

Management Practices of Conventional and Non-Conventional Water Resources: Study case in Emirate of Sharjah, UAE

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Abstract

This paper identifies the essential critical factors and practical procedures for successful water resources management in the emirate of Sharjah, UAE. These factors are the planning and management of water resources, groundwater management, efficient water use in agriculture, sustainability of desalination, domestic and industrial demand management, the sustainability of the desalination and wastewater treatment and reuse. The latest main conventional and non-conventional water resources in Sharjah are highlighted, including evaporation, the hot climate, and the associated reduction in the water resources. The water resources in UAE are also evaluated and included in our proposed water management model, which is made to overcome the scarcity of natural water quantities in Sharjah, which presents a continuous challenge to the government and one that it deems a priority to solve.

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Introduction

Due to the significance of water for life and health, it was listed among the 17 Sustainable Development Goals (set by the United Nations in 2015), where SDG 6 is focusing on Clean Water and Sanitation as one of the United Nation's most important goals. (Hazelton, 2015).

It is forecasted that more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025, and by 2050 the number of countries at risk will rise to 54 with a combined population of 4 billion people, i.e. representing 40% of the projected world population in 2050 (about 9.4 billion). Figure 1 demonstrates the countries that are vulnerable to water stress and scarcity (Rekacewicz, 2006).



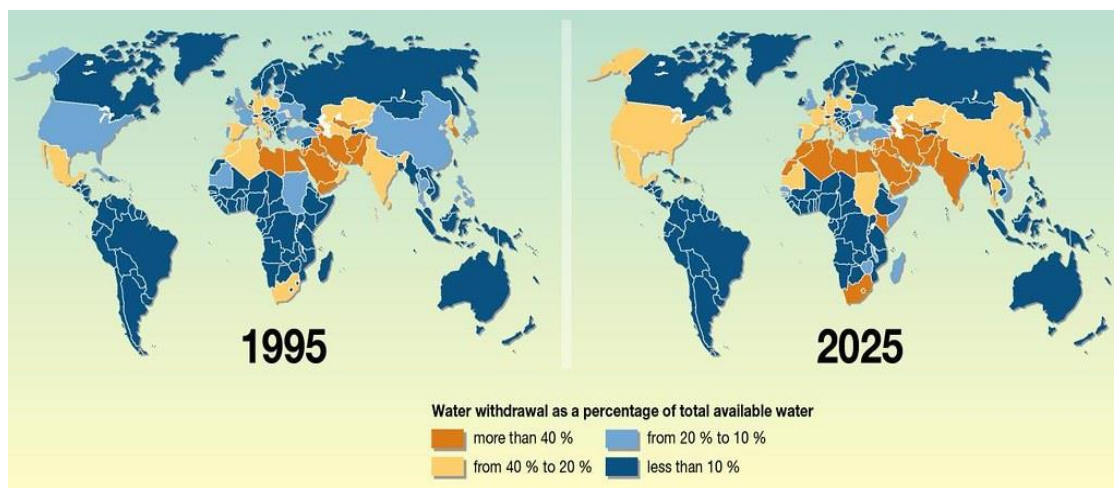


Figure 1. Global water stress map (Rekacewicz, 2006)

Therefore, water management is an essential tool to optimise the flow of natural water, including surface water and groundwater. However, the uncertainty due to climate change makes the management more complex. Groundwater stands as an important element in water management as it meets the need of two-thirds of the world's population (Adimalla and Li, 2019; Mukherjee and Singh, 2018).

World water scarcity is categorised into four areas: Physical water scarcity, Approaching physical water, Economic water scarcity and finally, Little water scarcity. These areas have all been changing adversely over the years. Figure 2 shows the expected global water scarcity by 2025 (Wecker, 2017).

Challenges in water policies facing the Gulf Cooperation Council (GCC) countries has had to be addressed. It requires major revisions and shifts if sustainability in water is to be assured and to serve the socio-economic development needs of the region. Innovation in the mainstream is highly needed along with research, strategy, management, and effective low emission and low energy cost of operation. Innovative proactive solutions are significant to water sustainability and security challenges that the region is facing, now and in the future. The solutions also need to be viable, long-term, and cost effective. Investments in technological and non-technological innovation (financial, institutional, management) are therefore essential.

The evaluation and prioritizing of major water challenges in GCC countries needs much discussion, thought and study. Innovative technological and non-technological solutions to water challenges needs to be implemented internationally, regionally and locally (UAE). The sharing of knowledge, best practice and experience through a networking system that brings together researchers, executives, policy makers, private sector, and other stakeholders from GCC countries and other Arab countries will be hugely beneficial.

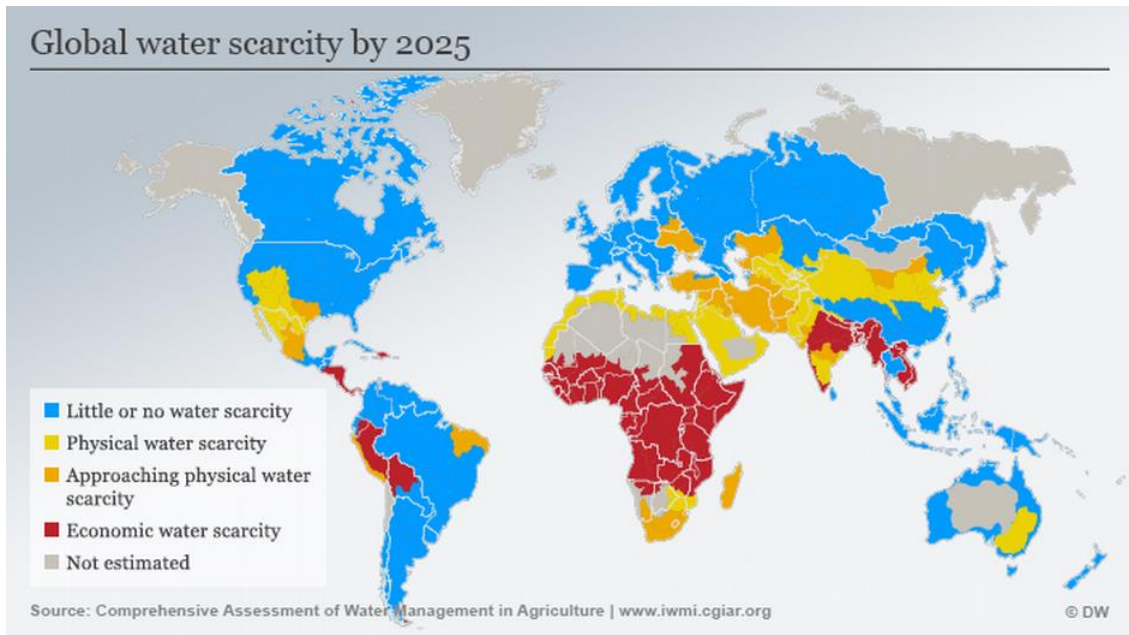


Figure 2. Global water scarcity by 2025 (Wecker, 2017)

Goal 6 of SDG's (UN India, 2020) has urged world countries to achieve universal access to safe drinking water and provide adequate sanitation and hygiene in the next 15 years. All are aiming now to make more water available for domestic, agricultural, industrial, and environmental uses. However, this can be made only if better water resources management is made and cross-sectoral planning and integration are achieved (DataBank, 2020).

The UAE is striving to fully comply with SDG 6, especially groundwater and desalination of seawater, to meet this goal. Being in an Arid zone (vicinity of Cancer latitude 23.45° N) with lack of rain, a high evaporation rate, high solar radiation, and lack of vegetation) it lacks surface resources. This issue is augmented with the continuous population growth, rising standard of living, expansion in agricultural and industrial activities (Murad, 2010). To make the picture clearer in this respect, it is worth mentioning that the annual per capita of surface water availability in UAE is 64 m^3 ; this is only 1% of the world average! Therefore, the Government has supplemented these limited renewable natural water resources by depending on so-called "overall water resources" which includes groundwater, desalination, surface water and treated wastewater (United Arab Emirates ecology & nature protection laws and regulations handbook, 2010) (Zein et al., 2003).

Figure 3 shows the water usage of residents in Arab countries and allows per capita comparison between them in the available and used water resources (Elgendy, 2020). It also shows the percentage of available renewable water resources. The UAE uses water at a rate of 1600% of renewable resources.

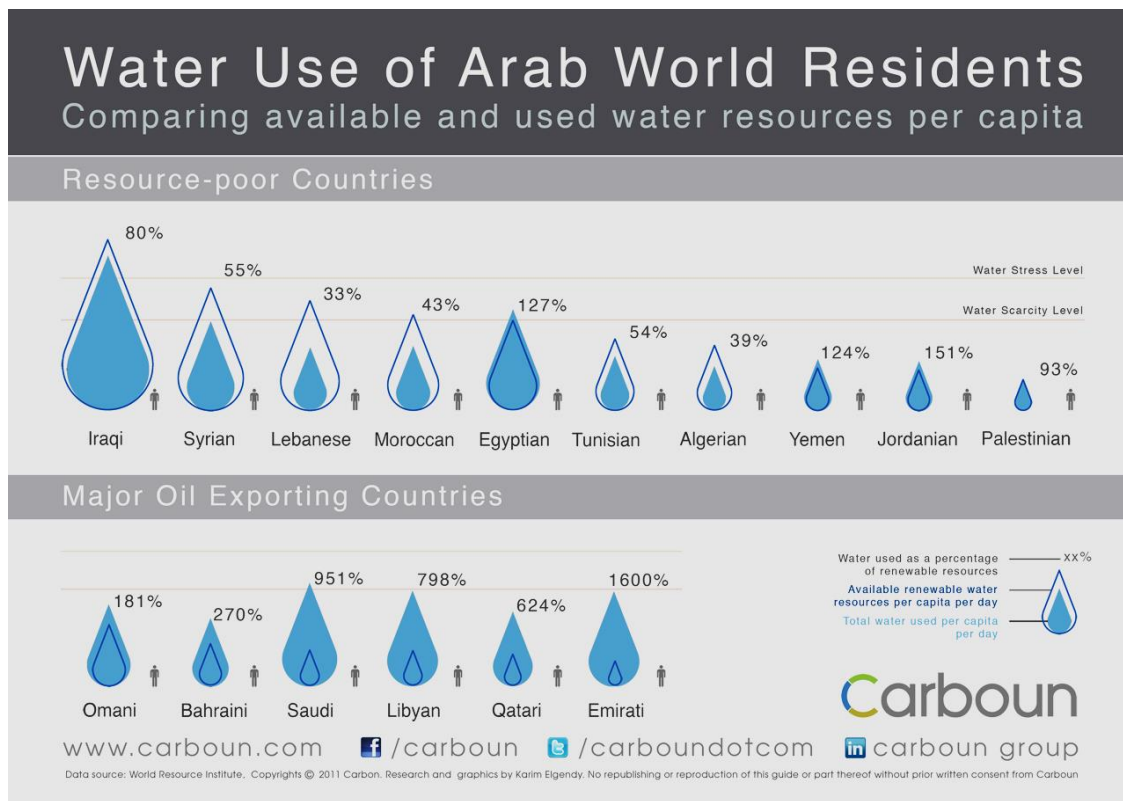


Figure 3. Water use in the Arab world percentage of renewable water (Elgendy, 2020)

Due to such scarce natural water resources in the UAE, it has become a matter of great urgency to set an ambitious policy of water management and a sound water management model. Part of this is concerning the UAE government, and the other is concerned with the emirate of Sharjah (one of the 7 UAE sisters). These are elaborated in the following sections.

Water Management Principles

According to Karunya (Karunya, 2013), the basis for water resources management been confined to 4 issues:

1. Freshwater is limited and constantly subjected to stress and risk. It's a source that is essential to sustain our lives, development, and the environment.
2. The water development and management must follow a participatory approach that involves users, planners and policymakers at all levels.
3. Women have a significant role in the provision, managing and safeguarding of water.
4. Water must be recognised as an economic source with a precious economic value.

Legal Framework and Policy of Water Resources Management

When planning for the construction of new infrastructure for water resources management, it is important to plan for an economically viable system as well as one that considers the possible environmental and social impacts of this new infrastructure. An essential step is to formulate relevant water management objectives related to each function made (Dongre et al., 2016). These water resource management objectives should deal with

the functions in more manageable and understandable ways. The objectives must set the goal and layout the strategy to answer how to implement the functions. Figure 4 illustrates the relevant water management objectives related to each function.

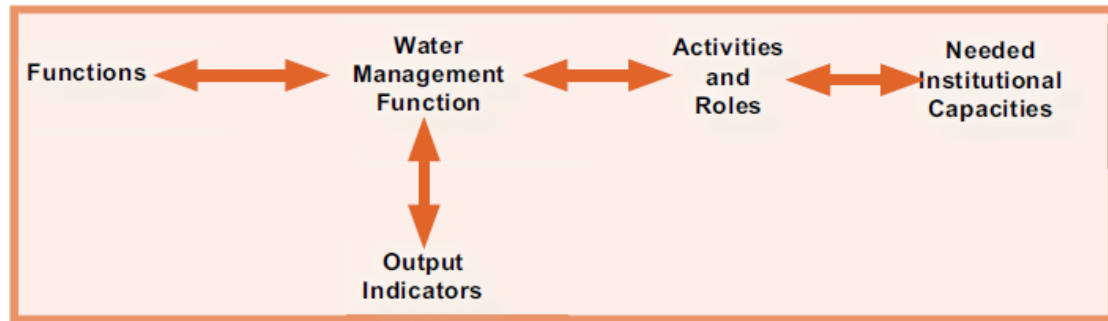


Figure 4. Relevant water management objectives related to each function

Water Management in the UAE

Although UAE is among the most water-scarce countries globally, it has one of the highest per capita water consumption rates globally, with 550 litres per day! This is because it is witnessing a rapid increase in population and development, leading to an increase in water demand. Table 1, shows the UAE's water resources in a million cubic metres (MCM) from 2002 and projections to 2050 (Water.Fanack, 2017).

Table 1: Historical and projected water resources (Water.Fanack, 2017)

Quantity of water resources (MCM)	2002	2005	2010	2015	2020	2025	2050
Surface run-off	150	150	150	150	150	150	150
Average groundwater feed	125	125	125	125	125	125	125
Desalination	720	945	1.488	2.342	3.688	5.806	11.612
Treated water	227	273	387	615	754	1.053	2.106
Total	1.22	1.493	2.150	3.232	4.717	7.134	13.993

1. Conventional Resources in The UAE

1.1. *Surface water*

Surface water is negligible, including floodwater, water retained in dams, some very small streams, ponds, and spring water. Floodwaters are either evaporated or leaked into the ground due to the dry weather and sedimentary areas. Therefore, dams are built to harvest rainwater and store surface water (Water.Fanack, 2017).

1.2. *Groundwater*

The total volume of groundwater is around 640 billion cubic metres (BCM), but only 3% of it is fresh. Most of the groundwater used in the UAE is brackish. The available groundwater resources are both renewable and non-renewable. Renewable where shallow aquifers depend on rain fall events and surface run-off, and non-renewable resources are the deep aquifers. Due to the dry weather, a reduction to the shallow aquifers, 10-14% are recharged by the mountains (ESCWA, 2003).

2. Non-conventional water sources

2.1. Desalination

99% of the domestic water supplies rely mainly on desalinated water to meet the demanded quantities at the standard quality.

2.2. Treated wastewater

Municipalities use modern treatment facilities in the UAE that manage sewage systems, creating networks for stormwater collection and reusing treated wastewater. The treated water is used for urban purposes like garden irrigation and highway landscaping. Nearly 50% of the treated effluent is discharged into the Arabian Gulf Sea (Water.Fanack, 2017).

In 2009, the total water demand in the UAE was estimated at 4.5 BCM, which were met through groundwater (72%), desalinated water (21%) and recycled water (7%). Water consumed is mainly for industrial activities, agriculture and for domestic usage (Dakkak, 2020): Figure 5, shows the water demand in the UAE (Siddique, 2015). Water for domestic usage accounts for 24% of total water consumption in the UAE. This is not surprising considering that air conditioning systems consume large quantities of water as well as consuming lots of electricity. Chilled water pumps make further demands on the water supply. (Dakkak, 2020).

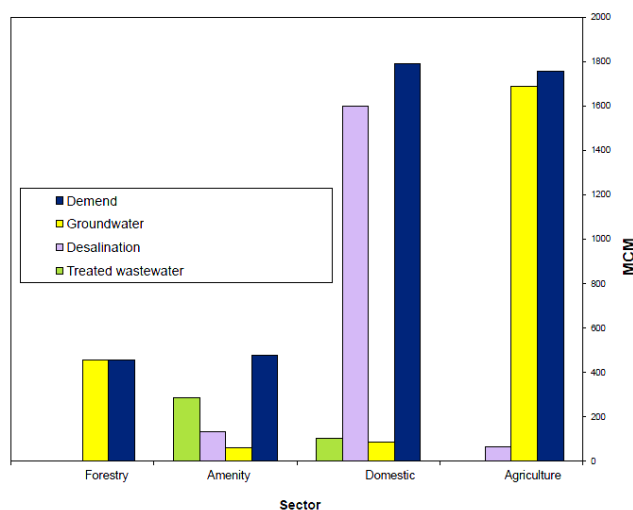


Figure 5. water demand compared with supply in UAE (Siddique, 2015).

According to Masdar (Sanchez, 2018), UAE's groundwater is pumped out for irrigation at a rate of about 860 billion litres per year, and it is depleting at a rate of 0.5 cm per year. This is encouraging considering that that UAE provides about 50% of the country's freshwater.

Water Management in The Emirate of Sharjah

The Conventional water resources in Sharjah depend on rain fall (which forms groundwater), falajes, springs and flash floods. The non-conventional water resources are desalinated water and treated wastewater, Figure 6. Previously, Sharjah mainly depended on conventional water resources and groundwater, but at present, it relies on non-conventional resources and desalinated water.

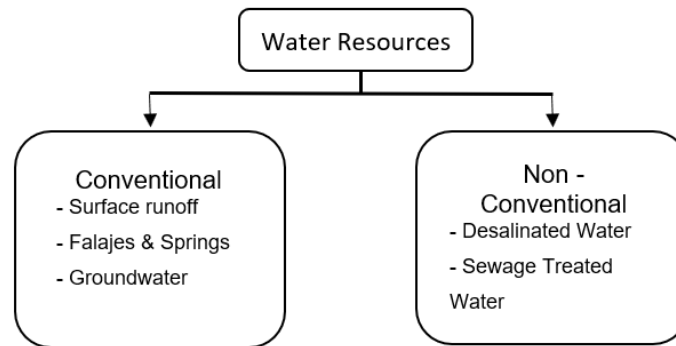


Figure 6. Water resources in the Emirate of Sharjah

SEWA is responsible for supplying all the UAE with drinking water from both underground and desalinated sources. Modern desalination and production plants produce and treat seawater and underground water distributed to residential, commercial, and industrial consumers through transmission and distribution networks.

The process of offering water services is subject to inspection, specification preparation, cost evaluation, issuing A/c Nos- in accordance with the location - and finally, the connection of the required service.

1. Sharjah Climate change and rain fall

The scarcity of the currently witnessed rain fall is attributed to Climate Change. The UAE is located within the arid zone, i.e. characterised by low rain fall and a high evaporation rate. The emirate of Sharjah experiences some seasonal variation in monthly rain fall. It is found that for nearly three known “rainy” months (from December 27 to March 25), the rain level was only 13 mm – as shown in Figure 7 (Weatherspark, 2020). The average rain fall (solid line) accumulated throughout a sliding 31-day period centred on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line in Figure 7 is the corresponding average liquid-equivalent snowfall. The most rain fall during the 31 days is centred around February 5, with an average of 18 mm.

The rainless period of the year lasts for 9.1 months, from March 25 to December 27. The least rain fall is around September 7, with an average total accumulation of 0 millimetres. Figure 8 shows the average rainy days in Sharjah (Climate, 2020). Rain fall in (mm) is shown in Figure 9.

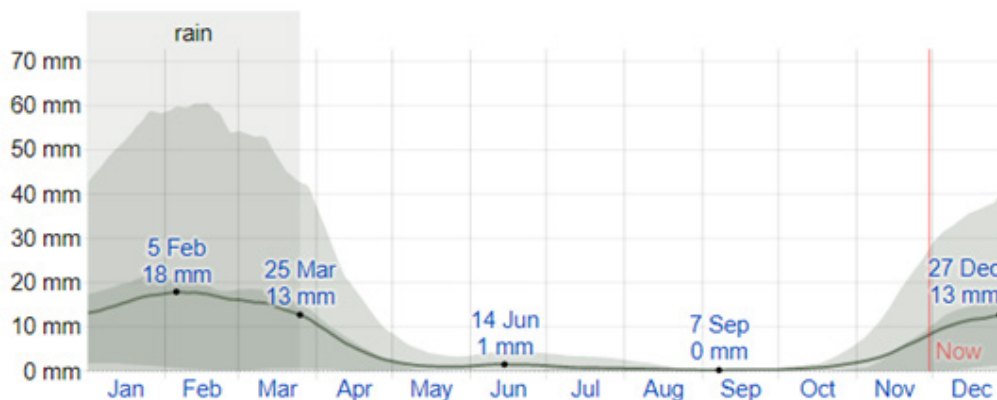


Figure 7. Average Monthly Rain fall (Weatherspark, 2020).

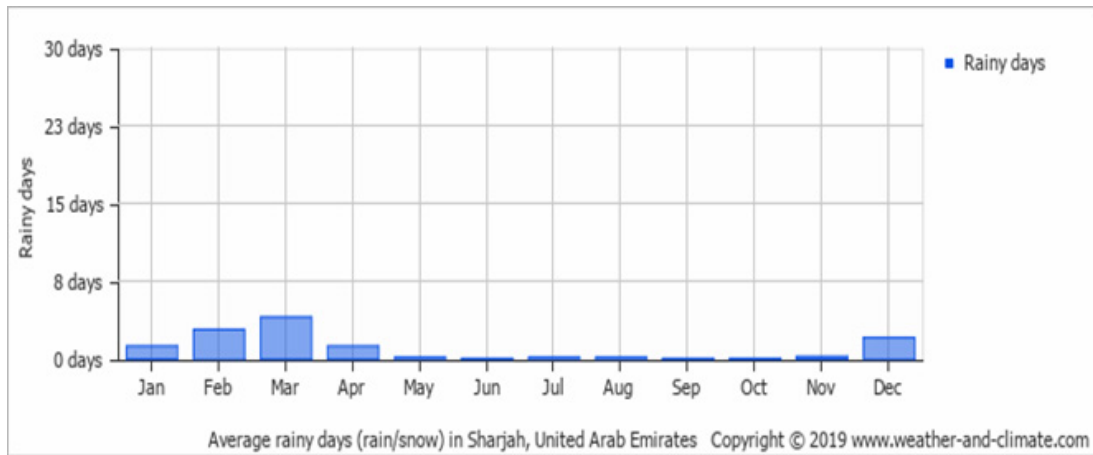


Figure 8. Average rainy days in Sharjah (Climate, 2020)

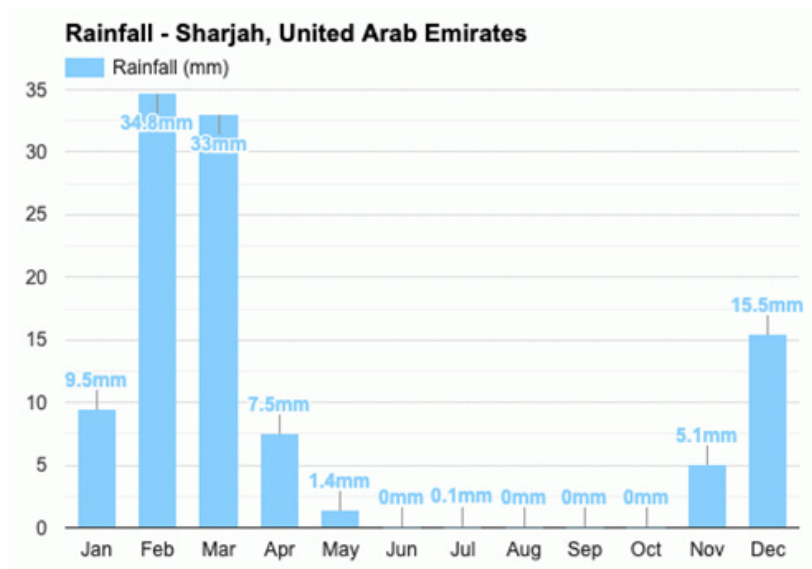


Figure 9. Average rain fall in Sharjah in (mm) (Atlas, 2020).

2. Conventional Water Resources Management - Sharjah

2.1. Surface Run-off

The availability of surface water in Sharjah is limited and temporary because of the low rain fall rate and high evaporation rates. The estimated surface water in the UAE was about 39.6 billion gallons/yr (0.15 billion m³/year) (Murad, 2010). Nevertheless, dams are effective in flood control and the Government intends to increase the number of dams. Figure 10, shows the dam site suitability map (DSSM) (Al-Ruzouq et al., 2019) and is divided into five classes: very high, high, medium, low, and very low. Three locations were considered and suggested for dam construction based on spatial analysis.

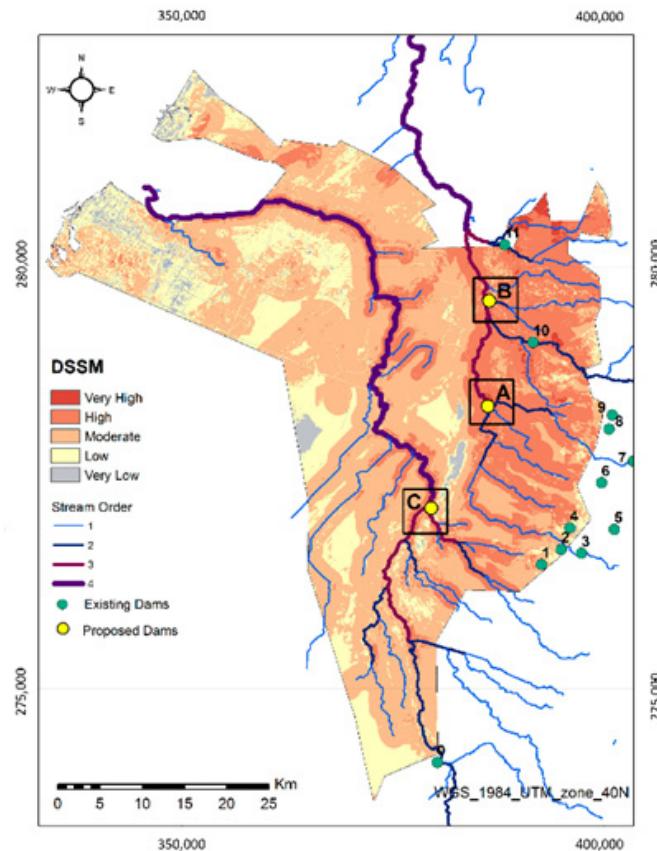


Figure 10. Dam site suitability map (DSSM) (Al-Ruzouq et al., 2019)

2.2. Springs

In the UAE, several springs, such as Khatt (Ras Al Khaimah), Maddab (Al Fujairah) and Bu Sukhanah or Ain Al Faydah (Al Ain), have been utilised as recreational and touristic sites (Zein et al., 2003). Thus, no springs are available in the Emirate of Sharjah.

2.3. Falajes

Falajes represented the main routes of life in the eastern UAE. However, many of the UAE's falajes are dry because of excessive groundwater pumping (Zein et al., 2003).

2.4. Groundwater

Groundwater is the main conventional water resources in the Emirate of Sharjah produced by SEWA and by the public through private wells. The major aquifers in Figure 11, UAE include the limestone aquifers in the east and north, gravel aquifers lining the eastern mountain ranges, fractured ophiolite rocks in the east and west and sand dune aquifers in the west and south (Zein et al., 2003). Management of groundwater potential is essential in semi-arid and arid regions due to significantly less rain fall and a high evaporation rate (Mohamed and Almualla 2010a, b). The most critical water resource problems in the Sharjah Emirate are the depletion of aquifers in many areas, such as at Al-Ain and Al-Dhabi; as well as saline water intrusion, and water quality degradation, which are associated with the oil industry and agricultural activities (Rizk and Al Sharhan 2003). In the UAE, the Groundwater abstraction is about 3 billion m³ / year. In the North of the UAE, a decline in water tables and is attributed to exacerbation by agricultural development. This has led to saltwater intrusion in coastal zones. Unfortunately, saltwater intrusion

is highly conspicuous in the UAE's eastern coastal. Saltwater from the Gulf of Oman intrudes into the freshwater of coastal aquifers, raising its salinity and deteriorating its quality.

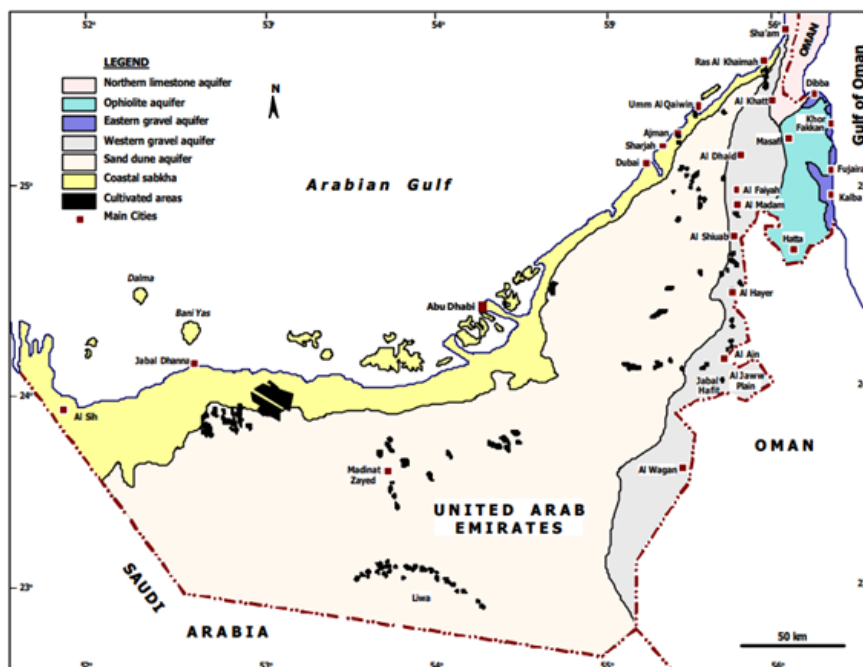


Figure 11. Main aquifers in the United Arab Emirates (Al Hamadi, 2003).

Groundwater salinities are low to high brackish. Groundwater hydrochemistry is very variable: magnesium bicarbonate, calcium bicarbonate, calcium sulphate, magnesium sulphate, and Sodium Chloride type. Figure 12 demonstrates treatment management to produce fresh water in Sharjah. Figure 13 shows the sites of the Emirate of Sharjah's daily average water production. Moreover, Figure 14 shows SEWA's drinking water storage tank capacity (in Million Gallons) in 2016 (SWEA, 2016). To demonstrate freshwater management, Figure 15 shows the sold water quantities (in Million Gallons) (SWEA, 2016).

Recently, (Dawoud , 2020) studied the Groundwater economics in Abu Dhabi . According to his study, in the year 2014, groundwater usage accounts for about 63% of total water demand in the U.A.E , with the remaining portion of demand being met through desalinated (28%) and recycled water (9%). The agriculture and forestry sectors also make huge demands on the water supply. Together they account for over 95% of total annual. Agriculture on its own has consumed 20% of recent withdrawals. The stress on groundwater aquifers is no less significant. The total present annual abstraction from the groundwater aquifers is about 2,300 million m^3 and the annual natural recharge to the aquifer systems ranges between 90 and 140 million m^3 , leading to a significant deficit. (Dawoud, 2020) established a model which enables the evaluation of the net benefits and economic tradeoffs across alternative water. This was made possible by simulating groundwater reserves and withdrawals for different regions, time periods, and development sectors. The value of Abu Dhabi's groundwater resources marginal economic value was found to range 4.5–6.0 AED/ m^3 (USD1.2 -1.6 / m^3) compared with 7.0 AED/ m^3 (USD1.85 / m^3) for wastewater and 11.3–15 AED/ m^3 (USD 2.9 -4.0 / m^3) for desalinated water.

Capacity of Fresh Water Produced in Emirate of Sharjah in 2016 (Sources of Production Wise) in Million Gallon Per Day (MGPD)

Desalinated Water														
Total Desal	Zibair	Nazwa	Tahel	Mohaddab	Seir BuNeir	Abu Mussa	KFK plant	Kalba plant	ADWEA	Hamariah plant	Hamariah plant	Rahmaniya plant	Layyah plant	
121.23	0.10	0.33	0.03	0.03	0.03	0.36	5.00	7.30	17.50	20.00	1.55	5.50	63.5	Installed capacity
107.69	0.08	0.33	0.03	0.03	0.03	0.36	5.00	6.54	17.10	16.50	1.34	4.00	56.36	Available capacity
91.95	0.08	0.22	0.02	0.01	0.01	0.24	3.68	4.07	13.20	14.80	1.30	3.20	51.13	Daily Average Production

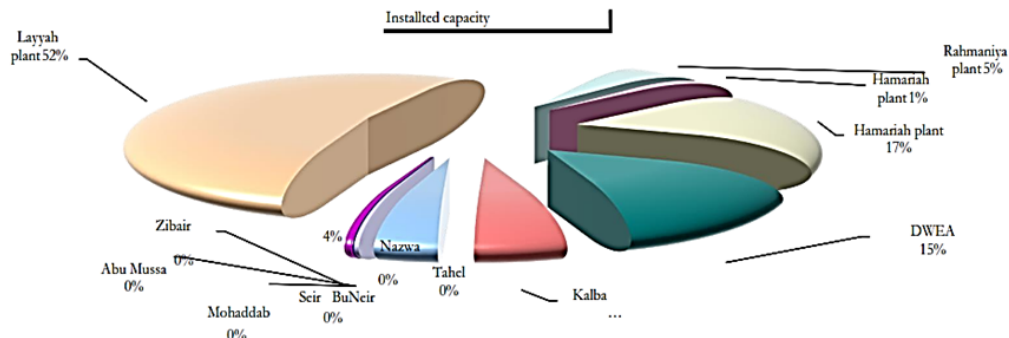
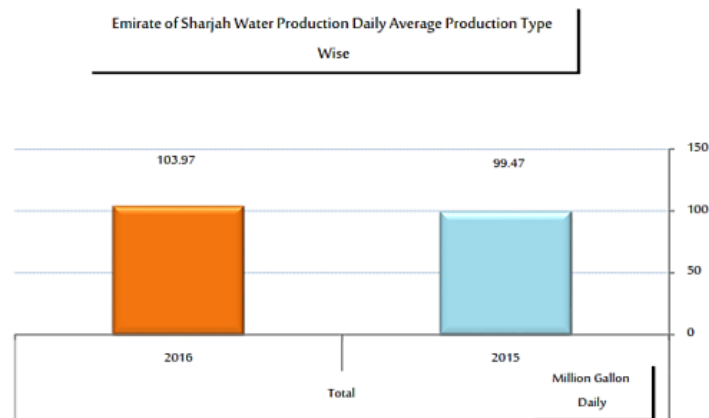
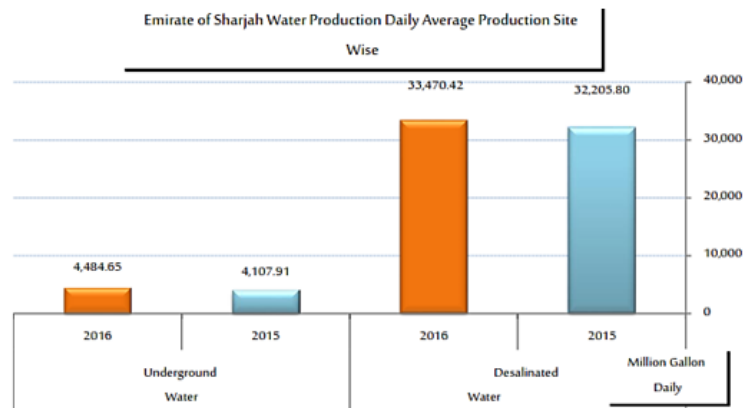


Figure 12. Capacity and quantity of freshwater produced in Sharjah in 2016 (SWEA, 2016)



Total		Underground Water		Desalinated Water		Wellfields & Desalination Stations
2016	2015	2016	2015	2016	2015	
37.955.06	36.313.70	4.484.65	4.107.91	33.470.42	32.205.80	Total
103.97	99.47	12.29	11.25	91.68	88.22	Daily Average
100.00%	100.00%	11.82%	11.31%	88.18	88.69%	Percentage %

Figure 13. Emirate of Sharjah Water Production Daily Average
Production Site Wise (SWEA, 2016)

SEWA Total		Kalba		Korfakkan		Shargah		← Cities ↓ Type & Capacity of Tanks
Capacity	No	Capacity	No	Capacity	No	Capacity	No	
30	2	0	0	0	0	30	2	15
20	2	0	0	0	0	20	2	10
7.5	1	0	0	0	0	7.5	1	7.5
6	2	0	0	0	0	6	2	3
5	2	0	0	5	2	0	0	2.5
4	2	4	2	0	0	0	0	2
3	3	1	1	0	0	2	2	1
0.2	2	0	0	0	0	0.2	2	0.1
0.05	1	0	0	0	0	0.05	1	0.05
0.01	1	0	0	0	0	0.01	1	0.01
75.76	18	5	3	5	2	65.76	13	Sub-Total 1
0.3	3	0	0	0	0	0.3	3	0.1
0.05	1	0	0	0	0	0.05	1	0.05
0.35	4	0	0	0	0	0.35	4	Sub-Total 2
76.11	22	5	3	5	2	66.11	17	Total

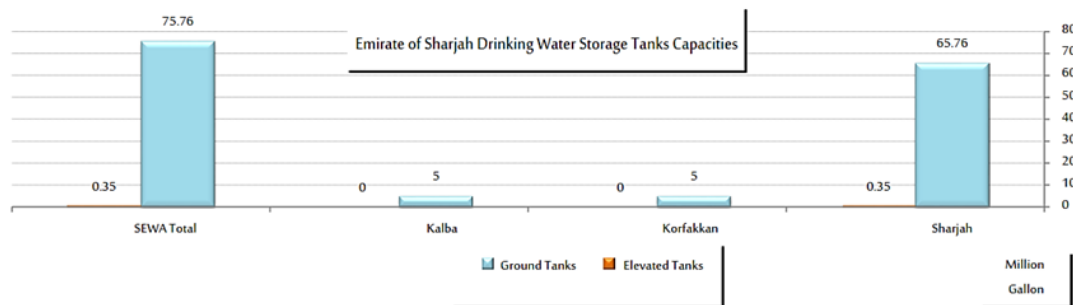


Figure 14. SEWA's Drinking Water Storage Tanks Capacity in Million Gallons-2016, (SWEA, 2016)

Emirate's Total		AGR Sectors		Government Sector		Commercial Sector		Industrial Sector		Residential Sector		SECTORS
2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	Year
26,483.307	25,291.547	8.955	11.184	2,147.499	2,156.777	5,937.507	5,374.836	1,277.272	1,315.744	17,112.073	16,433.006	Total
4.71%		-19.93%		-0.43%		10.47%		-2.92%		4.13%		% (+/-)

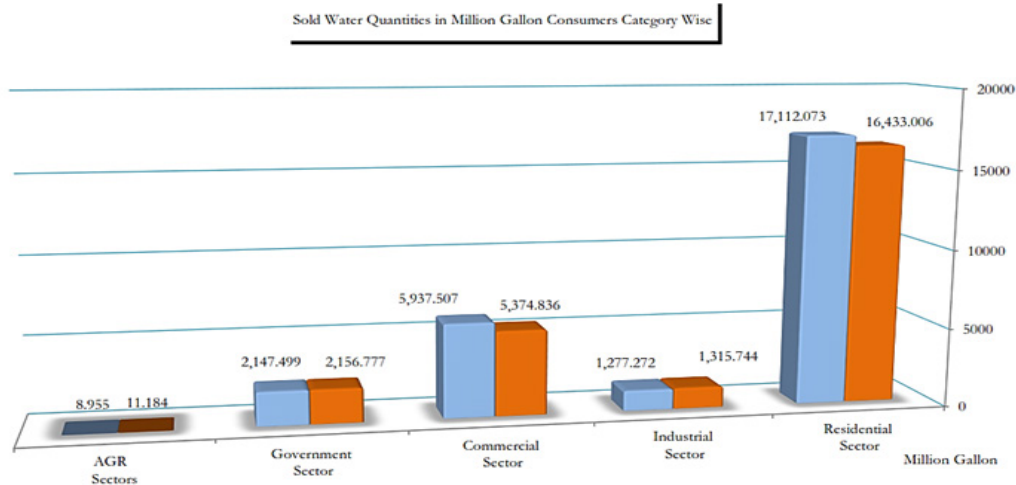


Figure 15. Emirate of Sharjah Sold Water Quantities in Million Gallon Consumers Category Wise (SWEA, 2016).

3. Non - Conventional Water Resources Management - Sharjah

3.1. *Desalinated Water*

SEWA has built in recent years several desalination plants and is intending to invest in the development of further plants. See Table 2 (Mogielnicki, 2020).

Table 2. Some existing desalination plants in Sharjah – UAE (Mogielnicki, 2020)

Desalination Plant Name	Type	Production (Mm ³ /yr)
Sharjah Layyah	Multi-Effect Distillation (MED)	51.60
Kalba	Reverse Osmosis (RO)	0.01
Abu Mussa	Reverse Osmosis (RO)	0.01
Al Hamriyah	Reverse Osmosis (RO)	0.02

Moreover, Sharjah's Electricity and Water Authority desalination plants' installed capacity in the United Arab Emirates shows stability in capacity of water derived from desalination plants over a period of 10 years, as shown in Figure 16 (Statista, 2020).

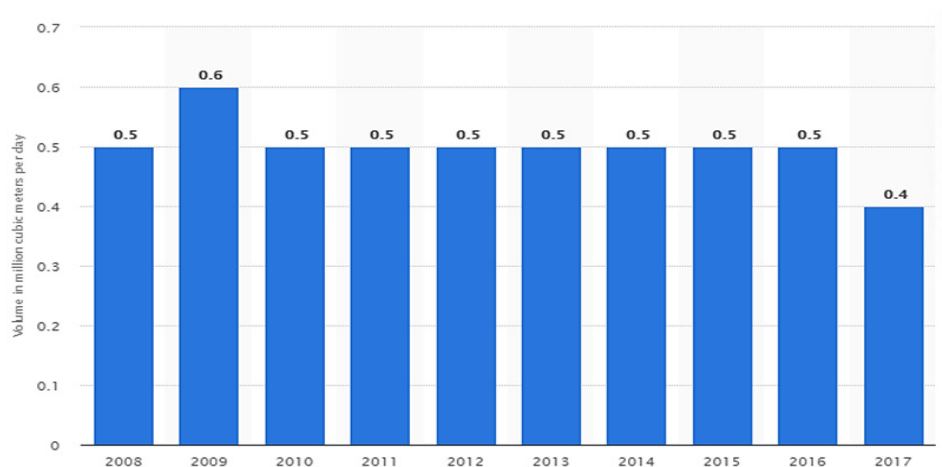


Figure 16. installed capacity of Sharjah Electricity & Water Authority desalination plants in the United Arab Emirates from 2008 to 2018 (Statista, 2020)

3.2. *Sewage Treated Water*

Treated wastewater is one of the non-conventional water resources. It is considered a supportive source of freshwater used for irrigation activities that accounts for 70% of groundwater production in the UAE. In April 2012, Sharjah Municipality launched a new underground sewerage treatment plant to cater for residential areas. In addition to the AED 227 million (USD 60 million) sewerage treatment plant in the Al Sajaa area. The main sewerage treatment plant at the fifth industrial area will undergo an expansion to increase its capacity from 30,000 m³ to 50,000 m³ /day (UAE, 2020).

3.3. *Wastewater Treatment Process in Sharjah*

The process of the pumping station is as follows: the influent from Sharjah City arrives at the plant through three main pump stations. Preliminary or Primary Treatment, separating the floating materials & grit, sand etc. This includes removing floating papers rags, cloths, plastic materials & Detritors (grit track) for removing grit and sand. The Secondary Treatment involves further treatment of the screened & properly mixed flow for biological oxidation. Following this is the Tertiary Treatment; devoid of 85% solids. The Sludge Treatment: involves removing solid from the treatment system and is treated by the polyelectrolyte in two stages. The Odour Control: consists of two-stage air scrubbers used at the inlet and tanker discharge facility to neutralise the malodorous gases. Finally, the Effluent water for irrigation, a discharging process to the city through a network and the rest to the effluent water which is discharged into the sea.

After discussing the major elements that lead to the formulation of water resource management which are: The Water Management Principles, the Legal Framework and Policy of Water Resources Management, Water Management in the UAE and finally, the Water Resources Management in Sharjah, we can come up with a successful Water Resource Management model for the Emirate of Sharjah.

Water Management Model for Sharjah

Our model comprises the optimisation of the management plan, which are set in six function areas: The Planning and Management of Water Resources, Ground Water Management, Efficient Use of Water in Agriculture, Domestic and Industrial Demand Management, Sustainability of Desalination, Wastewater Treatment and Reuse and Use of Efficient and Clean Energy to produce water.

1. Planning and Management of Water Resources

- Development of a coordinated national water management policy.
- Development of legislative instruments to encourage water conservation.
- Improvements in water resources management statistics.
- Capacity-building in water resources management, in particular the participation of UAE Nationals.
- Map the freshwater - saline water interface in space and time along the eastern coast of the UAE.
- Determine the freshwater reserve, the annual rate of recharge and the annual rate of discharge.

2. Groundwater Management

- Implementation of a national program to conserve groundwater and promote rational use.
- Improvements in groundwater statistics including the documentation and licensing of groundwater abstractions.
- Programs to improve collection of rainwater and use for groundwater recharge.

3. Efficient Use of Water in Agriculture

- Rationalisation of water use in agriculture.
- Programs to improve water use through:
 - Better identification of crop water requirements.
 - Changes in cropping patterns.
 - Improved irrigation practices and efficiency.
 - Evaluation of the use of alternative water resources (such as treated wastewater) in agriculture.

4. Domestic and Industrial Demand Management

- Improved programs for distribution system leakage monitoring and control.
- Economic instruments to promote water conservation and to enhance cost recovery.
- Studies of the pattern of domestic water use to identify conservation opportunities including use of more water-efficient equipments.
- Promotion of water-efficient industry and discouragement of industry with high water use.

5. Sustainability of Desalination

- Research programs to assess the impact of increasing levels of desalination on the marine environment and optimise intake and discharge locations.
- Develop national emergency plans for desalination plants.
- Building of national capacities in desalination operations.

6. Wastewater Treatment and Reuse

- Programs for construction of wastewater treatment plants in areas not currently served.
- Evaluation of further uses of treated wastewater.
- Setting of harmonised standards for treated wastewater reuse.

7. Use of Efficient and Clean Energy to produce water

- Use of solar electricity to run reverse osmosis pumps.
- Use of wind electricity to run reverse osmosis pumps.
- Use of Nuclear Electricity to produce water.
- Use of the above sources of electricity to treat the effluent water.
- Use innovative method to treat greywater from buildings. A good example is using

techniques employed by Abdulrahim Al- Ismaili et al. (Al-Ismaili et al. 2017) in Extending the Use of Greywater for Irrigating Home Gardens in an Arid Environment; a winning research paper in King Hamad Prize in Agriculture, Kingdom of Bahrain.

- Follow criteria set by LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) Programs in building designs as they contained lots of guidance in water use and recycling. The differences between the two programs are that LEED's thresholds are based on percentages, while BREEAM uses quantitative standards. In addition, LEED is more straightforward in its approach, while BREEAM is more academic and rigorous.

8. Follow up Recommendations Raised by Sound Regional Water Organization

For a successful water management model there must be a mechanism to allow for dynamic approaches to problem solving and updating or rectifying technical, scientific or policy issues. It is not recommended to endorse an emerging solution just because the water management strategy has not addressed such issues. A successful water management model must involve incorporating any successful and sound recommendation. For example, the Water Science & Technology Association in the GCC countries issued very useful recommendations which are worth highlighting and should be incorporated as part of this model (Al- Zubari, 2019) . The Conference has recommended the following:

8.1. *On desalination*

1. The GCC needs to make greater investments in the desalination industry to increase its added value to the economies of the GCC countries. Joint investments, research, education, and training programs are all initiatives which will contribute to the long-term prosperity, sustainability, and security of the municipal water supply sector.

8.2. *On groundwater and surface water resources*

1. Groundwater storage is another area that needs both further investment and research as an important water source while the use of impaired water needs to be developed with attention paid to the related health and environmental risks that it presents. This will help in aquifer restoration initiatives. The establishment of underground strategic reserves is also highly recommended which can be used in emergencies as well as for further beneficial related uses such as in agriculture.
2. The utilization of groundwater must be regulated through supporting legislation as a state-owned asset. Appropriate tariffs for groundwater use need to be set and there needs to be an acknowledgement of the enormous value of groundwater as an asset to help in groundwater restoration efforts.
3. Surface water needs to be utilized with greater efficiency through the development of water harvesting programs which can benefit from and utilize episodes of extreme flooding. This will allow for the negative effects of climate change to be channeled into positive outcomes.

8.3. *On Wastewater*

Wastewater reuse strategies need to focus on maximizing the use of treated wastewater

while ensuring safety and confidence in its use by addressing the health risks associated with its use, such as those resulting from pharmaceuticals and disinfection byproducts. The reuse of wastewater has thus far been utilized largely in irrigation, but greater research and investment needs to be made to encourage and promote the use of treated water in other sectors too. There are further significant benefits and opportunity in the utilization and recycling of wastewater, such as the conversion of waste into energy and the utilization of sludge in the fertilizer industry. Such initiatives are already operating in developed countries.

8.4. *On Municipal Water Management*

1. Adopt Smart City approach in urban planning and integrating the water sector with other city components of energy, mobility, infrastructure.
2. Build environment by fully utilizing the IT opportunities to achieve smart, intelligent, and efficient water management system in the GCC countries.
3. Work on enhancing energy efficiency in the water sector by auditing its energy usage and utilizing renewable energies in the desalinization and wastewater sector. Best practice from successful international examples of water supply and sanitation providers should be incorporated which focus on customer satisfaction through quality of service. Leadership needs to focus on the key components of developing capacity, ensuring operational efficiency while ensuring that the system is cost-effective and sustainable.
4. Adopt the best practices from successful international practice in the management of Non- Revenue Water (NRW) levels to enable greater efficiency of the water supply, reduce its cost and to enhance its financial sustainability.

8.5. *On Agricultural Water Management*

1. The agricultural sector needs to embrace innovative approaches to water productivity and efficiency to meet the needs of agriculture specific to the Gulf region such as desert farming in dry lands through supporting research and development projects in these areas and more broadly with the aim of reducing the overall consumption of water in the agricultural sector.

8.6. *On Industrial Water Management*

1. The oil and industrial sector are making major demands on the consumption of water and will do so into the future. Therefore, it is imperative that research and development efforts to increase water efficiency in this area are supported to manage the demand.
2. Wastewater treatment and reuse programs need to be supported by legislation to ensure enforcement and compliance.

8.7. *On Public Health and Environmental Protection*

1. Ensure that risk assessments are carried out to identify the risks associated with the safety of drinking water and sanitation and then to enact relevant legislation to implement these safety plans by all water utilities providers responsible for these two sectors in the GCC countries.

2. To ensure the same approach in risk management about the reuse of wastewater in agriculture and irrigation through careful observation and tracking. To implement risk management interventions and regulation so that wastewater reuse for agricultural irrigation is consistent with national or international standards. This sort of scrutiny and legislation should also be extended to the safeguarding of the marine environment to protect it from the negative effects of industrial wastewater and the brine reject form desalination plants.

8.8. On Water Sustainability and Security

1. Further build on the GCC Unified water Strategy, adopted by the GCC as a guiding document or the development of national strategies, and activates its joint initiatives at the regional level by the General Secretariat.
2. A concerted effort needs to be made to meet SDGs goals for water management which provides practical guidance for achieving water security and sustainability. Pioneering work needs to be done in extending existing knowledge and addressing regional needs, especially in the field of groundwater-related challenges, so that effective and ambitious solutions can be developed.
3. Invite and encourage governments and research, whether through research institutions or individual initiatives to pioneer solutions and plans that are led by an understanding of the challenges that face the Arab region, not least of which is climate change and its impact on water resources and the vulnerability of the water sector to climate change.

The Use of Waterless Urinals Benefits and Pitfalls – Future Considerations)

For most, but not all, sites, waterless urinals are a good and cost-effective alternative. The type of waterless urinal you choose is important because, while all types of waterless urinals save the same amount of water, they have varied installation and operating expenses. The cheaper the waterless urinals are, the more probable the savings will outweigh the costs. It's crucial to calculate the overall cost of a waterless urinal system over the course of one to three years. It's worth noting that some vendors may not be eager to share all of the ongoing charges at the time of purchase (Waterless Urinals, 2021). There are around 8 million urinals in use in the United States alone, ranging from small office buildings to massive skyscrapers to massive sports venues. Approximately 100 million people use such urinals each year, consuming approximately 160 billion gallons (605 billion litres) of water. Waterless urinals, on the other hand, can save a significant quantity of water. Consider what would happen if those 160 billion gallons of water were cut in half, or even eliminated entirely. (Waterless, 2021).

Conclusions

The UAE government has made great efforts to deal with the impact of water scarcity. A national environmental strategy has been implemented with the aim of improving the situation of water resources. The policy of water management was planned for this purpose.

The results have seen an increase in activities such as desalination plants. However,

groundwater production is decreasing, and the deficit is made up by increasing the production of desalinated water. However, this has been expensive and has led to financial stress due to the increase in the cost of desalination. Significant water-related problems that the government is successfully dealing with in the Emirate of Sharjah are the depletion of aquifers in Al Dhaid, saline-water intrusion and water quality deterioration. In the northern Emirates, saltwater intrusion in coastal zones is now active along the UAE's eastern coastal plain extending between Dibba in the north and Kalba in the south for about 70 km. These issues present significant challenges going forward.

This paper has highlighted the latest conventional and non-conventional water resources being used in the Emirate of Sharjah. Comprehensive recommendations have been made to support successful water resources management, including planning and management of water resources, groundwater management, efficient use of water in agriculture, sustainability of desalination, domestic and industrial demand management, the sustainability of the desalination and wastewater treatment and reuse.

A water management model for Sharjah is made in an attempt to guide and create a vision for the future of Sharjah in water conservation, production, and management.

Recommendations come out of this research work are including GCC needs make greater investments in the desalination industry and groundwater storage sector. With regulations to be introduced supporting legislation as a state-owned asset. Moreover, surface water needs to be utilized with greater efficiency. Wastewater reuse strategies need to focus on maximizing the use of treated wastewater. Adopt Smart City approach in urban planning and integrating the water sector, fully utilizing the IT opportunities, and enhancing energy efficiency. The agricultural sector needs to embrace innovative approaches to water productivity. In addition it is imperative that research and development efforts to increase water efficiency in the oil sector. Ensure risk assessment is done for public health issues.

References

- Adimalla, N., Li, P., (2019). Occurrence, health risks, and geochemical mechanisms of fluoride and nitrate in groundwater of the rock-dominant semi-arid region, Telangana State, India. *Human and Ecological Risk Assessment: An International Journal*. 25 (1–2), 81–103.
- Al Hamadi, MK, 2003. *Assessment of Groundwater Resources using Remote Sensing and GIS*, M.Sc. Thesis, Water Resources Program, UAE University, UAE.
- Al-Ismaili, Abdulrahim M; Ahmed, Mushtaque; Al-Busaidi, Ahmed; Al-Adawi, Seif; Tandlich, Roman(2017) *Extended use of greywater for irrigating home gardens in an arid environment et al.Environmental Science and Pollution Research International*, Vol. 24, Iss. 15, (May 2017): 13650-13658. DOI:10.1007/s11356-017-8963-z
- Al-Ruzouq, Shanableh, Yilmaz, Idris, Mukherjee, Khalil and Gibril (2019). Dam Site Suitability Mapping and Analysis Using an Integrated GIS and Machine Learning Approach. *Water Resources Management, Policy and Governance*, 11(9), p.1880.
- Alsharhan A.S., Rizk Z.E. (2020) Water Resources and Water Demands in the UAE. In: Water Resources and Integrated Management of the United Arab Emirates. *World Water Resources*, vol 3. Springer, Cham pp 757-791.

- Atlas, W. (2020, November 29). Monthly weather forecast and climate Sharjah, United Arab Emirates. Retrieved from *Weather-atlas*. <https://www.weather-atlas.com/en/united-arab-emirates/sharjah-climate>.
- Al-Zubari, W.K. (2020) The WSTA 13th Gulf Water Conference Water in the GCC: Challenges and Innovative Solutions, *Conference Proceeding, State of Kuwait, 12-14 March, 2019*. <https://wstagcc.org/conference/wsta-13th-gulf-water-conference-kuwait-2019/>
- Climate, W. &. (2020, November 29). Climate in Sharjah (Sharjah Emirate), United Arab Emirates. Retrieved from *Weather & Climate*. <https://weather-and-climate.com/average-monthly-Rain-fall-Temperature-Sunshine,sharjah-ae,United-Arab-Emirates>
- Dakkak, A. (2020, March 12). *Water Management in UAE*. Retrieved from EcoMENA: <https://www.ecomena.org/water-management-ua> Databank.worldbank.org. 2020. Glossary | Databank. [online] Available at: <[https://databank.worldbank.org/metadataglossary/sustainable-development-goals-\(sdgs\)/series/ER.H2O.FWTL.K3](https://databank.worldbank.org/metadataglossary/sustainable-development-goals-(sdgs)/series/ER.H2O.FWTL.K3)> [Accessed 22 November 2020].
- Dawoud, M.A. (2020) Groundwater economics in arid regions: Abu Dhabi Emirate case study *Desalination and Water Treatment*, Volume 176, pp84-93 doi: 10.5004/dwt.2020.25501.
- Dongre, G. K., Kalubarme, M. H., Pandya, M. (2016). Site Suitability Selection For Proposed Ponds in the Gujarat State Using Gis and Remote Sensing. *International Journal of Engineering Development and Research*, 4(2). Retrieved from <https://www.ijedr.org/papers/IJEDR1602285.pdf> .
- Elgendy, K. (2020, November 26). Water Availability and Use in the Middle East. Retrieved from *Carboun*. Available Online at: <http://www.carboun.com/water/water-availability-and-water-use-in-the-arab-world-infographics/>.
- ESCWA, 2003. Water scarcity in the Arab world. *Population and development report*. Beirut, Lebanon.
- Hazelton, J. (2015), "Sustainability after Rio: developments incorporate water accounting and accountability", *Developments in Corporate Governance and Responsibility*, Vol. 8 No. 1, pp. 27-55. [2].
- Karunya University, k., 2013. *Technology for Social Needs*. [Online] Available at: <https://karunya13ms101.wordpress.com/> [Accessed 24 November 2020].
- Len, T., Xem L. (2012, March 13). Tutorial on Basic Principles of Integrated Water Resources Management. Retrieved from *phongdongnai wordpress*. Retrieved from phongdongnai wordpress: <https://phongdongnai.wordpress.com/2012/03/18/tutorial-on-basic-principles-of-integrated-water-resources-management/> .
- Mogielnicki, R., AGSIW (2020). *Water Worries: The Future of Desalination in the UAE*. Available Online at: <https://agsiw.org/water-worries-the-future-of-desalination-in-the-uae>.
- Mohamed M, Almualla A (2010a) Water demand forecasting in Umm Al-Quwain (UAE) using the IWR-MAIN specify forecasting model. *Water Resour Manage* 24:4093–4120

- Mohamed M, Almualla A (2010b) Water demand forecasting in Umm Al-Quwain using the constant rate model. *Desalination* 259:161–186.
- Mukherjee, I., Singh, U.K., (2018). Groundwater Fluoride Contamination, Probable Release, and Containment Mechanisms: a Review on Indian Context. *Environmental Geochemistry and Health*.
- Murad, A., 2010. An Overview of Conventional and Non-Conventional Water Resources in Arid Region: Assessment and Constrains of the United Arab Emirates (UAE). *Journal of Water Resource and Protection*, 02(02), pp.181-190.
- Nouh, M., 2008. An Overview for the Water Resources of the United Arab Emirates. *Proceedings of the 1st Technical Meeting of Muslim Water Researchers Cooperation*, December 2008, Malaysia.
- Sanchez, M. d. (2018, September). UAE Groundwater Levels Falling by .5cm Per Year, According to New Masdar Institute Research. Retrieved from *Khalifa University*. <https://www.ku.ac.ae/uae-groundwater-levels-falling-by-5cm-per-year-according-to-new-masdar-institute-research#:~:text=Masdar%20Institute%20graduate%20student%20Maria,of%20about%20860%20billion%20liters> .
- SEWA. (2016). *Water Statistics*. Sharjah: Sharjah Electricity, Water and Gas Authority - UAE. Available online at: <https://www.sewa.gov.ae/uploads/statspdfen/2016/WATER2016.pdf> .
- Siddique, M. (2015, March 16). *Review of water resources in uae*. Retrieved from Slideshare: https://www2.slideshare.net/yourmohsin/review-of-water-resources-in-uae?from_action=save .
- Statista, R. D. (2020, August). *Energy & Environment - Water & Wastewater*. Retrieved from Statista: <https://www.statista.com/statistics/745166/uae-desalination-water-plants-capacity-of-sharjah-electricity-and-water-authority/> .
- UAE, G. P. (2020, August 20). *Sewerage projects*. Retrieved from The United Arab Emirates' Government Portal: <https://u.ae/en/information-and-services/infrastructure/civic-facilities/sewerage-projects>.
- UN India. 2020. SDG 6: *Clean Water And Sanitation*. [online] Available at: <<https://in.one.un.org/page/sustainable-development-goals/sdg-6/>> [Accessed 22 November 2020].
- United Arab Emirates Ecology & Nature Protection Laws And Regulations Handbook (2010). Washington, DC: *International Business Publications*, USA, Volume 1, pp106.
- Zein S. Rizk, Abdulrahman S. Alsharhan, (2003). Water resources in the United Arab Emirates. *Developments in Water Science*. Elsevier, Volume 50, Pages 245-264.
- Water.Fanack. (2017, October 23). Water Resources in UAE. Retrieved from *Water Fanack*: https://water.fanack.com/uae/water-resources/#_ftn9.
- WaterlessUrinals. (2021, October 27). Waterless Urinals Benefits and Pitfalls. Retrieved from *Waterless Urinals*: <https://www.waterlessurinals.co.uk/Waterless-Urinals-Benefits-and-Pitfalls.html>

Waterless Urinals: <https://www.waterlessurinals.co.uk/Waterless-Urinals-Benefits-and-Pitfalls.html>

Weatherspark. (2020, October 21). Average Weather in Sharjah. Retrieved from *Weather Spark*: <https://weatherspark.com/y/105471/Average-Weather-in-Sharjah-United-Arab-Emirates-Year-Round> .

Wecker, K. (2017, August 29). Are we running out of fresh water? Retrieved from *Deutsche Welle* (DW): <https://www.dw.com/en/are-we-running-out-of-fresh-water/a-40241057>.

الممارسات الإدارية لموارد المياه التقليدية وغير التقليدية: دراسة حالة في إمارة الشارقة - الإمارات العربية المتحدة

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المُستخلص

تحدد هذه الورقة العوامل الحاسمة الأساسية والإجراءات العملية للإدارة الناجحة لموارد المياه في إمارة الشارقة - الإمارات العربية المتحدة. وتتضمن هذه العوامل تخطيط وإدارة موارد المياه، إدارة المياه الجوفية، الاستخدام الفعال للمياه في الزراعة، واستدامة تحلية المياه، إدارة الطلب المنزلي والصناعي، استدامة تحلية المياه، ومعالجة مياه الصرف الصحي وإعادة استخدامها. تم تسليط الضوء على أحدث موارد المياه التقليدية وغير التقليدية في الشارقة، بما في ذلك التبخر والمناخ الحار وما يرتبط به من انخفاض في موارد المياه. وقد تم أيضاً تقييم موارد المياه في دولة الإمارات العربية المتحدة وإدراجها في نموذج إدارة المياه المقترح لدينا، والذي تم تصميمه للتغلب على ندرة كميات المياه الطبيعية في الشارقة، مما يمثل تحدياً مستمراً للحكومة والذي تعتبره أولوية لحلها.

مفاتيح الكلمات: نموذج إدارة المياه، المياه الجوفية، مياه الصرف الصحي، الشارقة، الإمارات العربية المتحدة.

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