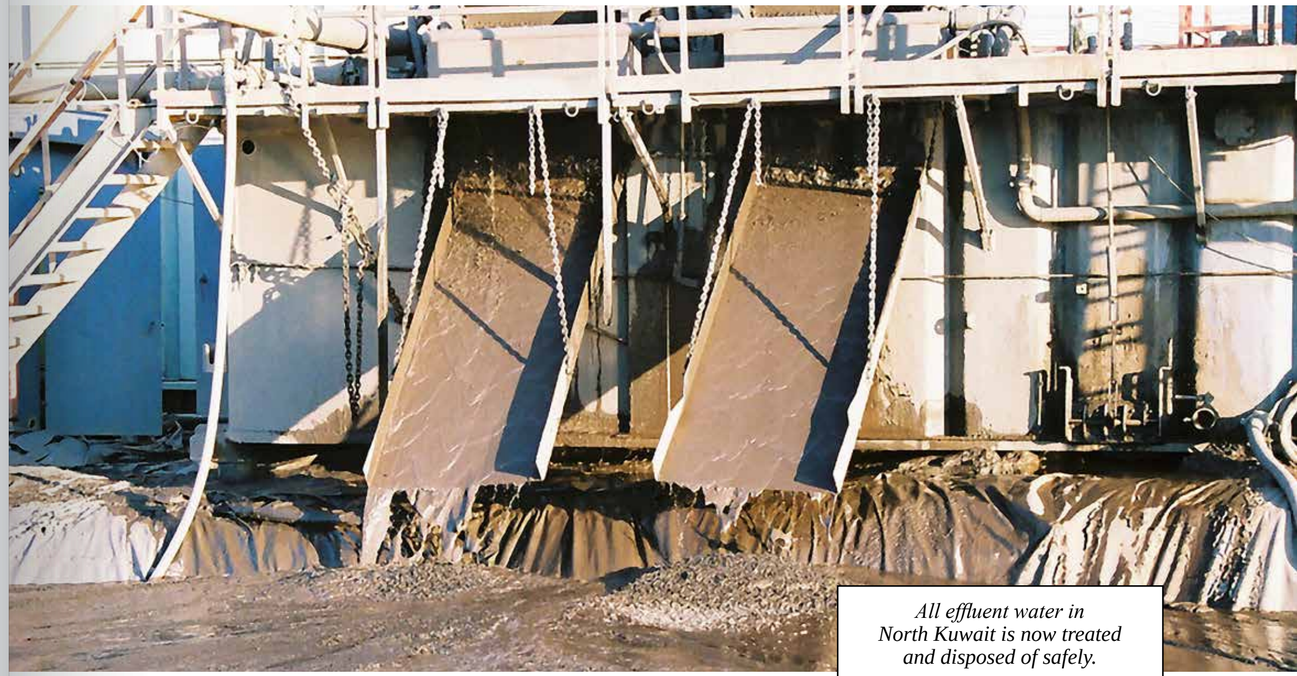
• Two experimental wastewater treatment plants were successfully implemented from the Sulaibiya sewage treatment plant, with the aim of reusing water for the daily industrial purposes of KOC, and the results were encouraging and had a positive impact to stop the process of disposing of this wastewater in Kuwait Bay, or finding a permanent and inexpensive source of brackish water suitable for industrial and even public uses (Figure 13).

• Evaluation and application of a new technology that can be placed inside the oil-water and gas separators, which would significantly raise the performance of separators.

• There are many projects and technologies in the process of evaluation or completion. These aim to capture and keep the associated water within the oil-bearing layers, or separate it under the surface, in addition to evaluating and applying techniques to improve the quality of injected water, raise the efficiency of treatment equipment, and improve the quality of treated oil [7].

As part of efforts to live up to the company's HSE obligations, *Emad Sultan (Ex. Chief Executive Officer – KOC)* announced that the North Kuwait Directorate has achieved an environmental milestone by successfully implementing the "Zero Disposal to Pits" effort [7].

KOC officials maintained that this recent achievement in North Kuwait is important because it safely and effectively disposes of effluent water that is associated with the production process. The "Zero Disposal to Pits" effort involves collecting effluent water and safely disposing of the material in designated injection wells. Before the injection process begins, the effluent water is treated through new and specialized water treatment systems and a new Water Center in north Kuwait.



All effluent water in North Kuwait is now treated and disposed of safely.

"Zero Disposal to Pits" Goal Achieved.

Figure 13. Wastewater treatment at KOC.

7.2.6 Recycling at KOC

KOC is involved in operations that generate wastes. These operations include oil exploration, drilling, production of oil and gas, gathering centers, drilling rigs, storage tanks, marine transport loading facilities and many others. For many years, wastes have been left untreated or ignored due to the lack of awareness until regulations and decisions were made to halt any further damage to the environment. This resulted in implementing environmental protection systems for the benefit of all.

At KOC, company officials have long understood the importance of sustainable and efficient containment of waste that is generated in Ahmadi and within the company's areas of operation. As a result, KOC has worked hard to help preserve and protect Kuwait's environment, which is one of the company's priorities. This has also given rise to the creation of KOC's Environmental Waste Management Program, a pioneering project for Kuwait and KOC which was born out of the recognition of the importance of environmental custodianship [8].

7.2.6.1 Recycling at KOC

Studies indicate that Ahmadi produces approximately 25-30 tons of waste daily, out of 2,500 tons of the total waste production in Kuwait. KOC has refocused its attention on environmental protection by dedicating a significant amount of money, time and energy into developing the Environmental Waste Management Program for KOC residences and offices in Ahmadi. This project took more than ten years of research, study, and experimentation until it reached its form today as an integrated system that helps preserve the environment by adequately disposing of and eliminating the risks associated with home and office waste. The project includes the transport, sorting, and primary treatment to transform these materials from undesired waste to raw materials that support local industries. In addition, this pioneering project was awarded UN recognition. The UN is a major supporter of environmental preservation systems and projects, and the recognition by the UN has done much in the way of bolstering confidence in this important KOC project.

7.2.6.2 Recycling Center

The recycling center project, which falls under the purview of the Road and Support Team (RST), aims to decrease the amount of waste by repurposing disposed of materials in a proper way. Therefore, the company has enacted several procedures and methods that will enhance the recycling culture and implement best practices in accordance with effective procedures used around the world. As part of the work being conducted to achieve these objectives, the RST inaugurated a center to receive waste in Ahmadi. It is worth mentioning that the first beneficiary of this project that has been under construction since 2004 is the citizen. One of the goals of the project is to help KOC meet its objectives as they relate to environmental protection and custodianship.

7.2.6.3 Sorting Methods

Sorting methods at the center depend on the awareness that the consumer has about his role in implementing this operation. This happens through the utilization of the bins that the company distributed to offices and KOC houses which consist of four different types, in addition to a paper bin that exists in offices. The first phase of sorting solely depends on KOC employees and their families by sorting waste in the proper bins. Wrong sorting of these materials, whether it is paper, glass, metal or food will lead to the damage of these products and the inability to recycle them.

Afterwards comes the second phase, which is the responsibility of the specialized team whose role is to collect the waste from the distributed bins and transfer it to the recycling center in the city. Then, it must be ensured that sorting has been done properly so that waste can be transferred to the contractor in charge of recycling and environmental treatment of the products and materials.

7.2.6.4 Smartcard

The recycling center works in conjunction with an electronic system where the residents of KOC homes have an electronic smartcard that contains all data related to them. This card allows communication with residents and helps verify their commitment to the project. It also allows the team and the resident to know the interaction level and the waste amount that has been maintained since the launch of the project. Furthermore, this smartcard enables the RST to determine the different contributions of KOC home residents in the recycling project for the team to distribute gifts and awards to the most organized residents. This initiative aims to encourage KOC employees and home residents to sort waste properly and contribute more, which will result in a recycling culture in the city.

7.2.6.5 Awareness Campaigns

The team in charge of this project is keen to enforce the recycling culture among KOC employees and home residents through several successive awareness campaigns that aim to focus on the importance of proper waste sorting and placement in the proper bins.

This campaign does not only target KOC employees and home residents. Instead, the team began to conduct seminars and distribute awareness brochures in Ahmadi schools, especially after setting aside several bins and smartcards for the schools to include them in this major environmental project. Furthermore, the team conducted a competition among participating schools in implementing this project and granted awards accordingly.

7.3 Future Challenges: The Way Forward

KOC has focused its strategies and plans to further develop the 17 SDGs through current and future wide initiatives. These 17 SDGs represent an urgent call for action by all countries in a global partnership. As mentioned in Chapter 1, the SDGs recognize that ending poverty and other deprivations must go together with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to improve the Earth's oceans, forests, deserts, and biodiversity. Throughout its areas of operations and local community outreach initiatives, KOC remains committed to the realization of these goals.

A comprehensive and ever-expanding list of KOC's past, current, and future activities as they relate to the SDGs is included in Table (1). This document should be treated as an organic, evolving template that can be updated regularly by the concerned KOC groups, teams, and personnel who are familiar with the SDGs and current and future KOC activities, which are ongoing to support these goals.

KOC employees are encouraged to put forth their specific work activities and projects by adding their project goals in detail to this comprehensive list if those activities fall under one of the UN's 17 SDGs. The 17 SDGs are listed below for the reference of all employees, followed by the initial report detailing KOC's current activities as they relate to the relevant SDGs. In the following table, the activities to achieve each SDG by KOC is shown.

Table 1. KOC past, current and future activities as they relate to Sustainable Development Goals (SDGs).

Relevant SDG	KOC Action/s	Description
1. No Poverty	NA	Kuwait supports least developed countries worldwide.
2. Zero Hunger	Food Distribution (Palm Dates to Charities)	KOC has overseen a long tradition of corporate-driven donations to charitable organizations. However, these donations do not always necessarily have to take place in the form of financial assistance (which is also rendered). Instead, KOC has overseen the distribution of dates from the palm trees of KOC's Abdaliya Nature Reserve to those in need throughout the region and beyond. Over the years, many tons of dates have been delivered to charitable organizations.
	Food Distribution (Charity during Ramadan)	The Holy Month of Ramadan is also a period where KOC lives up to its reputation as a responsible corporate entity. Over the years, millions of "Iftar Al-Sayim" or fast-breaking meals have reached individuals who otherwise would have gone without. KOC has ensured that it remains committed to the goal of engaging in some form of charitable food program during Ramadan.
3. Good Health and Well-Being	Construction & Operation of Ahmadi Hospital	KOC's Ahmadi Hospital currently offers a wide range of medical treatment and related services, including: Accident & Emergency; General Practice; Internal Medicine; General Surgery; Orthopedics; Dermatology; Obstetrics & Gynecology; Pediatrics; Ophthalmology; Ear, Nose & Throat; Dentistry; Preventative Medical Services; Radiology; Anesthesia; an Intensive Care Laboratory; Physiotherapy; and Dietary Services. In addition, specialists from the Ministry of Health conduct consultative clinics once a week (See section 1.2.2 in this Chapter).
	Construction of Kuwait Field Hospital during COVID-19	The COVID-19 global pandemic created a major health crisis for every nation around the globe. However, under the leadership of KOC, the construction of the Kuwait Field Hospital helped alleviate much of the pressure on Kuwait's public health institutions. The Kuwait Field Hospital houses patients and medical staff, and the facility can accommodate approximately 50 doctors and 100 nurses. It includes wards with a capacity for 200 beds, as well as 40 Intensive Care Unit beds and 19 emergency beds.
	COVID-19 Support Initiatives	KOC ensures the Company's logistical and technical proficiencies are put to good use. Some of the recent achievements registered during the COVID-19 pandemic include the following: • Construction of a quarantine facility in Ratqa for Kuwaiti citizens returning from abroad (capacity of 564 beds for citizens and 172 beds for medical and nursing staff). • The provision of resources from Ahmadi Hospital (including equipment, beds, and personnel) to the Kuwaiti Government in its effort to fight COVID-19, including the provision of KOC's Ahmadi Hospital ambulances to assist in transporting Kuwaiti citizens returning from abroad directly to official quarantine facilities in Kuwait. • Overseeing awareness campaigns, which aim to inform the community at large of the important health and safety measures which must be taken to protect Kuwait during the pandemic.
	Health Campaigns	Other programs have flourished under KOC's leadership. Many health campaigns, which aim to create awareness in the local community, have been launched as part of KOC's commitment to contribute to the dissemination of health education and a belief in community partnership.. KOC has supported a long list of health initiatives throughout its history, including countless blood donation drives, health awareness campaigns, and first aid/CPR workshops, in addition to official support of international health days, such as World Diabetes Day, World Heart Day, and Breast Cancer Awareness Day, to name a few

4. Quality Education	Ahmad Al-Jaber Oil & Gas Exhibition	KOC oversees the provision of educational services to Kuwaiti citizens and residents through Ahmad Al-Jaber Oil & Gas Exhibition. As Kuwait's premier resource for all information related to the history of oil production, this exhibition creates a better understanding among students about the critical role oil and gas play in the day-to-day lives of billions of people around the world. KOC has ensured that this world class exhibition does everything possible to inspire Kuwait's next generation of oil and gas professionals by shedding light on the enormous role oil has played in the development of the State of Kuwait. By creating an intimate understanding of the way oil has shaped the world we live in, the exhibition serves as a critical pillar of Kuwait's oil and gas industry and encourages future leaders to learn about the responsibilities associated with the sustainable production of Kuwait's hydrocarbon resources.
	Nabdh Summer Camp Program	As part of an effort to encourage Kuwaiti youth to learn more about the country's national industry, KOC organizes a summer camp program called "Nabdh" which features the participation of young students. The program is unique in the sense that volunteers from KOC participate by dedicating their time and effort to educate young students about Kuwait's exploration and production process. The event culminates with an oil & gas quiz show/competition that is broadcast on national television.
	Internship Program for Students	KOC ensures various internship programs are provided to support students in developing their skills and potential. These internship programs are availed to students at the university level and include on-the-job learning activities in a variety of fields. Specifically, technical internships in various oil and gas facilities help prepare students for future careers in the field. Moreover, students are also provided with opportunities to work at the KOC Office Complex, where hands-on data analysis provides them with a preview of what it is like to work in the oil and gas industry.
	Employee Training	KOC continues to develop the skills and capabilities of Kuwaiti and non-Kuwaiti employees at all levels through a large number of training and career development programs, such as the Harvard Leadership Development Program, the Specialist Development Program, and the Young Talent Development Chapter. Moreover, many programs feature close cooperation with Kuwait's Applied Institutes, in addition to cooperation with Kuwait University and private universities in Kuwait which oversee job-shadowing, training, and mentorship programs for students at KOC. It should be noted that the training programs which KOC organizes include the provision of learning opportunities for employees at all levels. All employees, from new recruits (UDs) to managers receive equal attention. For example, many young employees, in addition to receiving training through courses, are sent abroad for attachment training at leading international oil and gas companies. Employees at the managerial level, on the other hand, benefit from "Kaizen" training initiatives, which sometimes include coursework that is conducted overseas.

5. Gender Equality	Female Recruitment	KOC has overseen the recruitment of thousands of female Kuwaiti employees over the past five years alone for positions throughout the company's areas of operation. Adjusted on a year-by-year basis, this figure becomes significantly higher, and demonstrates KOC's determination to encourage Kuwaiti youth, especially females, to seek careers in the oil and gas industry through the company's official policy of "Kuwaitization". Under KOC's initiative, support for current and prospective female employees has had a transformational effect on Kuwaiti society by creating new opportunities where they simply did not exist before. KOC has also elevated women in Kuwait's oil and gas sector to managerial positions throughout the company's areas of operation. At KOC, a historically male-dominated company, women have revolutionized the way in which the company does business after attaining top-level positions across the board, including positions as Data Center Engineering Operation (DCEO). Female employees are increasingly being placed in positions as Group Managers and Team Leaders, where they have obtained these positions through the merit of their hard work and perseverance. In addition to elevating women into leadership roles, KOC has supported an initiative called the PWN. The network was established to promote professional growth of the female workforce, empower and integrate female professionals throughout all areas of work, and serve as a forum where female professionals can come together for the purposes of networking and support. KOC has often stated that initiatives like PWN allow for the creation of a more collaborative atmosphere, which helps KOC achieve a leading position in the global oil and gas industry. KOC has singled out field facilities such as gathering centers, drilling rigs and gas booster stations, which have become more accommodating to female employees over the years who are increasingly seeking positions in the field.
6. Clean Water and Sanitation	KOC Recycling Program	KOC understands the importance of sustainable and efficient containment of waste that is generated in Al-Ahmadi and within the company's areas of operation. As a result, and to help preserve and protect Kuwait's environment, KOC ensures the company's recycling program remains one of its top priorities, as studies indicate that Ahmadi produces approximately 25-30 tons of waste daily, and this is out of 2,500 tons of the total waste production in Kuwait. The recycling program aims to decrease the amount of waste by repurposing disposed of materials in a proper way, and KOC has ensured that recycling bins within Ahmadi are regularly collected and delivered to the recycling center. KOC maintains that one of the goals of the project is to help KOC meet its objectives as they relate to environmental protection and custodianship.
	"Tarsheed" Campaign	Over the years, KOC has supported environmental campaigns such as "Tarsheed", which aims to raise awareness among the local population about the importance of energy conservation efforts, such as turning off lights and electronics whenever necessary and minimizing water usage.
	Improved Water Usage in the Field	As part of an overall campaign to sustainably manage water within Kuwait's oil and gas operations, KOC has overseen the responsible usage of water throughout field operations. In addition to limiting the unnecessary wasting of water, KOC has ensured that water associated with field operations is properly treated before it is released back into the environment.

7. Affordable and Clean Energy	KOC Energy Conservation	KOC ensures energy conservation measures are consistently implemented. In part, this includes the installation of energy-saving LED lights throughout all offices and facilities in the field.
	Energy Conservation in Ahmadi	KOC oversees the refurbishment of company homes in Ahmadi, which include new energy-saving features such as energy-efficient lights and appliances.
8. Decent Work and Economic Growth	Encouraging Economic Growth	KOC has solidified its place as a major exploration, drilling and production company in the region, which employs men and women from Kuwait and around the world. In addition to producing oil from Burgan field, the world's second largest oilfield, KOC continues to make new discoveries of oil and gas fields that then go into production. Today, KOC continues to make progress in the effort to grow Kuwait's production capacity with the help of specialists from many different countries. KOC remains committed to its future production goals and targets. Recent exploration and production achievements include, but are not limited to, the following: • KOC's North Kuwait Heavy Oil Program: The company registered an average crude production capacity of 23,000 BOPD of heavy oil. The production of heavy oil remains one of the most important projects, and it is a critical component of KOC's strategic objectives for the future. • The KOC Offshore Drilling Project: KOC has conducted seismic surveys of Kuwait Bay and is on track to drill six Jurassic and Cretaceous exploratory wells offshore. • Production of light oil: Production of light oil reached an average capacity of 159,000 BOPD. • Increasing non-associated gas production to 490 MMSCFD. • The drilling of 383 new wells (for both crude oil and non-associated gas operations). • Four new hydrocarbon discoveries were announced during the 2019/20 fiscal year throughout KOC's areas of operations. • The completion of three major projects: 1) Sabriyah Maudud (SAMA) – EOR Pilot, 2) New Desalter Trains for Gathering Centers, 3) Multi-Phase Pumps in West Kuwait.

9. Industry, Innovation, and Infrastructure	Sidrah 500 *Umm Gudair*, southwest Kuwait	KOC oversees the Sidrah 500 project, which is the first large-scale photovoltaic solar energy project implemented by the company. The plant has a capacity to generate 10 MW of electrical power solely from solar energy. This project will help KOC save approximately 500,000 barrels of oil over the course of 20 years.
	Kuwait Integrated Digital Field (KwIDF)	KOC oversees the high-tech KwIDF project, which provides engineers and geologists with a means to collect various data about wells and fields in real-time, which are then analyzed by specialists so that appropriate decisions can be made in a timely manner. The project is unique in the sense that it provides innovative technological solutions which save time and effort in comparison to traditional fields. KwIDF aims to increase productivity and provide optimal management of oil reservoirs, which in turn will lead to increased and sustainable production for KOC.
	Facilities Management	KOC attaches great importance to matters pertaining to HSSE. In this regard, KOC ensures best practices are utilized which abide by international standards while operating all oil and gas facilities. Regular inspections and dedicated teams ensure KOC facilities are operated safely for the benefit of employees and the community in which they operate.
11. Sustainable Cities and Communities	Employee Housing in Ahmadi	KOC ensures housing for employees remains as safe and comfortable as possible. This includes frequent maintenance of infrastructure and normal health and safety inspections of all company-operated facilities, including sport and recreational facilities.
	Recycling Program	Ahmadi's recycling program continues to eliminate the amount of waste delivered to Kuwait's landfills.
12. Responsible Consumption and Production	KOC Energy Conservation	KOC ensures energy conservation measures are implemented. In part, this includes the installation of energy-saving LED lights throughout all offices and facilities in the field.
	Energy Conservation in Ahmadi	KOC oversees the refurbishment of company homes in Ahmadi, which include new energy-saving features, such as energy-efficient lights and appliances.
	Optimization of Oil & Gas Production	KOC understands the future production of oil in Kuwait is going to be harder and more costly, thereby requiring smarter practices and active collaboration across disciplines, in addition to a wide range of interdisciplinary knowledge and expertise. In this regard, KOC has supported workshops and conferences that aim to shed light on the most current forms of optimization methods, and the company has also supported major optimization initiatives such as the KwIDF and Crude Oil Control Centers, which create greater efficiency.

Gas Flaring	KOC has played an important role in ensuring the company remained committed to the extremely significant achievement of maintaining gas flaring at a mere 1% or less. KOC won the "Excellence in Flaring Reduction Award" during a special forum held by the GGFR at the European Bank for Reconstruction & Development's premises in London.	
13. Climate Action	The One Million Trees Project	KOC oversees an undertaking that features company efforts to beautify and protect Kuwait by planting trees throughout the country. The planting of trees in Kuwait plays a major role in mitigating the effects of sandstorms and high winds.
	Environmental Reserves	KOC has taken significant actions against concerns related to the impact of oil production on the local landscape, which resulted in KOC initiating two projects, the Spirit of the Desert and the Kuwait Oasis, whose goal was to bring areas of the desert back to their natural state. Both projects involved the transformation of polluted land into green areas that are available for use by company employees. In addition to being leisure areas, the parks are also sanctuaries for local and migratory wildlife.
	Environmental Partnerships	KOC's concern for the environment has influenced partnership decisions, such as working with KEPA to review and improve local legislation pertaining to the environment and the actions of the oil industry.
	KOC Marine Colony	When retreating forces ignited nearly 800 oil wells and flooded Kuwait's waters with crude oil, the magnitude of the damage was on a scale that had never been experienced before. At the time, the long-term effects of such damage was uncertain. Wildlife on land and in the sea suffered greatly. The magnitude of the impact was so severe that soil remediation projects continue to this day, some 30 years after the fact. Damage to Kuwait's marine environment was extensive. Over the years, wildlife in Kuwait's waters slowly recovered. However, most of Kuwait's coral reefs continue to be negatively affected by bleaching. KOC initiated a renewed commitment to environmental efforts. From environmental awareness campaigns to new and exciting HSE initiatives, KOC has lent support to environmental projects, including the KOC Marine Colony Project, which KOC launched to help contribute to the important task of restoring harmony to the environment it operates in. The Marine Colony, near Ahmadi's South Pier in the State of Kuwait is a place where hope is kept alive. The project consists of 1,000 reef balls that have been placed on the seabed to help encourage marine life in the area. In addition, KOC commissioned KISR to conduct an ecological assessment of the Marine Colony, prompting its periodic monitoring by a joint diving team comprised of KOC employees and individuals from KISR. Equipped with state-of-the-art technology, the team gathers critical data that helps protect marine life in Kuwait's waters. Preliminary findings have been positive, and a plan is in place to follow-up on the significant impact the colony is making on Kuwait's marine environment.

14. Life Under Water	The Kuwait Environmental Remediation Program (KERP)	KOC plays a pivotal role in advancing the work progress of KERP, which relates to the remediation of oil lakes, tarcrete and other sources of contamination that have been left over from the 1990/91 Iraqi invasion of Kuwait. KOC works in coordination with the United Nations and other official bodies on issues related to the KERP Program (See Chapter 5 for more information).
15. Life on Land	Environmental Reserves	KOC oversees the development and maintenance of many environmental reserves that help combat desertification and increase biodiversity throughout Kuwait, including the Abdaliya Environmental Reserve situated in Abdaliya (West Kuwait). The company's initiative to set up this reserve stemmed from the need to remedy the environmental damages inflicted on the area and restore biodiversity in the region. KOC also installed a new underground water system at Jahra Pool Reserve as part of its contribution to social development. The initiative enhanced the reserve's capabilities and helped achieve its environmental goals (See Chapter 6 for more information on the reserves).
	Hiring People with Disabilities	KOC has made every possible effort to ensure those with disabilities are provided with an equal opportunity to build careers in the oil and gas industry. In addition to providing work opportunities for the disabled, KOC has made every effort to create office spaces that provide wheelchair access, as well as other measures that benefit disabled people.
16. Peace, Justice, and Strong Institutions	Public Outreach Initiatives	KOC continues to support a wide variety of public outreach programs and initiatives. Every year, KOC volunteers time and effort to organize corporate social responsibility (CSR) initiatives that aim to support the local community. Programs of note include outreach initiatives, which have created awareness about autism and other disabilities, violence against children, cyber-bullying, and a wide range of health and safety issues.
	Internal Campaigns	Across KOC, the company ensures that employees are provided with the resources they need to function at optimal levels. Moreover, KOC has made it possible for all employees to have their voices heard through official programs and initiatives where employees can communicate their comments and concerns.
17. Partnerships for the Goals	Environmental Partnerships	KOC's concern for the environment has influenced partnership decisions, such as a decision to work with KEPA to review and improve local legislation pertaining to the environment and the actions of the oil industry.

7.4 References

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Al-Shagaya
solar photovoltaic panels


KUWAIT
Desert Bloom

This book is the second edition of KOC publications on the remediation and restoration of the damaged environment of Kuwait. The first book was published in 2019 entitled: Restoring the Nature of Kuwait, by Kuwait Oil Company. The book was published by Ross Publishing and deposited in the Library of Congress, USA. This book provides more information and details on KOC responsibilities towards sustainable development and environment.

This book comprises seven chapters that tell a story of KOC over decades of oil production in Kuwait. Its responsibilities, functions, and operations towards preserving and protecting the environment of Kuwait are emphasized with a focus on remediation of contaminated soils after the oil fires that were ignited during the invasion of Kuwait in 1990-1991.
The Chapters cover in-depth information regarding KOC, its history, resources, and policies to give a clear understanding of KOC's inner workings and commitment to health, safety, security, and environment. KOC strategic plan for sustainable development is presented with emphasis on its role in the KNDP and SDG.

The environmental setting of Kuwait is given a clear descriptive overview providing information on the environment where it currently stands and how it is being affected by human activities. Climate Change and GHG emissions are presented for sectors in Kuwait with emphasis on oil production. Vegetation cover, wildlife, and plant communities that once dominated Kuwait's desert are presented emphasizing how environmental protection is important for biodiversity conservation and restoration. Updated imageries are shown for land degradation and soil erosion. By the end of this book, the reader will understand what Kuwait's environment is and how it is changing, if any, in time. The book also serves to showcase the positive impact Kuwait's environment has experienced through implementation of key protected areas, advanced technologies for remediation and restoration of degraded lands and perspectives for environmental protection.

In summary, this book provides information and images regarding KOC initiatives and achievements over the years as well as those pursued in the future. It provides a complete overview of KOC's environmental responsibility and efforts to produce clean energy, protect the environment, mitigate climate change, remediate contaminated soil, and contribute to society by providing services and enhancing awareness.

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