Baseline Assessment Study for SWIM-Sustain Water MED:

Wastewater Treatment Plant for Public Security Directorate Compound in Moqabalane area, Amman

FINAL REPORT

SUBMITTED TO

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Abbreviation

BA	Base Line Assessment
BAU	Al Balqa Applied University
BOD	Biological Oxygen Demand
CM	Cubic Meter
COD	Chemical Oxygen Demand
CW	Constructed Wetland
dB(A)	Decibel is unit used to measure sound level, (A) weighting filter
EIA	Environment Impact Assessment
EPA	American Environment Protection Agency
GIZ	Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH
JVA	Jordan Valley Authority
JOD	Jordanian Dinar
JS	Jordanian Standard
IUCN	International Union for Conservation of Nature
MWI	Ministry of Water and Irrigation
PSD	Public Security Directorate
QMRA	Quantitative Microbial Risk Analysis
RBC	Rotating Biological Contactors
SC	Steering Committee
SBR	Sequencing Batch Reactor
SWIM	Sustainable Water Integrated Management
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USAP	Upflow Anaerobic Sludge Blanket
WAJ	Water Authority of Jordan
WHO	World Health Organisation
WWT	Waste Water Treatment

1. Introduction

1.1 Project overview

The proposed project lies within the framework of SWIM-Sustain Water MED (SWM) project. The goal of SWM project is to demonstrate the potential application of decentralized wastewater management and contribute to achieving the millennium development goals. Decentralized wastewater management approaches can be the optimum solution in many locations in Jordan where groundwater and surface water can be exposed to pollution as a result of improper sanitation; namely cesspools (Halalsheh et al., 2008; Halalsheh and Wendland, 2008). This is specifically the case for areas that are not covered with sewerage network including parts of the Capital Amman. In fact, decentralized sanitation was adopted recently in the water strategy of Jordan and is considered as the only feasible solution for such cases; examples of decentralized sanitation projects include the wastewater treatment units in universities (Jordan University for Science & Technology and in Mutah University among others) and at municipal level such as in Tal Al Mantah and Al Shoubak. Introducing suitable decentralized wastewater management options necessarily include managing effluents of the suggested treatment options. In Jordan, wastewater is considered as important non-conventional water source and is almost completely used for agricultural irrigation; in 2010 about 103 MCM were the effluent of wastewater treatment plants usable in irrigated agriculture (DAI 2012, MWI 2010). Having this in mind, safe use of treated wastewater is obviously part of any wastewater management plan.

A new compound of Public Security Directorate (PSD) in Moqablane area (the site) is currently under construction. It is located in Muqabalane (Al Kodos Street), see Figure 1. At present the site is occupied by (350 persons), with the command and control units are already operating there. However according to PSD the full capacity is expected to reach 2466 once the compound is fully developed. At present, the wastewater is collected in a collection tank (70 m^3) and hauled by tankers 2-3 times a week. Sewerage network at the site is under construction with a current 60% coverage for the buildings. In order to provide sustainable sanitation for the compound, on-site wastewater treatment and reuse management will be suggested by the herein proposed project.

Figure 1: General view of the project site

1.2 Baseline report

The baseline study was conducted at watershed level since the concept is mostly applied when considering water management projects. The concept usually provides an efficient planning policy since it coordinates and integrates water management with land use planning in the study area (sub-catchment). Taking into account the local conditions specific to the project site (being a pilot project at a closed professional community; PSD), a study area was chosen for the baseline assessment to cover the main interactions with the surrounding environment (Figure 10).

1.3 Methodology

The methodology used in preparing this study was based on analyzing the current institutional, socio-economic and environmental settings in the study area. Moreover, PSD employees were solely targeted for some elements of the study due to the heterogeneity of existing settings in the study area. Ministry of Water and Irrigation, Department of Meteorology were a prime source of data for the water and environmental setting. Organizations like Petra University, Al-Quds College, Jordanian Gendarmerie were found to be the main heterogeneous anthropogenic bodies located in the study area with respect to institutional and socio-economic aspects. Remainder of the study area consists basically of residential settings.

Further work relevant to wastewater treatment plant selection process was based on a detailed analysis of the directorate institutional settings; pre-suggested location of the treatment plant; capacities existing at the directorate especially those related to operation and maintenance of the selected system; wastewater characteristics and; potential reuse options. Both package treatment units and built-in units were considered and compared using a sustainability analysis (involving economic, technical, operational and environmental factors). Conceptual design was then provided for the selected systems by the project technical committee.

For comprehensive description of the study area, available data regarding physical and environmental characteristics were collected. A special interest was given to PSD with respect to economic and social settings of the compound. For which case data were obtained through official correspondence, field visits and meetings with Eng. Murad Al Masri (project counter-part at PSD).

1.4 Data Sources

Public Security Directorate

Data and information related to the existing and planned compound was obtained by direct contact with Engineer Murad Al-Masri (PSD, Project Counterpart). All information regarding water consumption, consumption patterns, existing wastewater collection system were collected and analyzed. The location of the planned wastewater treatment plant was also discussed with PSD.

Department of Meteorology

All necessary data concerning climatic conditions prevailing in the area were collected through official correspondence with the department of meteorology. The provided data was tabulated; most relevant parameters were included in the text.

Ministry of Water and Irrigation

All data regarding water resources, existing wells, and existing monitoring wells were provided through official correspondence with the Ministry of Water and Irrigation.

Ministry of Agriculture

Relevant information regarding soil characteristics were collected from Ministry of Agriculture through personal contacts as well as from the results of boring and soil tests at the site of PSD.

Ministry of Environment

Information regarding the legal requirements pertaining to the pilot project was obtained from the Ministry of Environment.

2. Background of Pilot Project Area

2.1 Geographic location and settlement structure

For this pilot project, the community in consideration is PSD. The total area of PSD compound is 150,000 m^2. The green area in the compound is around 18,500 m^2. Another 15,500 m^2 is available for use as a green area inside the project borders. In addition, an outside border area of 90,000 m^2 exists and can be used as a green area after coordination with relevant parties (Jordan Telecommunication (vacant land used for towers) located next to the site and the Gendarmerie, adjacent to the Telecommunication land). The total area of buildings is 57,703 m^2 and they will be occupied by around 2466 people. Around 10% of the total employees are expected to be on call over 24 hours. The rest are on regular duty hours that extend from 8:00 until 16:00. Being a security directorate -in certain cases- all employees could be instructed to remain on duty 24 hours.

The buildings (Table 1) include headquarter, offices, recreation building, command and control center, internal affairs building, mosque, and energy center. The recreation building contains the main kitchen and restaurants with a total number of 3000 meals expected to be served daily. The recreation building also includes the laundry, which is expected to produce around 15000 kg of laundry each day. Site Plan of the Public Security Directorate compound can be found in Annex 1.

The study area is characterized by its heterogeneous human activities. It contains two private universities, Amman National Park, Ghamadan Park, Dunes Club, Gendarmerie Directorate and Public Security Directorate and the telecommunication towers and storage facility. In additional several residential blocks exist in the area including Northern Bnayyat district, Sothern Bnayyat district, Al-Husayneyyeh district, Moqabalane district, Khraibet Al-Souk and Al-Yadoodeh district.

Table 1: General Security Directorate incorporated buildings and their occupancies

No.	Building	No. of floors	Space area (m^2)	No. of occupants
1	General Headquarter	2+basement	11,464.08	400
2	Office A	3+basement	3,129.38	232
3	Office B	3+basement	3,678.09	230
4	Office C	3+basement	3,186.92	295
5	Office D	3+basement	4,323.71	235
6	Recreation	3+basement	10,250.50	224
7	Command and Control Center	2+basement	10,000	350
8	Internal Affairs	3+basement	9,800.00	400
9	Mosque	One floor	520.00	
10	Energy center	One floor	1,351.00	100
Total			57,703.00	2466

2.2 Socio-economic setting

From the meetings held with PSD, it is concluded that PSD community has a variety of education levels; the range is from non-skilled labor to staff members holding bachelor or postgraduate degrees. As the community is a professional organization, the age starts from 18 years and above. The average income for the staff ranges from 200 JOD / months to slightly above 1000 JOD/month. PSD has staff of both genders; females reach 30% of all PSD staff, while in the Command and Control females exceed 45% of staff.

The personnel who will be following up the overall performance of the treatment system have technical qualification. However, as will be described in the institutional framework, the operation and maintenance of the plant will be contracted to the private sector as adopted by the directorate in other compounds. The reuse of the reclaimed water will be managed by the responsible staff of the directorate; in which case, proper training on health aspects has to be given; as the labors are do not have proper education on such issues. A financial sustainability plan regarding the O&M costs to guarantee the future proper operation of the plant is recommendable.

In the past (30 years ago), the lands in the study area used to be seasonally used for rain fed agriculture (not necessarily owned by the farmers). However, with the expansion in the urban areas of Amman, the present land use pattern in the study area is residential / with public and commercial buildings (Figure 1). The area of PSD community is being totally used. Around PSD site residential, commercial, and administrative (public) buildings exist. The adjacent land on the eastern border of the site is a vacant governmental land and not allowed for building as it is used for the telecommunication towers. This lot is sometimes used for seasonal crops by nonpermanent farmer.

The pilot project is not expected to have direct interaction with the neighboring community around PSD in terms of water reuse. The community (from socio-economic perspectives) for this study is limited to PSD. However, the planned demonstration and awareness raising activities by the pilot project will in the future advance the knowledge and understanding of target groups on reclaimed water reuse.

3. Environmental Setting

3.1 Climatic conditions

In general the climate of the area is considered semi-arid to arid, with cold rainy winter and dry hot summer. Most of precipitation occurs during rainy season that would extend from October to April.

To obtain the necessary climatic data the Department of Meteorology was consulted on best location that would represent the study area, the station of Marka airport was recommended as it is closest to the site (12 km north east). Therefore, the data on climatic conditions including temperature, humidity, rainfall, evaporation, and wind speed and direction were obtained from the Meteorological Department for the nearest weather station (Amman Airport – Marka). The data was analyzed and presented for (2011) and the past 20 years to get to an understanding about the trend of major attributes as follows.

3.1.1 Temperature

Figure 2 shows the temperature curve over one year (2011); the mean maximum temperature reached (35°C) in July, while the mean minimum temperature reached (4.4°C) in January. The yearly mean air temperature and mean maximum and minimum temperature are also plotted in Figure 3 for the past 20 years.

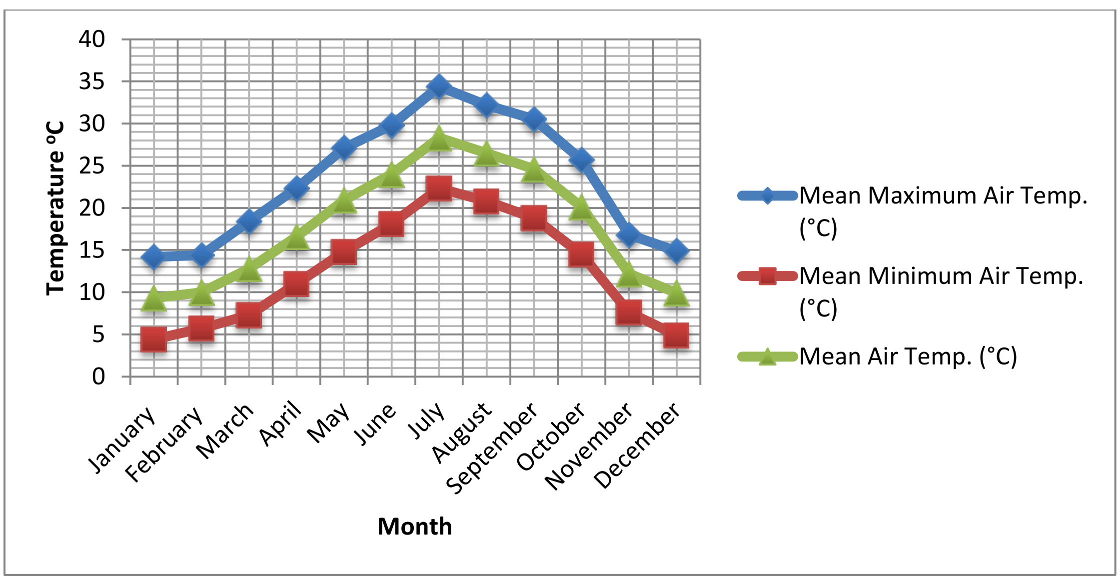


Figure 2: Temperature curve for 2011

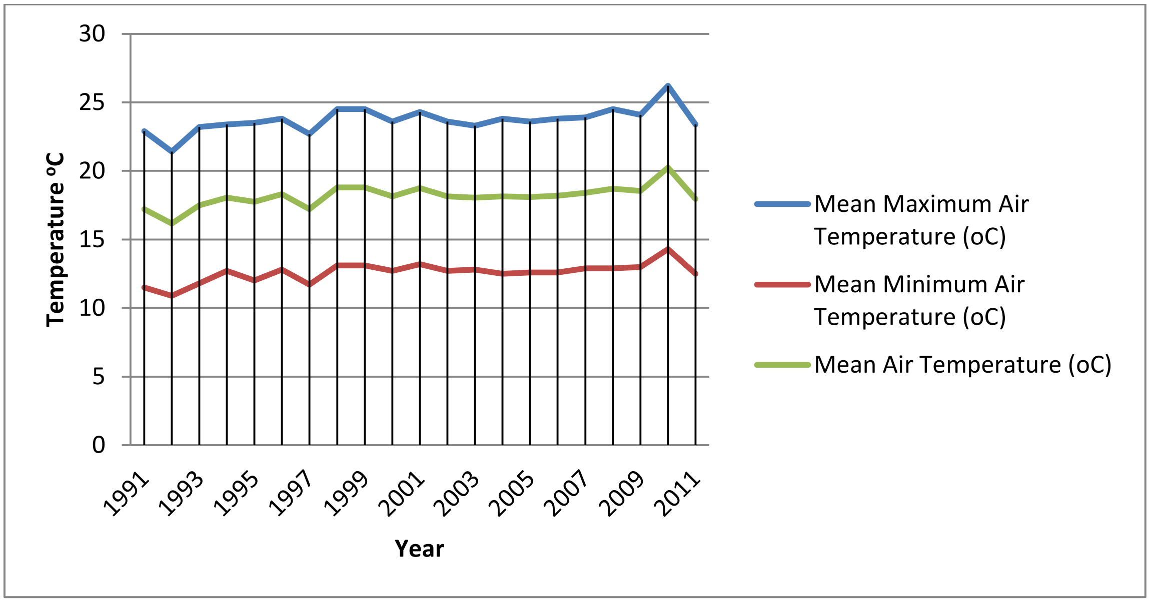


Figure 3: Mean air temperature

3.1.2 Humidity

Humidity curve over one year (2011) is given in Figure 4; where it is seen that lowest relative humidity was recorded in July, being the hottest month of the year.

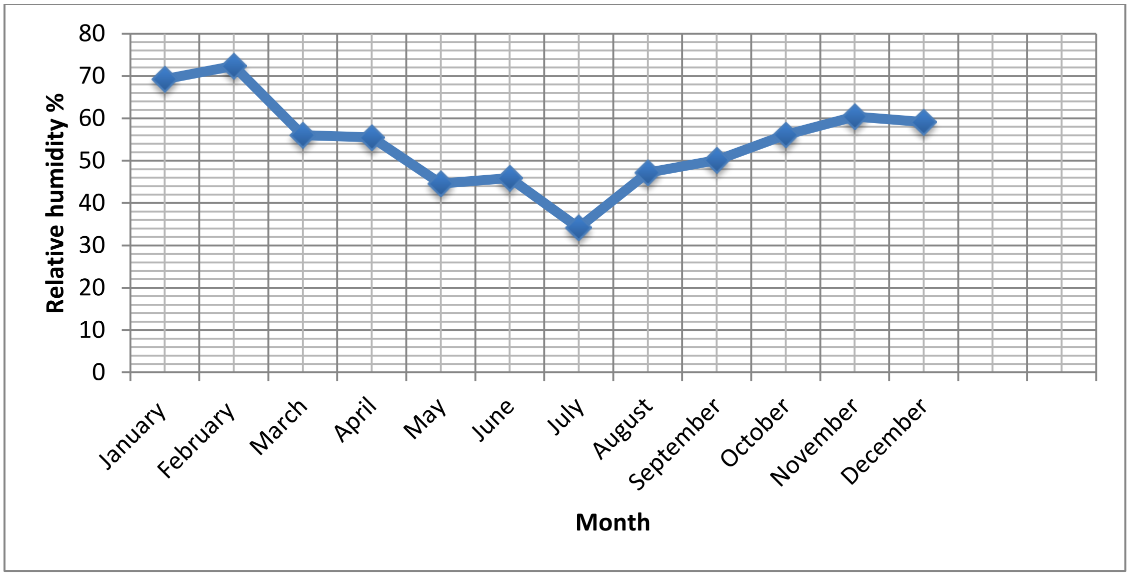


Figure 4: Relative humidity curve for 2011

The relative humidity for the past 20 years is shown in Figure 5; it is seen that there is a tendency for decreased humidity with time.

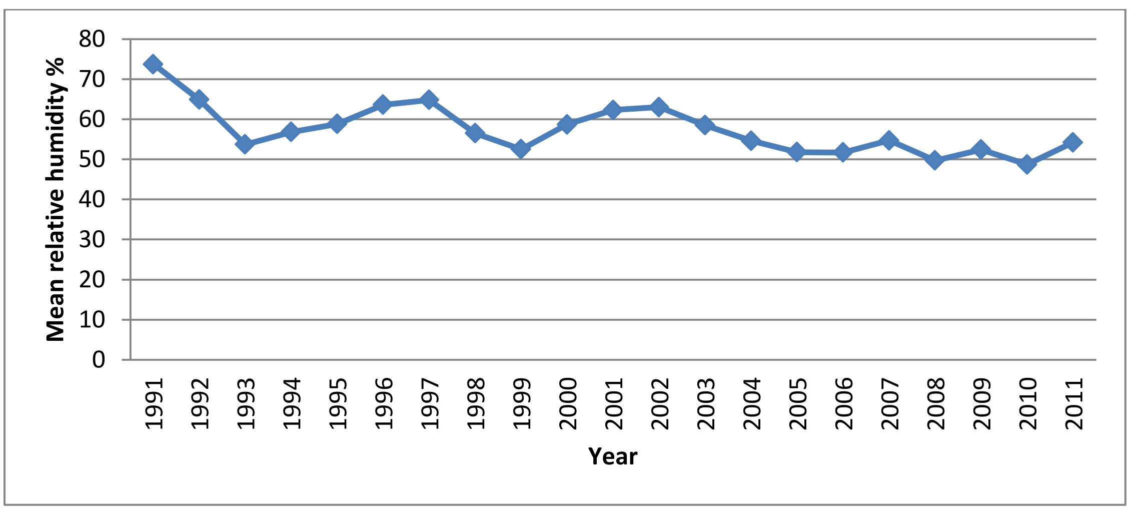


Figure 5: Mean relative humidity for the past 20 years

3.1.3 Rainfall

In 2011, the highest rate of precipitation was recorded in February and reached 64 mm only (Figure 6).The area has an average total yearly precipitation of 240 mm (Figure 7). In wet seasons, the precipitation becomes significant; in 1992 it exceeded 450 mm, while in 2003 it exceeded 300 mm.

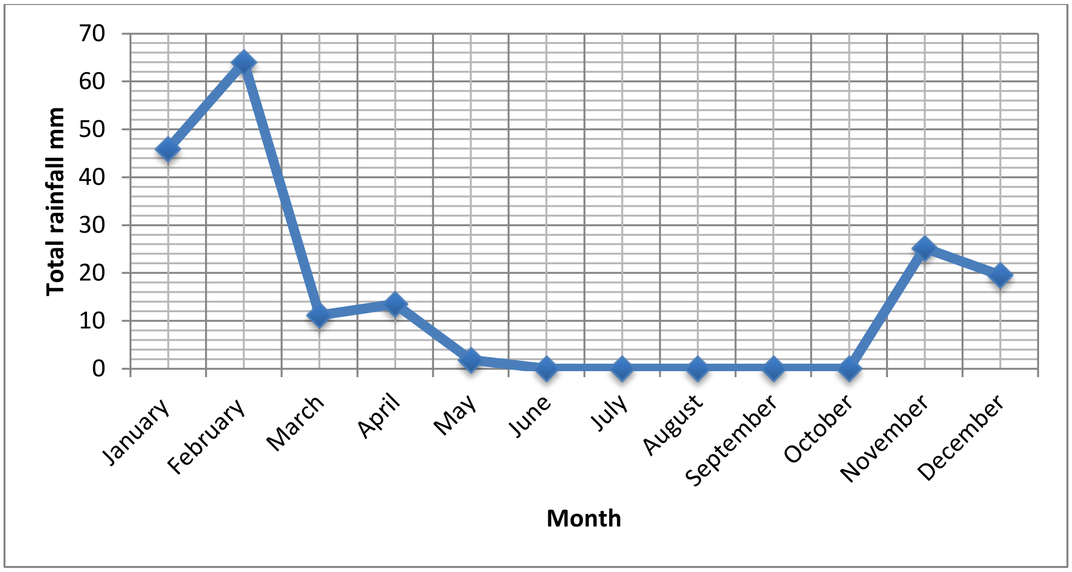


Figure 6: Rainfall curve for 2011

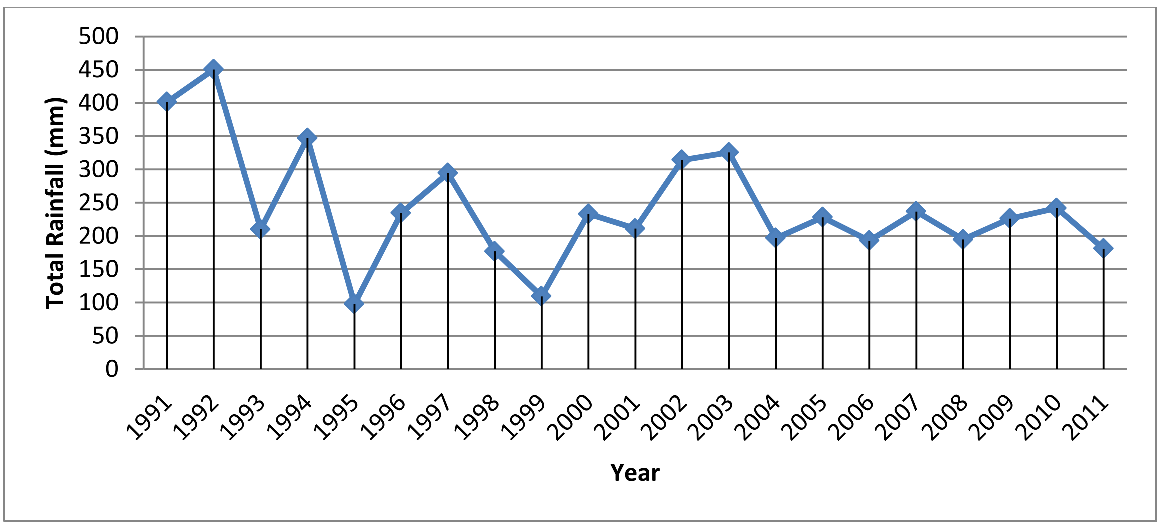


Figure 7: Total yearly rainfall (1991 – 2011)

3.1.4 Evapotranspiration

Total monthly potential evaporation reached the peak (350 mm) in July 2011 (the hottest month), see Figure 8. The profile over 20 years is shown in Figure 9, where the average yearly total evaporation is 183 mm. The figure shows a trend of slow reduction in total evaporation over the past 20 years.

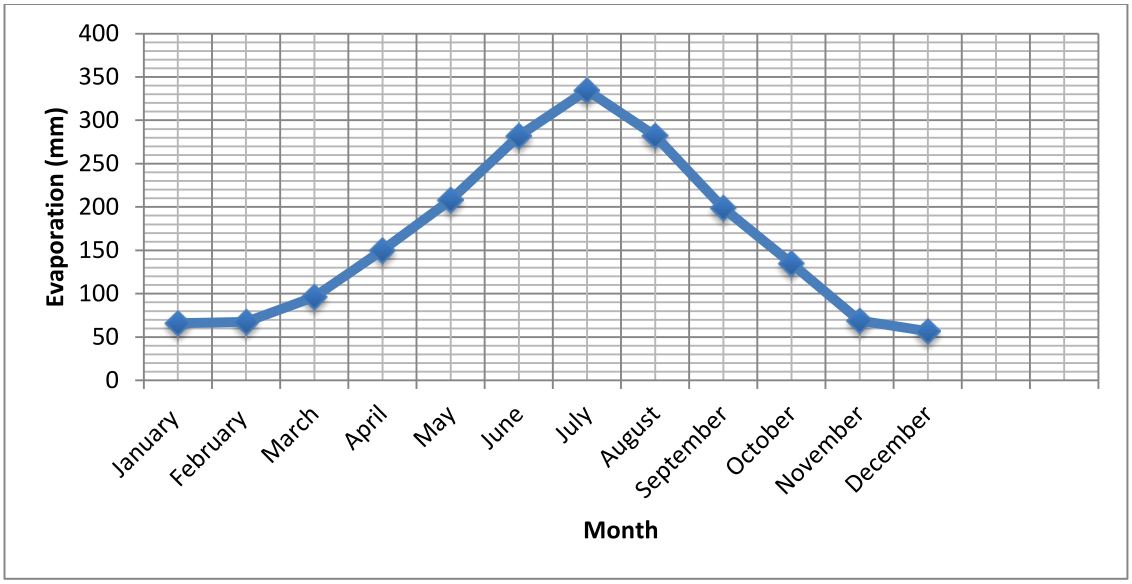


Figure 8: Evaporation curve for 2011, Class A Pan

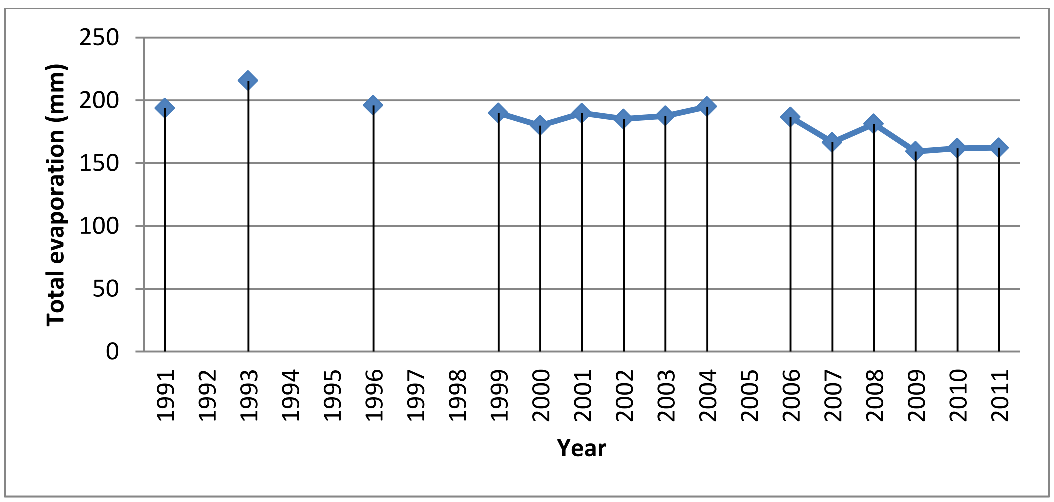


Figure 9: Yearly average total evaporation, Class A Pan

For such a type of study area (being arid – semi arid) the evapotranspiration under standard conditions[1] has been estimated by the Food Agricultural Organization (Allen, et al. 1998) as given in Table 2.

[1] Evapotranspiration under standard conditions is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.

Table 2: Evapotranspiration under standard conditions

Mean Daily Temperature (^oC)	Evapotranspiration (mm/d)
Cool: around 10^oC	1-3
Moderate: around 20^oC	4-7
Warm: higher than 30^oC	6-9

Evapotranspiration data were obtained from Mushaqar agricultural station for 2011. The station is at an elevation of about similar elevation of Marka station (750 m above sea level), the station is 24 km south west of the study area. The use of the data of evapotranspiration data from this station is related to the availability of data and its relevance to agricultural applications. From the data of Mushaqar, the evapotranspiration rate ranges from 0.29 mm/day to 8.6 mm/day with a yearly average of 4.0 mm/day.

3.1.5 Wind speed and direction

The prevailing wind direction data collected from the nearest meteorological station (in Marka), shows that the prevailing wind direction is from the west (Table 3); the wind direction in summer is mostly north westerly while it changes in winter to westerly and south westerly. The wind speed ranges in monthly average from 2.7 to 5.2 knot.

Table 3: Monthly wind speed and direction in 2011

Month	Degree from North	Wind Direction	Mean Wind Speed (Knot)
January	260	W	3.7
February	245	WSW	5.2
March	240	WSW	4
April	240	WSW	4.8
May	250	WSW	5.1
June	310	NW	5.5
July	305	NW	4.7
August	320	NW	5
September	310	NW	3.7
October	290	WNW	3.3
November	220	SW	2.7
December	230	SW	2.8

3.2 Water Related Characteristics

The project area (site) is located in the northern parts of Wadi Wala watershed that runs from south Amman at about 700 m above sea level to its confluence with the Wadi Mujib about 3 km from the Dead Sea at an elevation of 300 m below sea level. The total drainage area is around 1800 km^2. Taking into account the extent of the study, a study area around the project was chosen as shown in Figure 10 sufficient to address the surrounding environmental aspects including water. The area of study area is around 42.31 km^2. It extends from south-East Amman in the north to Zaitouneh University south Amman; and from Om Alqsair district east of Amman to Marj Al-Hamam district west of Amman.

The study area is drained by some wadis that run gently to the south. The northern segments of the area lay at an elevation of 962 m above sea level and slopes down to an elevation of 791 m above sea level in the southern segments of the study area as shown in Figure 11.

Rain during rainy season infiltrates into soil, collects in depressions and runs as a stream flow in the existing wadis. Amounts of water infiltrating depend on factors that include the slope of terrain, soil characteristics and volume of water that is already stored in the soil. In general the study area soil has can store water during the rainy season and between long dry periods that prevails between rains.

The main groundwater aquifer in the study area is A7/B2 of the Balqa group and the deeper Ajloun group as described in the following section. The discharge of the ground water is through springs and seepage zones. The study area of this project does not include springs. On the other hand, 12 wells exist in the study area of which 2 are governmental (belonging to WAJ). Remaining wells are private as shown in Annex 2. Yield of the two governmental wells are 26 and 6 m^3/hr, respectively. Yield of the private wells range 6 to 63 m^3/hr depending on the well. Data on water quality of the wells exist only with respect to salinity as shown in Annex 2. Salinity of water ranges from 304 mg TDS/l to 768 mg TDS/l. These values are within Jordanian drinking water quality standards that requests water TDS not exceeding 1000 mg/l.

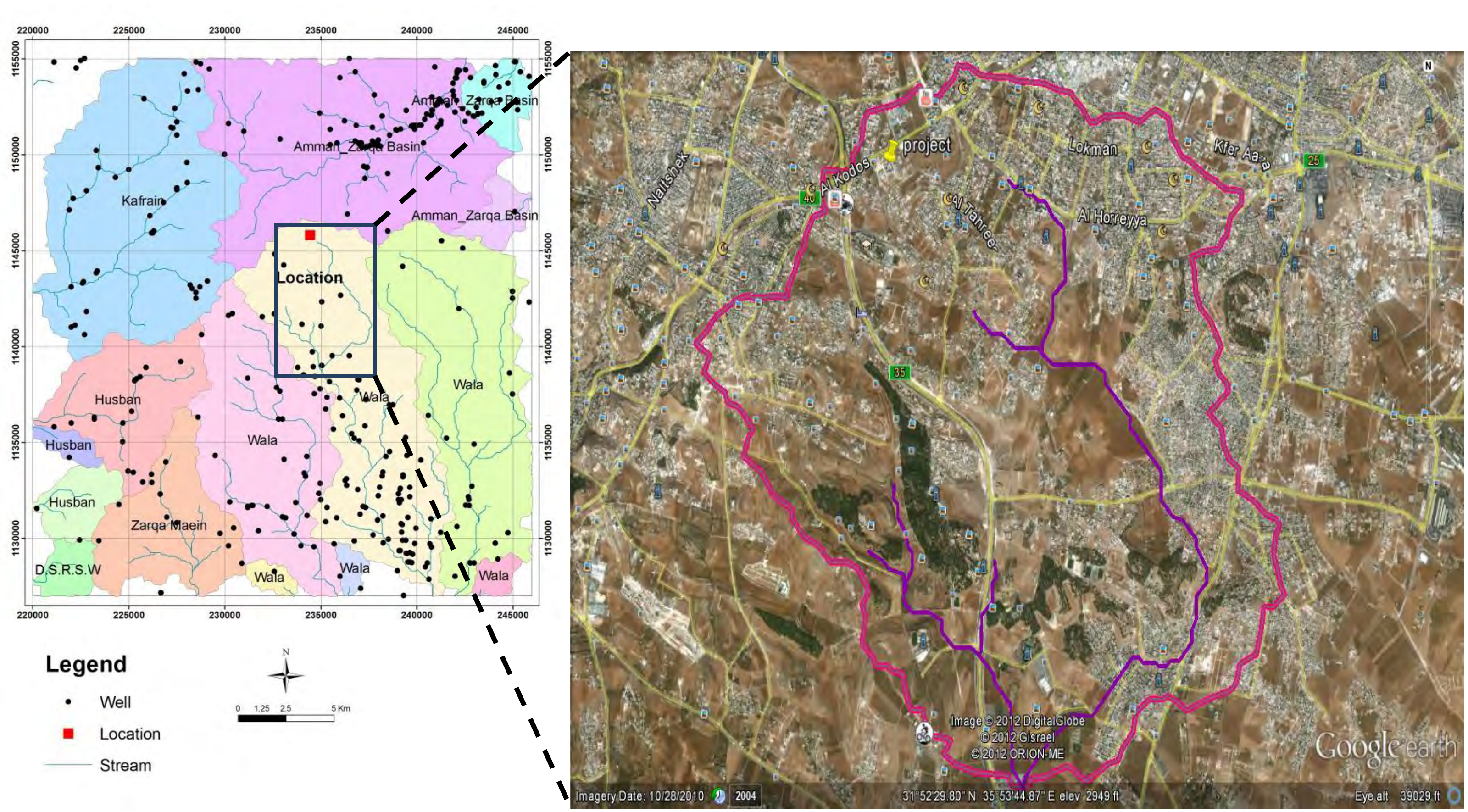


Figure 10: Study area

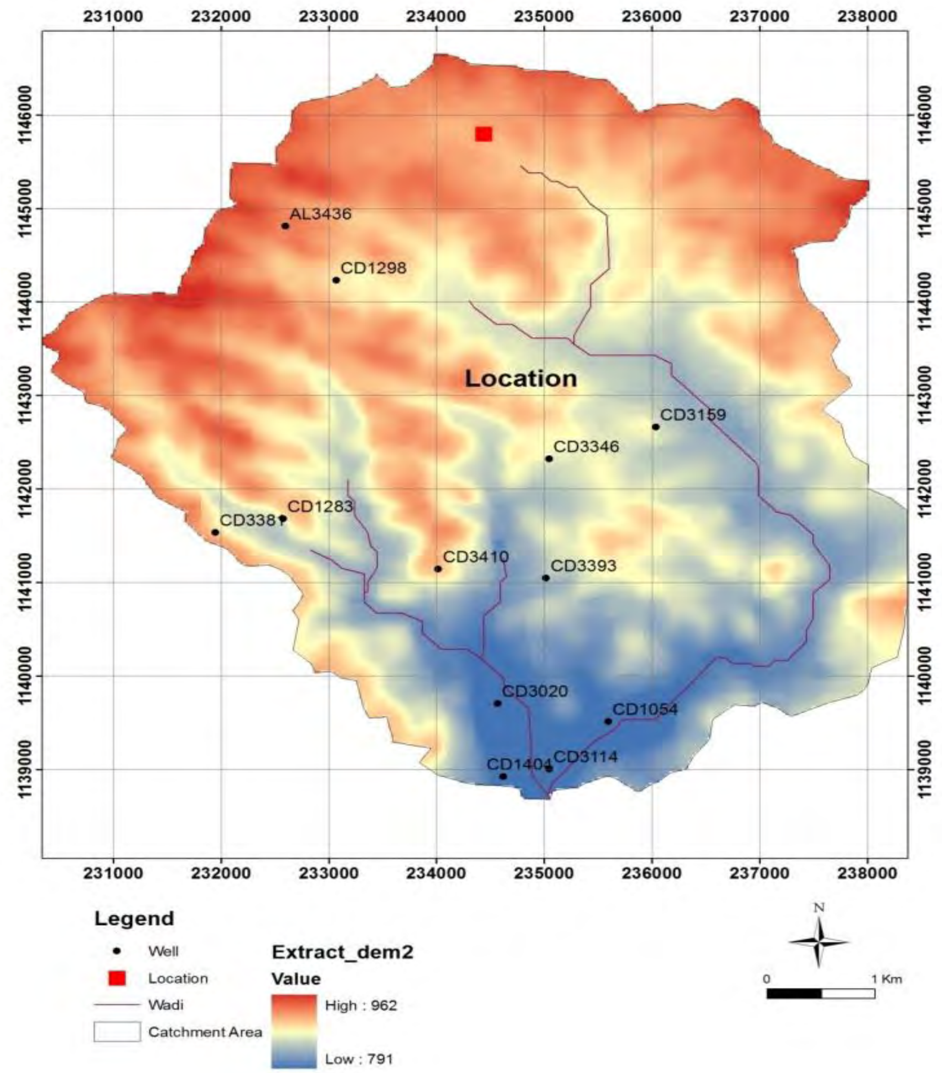


Figure 11: Topography of the study area

Over abstraction of ground water in the study area can easily be observed according to data obtained for the monitoring well CD3116 existing 3 km away from the study area as shown in Figure 12.The figure shows that water level declines at excessively high rate of around 4 m/y (no data is available after 2000). In general, A7/B2 aquifer suffers from enormous groundwater abstraction and water levels decline rapidly. Data on the effect of over abstraction on water quality and specifically on water salinity is not available.

On the other hand and with respect to surface water system, the area is characterized by dry wadis that only flow during limited periods of the year. As mentioned before, the area has an average yearly precipitation of 240 mm. In wet seasons, the precipitation becomes significant; in 1992 it exceeded 450 mm, while in 2003 it exceeded 300 mm, see Figure 7.

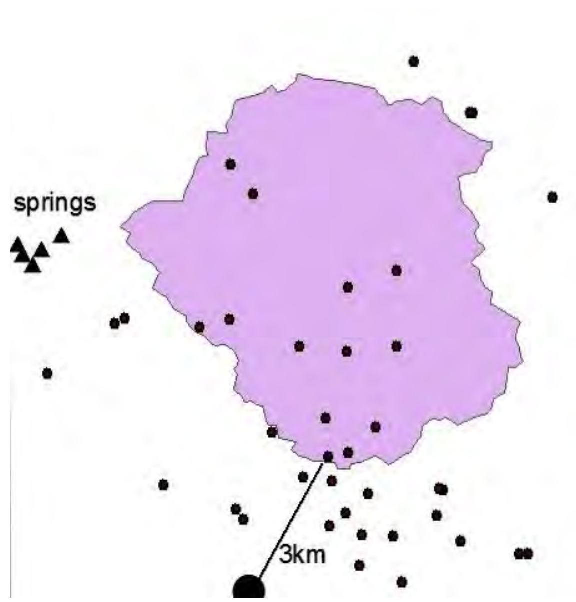
Water pollution in the area may be caused from municipal wastewater management, since the area is not connected to the sewer system. The buildings around PSD rely on cesspools to collect the wastewater and then haul it by tankers to the main station in Ain Ghazal (near city center); if the cesspools are infiltrating and then at some stage - depending on the soil and geological structure (existence of faults) - the practice will pose a risk to ground water pollution. The commercial and industrial facilities around PSD site are considered of light industries (not water intensive). However, downstream PSD to the south and south east, agricultural practices exist. These may also have a source of water pollution in terms of management of chemicals used such as fertilizers, herbicides and pesticides. The agricultural water runoff can be a concern. Such farms ought to be rain-fed, but many also rely on private wells for irrigation.

3.3 Soil and Ground Conditions

Geological formation in the study area is shown in Figure 13 and further explained in Table 4. The study area area consists of three main geological formations; namely Wadi Sir Formation, Amman Hasa formation and Wadi Um Ghudran formation. Wadi Sir Formation that covers the western parts of the study area is of late Turonia-Coniacian age and consists of limestone and dolomitic limestone with thin intercalations of marl and calcareous siltstone. The sequence comprises a massive limestone unit towards the top. Dolomite is more common in the lower and middle part of the section. Thickness varies between 80-150 m. At the base of this formation, finely laminated gypsierrous beds are encountered (MWI).

Amman silicified limestone formation consists of pale to dark grey and brown bedded chert which is intercalated with grey limestone, chalk and marl. The formation is of Campanian age. The thickness of the formation is between 50-50 m. its lower and upper parts were deposited in a lagoonal environment. The middle sequence indicates shallow marine conditions.

Wadi Um Ghurdan formation varies in thickness between 15 and 50 m. The lower parts of the formation composed of massive, buff-grey chalk. The chalk in the upper parts is laminated and pink-buff in color. This formation was deposited during the Santonian in a shallow marine environment.



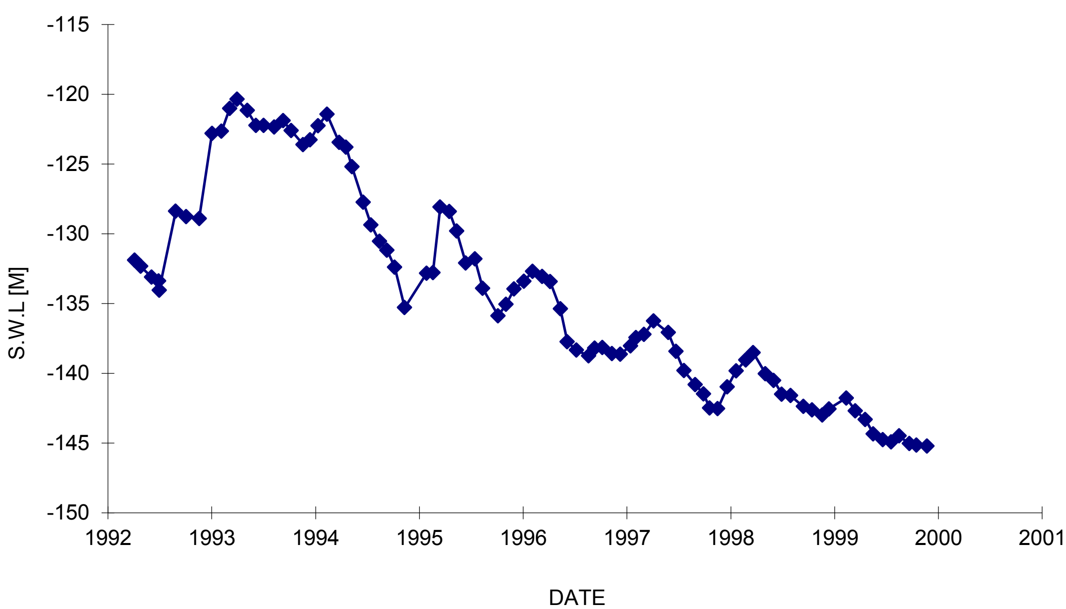


Figure 12: Over abstraction as shown for Um Al Basateen monitoring well CD3116. Data obtained from MWI, 2012.

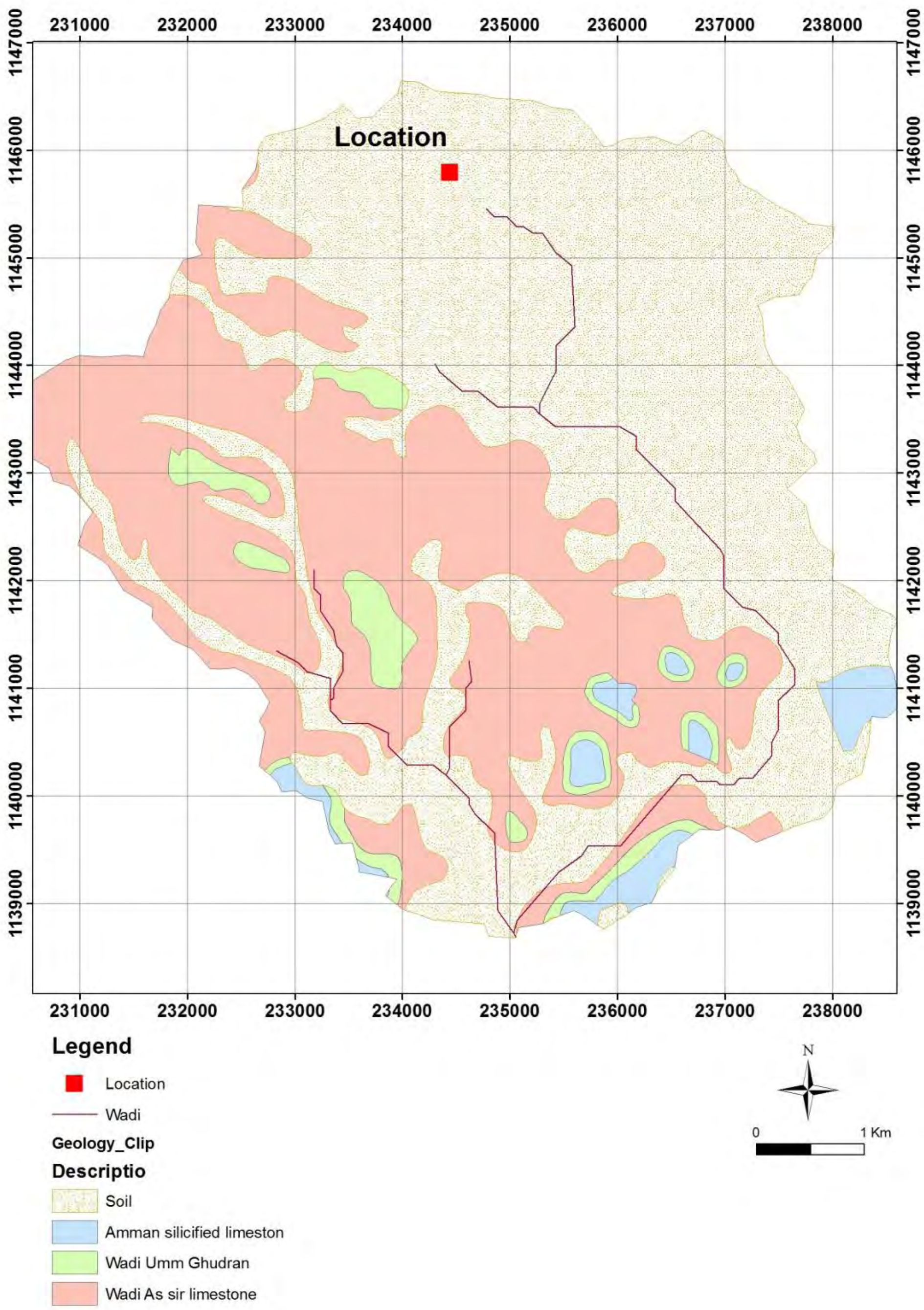


Figure 13: Geological formation in the study area

Table 4: Geological and hydrogeological classification of rock units in Jordan (modified after Margane *et al.* 2002)

System	Group	Formation	Symbol	Lithology	Thickness	Aquifer Unit
Quaternary	Jordan	Alluvium	Qal	Clastics		Alluvium (Aquifer)
	Valley		Basalt JV3			Basalt (Aquifer)
		Lisan		marl, clay, evaporites	>300 m	
Tertiary		Samra	JV1-2	conglomerate with silicious	100-350 m	
		Neogeneg		cement sand, gravel		
	Belqa	WadiShallala	B5	Chalky and marly limestone with glauconite	0-550 m	B4/5 (aquifer)
		Um Rijam	B4	limestone, chalk, chert	0-311 m	
Upper Cretaceous		Muwaqqar	B3	Chalky and marly limestone	80-320 m	B3 (Aquitared)
		Amman-Al Hisa	B2	limestone, chalk, chert, phosphorite	20-140 m	A7/B2 (Aquifer)
		W. Um Ghudran	B1	dolomitic marly limestone, marl, chert, chalk	20-90 m	
	Ajlun	Wadi Sir	A7	limestone, dolomite lst, chert, marl	60-340 m	
		Shueib	A5/6	marl, limestone	40-120 m	A1/6 (Aquitard)
		Hummar	A4	limestone, dolomite	30-100 m	
		Fuheis	A3	marl, limestone	30-90 m	
		Naur	A1/2	limestone, dolomite, marl	90-220 m	
Lower Cretaceous	Kurnub	Subeihi	K2	sandstone, shell	120-350 m	Kurnub (Aquifer)
		Aarda	K1	sandstone, shell	120-350 m	

With respect to hydrogeological formation and with reference to Table 4, the uppermost unit of the Ajlun Group and the lower part of the Balqa Group are considered one hydrogeological unit. Massive limestone, dolomitic limestone and dolomite with intercalated beds of sandy limestone, chalk, marl. Gypsum, chert and phosphorite are predominant in the A7/B2 unit.

It should be noted that A7/B2 aquifer represents the most important water source in the northern and central Jordan. The aquifer contributes to more than half of the ground water abstraction (MWI). Consequently, ground water in the aquifer should be protected from any pollution source including pollution that might result from inadequate sanitation.

Soil units in the study area are shown in Figure 14. “The natural vegetation in the Hisban soil (BAN) is degraded Mediterranean dominated by Poterium sp. There are limited pine plantations. Cereal cropping is carried out on the wadi alluvium and on the less steep colluvial slopes. Tree crops are an important component with groundwater irrigated horticulture in the valleys. The natural vegetation is an important source of grazing. The hill slopes in the area can be suitable for tree crops. The gently sloping colluvial footslopes can be suitable for cereals with appropriate conservation measures” (MWI).

The less steep slopes of the IRI soil unit are “cultivated by barley and wheat. Valleys are intensively cultivated with vegetables and flowers under irrigation. Tree crops are grown on foot slopes. This unit is moderately suitable for cereal cropping. The area is more suitable for tree crops. The valley fill alluvium is suitable for irrigated horticulture.

The Madaba soil (MAD)” is intensively cultivated with the only semi-natural vegetation being degraded Mediterranean species on the isolated limestone hills. Cereals are widely grown and a range of summer crops including tobacco. Significant areas produce horticultural crops and flowers usually under plastics. Tree crops are grown on the more sloping areas. The Madaba soil consists mostly of 90% deep fine soils. The soil is suitable for cereal crops production although the high clay content provides some problems in tillage” (MWI).

As for the exact location of the project, the top soil structure layer extend to about 2 m composed of dark brown, highly plastic Silty Clay with pebbles and gravels of limestone (Soil Test report of PSD). The permeability of such soil type is classified as slow to very slow (less than 0.2 inches of water /hr) (Soil Interpretation Help Sheet). This provides a safety layer to ground water (100 m deep).

Geological faults do not exist in PSD location (site). A few faults, however, exist in the study area (Figure 15). The closest to the site is about 450 m to the north –east and the other is 1 km to the south. The non existence of faults directly at the site is considered a favorable geological property for the safe management of wastewater at the site.

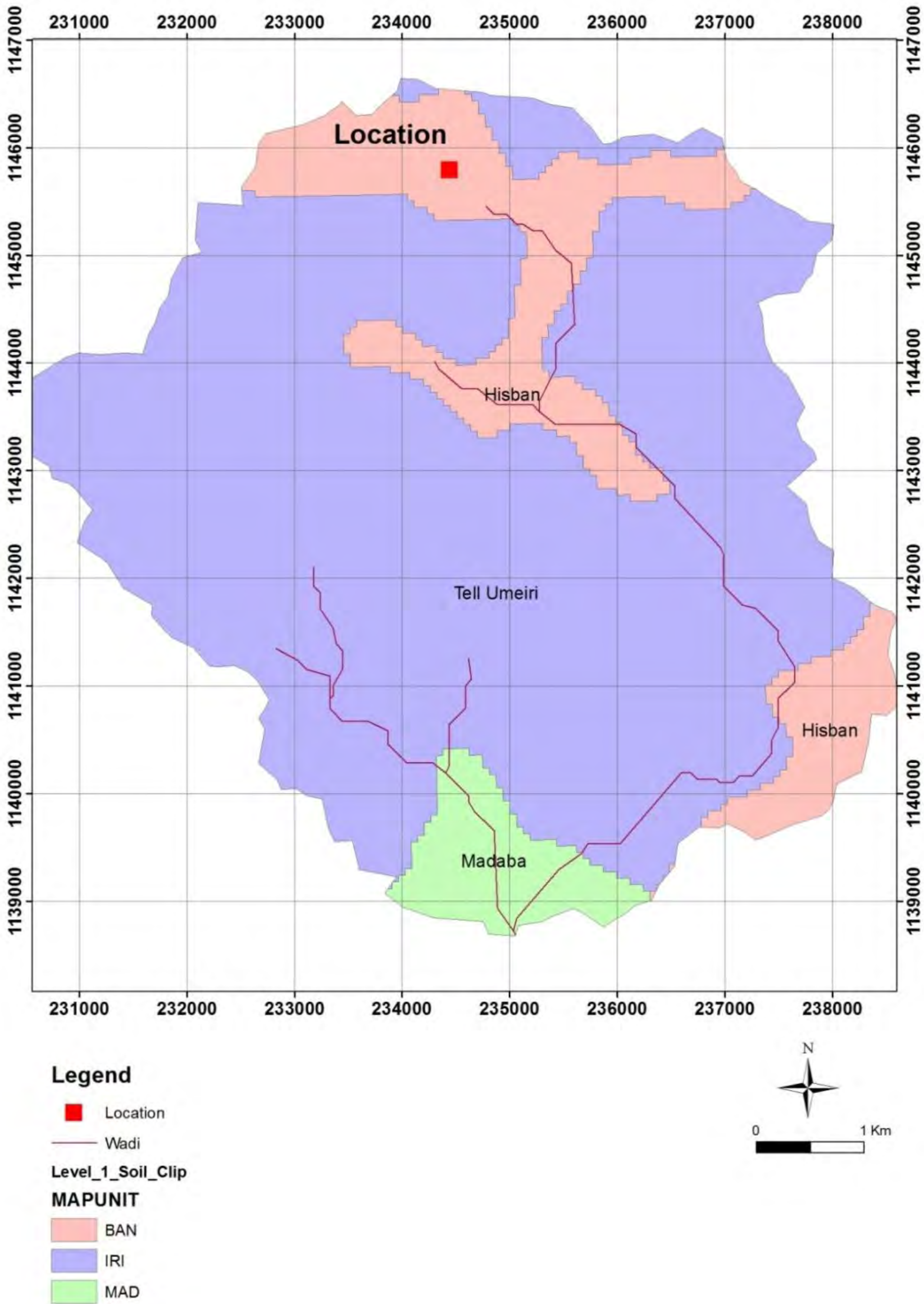


Figure 14: Soil units in the area

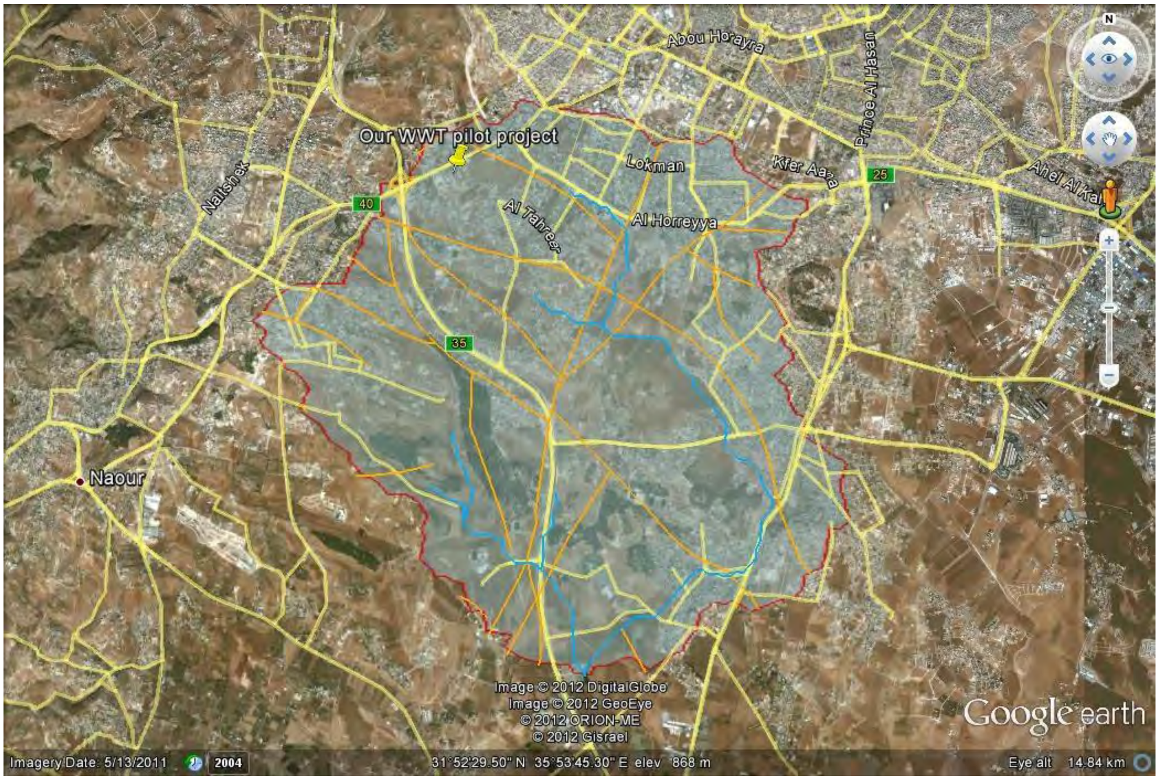


Figure 15: Geological faults in the study area (orange lines)

4 Water Supply and Sanitation

4.1 Water supply and demand

The main source of municipal water in the area of Moqabalane is the Zara Water by supplied by WAJ / Miyahuna Water Company. The Zara water is treated / desalinated water where the TDS is in average of 350 mg/l, the total hardness does not exceed 200 mg/l (according to consultation with WAJ Central Labs). As mentioned before, agricultural areas in the study area (and typically for the highlands) use ground water wells for irrigation.

PSD is connected to the water supply network. It receives municipal water twice a week. PSD also relies on private tanks to satisfy the demand for landscaping.
PSD has water storage tank with a total capacity of 2794 m^3. The tank is divided into two sections; the first section has a capacity of 2394 m^3 and is used for drinking purposes while the other section has a capacity of 400 m^3 and used in case of firefighting. Additionally, a tank of a total capacity of 1160 m^3 is used to produce soft water.

Current water consumption rate together with expected amounts of consumption in the future are shown in Table 5. The expected water demand after full occupation of the compound have been estimated based on both the average per capita share computed for the existing operational building (command and control center) and the total number of occupants after the compound is fully functioning (87.9 l/cap/d is the demand; this has been agreed upon by the technical committee and PSD).

According to data shown in Table 5, the present per capita water share in the compound is 174 l/d. Almost half of this amount is used for landscaping. Better management of water resources in the compound would definitely mean reclaimed water reuse for landscaping. In other words, the fresh water demand is expected to drop to half its current value when reclaimed water use is implemented. Adequate wastewater treatment will cover demand for landscaping. As shown in Table 5, sufficient amount of water will be available to irrigate the lands within PSD (34,000 m^2) using reclaimed water, while at full occupancy surplus water will be available to irrigate the additional area (90,000 m^2). The maximum estimated irrigation water demand would be 6932 m^3/month (231m^3/d) and the maximum available reclaimed water amount would be 217m^3/day.

Table 5: Current and future water demand of the command and control center public security directorate in Abdali

Building	Number of occupants	Water demand m^3/month	Per capita share liter/person - d	Location	Sources and use
		Present demand			
Command and control center	350	923	87.9	New compound	Municipal
Command and control center ***(irrigation of 18500 m^2)***	350	900	85.7	New compound	Tankers for irrigation
Sub-Total			**174**		
Public Security directorate	2116	1850	29	Abdali	Municipal
Public Security directorate	2116	1200	19	Abdali	Tankers
Sub-Total			**48**		
Total			**222**		
		Expected demand			
PSD at full occupancy	**2466**	**6500**	**87.9**	**New compound**	**Municipal + tankers**
Irrigation on site (34000 m^2)		**1654***			
Irrigation of additional 90000 m^2		**4378***			

**estimated based on current irrigation water demand at PSD*

4.2 Water cost

As mentioned before, the sources of water for the PSD site comprises the municipal water by WAJ and private sources. The municipal water is provided at a fee of 1 JOD / m^3 in addition to 0.56 JOD / m^3 for sewage services. Water from private sources is provided at a minimum of 3 JOD / m^3 (consultation with Mr Murad Masri, PSD). The water tariff may also increase in the future.

4.3 Sanitation, wastewater collection and treatment

Most of the study area is not served with sewerage network and inhabitants are mainly dependent on cesspools for the discharged wastewater. Cesspools present potential pollution hazard on groundwater. For the specific site of the public security directorate, wastewater is collected from building using a network and is currently discharged to an existing cesspool that is emptied every other day. The total capacity of the cesspool is around 70 m^3. The existing cesspool is shallow with effective height not exceeding 80 cm. Visual inspection indicates that the cesspool is located at almost the same level of the sewer system and wastewater is also accumulated in the manholes and the collection system. 'Septage' is transported to Ain Ghazal pre-treatment facility by tankers. Septage is then mixed with wastewater transported by a main sewer line to Khirbit As-Samra centralized wastewater treatment plant.

Currently, the fully functioning building is the command and control center. From the current consumption it can be estimated that the current wastewater flow is 31 m^3/ d. As the building is functioning at its full capacity, no increase in the flow is expected in the coming 15 yrs. After full occupation of the compound, the total wastewater flow can be predicted at 217 m^3/ d (the domestic consumption rate). The intended wastewater treatment plant should be designed to serve phase I of the project and based on an average flow of 217 m^3/d (this amount has been agreed upon with the technical committee and PSD). However, taking into account the expected demand for on-site irrigation (1654 m^3/month), the figures suggest that there could be excess amount of reclaimed water for use outside. In this case, PSD will coordinate with the neighboring land (owned by the government) to supply local farmers to use the surplus amounts of reclaimed water. Alternatively, the reclaimed water can be transported to the Gendarmerie for use in landscaping, thus also saving fresh water resources.

Wastewater sampling was carried out three times for the existing building. Main sewer system was cleaned before the sampling program since the sewer lines were found flooded and nearly blocked. Samples were collected using automatic sampler and analyzed at the Environmental Labs of the Royal Scientific Society. Results provided are shown in details in Annex 3. Characteristics were measured twice taking into account all sources of wastewater including restaurant. One sample was taken to characterize wastewater without restaurant contribution. The latter was considered in order to elaborate possible advices for improving wastewater quality. Wastewater characteristics are shown in Table 6. Wastewater is characterized by high concentrations of COD and

BOD with average values of 1725 mg/l and 745 mg/l, respectively. These concentrations are comparable with those reported for domestic wastewater influents to most municipal wastewater treatment plants in the Kingdom. The table also shows high concentrations of ammonium and nitrogen with average concentrations of 133 mg/l and 175 mg/l, respectively. Average ammonium concentration in domestic wastewater in Jordan is around 80 mg/l. The high concentrations of ammonium reported for the PSD wastewater should be further explored. It might be possible that less water used for showering contributed to some increase in ammonium concentration or that there is excessive use of shampoo and detergents in the showers, toilets and kitchen cleaning and dishwashing. It might also be possible that sex distribution with higher male/female ratio contributed to higher ammonium concentration. Perucca et al., (2007) reported that urine concentration based on urine/plasma creatanine concentration ratio was 21-39% higher in men than in women with no change in urine volume.

Table 6: Wastewater characteristics used for the design of WWTP

Parameter	Average value (total WW)*	Average value (without WW of restaurant)
pH	8.33**	__
COD (mg/l)	1725	1262
BOD_5 (mg/l)	745	320
TSS (mg/l)	788	225
TVSS (mg/l)	590**	200
T.K.N (mg/l)	175	210
NH_4^+-N (mg/l)	133	190
T-P (mg/l)	52**	49
PO_4-P (mg/l)	12**	__
FOG (mg/l)	43	9
MBAS (mg/l)	0.75	0.57
SO_4^{-} (mg/l)	34	33
Cl^- (mg/l)	203	217
***E*.coli (MPN/100ml)**	5.7×10^7	2.4×10^7
HCO_3^- (mg/l)	759	835
Mg^{++} (mg/l)	18	9
Ca^{++} (mg/l)	76	28
Nematode eggs (egg/5 liter)	Not seen	Not seen

* WW: wastewater
** Based on one measurement

Sulfate, calcium and magnesium concentrations are lower compared with domestic wastewater. This could be due to the source of water being treated and of low hardness. Heavy metals concentrations were measured once and found to be very low as shown in Table 7 compared with maximum limits set by Jordanian standards 893/2006.

Table 7: Trace metals concentrations as compared with maximum limits set by Jordanian standards 893/2006

Trace metal	Concentration in WW (mg/l)	Maximum limit (mg/l) Jordanian Standards 893/2006
Cu	0.049	0.2
Fe	3.74	5
Li	0.01	2.5 (0.075 for citrus)
Mn	0.081	0.2
Ni	0.04	0.2
Pb	0.09	0.2
Cd	0.005	0.01
Zn	0.605	5
Cr	0.02	0.1
Co	0.03	0.05
Mo	0.01	0.01
V	0.1	0.1
As	0.01	0.1
Be	0.02	0.1
Se	0.01	0.05
Hg	0.001	0.002

The flow of wastewater is related to the inhabitants' practices. The flow comes in 3 peaks, one after the morning, the second after lunch (being the highest peak) and the third is in the evening. In the night, from midnight to dawn the flow is nearly zero.

4.4 Aim of the planned Pilot Activity

The aim of the pilot activity is to provide a sustainable and effective treatment system. It should be of simple operation, economically viable and environmentally sound. The system is planned to treat all the expected amounts of wastewater from the community of PSD. The reclaimed water is to be used for irrigating the gardens around the campus (landscaping). It is not expected to have fresh vegetables on the site. The effluent should be meeting the relevant Jordanian Standard (893/2006).

5 Stakeholders Analysis

As mentioned in section 2.2, the community of PSD is mostly a professional community. The full time staff is well educated personnel. Consultation with Engineer Murad Masri (person in charge from PSD for the project) has been carried out. Eng. Masri pointed two important aspects related to the operation of the plant and the reuse of reclaimed water:

- The operation of the plant could be outsourced to a specialized private sector to run the day to day work. This idea will be explored further by PSD in due time. PSD has a unit responsible of facility services as well. However, if a person is to be nominated from the existing team, a proper treatment has to be given on the operation of the selected system.
- The reuse of reclaimed water will be done by the workers (gardeners) who are not permanent staff of PSD. They are unskilled labor, thus a proper awareness raising program should be given to such workers to enlighten them of the reclaimed water application practices.

It should be noted that taking these points into consideration, the system will be designed meeting the standards so as to reduce health risks; this will be elaborated in the health risks section.

Other than PSD internal community, the residential areas around PSD are not expected to be affected by the unit nor the reclaimed water. They do not have direct access to the site. If the use of excess reclaimed water by external farmers or the nearby site of Gendarmerie becomes possible (such as using the vacant land next to PSD), then the concerned persons (users) have also to be informed of the best practices requirements for applying the reclaimed water. This will contribute to reducing the health risks.

6 Institutional Framework

Water supply and wastewater management is under the administration of the Water Authority (WAJ) of Jordan as per the Law of WAJ. The strategy of WAJ has recently been encouraging decentralized management of wastewater to help ensuring treatment of wastewater in communities not served by the sewage network. In this respect, WAJ will be also responsible for performing routine checks on the performance of the treatment units to ensure compliance with the relevant standards (JS 893/2006).

As for this project, it will be operated by the PSD, which has a dedicated unit for utilities or will hire a private entity to run the system. As per the agreement signed among the project partners, the reclaimed water will be monitored by Balqa Applied University (BAU) and International Union for the Conservation of Nature (IUCN). PSD will also allow the use of the pilot project for research and awareness building on decentralized management as per SWIM objectives (see Minutes of Meeting in Annex 4).

7 Legal Framework

In general the management of water and wastewater is under the mandate of the Water Authority of Jordan (WAJ) according to WAJ Law of 1998.

The relevant environmental legal frame has been gathered for this pilot project as summarized below:

- Ministry of Water and Irrigation / Water Authority of Jordan: has the overall responsibility for managing water supply and wastewater. The project is already in close communication with WAJ and the Ministry. The steering committee is headed by HE Eng. Basem Telfah, the Secretary General of the Ministry.
- WAJ has also a dedicated section for water demand management and reclaimed water reuse projects. The section follows up the applications of reclaimed water reuse and their impacts on the soil and plants. The unit resorts to the JS 893/2006 in its assessments.
- Ministry of Environment requires, by the Environment Law for 2006, that new development project shall undergo environmental permitting phase. Depending on the size and type of projects, Environmental Impact Assessment may also be required. The level and depth of the assessment, however, is also subject to the type and size of the project and the sensitivity of the location. The committee from the Ministry, based on an inspection visit to the site, would recommend the level of the assessment needed. Small scale projects in closed premises such as this case may not be subjected to full assessment, a screening document or an initial review would be sufficient. To cover this aspect, and based on the 1st meeting of the steering committee, IUCN has taken the lead in cooperation with PSD to clarify and pursue the required work to prepare the environmental document as could be needed.
- Additionally, in terms of management of solid waste and hazardous materials, the solid waste management bylaw and the hazardous material handling bylaw are applicable. Safe management and disposal of debris and construction material should be ensured following the instructions of the municipality (as the site is within Greater Amman area). Hazardous material such as waste oils (during construction) and any hazardous chemicals that could be used in the operation have to be handled properly as per the bylaw and related instructions.
- In terms of noise protection, as per the Instruction for the Protection from Noise (2003) of the Ministry of Environment, the use of noisy and vibrating construction machinery is banned during night time (8pm -6 am). Since the site is within an urban area, the noise levels at the nearest recipient should not exceed 60 dB(A) during the day and 50 dB(A) during the night.

- Ministry of Agriculture: the Law of Agriculture would be applicable if the project land is of natural or man-made forestry or if the land is designated as an agricultural land. None of these is relevant to this pilot project, since the site is not within a designated agricultural land and neither of natural nor of man-made forestry. The land is owned by the government and has been assigned for building the PSD complex. Its primary use is not for agriculture.
- Ministry of Health: according to the Health Law causing any nuisance is not acceptable. This is not likely to occur in this pilot project. In cases of trouble shooting, the operation staff of PSD should be trained to avoid reaching such as situation. The Health Law will also be applicable in cases of health risks associated with the use of reclaimed water. A proper management plan has to be in place to avoid such cases.
- Department of Archeology: as per the Law of Archeology any discovery of archeological item shall be reported immediately to the department or the nearest Public Security Station. As the project site is already being constructed and no discoveries have been found and since there are no archeological signs on the surface, this law will unlikely be of concern. However, it is worth to be aware of this legal requirement in case of accidental finding of any items during the excavation work for project.

8 Environmental Risks

In this section the potential environmental risks / potential impacts and the environmental features of the project are presented in a light proactive approach. This is aimed to present the situation and where needed to introduce / implement necessary measures in advance.

8.1 Impact on nearby residential houses:

The nearby residents could potentially be affected by the project in case of generation of odour (aerosols) and/ or flies. The prevailing wind direction is north-west and the project is located downwind of the residential houses (see Figure 1). Treatment technology will be selected and its operation shall be managed to avoid the generation of odour. Indeed, the project will represent a remediation to the environment impacts generated by the present management, consisting in the wastewater collection into a tank to be emptied on daily basis (around 10 tankers needed at PSD full occupancy)

As to avoid visual impacts, the treatment site has been selected to be within the premises of PSD and not close to the border. The structure will be designed in order to avoid negative visual impacts. These aspects is going also to be summarized in the tender TOR as measures to be taken in to account by the contactor.

PSD also gives such impacts full attention as the employees should not be affected by any negative environmental risks noting that the Head Quarters of PSD are closest to the treatment unit location.

As for potential impact of noise, the nearest residential place is more than 150 m away. The project does not have major noise contributors during the operation. The use of machinery during construction will not impact the residential places since the noise level of the machines assumed (100 dB(A) at 1 m from source) will be damped with distance to reach less than 60 dB(A) at the nearest residential place. It should be taken into account that a major 4 lanes road separates the site from the nearest residential place.

8.2 Risk of ground water pollution

Risk of ground water pollution may occur in case of having unlined basins and / or cracks in wastewater storage basins and where the geological structure has a high permeability. Based on the soil and geological description of the study area and site specific characteristics (section 2.3 and Figure 15), the site has the following features:

- At the site and where reclaimed reuse will be applied there are no geological faults as indicated in Figure 15.
- The soil structure, being of thick plastic silt clay (about 2 m), provides an excellent protection layer against infiltration to ground water (Soil test report of PSD).
- The ground water table is deep (more than 100 m).
- Furthermore, the treatment system will be provided with proper liner (suitable for the structure to be used).

Based on the features described above, the risk on ground water pollution is considered low and can be avoided by proper design and operation. Detailed impact assessment can be addressed in the planned environmental impact assessment for the pilot project.

8.3 Eutrophication

As the site is not directly located near a surface water body (Figure 11) and since the treatment will ensure low levels of N, P, K meeting the JS 893/2006 then eutrophication is not expected to be an issue. The reclaimed water will be used on site (and in case of excess water) at a neighboring land. No discharge to the wadis will occur. Rain water is collected separately and is discharged to the storm water network.

8.4 Soil salinity

Soil salinity is also not expected to be a major issue for the following reasons:

a. The fresh water supplied is of low salinity (TDS = 350 mg/l in average).
b. The TDS of untreated wastewater is in average (1405 mg/l); the JS 893/2006 allows a TDS up to 1500 mg/l
c. The top soil will be treated with organics and sandy material to make it more permeable (loamy).
d. A drainage system will be fitted where needed depending on the type of plants and soil in the lot of land at PSD.
e. Seasonally the area receives relatively good amounts of rain which will contribute to refreshing / washing the soil from salts.

8.5 Effect of soil clogging

Soil clogging is may occur when the TSS in the wastewater is higher than 100 mg/l. the reclaimed water under this project will be meeting the JS 893/ 2006, where the TSS of effluent is required to be less than 50 mg/l max. As mostly of the irrigation will be subsurface, the clogging on top soil will not occur. In addition, PSD gardeners will be practicing to move the top layer of soil seasonally to improve its quality as part of their gardening work. This will reduce the clogging effect in areas where surface drip irrigation will be used.

The effect of fat oil and grease will be minimized by fitting in an oil and grease interceptor. This is necessary to reduce the effect on the treatment system anyways. Remaining organics will be treated in the biological treatment system. The effluent BOD will not exceed 100 mg/l as per the standard, thus will minimize the clogging effect due to fat, oil and grease as well.

9 Health Risks

Health risks of wastewater reuse has been a subject of attention for many researchers and health organizations. Wastewater reuse has been known to be practiced since more than 100 years (Metcalf and Eddy). However, with the increased risks and to provide a guide to control such reuse practices, the World Health Organization (WHO) published the third edition of its Guidelines for the safe use of wastewater in agriculture in September 2006 (WHO, 2006). These Guidelines are essentially a code of good management practices to ensure that, when wastewater is used in agriculture (mainly for irrigating crops, including food crops that are or may be eaten uncooked), it is used safely and with minimal risks to health. They are therefore much more than a set of guideline values. They are intended to help in designing safe treatment and reuse of wastewater. The national JS 893/2006 is also in agreement with the WHO guidelines of 2006.

There are two broad groups of diseases considered in the Guidelines:

- viral, bacterial and protozoan diseases, for which the health risks are determined by Quantitative Microbial Risk Analysis (QMRA), and
- helminthic diseases, for which the Guidelines set a guideline value on the basis of epidemiological studies.

9.1 Restricted Irrigation

The exposure scenario developed in the Guidelines for restricted irrigation (irrigating landscape/gardens) is the involuntary ingestion of soil particles by those working in wastewater irrigated fields. This is a likely scenario as wastewater-saturated soil would contaminate the workers' fingers and so some pathogens could be transmitted to their mouths and hence ingested. The quantity of soil involuntarily ingested in this way has been reported (but not specifically for this restricted-irrigation scenario) as up to ~100 mg per person per day of exposure (Haas *et al*. 1999; WHO 2001). In this study, the main sub-scenario that will be investigated following the WHO 2006 Guidelines is the labor-intensive agriculture.

<u>Labor-intensive agriculture</u>:

The results of the Monte Carlo-QMRA risk simulations are given in Table (8) for various wastewater qualities (expressed as single log ranges of *E. coli* numbers per 100 ml) and for 300 days exposure per year. From Table (1) it can be seen that the median rotavirus infection risk is ~10^{-3}pppy for a wastewater quality of 10^3–10^4 *E. coli* per 100 ml. Thus, the tolerable rotavirus infection risk of 10^{-3}pppy is achieved by a 4-log unit reduction −i.e. from $5.7\times10^7$to 10^3–10^4 *E.coli* per 100 ml. The table also shows that the *Campylobacter* and *Cryptosporidium* infection risks are all lower than those for rotavirus.

This 4-log unit reduction is best achieved by a wastewater treatment, the subject of our project.

Table 8: Restricted irrigation – labor-intensive agriculture with exposure for 300 days per year: median infection risks from ingestion of wastewater-contaminated soil estimated by 10,000-trial Monte Carlo simulations

Soil quality (*E. coli* per 100 g)	Median infection risk pppy		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	0.99	0.50	1.4×10^{-2}
10^6–10^7	0.88	6.7×10^{-2}	1.4×10^{-3}
10^5–10^6	0.19	7.3×10^{-3}	1.4×10^{-4}
10^4–10^5	2.0×10^{-2}	7.0×10^{-4}	1.3×10^{-5}
10^3–10^4	1.8×10^{-3}	6.1×10^{-5}	1.4×10^{-6}
100–1000	1.9×10^{-4}	5.6×10^{-6}	1.4×10^{-7}

It is worth mentioning that 2–4-log unit reduction can also be achieved by applying drip Irrigation technique as one of the post-treatment health-protection control measures (Table 9).These post-treatment health-protection control measures are extremely reliable: in essence they always occur.

Table 9: Post-treatment health-protection control measures and associated pathogen reductions

Control measure	Pathogen reduction (log units)	Notes
Drip irrigation	2–4	2-log unit reduction for low-growing crops, and 4-log unit reduction for high-growing crops.
Pathogen die-off	0.5–2 per day	Die-off after last irrigation before harvest (value depends on climate, crop type, etc.).
Produce washing	1	Washing salad crops, vegetables and fruit with clean water.
Produce disinfection	3[a]	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water.
Produce peeling	2	Fruits, root crops.

[a]Amoah *et al*., (2007).

EPIDEMIOLOGICAL VERIFICATION OF THE QMRA APPROACH

Mara *et al*. (2007) used the field data reported by Blumenthal *et al*. (2003) on diarrhoeal disease incidences amongst fieldworkers and consumers in Mezquital Valley, Mexico to obtain QMRA estimates of rotavirus infection risks in the five-month dry season. It was found that, provided the assumptions used in the QMRA-Monte Carlo risk simulations closely reflected field conditions, the agreement between the observed incidences of diarrhoeal disease and the estimated rotavirus infection risks was very close for both field workers and consumers (Table 10).

Table 10: Comparison between observed incidences of diarrhoeal disease and estimated rotavirus infection risks in Mezquital Valley, Mexico

Irrigation scenario	Wastewater quality (*E. coli* per100 ml)	Observed diarrhoeal disease incidence per person per 5 months	Estimated median rotavirus infection risk per person per 5 months
Restricted irrigation	10^3–10^5	0.37	0.33
Unrestricted irrigation	10^3–10^5	0.38	0.39

HELMINTH EGGS

The recommendation in the Guidelines is that wastewater used in agriculture should contain≤1 helminth egg per liter.

From the above it can be deduced that in this pilot project the health risks will be well controlled due to the following reasons / features:

- *The treatment of wastewater will provide 4 log reduction to the E.coli (=5.7x10^7, Table 6). Thus will reduce the E.coli to 10^3 – 10^4 allowing the use of the reclaimed water for restricted irrigation as depicted in Table A. at this level the other microbial risks will also be under control (Rotavirus, Campylobacter, and Cryptosporidium).*
- *Further the adoption of drip irrigation technique will augment the safety level by 2 logs; thus the subsurface irrigation will reduce the risks even more.*
- *In the raw wastewater samples no nematodes were seen (see Table 6), therefore it will not be of concern.*
- *For further protection, the workers will be made aware to follow hygiene practices when dealing with wastewater (in case of fitting pipes or moving earth etc.)*

10 Wastewater Treatment Options

10.1 Introduction

When looking for the best wastewater treatment option, priority is mostly given to lowest construction cost alternative. However, alternatives should be evaluated based on other different factors including labor costs, energy costs, land costs and equipment replacement costs in addition to environmental and health factors. Although PSD has the capacity to run high technology alternatives, low technology alternatives that can run with minimal expertise and few number of labor may present very good examples for sustainable systems.

In selecting and assessing alternative technologies, the local experience has been taken into account. A few treatment systems based on sequencing batch reactor (SBR) have been erected in complexes or professional bodies in Jordan, such as in Mutah University and Security Training Centre site in Muwaqar. Although, data about the performance of these systems could not be obtained during the course of this study, however, Jordanian companies have developed experience in commissioning and operating such systems. Other examples of testing decentralized sanitation system using constructed wetlands are being carried out by SMART/NICE project in cooperation with Balqa University.

In this study, four different treatment systems were considered and compared according to certain criteria (covering economic efficiency, plant technology, operational requirements, and effects on environment), see Annex 5. A matrix was prepared following DWA (2010) proposed matrix for qualitative comparison between treatment options (Annex 5). Systems were nominated to cover a range of treatment systems spectra including different aerobic processes i.e. suspended growth and attached growth systems; their availability as package systems; aerobic and combined anaerobic-aerobic systems; and combined anaerobic-natural systems. Nominated systems were: (1) Sequencing Batch Reactor (SBR); (2) USAP (Upflow Anaerobic Sludge Blanket) reactor followed by constructed wetlands (CW); (3) USAP reactor followed by Rotating Biological Contactors (RBC) and (4) Extended Aeration system. The SBR and extended aeration systems are examples of suspended growth systems that are commonly applied for small communities. Moreover, SBR can be provided as package system. The UASB reactor followed by RBC represents an example of combined anaerobic and aerobic treatment systems that can be applied for small communities. The UASB reactor followed by a Constructed Wetlands represents an example of combining anaerobic systems with natural systems. A description of the nominated systems is given below.

10.2 Sequencing batch reactor (SBR)

The SBR is a fill-and-draw activated sludge system. Wastewater is filled in the tank and operated at a batch mode. Feeding, aerobic/anoxic treatment and settling are all occurring in the same tank using a single batch. Two or more reactors are needed in predetermined time controlled operational sequence. In addition to the advantage of having wastewater treatment and clarification occurring in the same tank, SBRs are known as good options for applications characterized by high fluctuation of incoming flow rates. The latter is the case for PSD. Process flow schematic for SBR wastewater treatment plant is shown in Figure (16). Some manufacturers recommend a primary clarifier to be installed before the SBR when TSS and BOD concentrations exceed 400 mg/l and 500 mg/l, respectively (reference). Advantages and disadvantages of the system are shown in Box 1.

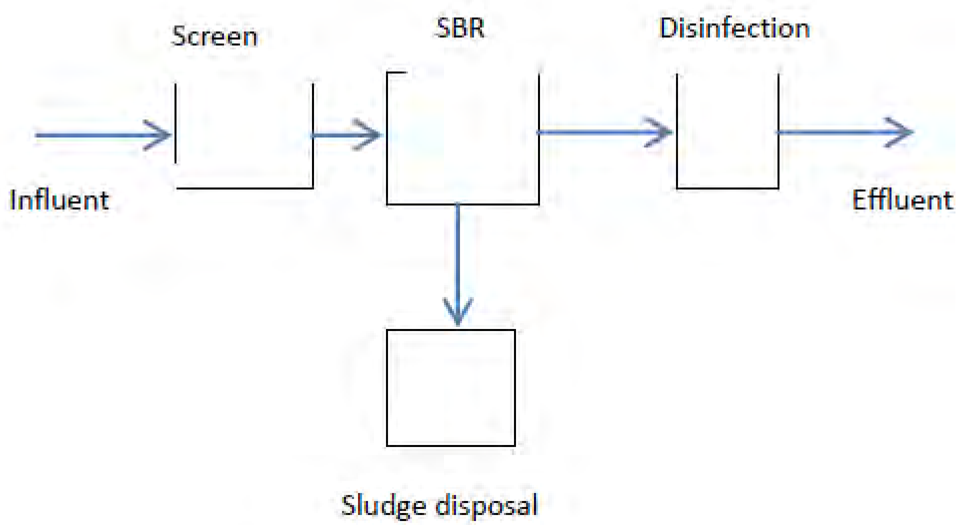


Figure 16: Flow process schematic for SBR treatment plant

Box 1: SBR treatment plant
*Key advantages ** + Minimal foot print + Biological treatment and secondary clarification can be achieved in a single reactor. + Operational flexibility and control. + Potential capital cost savings due to elimination of clarifiers and other equipment. *Key concerns** – High level of sophistication is needed (compared with activated sludge system) due to timing units and control. – Higher level of maintenance needed for the controls, automated switches and automated valves. – Potential plugging of aeration devices depending on aeration system provided by manufacturer. * Adopted from EPA (1999)

10.3 Upflow anaerobic sludge blanker reactor followed by constructed wetlands (UASB-CWL) treatment plant

Screened wastewater is introduced into the UASB reactor, in which influent is distributed at the bottom of the reactor and flows in an upflow mode through the sludge blanket that contains high concentration of biomass. The main purpose of the UASB reactor is to remove approximately 70% of COD load using high rate system characterized by:

- None or nominal energy requirement (only for pumping)
- Operational simplicity
- Low production of excess sludge
- Production of energy in form of biogas

A very important feature of UASB reactors is that excess sludge produced is well stabilized and can be discharged immediately into drying beds. Screened influent is introduced into the UASB reactor via number of inlet feed pipes that are used to direct flow to different areas of the bottom of the reactor from a common feed source. UASB reactor also encounters the gas solids separator (GSS), which collects the biogas and stimulate separation of gas and solid particles, allowing solids to slide back into the sludge blanket zone and help improve effluent solids removal.

Within the context of this option, UASB effluent shall pass through a dosing chamber (i.e. the chamber that contains a dosing pump) from which the constructed wetland will be intermittently loaded. Wetland is a shallow basin that is filled with a filter material. Filter material is usually sand or gravel. Wetlands are usually planted with vegetation tolerant of saturated conditions. Wetlands are usually comprised of the following components: basin; substrate; vegetation; liner; and inlet/outlet arrangement system. Various design configurations for the wetlands exist and classified according to different items including flow patterns. Subsurface flow CWL can be introduced either horizontally or vertically. In many cases, vertical flow constructed wetlands (VFCWL) are preferred over horizontal flow constructed wetlands (HFCWL) due to the following reasons:

1. VFCWL are considerably smaller than HFCWL.
2. VFCWL are effective in removing organic pollutants, pathogens and nitrogen.

However, HFCWL is known to be more efficient in removing BOD and TSS compared with VFCWL. For this reason it is now more common to see a hybrid CWL consisting of a combination of both systems. A schematic representation of the treatment plant is shown in Figure 17. Key advantages and disadvantages of such a treatment system are shown in Box 2.

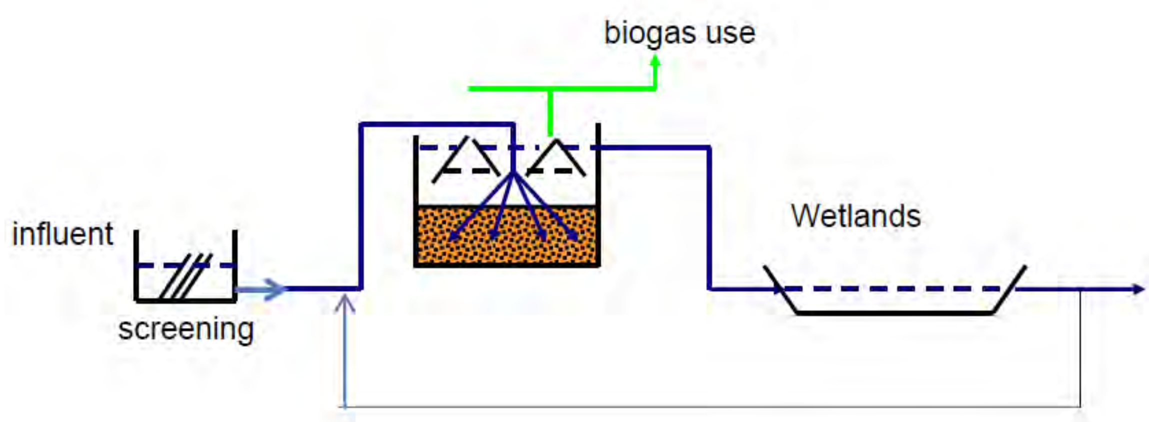


Figure 17: Flow process diagram of UASB followed by constructed wetland

Box 2: Key advantages and concerns for the UASB-constructed wetland system

Key advantages

- + Aesthetically pleasing and provides wild habitat if planted.
- + Low maintenance requirements,
- + Simple operation
- + No sludge discharge.
- + Nitrification efficiency.
- + Can be built and repaired with locally available material.
- + Minimal energy requirements

Key concerns

- – Require large land area.
- – Long start up time to work at full capacity.

10.4 Upflow anaerobic sludge blanket reactor followed by rotating biological contactors (UASB-RBC) system

Description of the UASB reactor is presented in section 4.3 above. The RBCs are fixed bed reactors consisting of stacks of rotating discs mounted on a horizontal shaft. The discs are partially submerged and rotate as the wastewater flow through. Microbial communities attached to rotating discs are exposed to atmosphere and to wastewater allowing aeration and degradation of organic pollutants and nitrogen removal. The submerging level of the discs varies from 40% to 80% (Crites and Tchobanoglous, 1998). RBCs are known to remove 80-90% of the BOD. They are also effective in nitrogen removal. A secondary sedimentation tank is also needed for sludge removal. A schematic presentation of the UASB-RBC system is shown in Figure 18. Advantages and disadvantages of the system are shown in Box 3.

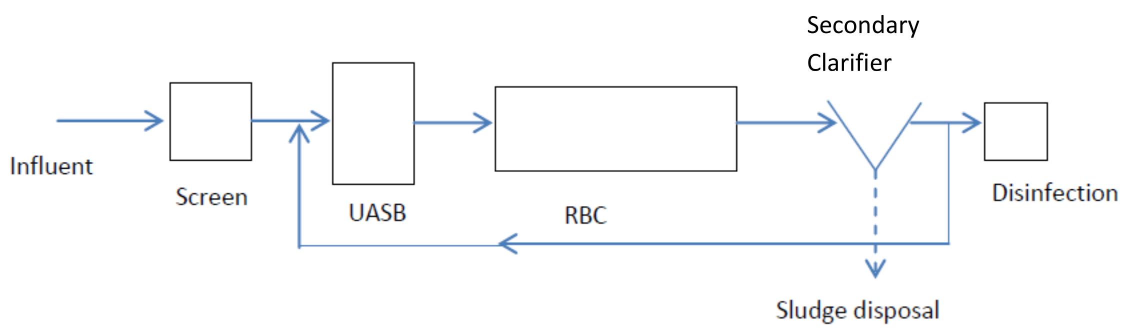


Figure 18: Schematic presentation of the UASB-RBC treatment plant

Sludge disposal

Box 3. UASB-RBC wastewater treatment system
Key advantages + Small foot print + Low maintenance requirements, as compared to activated sludge systems. + Simple operation, especially if compared with activated sludge systems. + Robust system. + Nitrification efficiency. + Low sludge production compared to activated sludge system + Sludge produced from the RBC settles well, permitting shallower secondary clarifiers designed for higher overflow rates. *Key concerns* – RBC operation is sensitive to temperatures below 5˚C. Accordingly, coverage is necessary. – For total nitrogen removal, recirculation to UASB reactor is required – Compared to natural system, daily discharge of sludge produced from the RBC is required. – Equalization basin is needed in case high variations in flow rate are expected.

10.5 Extended aeration system

Extended aeration system is a modified activated sludge biological treatment process where long sludge retention times are considered to remove pollutants. Wastewater in the extended aeration tank is aerated and mixed with returned activated sludge from secondary clarifier. Aeration increases dissolved oxygen concentration that is needed for degradation process while return activated sludge keeps the necessary mixed liquor suspended solids (MLSS) concentration in the tank. The system is known to be efficient in removing BOD, suspended solids and nitrogen (when designed for that). Effluent from the tank flows to a clarifier in order to settle down the activated sludge. Denitrification is achieved through circulating the effluent from the tank to an anoxic zone located at the first part of the aeration tank. In general primary sedimentation tank in an extended aeration treatment plant is optional. Schematic presentation of extended aeration treatment system is shown in Figure 19. Advantages and disadvantages of the system are shown in Box 4.

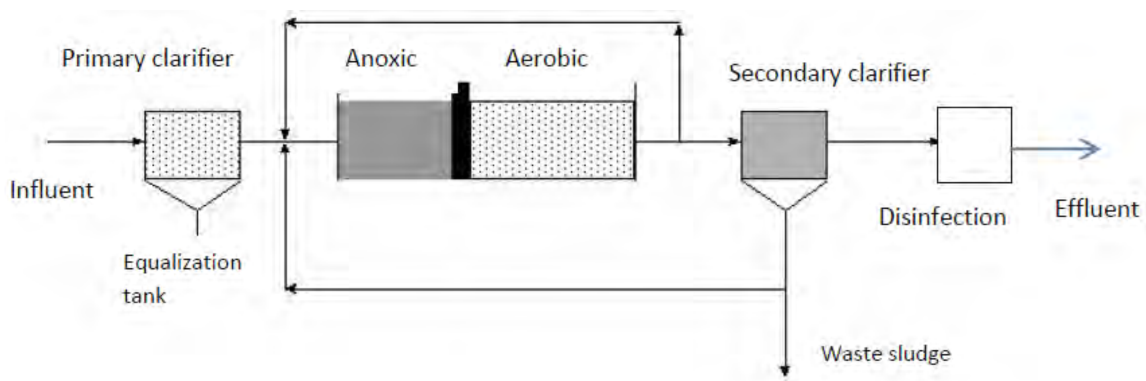


Figure 19: Extended aeration system, modified from Parsons Engineering Science Inc. 1999, as taken from EPA (2000)

Box 4. Extended aeration wastewater treatment system

Key advantages

+ Reliable wastewater treatment method
+ Less sludge production owing to extended biological activity during the process.

Key concerns

– Effluent suspended solids are relatively high compared to other modifications of activated sludge process.
– Requires larger land area compared with other activated sludge treatment options.

10.6 Comparison between the nominated systems

Comparison matrix is shown in Annex 5. Assessment takes place through categories such as 'high', 'medium' and 'low'. Systems were compared relative to each other. Details were collected based on literature and on own experience. Comparison was made based on the following criteria:

A. Economic efficiency that takes into accounts both the investment costs and operation & maintenance costs.
B. Plant technology
C. Requirement of operating personnel
D. Effect on the environment

Economic efficiency refers to both investment costs and operation costs. Investment costs are sub-divided into surface requirements, structural engineering, mechanical engineering, and electrical and control systems. Operation costs are subdivided into personnel requirements, energy requirement costs, residues disposal costs, and preventive maintenance costs. However, it should be noted that determination of investment and operation costs are to be carried out from scratch for each project since economic efficiency is a very important factor in the assessment process.

Plant technology particularly considers treatment performance with respect to COD and BOD removal, suspended solids (SS) removal, nutrients removal, and pathogens removal. It also reflects factors like reliability and flexibility, and sludge production. In addition, the matrix includes elements related to requirements for operating personnel; particularly for level of needed training, complexity of operation and required preventive maintenance. Finally, the effect on environment was assessed based on the following elements:

1. CH_4 emissions
2. Odor nuisance
3. Sound noisiness
4. Aerosols, and
5. Insects

Detailed EIA assessment for the site based on the recommended and to be selected technology is going to be conducted. This EIA will take all environmental aspects including flora and fauna, sludge disposal in to consideration.

Based on the matrix, a system consisting of UASB-CW can be considered as the preferred system. The system is characterized by low operational and maintenance costs; minimum energy requirements; and high treatment efficiency. It is a non-conventional system that has potential for application in Jordan. The main disadvantage of the system is the high land requirement for the constructed wetlands. Some experience already exists in Jordan for operating such systems. Pilot plants of UASB reactors with capacity of 100 m^3 already exist in Jordan. Moreover, pilot plants consisting of septic tanks followed by constructed wetlands also exist in Balqa governorate and already applied for house on-site treatment. Therefore, conceptual design for such a treatment plant will be presented in this report. In addition, and based on the client wish, an SBR plant will be considered since local companies having experience with SBR package units are already available. As a summary, conceptual design will be provided for UASB-CWL system and SBR system in this baseline assessment.

10.7 Conceptual design for UASB- CWL treatment plant

The treatment systems have been designed to meet the effluent quality standards JS (893/2006) for irrigating parks, play grounds and cooked vegetables except for nitrate concentration where a value of 50 mg NO_3^-/l was chosen. This concentration is mainly expected during cold winter when water temperature drops to less than 15^{o}C. The maximum permissible limit of NO_3^- set by JS (893/2006) is 30 mg/l. However, and according to drinking water quality standards, a maximum permissible NO_3^- concentration is 50 mg/l. This value can even be up to 70 mg NO_3^-/l when no other drinking water sources are available. Design of the UASB reactor was based on the experience gained from operating such a system for more than 10 years in Jordan (Halalsheh et al., 2005; Alrajoula et al., 2009; Halalsheh et al., 2010). Main design parameter selected for sizing was the allowed organic loading rate. Feed inlet points, calculations of the gas liquid separator (GLS) height, slope of the GLS, and influent and effluent channels were selected according to (van Haandel and Lettinga, 1994). Main design elements of the system including sizing and number of feed inlet points are shown in Table 11. Engineering drawings are shown in Annex 6.

Design of the CWL was based mainly on literature (Crites and Tchobanoglous, 1998; UN-Habitat, 2008) and personal communication with colleagues working on pilot plants in Jordan through SMART project. 42% of area required for the CWL was designed as horizontal flow constructed wetlands while the rest was configured as vertical flow constructed wetlands. The reason is the reported higher removal of solids and BOD for horizontal flow configuration. The vertical configuration was reserved for nitrification and was designed in such a way for the reported better nutrient removal in vertical flow constructed wetlands (UN-Habitat, 2008). This is mainly due to better supplied oxygen in the VFCWL. Nitrified effluent from the VFCWL shall be circulated to the UASB reactor for denitrification. Main design of the system is shown in Table 12 including sizing, main substrate (media) used and the nominal size, and lining requirement. Engineering drawings that include cross sections of both wetlands and influent distribution system are shown in Annex 6.

Horizontal and vertical flow constructed wetlands shall be planted with *Phragmites* sp. or *P.australis*, which are widely known to be the reed used in CWL. Those are known to be most productive, climate tolerance and have rapid growth. Both horizontal and vertical constructed wetlands should be lined with high density poly ethylene (HDPE) liner with a thickness of 800 micrometer. A layer of sand should be placed beneath the liner if needed.

The media in the HFCWL should be between 40-80 mm in diameter for the inlet and outlet zones in order to minimize clogging. For the treatment zone, media size can be selected between 10 to 60 mm in diameter. Before introducing the media, it should be washed to remove any soil that may cause clogging.

Table 11: Design elements of the UASB reactor in UASB-CWL treatment system

UASB	
Volume (m^3)	256.5
Surface area (m^2)	51.3
Height (m)	5.0
Width (m)	5.7
Length (m)	9.0
Comment: No sludge will be discharged from reactor	
No. of inlet points = 53 distributed at tank's bottom **Height of GLS = 1.5 m** **No. of GLS = 2** **Slope of GLS = 55^o** **Aperture width = 0.3 m**	

Table 12: Main design elements of HFCWL and VFCWL in the first treatment option

CWL	
Total surface area (m^2)	8118
Surface area of HFCWL (m^2)	3408
Effective depth of HFCWL (m)	0.5
Width (m)	24
Length (m)	142
HLR (mm/d)	64
Surface area of VFCWL (m^2)	4710
Effective depth (m)	1.0
Width (m)	30
Length (m)	157
HLR (mm/d)	46

Diameter of influent distribution pipes (laterals) mm (inch)	3.125 (1.25)
Holes diameter in laterals (mm)	5
Space between holes in laterals (m)	0.5
Slope of the bottom = 0.5% **Drawings will be provided for the wetlands; influent distribution system; and effluent collection system**	

Media in the VFCWL should be selected based on d_{10} (effective grain size), d_{60} and the uniformity coefficient. $0.25 < d_{10} < 1.3$ mm. d_{60} should be between 1-4 mm. Uniformity coefficient should be less than 3.5. The hydraulic conductivity should range 10^{-3} to 10^{-4} m/s. Details on influent distribution system; effluent collection system and cross sections are shown in Annex 6. It should be noted that heavy machinery use should be avoided during construction of WL in order to prevent compaction of the filter layer. Each HFCWL and VFCWL should consist of two trains. Sewage should be distributed using a pressurized system to guarantee even distribution of the influent over and across the filter media. For this purpose, flow can be provided in 8 pulses per day.

Effluent from the VFCWL should be circulated to the UASB reactor at a ratio of 1:1 for denitrification. The CWL should be planted at a density of 4 plants / m^2. Plantation process should be avoided during cold winter months.

10.8 Conceptual design of SBR treatment plant

SBR package units are already installed in some locations in Jordan including some border points and military units. However, data on performance of such units were not available. Therefore, design was based on guidelines and procedures described by MetCalf and Eddy, (2003). Main design elements are shown in Table 13. Engineering drawings are shown in Annex 6. It should be noted that nitrogen is the main parameter that contributed to the excessive needed volume for treatment. Accordingly, two trains are needed with three reactors per train.

Table 13: Main design elements of the SBR treatment plant

Design summary for SBR		
Design parameter	Unit	Value
Average flow	m^3/d	217
Average BOD load	kg/d	162
Average TKN load	kg/d	38
Number of trains	number	1
Number of tanks for each train	number	3
SRT	D	15

Tank volume	m^3	271
No. of cycles per tank per day		2.6
Cycle time	hours	9.0
Fill volume	m^3	18.2
MLSS	g/m^3	3500
MLVSS	g/m^3	2400
F/M	kg BOD/kg MLVSS.d	0.092
Sludge production	kg TSS/d	190

10.9 Rough cost estimate of UASB-CWL treatment systems

Costs estimates of the UASB-CWL treatment system are shown in Table 14. Costs were estimated based on current local market price. HDPE membrane price was estimated based on a membrane thickness of 1000 micrometer. A sand layer with a thickness of 20 cm should be applied beneath the HDPE membrane depending on the need. It should be noted that land cost and plants cost are not included in this option.

Table 14: Estimated costs for the UASB-CWL treatment system

#	Items	Total cost (JOD)
1	Mechanical bar screen	6,000
3	Flow Meter (ultrasonic)	8,000
4	Distribution box with gates	10,000
5	**UASB reactor (**Volume= 256.5 m^3)	
	Excavation and leveling	1,800
	Water proofed concrete tank	54,000
	GSS + effluent weirs	20,000
	UASB cost	**75,800**
6	**HFCWL, two trains (**Total surface area 3408 m^2)	
	Media cost	17,040
	Excavation and leveling	16,358
	HDPE membrane liner	21,360
	Dosing chambers	10,000
	20 cm sand layer under the HDPE membrane	4,090
7	**VFCW, two trains (**Total surface area= 4710 m^2)	
	Excavation and leveling	36,738
	HDPE membrane liner	28,260
	Gravels	47,100
	Sand layer (0.2m) below HDPE membrane	5,652

	Dosing chambers	10,000
8	**Piping for CWL**	8,714
9	**Fence and site work**	15,000
	Sub-total cost (JOD)	**296,112**
Contingency cost (JOD)		**44,417**
Total cost (JOD)		**340,529**
Cost per capita (JOD/cap)		**138**

10.10 Packaged SPR or Compact Systems

The consultant obtained the following packaged and compact systems for the technical committee to consider:

- A package containerized system has been offered by Mira Water Tech (Annex 9), price 164,500 JOD, operational cost could be in the range of 3,000 JOD / month

- Bauer International Corporation (SBR Compact Dynamic Technology) (Annex 10), offered a complete technology system including treatment of sludge (concrete work (structures) are excluded). Price 203,000 USD = 144,000 JOD excluding supervision and training (8756 JOD); concrete work is also excluded. Operational cost could be in the range of 3000 JOD/month.

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Annex 1: PSD site plan

Annex 2. Governmental and private wells existing in the study area

Station ID	Station Name	Palestinian Grid N	Palestinian Grid E	Altitude (m)	Well depth (m)	AQUIFER	Owner	Static water level	Draw down	Yield m^3/hr	Salinity TDS mg/l
CD1404	JAMAL BSH	1138920	234620	839	225	B2/A7	Private	95	1.88	62	337
CD3114	YADUDAH N	1139000	235050	809	330	A4	Government	113	85.2	26	
CD1054	FAHED ABU	1139510	235600	820	180	B2/A7	Private	73	30.75	63	320
CD3020	FAHED S.	1139700	234570	820	201	B2/A7	Private	91	27.57	20	304
CD3393	GHAMADAN	1141043	235021	920	420	A2/A1	Government	185	134.15	6	
CD3410	SAMI A'AS	1141140	234020	880	252	A4	Private	112	32	15	
CD3381	LATIN PAT	1141530	231950	900	325	B2/A7	Private	190	42	20	435
CD1283	JAMAL BSH	1141680	232580	920	349	B2/A7	Private	116	33	15	377
CD3346	GHALEB SA	1142320	235050	900	310	B2/A7	Private	180	81	6	435
CD3159	SA'EED FA	1142660	236040	870	250		Private				
CD1298	BASHEER A	1144230	233070	900	190	B2/A7	Private	125	46.1	32	768
AL3436	JORDAN UN	1144810	232600	919	400	B2/A7	Private	186	56	17	

Annex 3: Results of waste water sampling

Annex 4: Agreements signed for the pilot activity follow up

Annex 5: Comparison between suggested systems

	UASB-RBC system	***Extended aeration; modification of activated sludge system***	***UASB-CWL system***	***SBR system***
Economic efficiency				
Investment cost Surface requirement	Low	Low	High	Low
Structural Engineering	Medium	Medium	Medium	Medium
Electrical and control systems	Medium	High	Low	High
Mechanical	Medium	High	Low	High
Operating cost Personnel requirement costs	Low	Medium	Low	Medium
Energy requirement costs	Medium	High	Low	High
Disposal of residues	Low	Medium	Very Low	High
Preventive maintenance	Low	Medium	Low	Medium
Plant Technology				
Removal efficiency	High	High	High	High
Degree of mechanization	Medium	High	Low	High
Reliability	High	High	High	High
Ability to influence effluent quality	Medium	High	Medium	High
Sludge residues (production)	Low	Medium	Very low	High
Requirement on operating personnel				
Complexity of operation	Medium	High	Very Low	High
Required skills	Medium	High	Low	High
Preventive maintenance	Medium	High	Low	High
Effect on environment				
Greenhouse gases	High	Medium	High	Medium
Odors	Medium	Medium	Low	Medium
Noisiness	Medium	Medium	Low	Medium

Aerosols	Low	High	NA	Low
Insects	Low	Low	Low	Low

Annex 6: Engineering drawings of the proposed UASB - CWL

Annex 7: Second Choice, UASB-RBC system

A) Size of equalization basin = 255 m^3
B) Dimensions of UABS reactor are the same as in the first choice
C) Dimensions of the RBC reactor

RBC reactor	
No. of trains	2
Flow rate/train (m^3/d)	109
No. of stages	2/train
Total disk area per stage (m^2)	12,270
No. of shafts	2
Standard tanks	23’ 6’’× 13’ 0’’ ×6’ 6’’
Total area of tanks (m^2)	113
Recirculation ratio 3	
Expected sludge production is around 15 m^3/d	

D) Secondary sedimentation tank with a rough size of 45 m^3.

Cost Estimate			
UASB followed by RBC			
#	Items	Information	Total cost (JOD)
1	mechanical bar screen	-	6,000
3	Flow Meter (ultrasonic)		8,000
4	Distribution box with gates		10,000
5	**Equalization tank**	volume=250 m^3	
	Excavation and leveling		1,500
	Under ground water proofed concrete tank		50,000
	Electro-mechanical systems		10,000
			61,500
6	**UASB reactor**	volume= 263 m^3	
	Excavation and leveling		1,800
	Underground water proofed concrete tank		54,000
	GSS + effluent weirs		20,000
	UASB cost		**75,800**
7	RBC, two trains with two stages/train + secondary sedimentation tank		300,000
8	Fence and site work		8,000
		Total Cost	**469,300**
	cost per capita		**188**

Annex 8: The design of the selected options at a reduced flowrate

(Assuming that SMART program treats 50 m3/d)

Since there is a possibility for cooperation with SMART project on piloting wastewater treatment at the compound, it was decided to repeat the design for the preferred selected two options taking into account that SMART team will provide treatment services for a total flow of 50 m^3/d. This would mean that a total flow of 167 m^3/d should be considered in this section.

a. **Option I**: UASB- CWL treatment plant

The treatment systems were designed to meet the effluent quality standards JS (893/2006) for irrigating parks, play grounds and cooked vegetables. Design of the UASB reactor was based on the experience gained from operating such system for more than 10 years in Jordan (Halalsheh et al., 2005; Alrajoula et al., 2009; Halalsheh et al., 2010). Main design parameter selected for sizing was the allowed organic loading rate. Feed inlet points, calculations of the gas liquid separator (GLS) height, slope of the GLS, and influent and effluent channels were selected according to (van Haandel and Lettinga, 1994). Main design elements of the system including sizing and number of feed inlet points are shown in Table (A1).

Design of the CWL was based mainly on literature (Crites and Tchobanoglous, 1998; UN-Habitat, 2008) and personal communication with colleagues working on pilot project in Jordan through SMART project. 48% of area required for the CWL was designed as horizontal flow constructed wetlands while the rest was configured as vertical flow constructed wetlands. The reason is the reported higher removal of solids and BOD for horizontal flow configuration. The vertical configuration is needed for nitrification and was designed in such a way for the reported better nutrient removal in vertical flow constructed wetlands (UN-Habitat, 2008). Nitrified effluent from the VFCWL shall be circulated to the UASB reactor for denitrification. Main design of the system is shown in Table (A2) including sizing, main substrate (media) used and the nominal size, and lining requirement.

Table (A1). Design elements of the UASB reactor in UASB-CWL treatment system

UASB	
Volume (m^3)	195
Surface area (m^2)	39
Height (m)	5.0
Width (m)	5.2
Length (m)	7.5
Comment: No sludge will be discharged from reactor	
No. of inlet points = 38 distributed at tank's bottom Height of GLS = 1.5 m, No. of GLS = 2 Slope of GLS = 45^o Aperture width = 0.3 m	

Constructed wetlands shall be planted with *Phragmites* sp. or *P.australis*, which are widely known to be the reed used in CWL. Those are known to be most productive, climate tolerance and have rapid growth. Both horizontal and vertical constructed wetlands should be lined with HDPE membrane liner with a thickness of 800 micrometer. A layer of sand should be placed beneath the liner if needed.

The media in the HFCWL should be between 40-80 mm in diameter for the inlet and outlet zones in order to minimize clogging. For the treatment zone, media size can be selected between 10 to 60 mm in diameter. Before introducing the media, it should be washed to remove any soil that may result in clogging.

Table (A2). Main design elements of HFCWL and VFCWL in the first treatment option

CWL	
Total surface area (m^2)	5529
Surface area of HFCWL (m^2)	2625
Effective depth of HFCWL (m)	0.5
Width (m)	21
Length (m)	125
HLR (mm/d)	64
Surface area of VFCWL (m^2)	2904
Effective depth (m)	0.8
Width (m)	22
Length (m)	132
HLR ($m^3/m^2.d$)	58
Slope of the bottom = 0.5%	

Media in the VFCWL should be selected based on d_{10} (effective grain size), d_{60} and the uniformity coefficient. $0.2 < d_{10} < 1.2$ mm. Uniformity coefficient should be between 3 and 6. The hydraulic conductivity should range from 10^{-3} to 10^{-4} m/s.

b. **Option II**: SBR treatment plant

Some SBR package units are already installed in some locations across Jordan including some border points and military units. However, data on performance of such units were not available. Therefore, design was based on guidelines and procedures described by MetCalf and Eddy, (2003). Main design elements are shown in Table (A3).It should be noted that nitrogen is the main parameter that contributed to the excessive needed volume for treatment. Accordingly, two trains are needed with two reactors per train.

Table (A3). Main design elements of the SBR treatment plant

Design summary for SBR		
Design parameter	unit	value
Average flow	m^3/d	167
Average BOD load	kg/d	124
Average TKN load	kg/d	29
Number of trains	number	2
Number of tanks for each train	number	2
SRT	d	20
Tank volume	m^3	166
MLSS	g/m^3	3500
MLVSS	g/m^3	2400
F/M	kg BOD/kg MLVSS.d	0.078
Sludge production	kg/d	116

Annex 9: Packaged treatment system based on SBR (Mira Water Tech)

Cost: 164,500 JOD

Annex 10: Treatment system offered by Bauer International Corporation; compact Bauer Dynamic SBR system

EXCLUDES CONCRETE WORK

Price: 203,000 USD = 144,000 JOD (excl. construction work)
+ 9500 USD (6735 JOD) for supervising installation
+ 2850 USD (2020 JOD) for training