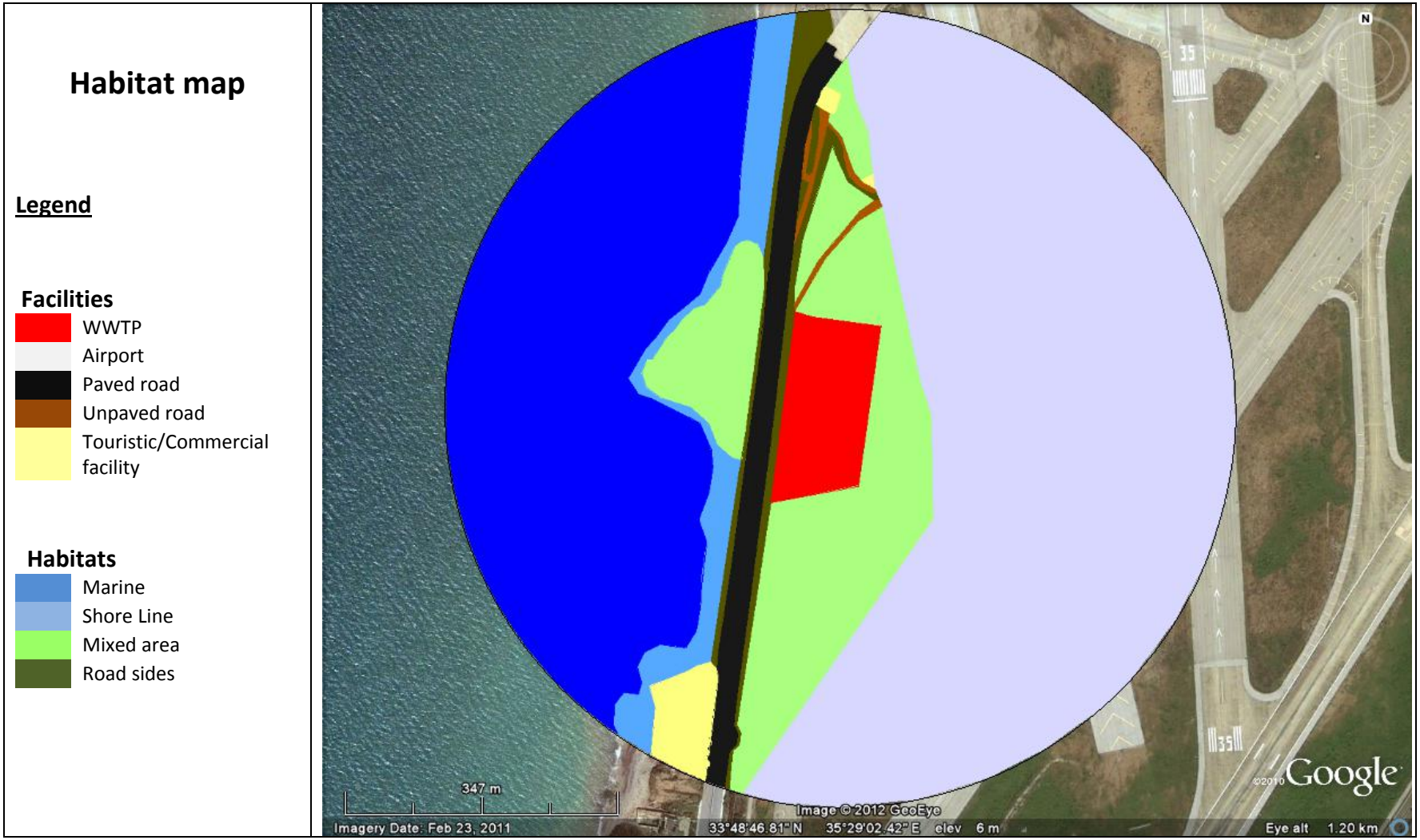


Figure 6.15 Habitat map

Mixed habitat

This habitat is located mainly over the Rubble Dump facing the Preliminary WWTP and over the area surrounding the Plant. The vegetation cover is considered important. It is also a highly mixed area given the different sources of soil and waste making up the dump.

Main species reported are species normally found around dumpsites such as: *Ricinus communis*, *Datura metel*, *Inula sp*, *Chrozophora tinctoria*, *Heliotropium hirsutissimum*, *Verbascum sinuatum*, *Alhagi maurorum* and *Oryzopsis miliacea.*

Other species observed represent the different micro habitats found within this area, such as the *Capparis spinosa* and the *Washingtonia robusta*, or species which mainly belong to humid areas such as the *Phragmites australis* and *Erigeron (Conyza) canadense*, and the *Nicotiana glauca* mainly found in coastal areas.



Figure 6.16 Mixed habitat in different survey points

Shoreline habitat

As shown in the habitat map (Figure 6.15), the shoreline habitat faces the WWTP and follows the coastline. It can be divided into two main parts:

- The shoreline, considered as a typical sea shore habitat, covered with coastal plant species such as: *Nicotiana glauca, Solanum nigrum,* Cakile aegyptia *and* Beta *vulgaris maritime; and*
- The second part of the shore line, mainly covered with algae and other marine plant species.
-



Figure 6.17 Shore line habitat in different survey points

Roadside Habitat

The road side ecosystem is composed of mixed vegetation and shrubs like *Salsola Kali, Inula sp* and *Ricinus communis* (widely spread), in addition to some cultivated trees such as Eucalyptus and palm trees.



Figure 6.18 Road sides Habitat in different survey points

Marine habitat

The marine environment is home to phytoplankton which includes all microphytic algae, constituting the basis of the food chain through their primary productivity, and the micro and macrophytic benthic algae which are highly affected by the coastal pollution.

6.3.1.2.2 Flora species

Three (3) study points, shown on Figure 6.19, were thoroughly surveyed during the field visit. In each of the study points, the number of different species was evaluated. A list of flora species observed on site is provided in Figure 6.19, while Figure 6.20, Figure 6.21 and Figure 6.22 display some of the pictures collected.

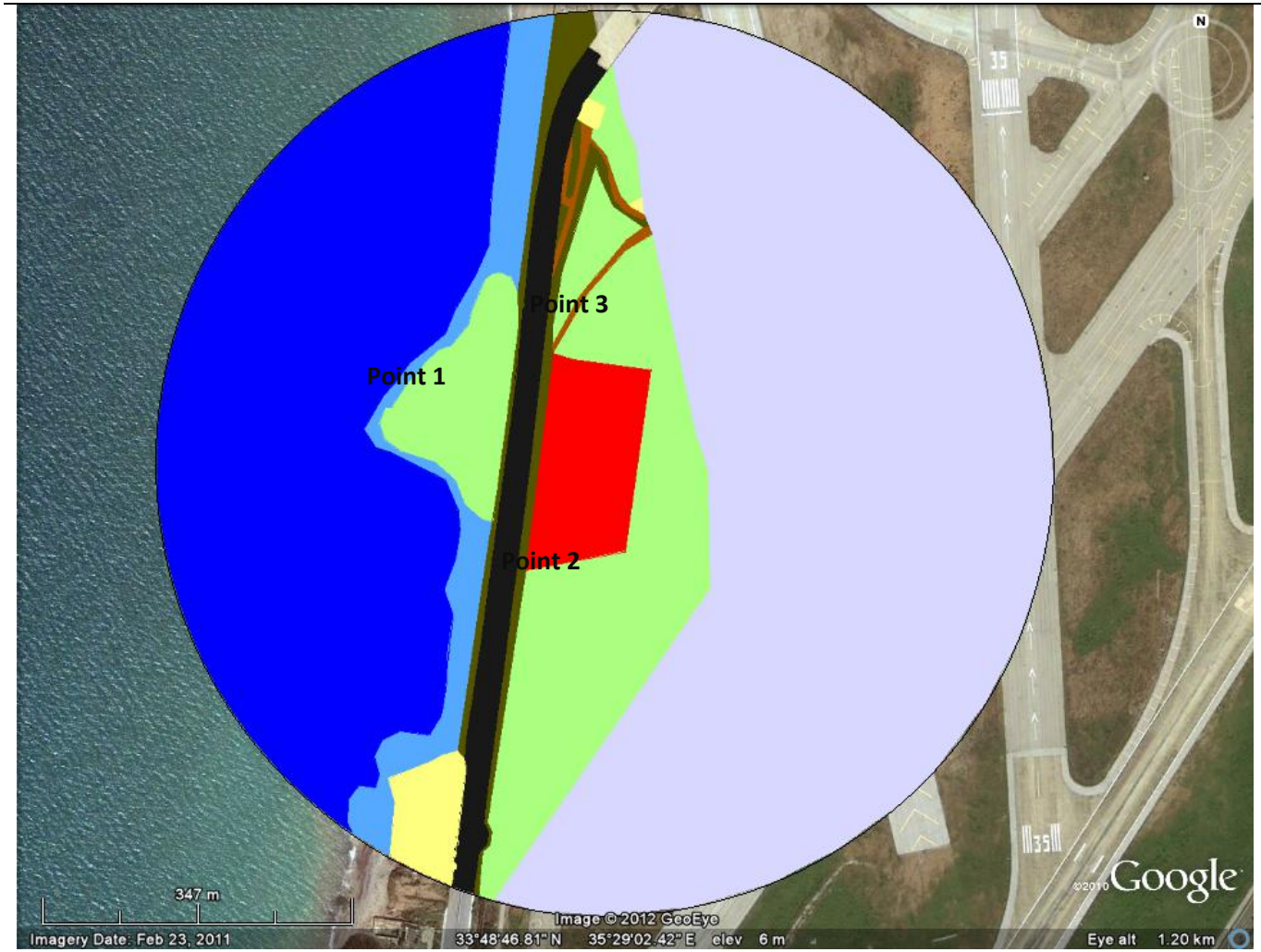
As a conclusion of the rapid field visit, two major types of species were identified:

- Species that are originally considered as coastal species; and
- Common species that belong to dump areas.

The highest ecological interest in terms of flora is related to the presence of coastal species. They are strongly related to the habitat type they occur in.

It should be noted that no endemic, rare, endangered or protected species were identified within the buffer zone around the WWTP.

Plant communities in the Study Area are expected to have been subject to significant pressures, especially around the coastal strip, due to urbanization and land-based pollution. Similarly, and as a result of the destruction of the vegetation cover by various factors including the extensive coastal urbanization, disturbances to fauna species are expected to be significant. It is thus assumed that they are already in a somewhat degraded state.



Species observed in Point 1
Cakile aegyptia
Chrozophora tinctoria
Datura metel
Erigeron (Conyza) canadense
Heliotropium hirsutissimum
Inula sp
Nicotiana glauca
Ricinus communis
Salsola Kali
Solanum nigrum
Plantago sp
Capparis spinosa
Washingtonia robusta
Beta vulgaris maritime

Species observed in Point 2
Oryzopsis miliacea
Inula sp
Verbascum sinuatum

Species observed in Point 3
Echinops sp
Alhagi maurorum
Phragmites australis

Figure 6.19 List of flora species observed in different survey points

		
Cakile aegyptia	*Beta vulgaris maritima*	*Chrozophora tinctoria*
		
Datura metel	*Erigeron (Conyza) canadense*	*Heliotropium hirsutissimum*



Capparis spinosa



Washingtonia robusta



Nicotiana glauca



Ricinus communis



Solanum nigrum



Salsola Kali

Figure 6.20 Pictures of observed species in point 1



Verbascum sinuatum



Inula sp



Oryzopsis miliacea

Figure 6.21 Pictures of observed species in point 2



Alhagi maurorum



Phragmites australis



Echinops sp

Figure 6.22 Pictures of observed species in point 3

Table 6.5 List of observed species

LATIN NAME	ENGLISH NAME	FRENCH NAME	ARABIC NAME	FAMILY NAME	HABITAT	CHARACTERISTICS/COMMON USAGE
Nicotiana glauca	Tobacco-shrub	Nicotiane d'un vert bleuaitre	التنبـــــك شـجرة	Solanaceae	Coastal areas.	Venomous
Ricinus communis	Common Palma-Christi	Ricin Common	شـــائع خروع	Euphorbiaceae	Waste ground Fairly common around towns.	Toxic seeds Medicinal, ornamental plant
Datura metel	Hairy throne –apple	Stramoine metel	مشـعرة داتـورة	Solanaceae	Waste ground	Venomous
Solanum nigrum	Black nightshade	Morelle noir	الثعلـــب عنـب	Solanaceae	Sandy ground	Medicinal plant
Cakile aegyptia	Egyptian sea-rocket	Coquillier d'Egypte	البحـــر رشـاد	Brassicaceae	Seashore	Has the potential to become a noxious weed.
Inula sp				Asteraceae	Rocks near sea, waste ground roadsides	-
Chrozophora tinctoria	Turnsole	Chrozophore des teinturies	غبـــيري	Euphorbiaceae	Waste ground	Medical and edible use
Heliotropium hirsutissimum	Hairy heliotrope	Heliotrope herisse	الشـمس رقيـــب مقنفـــذ	Boraginaceae	Waste ground	-
Erigeron (Conyza) canadense	Canadian fleabane	Conyze du Canada	كنـدا كزنـــيزا	Asteraceae	Humid fields	Noxious weed
Capparis spinosa canescens	Spiny caper	Caprier epineux	وبـر كـــبر	Capparidaceae	Common, walls, rocks	-
Salsola Kali	Prickly saltwort	Soude Kali	القلـــي حرض	Chenopodiaceae	Fairy common on coastal sands	-
Plantago sp	Plantain	Plantain	الحمـل لســان	Plantaginaceae		-

LATIN NAME	ENGLISH NAME	FRENCH NAME	ARABIC NAME	FAMILY NAME	HABITAT	CHARACTERISTICS/COMMON USAGE
Washingtonia robusta	Mexican Fan Palm		مروحي نخيل	Arecaceae		Ornamental tree
Verbascum sinuatum	Sinai mullein	Molene sinuee	بوصير متعرج	Scrophulareaceae	Waste ground	
Alhagi maurorum	Sinai manna	alhage – des – maures	عاقول	Fabaceae	Waste places	Noxious weed
Phragmites australis	Southern reed	Phragmite austral	قصب المكانس	Poaceae	Near water	Important in terms of industrial use, baskets, mats, pen tips, and a rough form of paper
Beta vulgaris maritime	Sea garden beet	Bette maritime	بحري سلق	Chenopodiaceae	Waste ground	-
Oryzopsis miliacea	Millet Mountain-rice	Oryzopsis faux-millet	بريـة مكنسة	Poaceae	Waste ground	Ornamental grasses

6.3.1.3 FLORA IN THE SERVICE AREA (NETWORKS)

The service area covers an area of about 176Km^2, encompassing the whole Southern part of Beirut city, a portion of the Northern Part of Beirut city and parts of the districts (cazas) of Baabda, Aaley, and the Chouf.

The network area will be referred to as "Assessment Area" throughout this sub-section.

6.3.1.3.1 Description of Vegetation Communities

The bio–ecological approach was used in the floristic diversity study presented in this section. Accordingly, two levels and series of vegetation can be revealed in Lebanon, which are the Mediterranean and pre-steppe Mediterranean, each divided into different sub-units[6] as shown in Figure 6.23 below.

Based on Figure 6.23, the Assessment Area is located within the Thermomediterranean and the Eumediterranean zones. These are described below, and the floral diversity they may hold is assessed based on the types of mother rocks present in each area.

6.3.1.3.2 Thermomediterranean Zone

This zone rises from the coast to around 500m altitude, on the western slopes of Mount Lebanon. From the point of view of the mother rock, 3 situations need to be taken into account:

1st situation: on limestone

- The Caroubier-Lentisque series is the warmest. Represented here and there on the Lebanese coast, this series is presented either: a) in the form of scrubland, where Pistacia lentiscus L. is dominant and where Myrtus communis L. is relatively abundant. Ceratonia siliqua L.is always present, but generally sparse because it is very sensitive to human activities, or b) in the form of woods of Pinus halepensis Mill, especially to the south of Beirut, or Pinus brutia Ten. May also be widespread.
- The series of Quercus calliprinos Webb. covers most of the Thermomediterranean zone on compact limestone. Altitudinal leveling of the series goes from the sea-side to around 400-500m.

2nd situation: on marl and marly limestone

- Marly substrata are widespread at low altitude. Vegetation is dominated by the Conifers: Pinus brutia Ten, which is the most common, Pinus halepensis Mill. And Cupressus sempervirens L. also occupy a considerable part.
- The distribution of Pinus halepensis Mill. Is fragmentary in Lebanon. The only community to the north of Beirut is that of Sahel Byblos and it appears to have been planted. It is only south of Baabda that this species becomes abundant, forming pure communities or mixed with Pinus brutia Ten,of which the southern limit appears to be in Lebanon.

[6] Valuing Mediterranean Forests –Towards Total Economic Value, University of Padova, Italy- 2005

3rd situation: on sandstone

- All the pinewoods at low altitude on sandstone substrata, especially those situated to the east of Beirut, must be added to the series of Pinus pinea L. the same is true for the old communities to the south of the town.
- The arborescent communities of the series of Pinus pinea L. take the form of pure pinewoods, sometimes with Pinus brutia Ten.

6.3.1.3.3 Eumediterranean zone

The Eumediterranean zone falls between 500 m and 1000 m on the western slopes of Mount Lebanon. It'supper limit is a little higher in the southren part of the eastren slopes of the same chain. From the point of view of the mother rock, 2 situations should be taken into consideration:

1st situation : on limestone

- The series Quercus calliprinos Webb. is the most widespread territorially. It is the most important climatic species on the whole of the Mediterranean slopes of Lebanon.
- The Mediterranean series of Quercus infectoria Oliv. corresponds to the caducifoliated oak grove within the limits of the evergreen oak grove. It is always found on deep soil exposed to the north and in the thalwegs.
- The Mediterranean series of Pinus brutia Ten. and Cupressus sempervirens L. are found mostly in the north of the country. Arborescent groups are either pure pinewoods or mixed with cypresses. The latter, in certain places, may form pure communities.

2nd situation: on sandstone

The Mediterranean series of Pinus pinea L. Covers most forests of umbrella pines. They are especially well developed in central Lebanon.

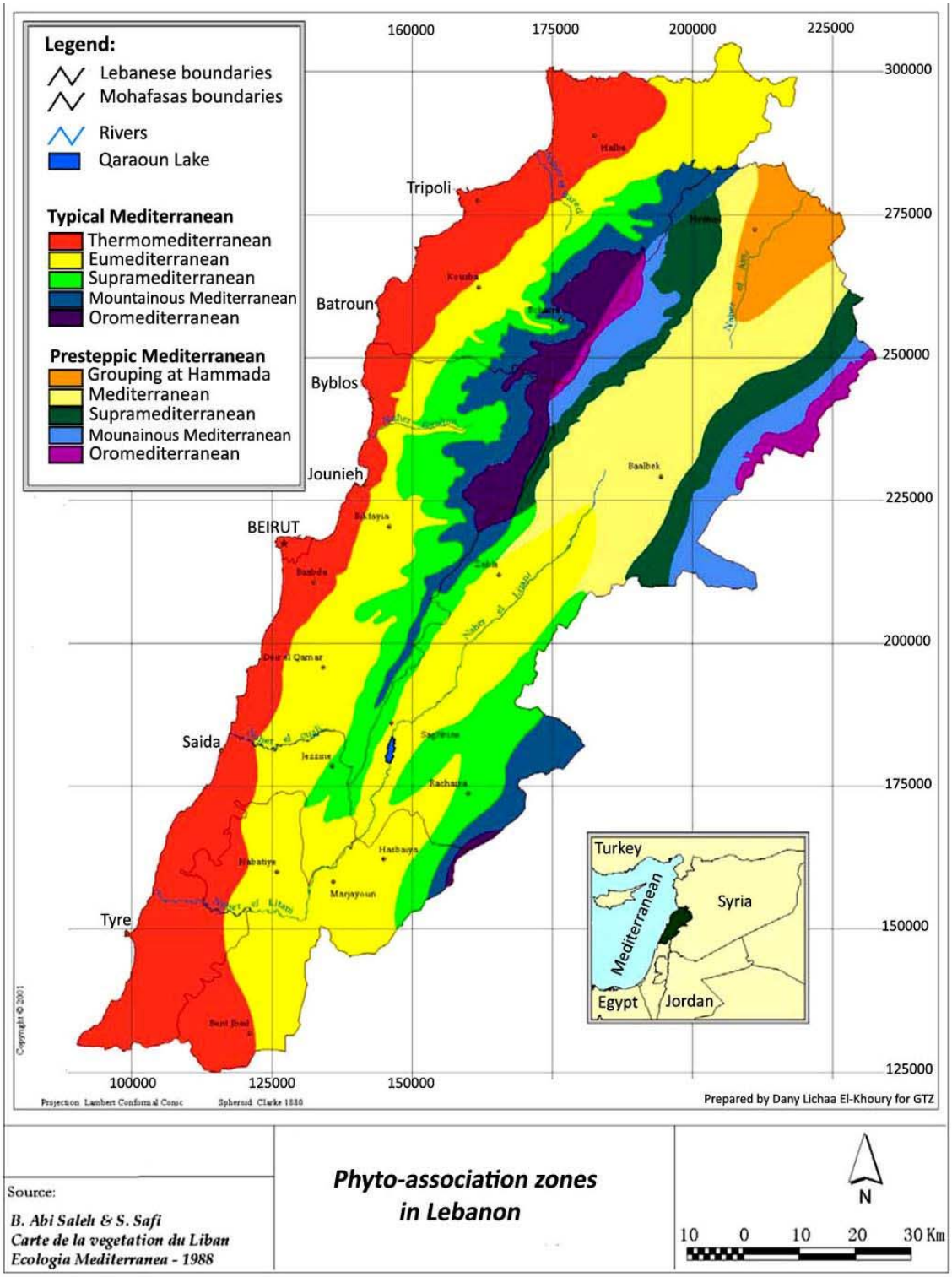


Figure 6.23 Map of typical and pre-steppe Mediterranean vegetation zones in Lebanon. Source: Abi- Saleh and Safi (1998)

6.3.1.3.4 Land use

The land use in the Assessment Area differs widely as shown in Figure 6.24. The percentage and the area of each type of land use are presented in Table 6.6.

Table 6.6 Percentage and area per type of land use

TYPE OF LAND USE	TYPE	AREA (M2)	%
Agricultural Land	Agricultural Land	41405500	23.43
Artificialized Land	Dense Urban Tissue	8433380	4.77
	Moderately Dense Urban Tissue	5612690	3.18
	Sparse Urban Tissue	22847800	12.93
	Undeveloped Artificialized Land	9009360	5.10
	Green Artificialized Land	733352	0.42
	Commercial or Industrial Area	3046370	1.72
	Informal Moderately Dense Urban Tissue	454304	0.26
	Equipment	727169	0.41
	Informal Dense Urban Tissue	3939740	2.23
	Touristic Resort	65096	0.04
	Airport	4802140	2.72
	Informal Sparse Urban Tissue	275681	0.16
Herbaceous Vegetation	Herbaceous Vegetation	19469600	11.02
Permanent Streams	Permanent Streams	68828	0.04
Unproductive Land	Unproductive Land	172136	0.10
Wooded land	Mixed Dense Forest	2526160	1.43
	Mixed Sparse Forest	2690440	1.52
	Shrubland	11002500	6.23
	Shrubland (Scattered Trees)	10298200	5.83
	Woodlands or Burnt Areas	134768	0.08
	Urban Sprawl on Dense Forest	348964	0.20
	Dense "Pinus spp" Forest	3238010	1.83
	Dense "Quercus spp" Forest	7641130	4.32
	Other Types of Dense Deciduous Forests	14073	0.01
	Urban Sprawl on Sparse Forest	1962950	1.11
	Sparse "Pinus spp" Fforest	7536590	4.27
	Sparse «Quercus spp» Forest	6909170	3.91
	Other Types of Sparse Deciduous Forests	199285	0.11
	Urban Sprawl on Shrubland	388796	0.22

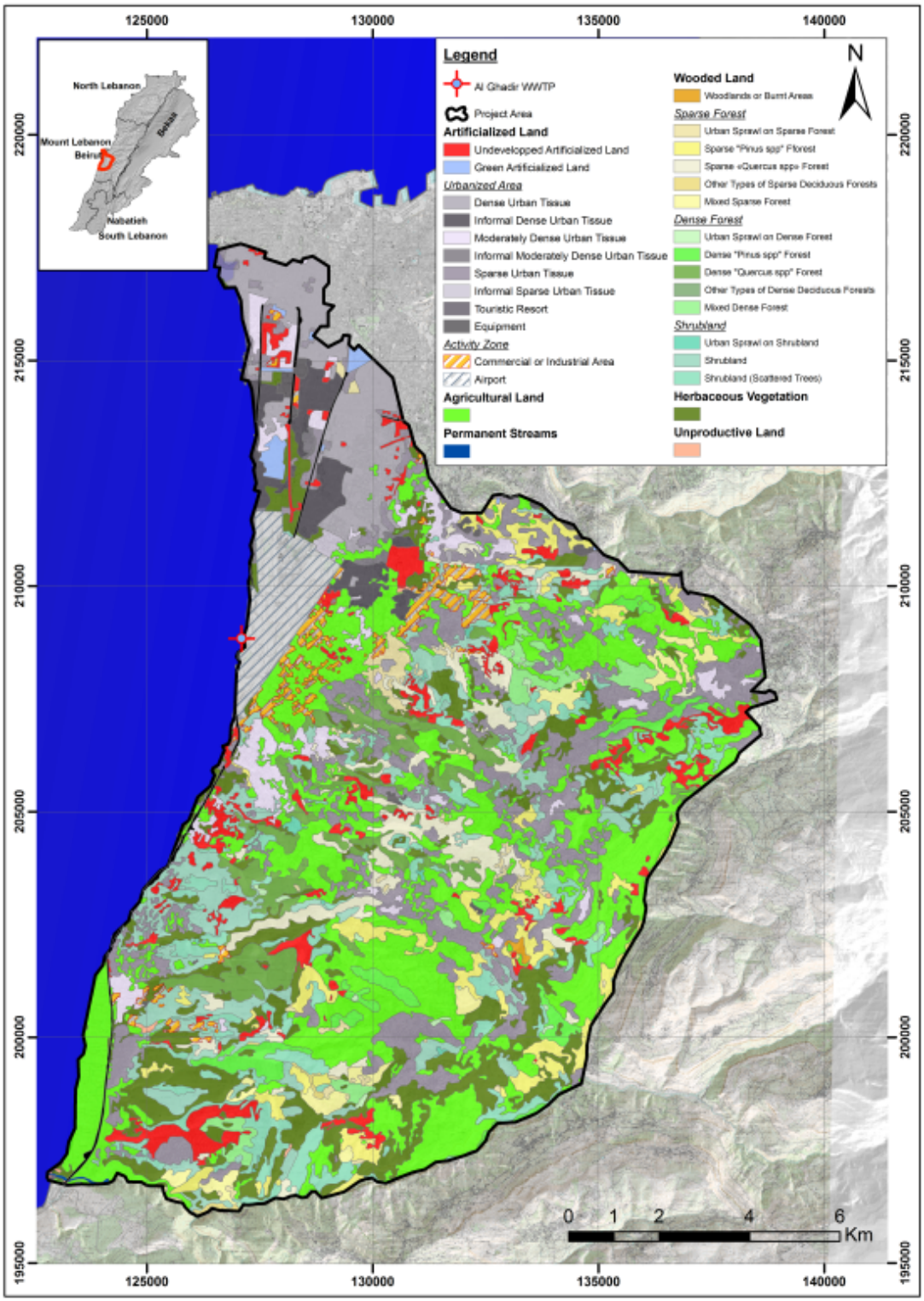


Figure 6.24 Land use map in the area of assessment (Network Area)

6.3.1.3.5 Forests in the area of assessment

According to the forest map in Lebanon (Figure 6.25), a number of forests are located in the Assessment Area, mainly consisting of Coniferous forest Pinus pinea, Coniferous forest "other pines", mixed coniferous forest, broadleaved evergreen forest, broadleaved deciduous forest, mixed coniferous forest and broadleaved forests, and other wooded lands without trees.

The Coniferous forest with "other pines" is considered as the dominant type of forests in the Assessment Area.

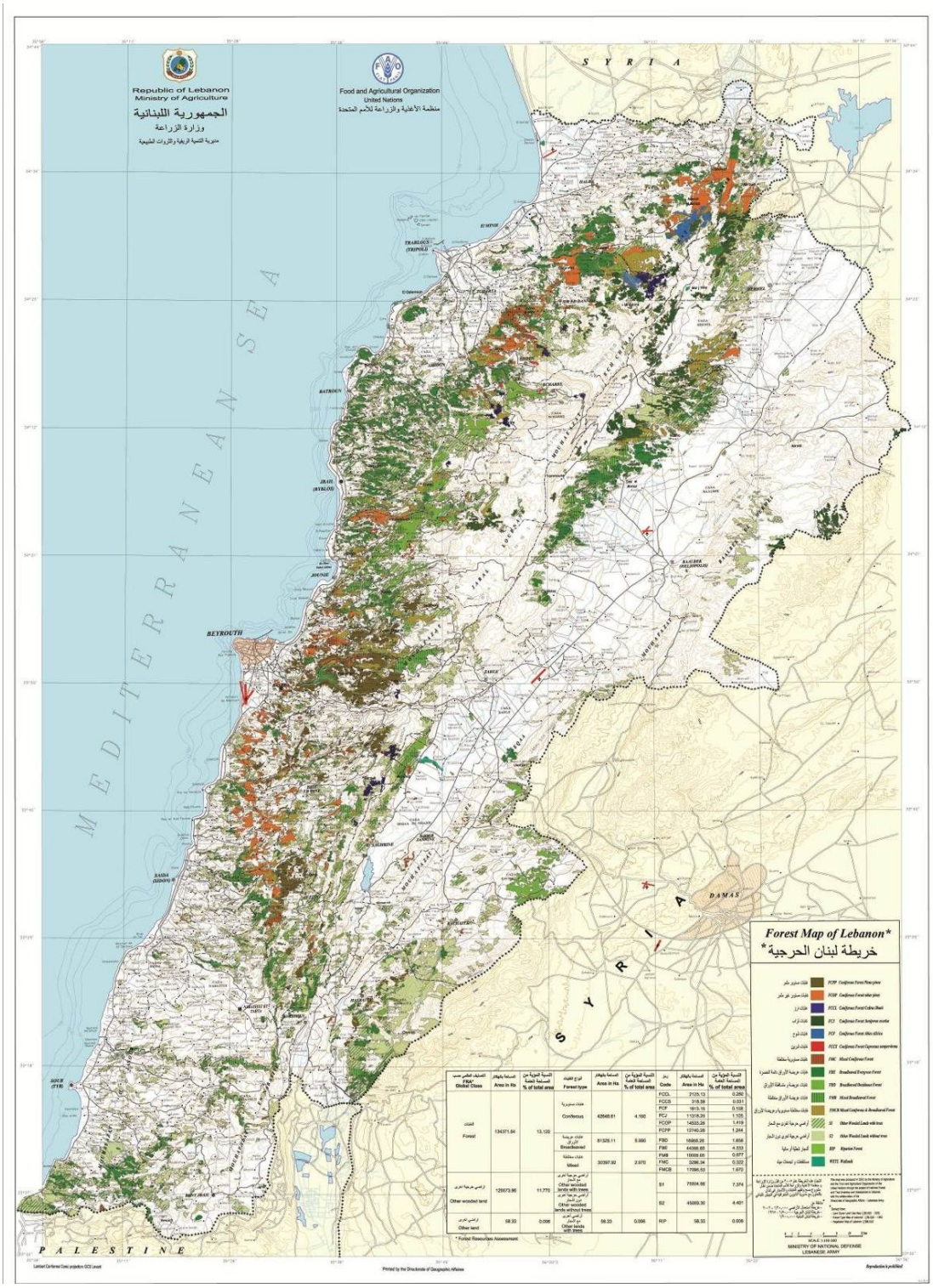


Figure 6.25 Forest map of Lebanon

6.3.2 FAUNA

There are 4.486 known fauna species in Lebanon. 13% of these species are found in the coastal region, while 47% are found in the overall Mount Lebanon region (MoE, 2010). Identified species currently close to extinction in Lebanon include the wolf, the wild cat, the mongoose and the squirrel, whereas the rare species include shrews, bats, the weasel and spiny mouse. However, a variety of vulnerable species such as the four species of bats, the wild boar, and the common field mouse still exist (MoE, 1998).

The terrestrial fauna in Lebanon counts 2085 species. The fresh water ecosystems count 987 species of which the invertebrates constitute 656 species. Pouring into rivers a great variety of untreated chemicals substances from factories together with untreated organic waste from the sewers of residential zones brings about deep changes in the biocenotic structure of these rivers.

Marine ecosystems contain 1685 species of fauna of which 50 species of fish are caught and are of economic interest, the number of taxons of zooplankton found in Lebanese waters so far amounts to 747 species.

It is difficult to perform a complete faunal survey; however, information was collected from available literature such as the MoA/UNEP biodiversity study, 1996, as well as from personal contacts, interviews with locals and researchers, and species encountered during the field visit

Furthermore, several species remain unknown and may not have been included in this report due to the lack of comprehensive studies and long term monitoring projects.

6.3.2.1 INVERTEBRATES AND INSECTS

Invertebrates, in particular insects, are expected to form the most abundant and widespread group of land fauna in the Study Area.

A number of dragonflies and butterflies was observed during the field survey. Also, a wasp hive was documented (Figure 6.26)

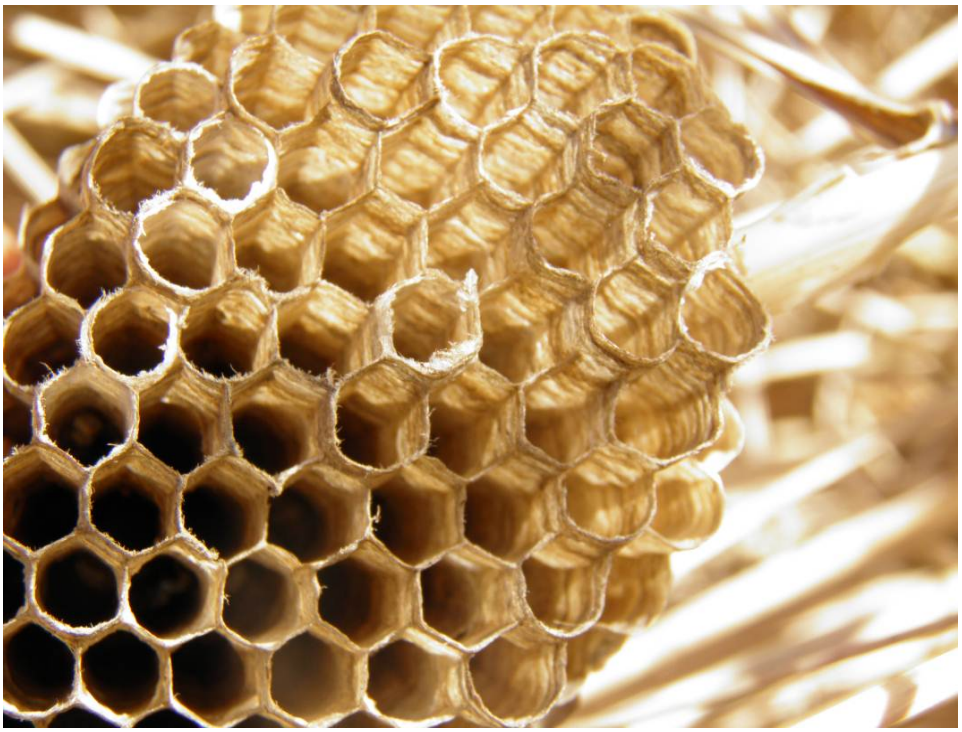


Figure 6.26 Wasp hive

6.3.2.2 AMPHIBIANS AND REPTILES

There are in total 5 reported species of amphibians in Lebanon: 4 species of frogs and toads, and 1 species of salamander. However, this list was identified as "undoubtedly incomplete" (MoA/UNEP, 1996). Reported species of reptiles in Lebanon is 43.

No endangered amphibians' species were recorded in Lebanon according to IUCN references. However, a high percentage of threatened reptiles are recorded. Reptiles are considered as a very important portion of fauna diversity in the country, as it is reported as one of the reptiles with highest species richness on average in the Mediterranean basin (see Figure 6.27 and Figure 6.28)

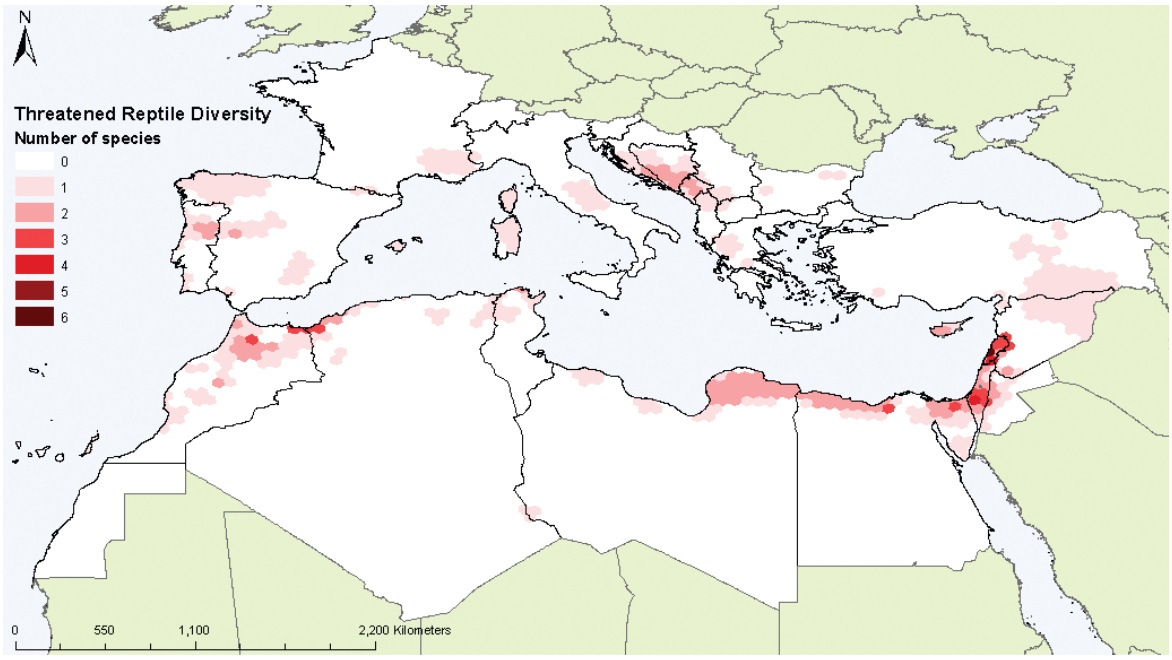


Figure 6.27 Species Richness of Threatened Reptiles in the Mediterranean Basin

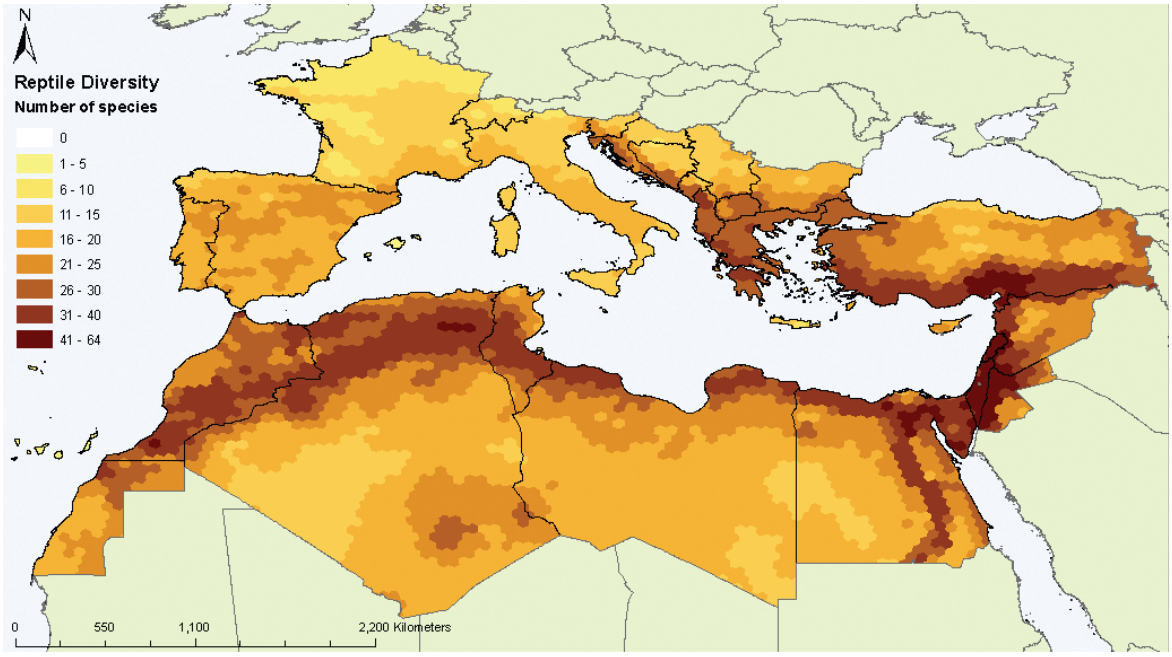


Figure 6.28 Species Richness of Reptiles in the Mediterranean Basin

6.3.2.3 MAMMALS

There are 52 reported mammal species in Lebanon; in addition 7 are already extinct. Bats make up the largest single group of mammals (16 species). About one third are rare, and another 39% are vulnerable species or species in apparent danger (Ecodit, 2001). According to the national biodiversity study (MoA/UNEP 1996), 7 mammal species are already extinct from the Lebanese wild lands

6.3.2.4 BIRDS

There are 337 bird species noted in Lebanon, of which 65 species that have strayed into the region, 100 nesting species, 170 migratory species that winter here, 2 recently introduced species, and 10 with no recent data. Although there are no endemic species in Lebanon there is however a semi-species (Alectoris chukar) and some Asian breeds. Rare and quite rare species make up 26.5 % of all species observed in Lebanon or mainly 37 species. According to the analysis of the national biodiversity report study team (MoA/UNEP, 1996), the avifauna of the forests of the high mountains is as large as that of the Bekaa (71 species). The forests and woods of Mount Lebanon provide shelter to 87 species, which is considered as an underestimation due to the difficulty to spot migratory birds in thick woods.



Figure 6.29 Birds observed around the WWTP area on September 5, 2012

The marine ecosystem of Lebanon is part of the eastern Mediterranean marine division. Studies were mainly conducted in the 60's and 70's where a range of pelagic marine species in local waters were recorded and documented. Later, studies mainly focused on determining phytoplankton species with little interest on other species.

A summary of marina fauna and flora is found in Table 6.7 and Table 6.8.

Table 6.7 Fauna Found in the Lebanese Marine Environment (source: Lakkis, 1996)

MARINE FAUNA	DESCRIPTION
Ichtyofauna	Some 325 species of fish have been identified in the Lebanese water, of which 28 originate from the Red Sea. Of those 325 species, 281 are bony, and 43 are cartilaginous.
Crustaceans	A total of 404 species of crustaceans reported in Lebanese waters, 16 species of which are crabs and the remaining are species of shrimps and crayfish. Sand dredging operations particularly affect the distribution and abundance of these species.
Molluscs	354 species of molluscs exist in Lebanon. Six species of cephalopods have been identified, with cuttlefish, sepia, and octopus being the most common and commercially exploited. Gastropods and bivalves are also common but have no commercial value.
Echinoderms	Several species of sea urchins and sea cucumbers exist usually on soft limestone and sandstone.
Porifera	Some 21 species of sponges have been identified in the Lebanese waters, and their fishing has been long established in the Lebanese tradition particularly in the Sarafand area, namely Spongia officinalis and Hippospongia equina. These sponges live on rocky bottoms and have been exploited for commercial purposes.

In addition, more than 60 species were found to have commercial interest due to their economic or recreational value. A summary of these species is given in Table 6.8.

Table 6.8 Marine Species of Commercial Value (Source: Lakkis, 1996)

TYPE	SPECIES NUMBER	SCIENTIFIC NAME
Porifera	2	Spongia officinalis, Hippospongia equina
Molluscs	4	Pinctada radiata, Charonia lampas, Octopus vulgaris, Sepia officinalis
Crustacean	3	Portunus pelagicus, Maja squinado, Scyllarides latus
Echinoderm	1	Paracentrotus lividus
Ichtyofauna	50	Not available

6.4 SOCIO-ECONOMIC AND CULTURAL CONTEXT

6.4.1 GENERAL OVERVIEW

6.4.1.1 POPULATION

In the Feasibility Study Part I: Project background and baseline data (2012), the projected population figures as given by different studies were compared. The projection methodology adopted by the FS 2000 was considered as the most reliable one, and have been followed after certain adaptations to reflect changes since the year 2000. The area is divided in four zones taking

into consideration social and geographical criteria along with population movements, during and after the war, for the future projections.

The projected population in the Project area in year 2015 is 1,049,686 inhabitants and the projected one in year 2040 is 1.571.258 inhabitants and in 2050, 1.664.830 inhabitants. The total population estimates per zone till 2050 are provided in Table 6.9.

Table 6.9 Total population estimates, per zone till 2050

Zone	2015	2020	2025	2030	2035	2040	2045	2050
Zone 1-Aley	59.077	65.288	72.156	79.746	88.131	97.401	107.645	118.966
Zone 2-Baabda	45.948	50.781	56.121	62.025	68.546	75.756	83.723	91.458
Zone 3-Southern Beirut	854.000	950.000	1.036.500	1.093.000	1.130.000	1.154.000	1.171.000	1.182.000
Zone 4-Naame-Damour	90.661	100.698	131.771	216.215	239.705	244.101	248.983	254.406
Total	**1.049.686**	**1.166.767**	**1.296.548**	**1.450.986**	**1.526.382**	**1.571.258**	**1.611.351**	**1.646.830**

Source: Extension of Al-Ghadir WWTP Feasibility Study Part I : Project background and baseline data. 2012

6.4.1.2 EDUCATION[7]

School enrolment rates are generally high in Lebanon and in the Study Area, reaching 98 to 100% at the elementary level for both males and females (Central Administration for Statistics, 2008). However, rates start declining for the 15-19 age group and reach their lowest for the 25-29 age group. Observed enrolment rates are slightly lower for the Southern Suburb compared to the rest of Mount Lebanon and the city of Beirut, particularly for the 15-19 age group.

6.4.1.3 EMPLOYMENT[7]

The highest economic activity rate for both Lebanon and the Study Area is found in Beirut, with 49.1% of the capital's residents economically active. Rates are very similar for the Governorate of Mount Lebanon (49.0%) when excluding the Southern Suburb of Beirut, where economic activity is slightly lower (44%). However, economic activity rates show major disparities when disaggregated by sex. This is particularly true for the Southern Suburb of Beirut, where only 16.1% of females are economically active compared to 72.3% of males (Central Administration for Statistics, 2008).

Furthermore, the unemployment rate in the Southern Suburb of Beirut is the highest in Lebanon, reaching 14.1%. Beirut and Mount Lebanon, excluding the Southern Suburb of Beirut, follow, with unemployment rates of 10% and 8% respectively (Central Administration for Statistics, 2008).

The economic activity rates and unemployment rates for the two Governorates encompassing the Study Area are presented in Table 6.10 and Table 6.11.

[7] It is to be noted that the socio-economic data presented in these sub-sections refers to a larger area that encompasses the Study Area without being strictly restricted to it.

Table 6.10 Economic activity rates by Governorate in the Study Area
(Source: Central Administration for Statistics, 2008)

Governorate	Females (%)	Males (%)	Females & males (%)
Beirut	32.2	70.2	49.1
Mount Lebanon (excluding the Southern Suburb)	30.8	68.5	49.0
Southern Suburb of Beirut	*16.1*	*72.3*	*44.0*

Table 6.11 Unemployment rates by Governorate in the Study Area
(Source: Central Administration for Statistics, 2008)

Governorate	Females (%)	Males (%)	Females & males (%)
Beirut	8.2	11	10.0
Mount Lebanon (excluding the Southern Suburb)	10.5	8.1	8.9
Southern Suburb of Beirut	*19.9*	*12.8*	*14.1*

Workers in the Study Area mainly work in the trade and services sectors (respectively 52%, 43% and 37% in the services sector; and 24%, 23%, and 26% in the trade sector; for residents of Beirut, Mount Lebanon excluding the Southern Suburb, and the Southern Suburb of Beirut). The processing industry sector comes third, employing 16.3% and 16.8% of workers in Mount Lebanon and the Southern Suburb of Beirut respectively, and 9% of workers in Beirut.

Over 85% of workers work for private sector companies and institutions, while the rest are employed by public sector and international/non-governmental institutions and organizations.

6.4.1.4 INCOME[7]

Average salaries in Lebanon amounted to 679,000 LBP (about 350 EUR) in 2007, while the median salary amounted to 560,000 LBP (about 280 EUR) (Central Administration for Statistics, 2008). Large disparities can be observed in the Study Area, with residents of the Southern Suburb of Beirut earning about 35% less (average salaries) than those in Beirut (Table 6.12).

Table 6.12 Average and median salaries in the Study Area

Governorate	Average Salary (lbp, in thousands)	Median Salary (lbp, in thousands)
Beirut	909	700
Mount Lebanon (excluding Southern Suburb of Beirut)	767	600

Southern Suburb of Beirut	*577*	*500*

Source: Central Administration for Statistics. Living Conditions of Households - The National Survey of Household Living Conditions. Beirut: Central Administration for Statistics, Ministry of Social Affairs, UNDP. 2008.

Similarly, the Average Household Income in Lebanon, as assessed in 2007, ranged between 1,586,200 LBP (about 800 EUR) and 751,500 LBP (about 380 EUR). Again, the rate observed for the Southern Suburb of Beirut is the lowest in the area (Table 6.13) (Central Administration for Statistics, 2008).

Table 6.13 Average Household Income in the Study Area

Governorate	Average household income (lbp, in thousands)
Beirut	1,586.2
Mount Lebanon (excluding Southern Suburb of Beirut)	1,327.8
Southern Suburb of Beirut	*813.2*

Source: CAS. Living Conditions of Households - The National Survey of Household Living Conditions. Beirut: Central Administration for Statistics, Ministry of Social Affairs, UNDP. 2008.

6.4.2 INDUSTRIAL ZONES IN THE GHADIR DRAINAGE AREA

Major industrial areas within the Ghadir drainage area are the Beirut Southern Suburbs, Choueifat/Kfarchima and Haadath/Baabda. There is no accurate information as to whether these industries are connected to the existing municipal wastewater collection system or whether they discharge to the Ghadir River, other surface water or to soil. Information on whether the plants are pre-treating or treating their wastewater prior to discharge to the respective receptors is not available; on site pre-treatment is however rare. Nevertheless, and as discussed in section 3.2.1.2.2, elevated concentrations of certain pollutants such as Fe, Cd, Ni, Hg and CN observed in the wastewater currently reaching the plant may be explained by discharge of industrial wastewater into the municipal sewage network and the Ghadir River.

No law-enforcement mechanism has been established to assure that all industries comply with their respective discharge requirements under MoE Decision 8/1 (2001). With the recent enactment of the environmental compliance decree (Decree 8471), this situation is likely to improve in the near-to-medium future, assuming that a suitable enforcement mechanism is developed and adequate resources are allocated by the Competent Authorities.

6.4.3 FISHING ACTIVITIES NEAR THE OUTFALL SITE

The outfall's site is subject to marine traffic and fishing activities that could damage diffusers through the deployment of anchors and fishing nets. A number of diffusers are reported to have been destroyed between 1983 and 1995 (Costain, 1995). Although these diffusers had been repaired in 1997, it is quite likely that some damage to diffusers has occurred over the last 15 years.

6.4.4 BEACH RESORTS NEAR THE WWTP

Three beach resorts are located at the direct vicinity of the WWTP's site: one entirely enclosed beach club for women, where most activities occur at the level of the enclosed pool; and 2 other small beaches mainly frequented by locals. These are shown in Figure 6.1 and discussed under section 6.1.

6.4.5 ARCHAEOLOGY AND CULTURAL HERITAGE

Contacts with the Directorate General of Antiquities (DGA), which operates under the Ministry of Culture (MoC), were established with a view to retrieving information regarding cultural heritage in the Study Area. In a letter dated November 15, 2012, the DGA notified ELARD that the networks' area could potentially be home to a rich archaeological and cultural setting. As a result, it was recommended that exact network routes be sent to the DGA as soon as they are set and agreed upon in order to prepare a suitable "Archaeological Intervention Plan".

6.4.6 TRAFFIC

Most roads in the project area are in good condition, especially major axes leading from and to the Beirut International Airport (BIA). Few remaining internal roads remain in poor condition. Public transportation services are mainly provided by public and private mini-vans and "taxi-services".

6.4.7 SOLID WASTE MANAGEMENT

6.4.7.1 MUNICIPAL SOLID WASTE

Approximately 700 to 1000 tons of solid waste is produced within Ghadir WWTP drainage area per day. Waste collection in the area is covered by a private company, under a contract from the CDR for the collection of household solid waste and street sweeping in Greater Beirut and some areas of Mount Lebanon.

The following facilities currently exist in the Greater Beirut Area (Figure 6.30 and Figure 6.31):

- Two facilities for sorting and processing municipal waste (Aamroussiyeh and Karantina);
- One composting plant for sorted organic material (Coral composting plant);
- One warehouse facility for storing and shredding bulky and recyclable materials (located along the seashore, next to the entrance of the Borj Hammoud dump site);
- One landfill site for the disposal of sorted MSW in the form of balled waste supposed to be consisting primarily of inert materials (Naameh); and
- One landfill for the disposal of inert and bulky materials (Bsalim).

After fully utilizing cells (1) and (2) of the Naameh sanitary landfill site, an additional area of 62,000 m^2 was prepared for a new cell (3). The latter has been used as a sanitary landfill for the solid waste produced by Greater Beirut and some areas in Mount Lebanon. The Council of Ministers (CoM) approved, under Decision of 28/6/2006, the expropriation of an additional area of about 25,000 m^2 for expanding the Naameh landfill (about 7Km from the the Ghadir WWTP).

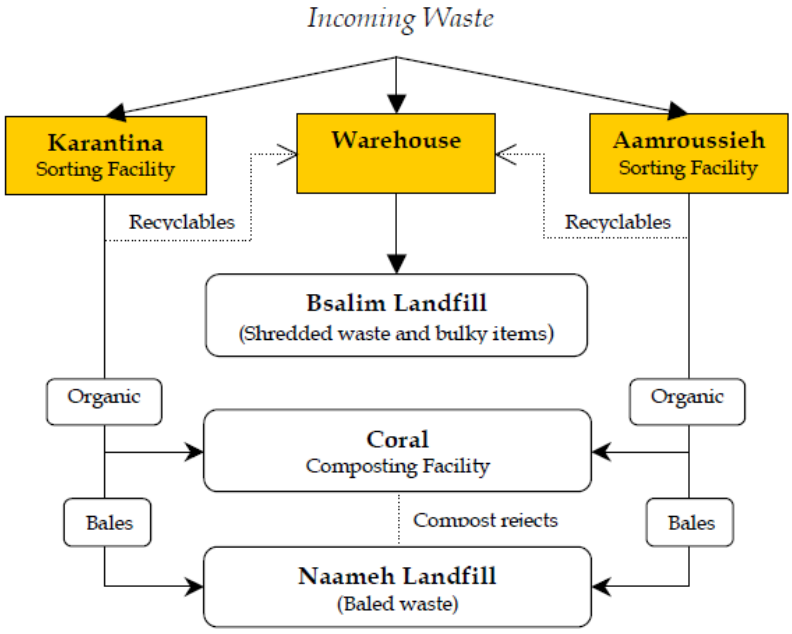


Figure 6.30 Solid waste management scheme for the Greater Beirut Area
(Source: Extension of Al-Ghadir WWTP Feasibility Study Part I : Project background and baseline data. 2012)

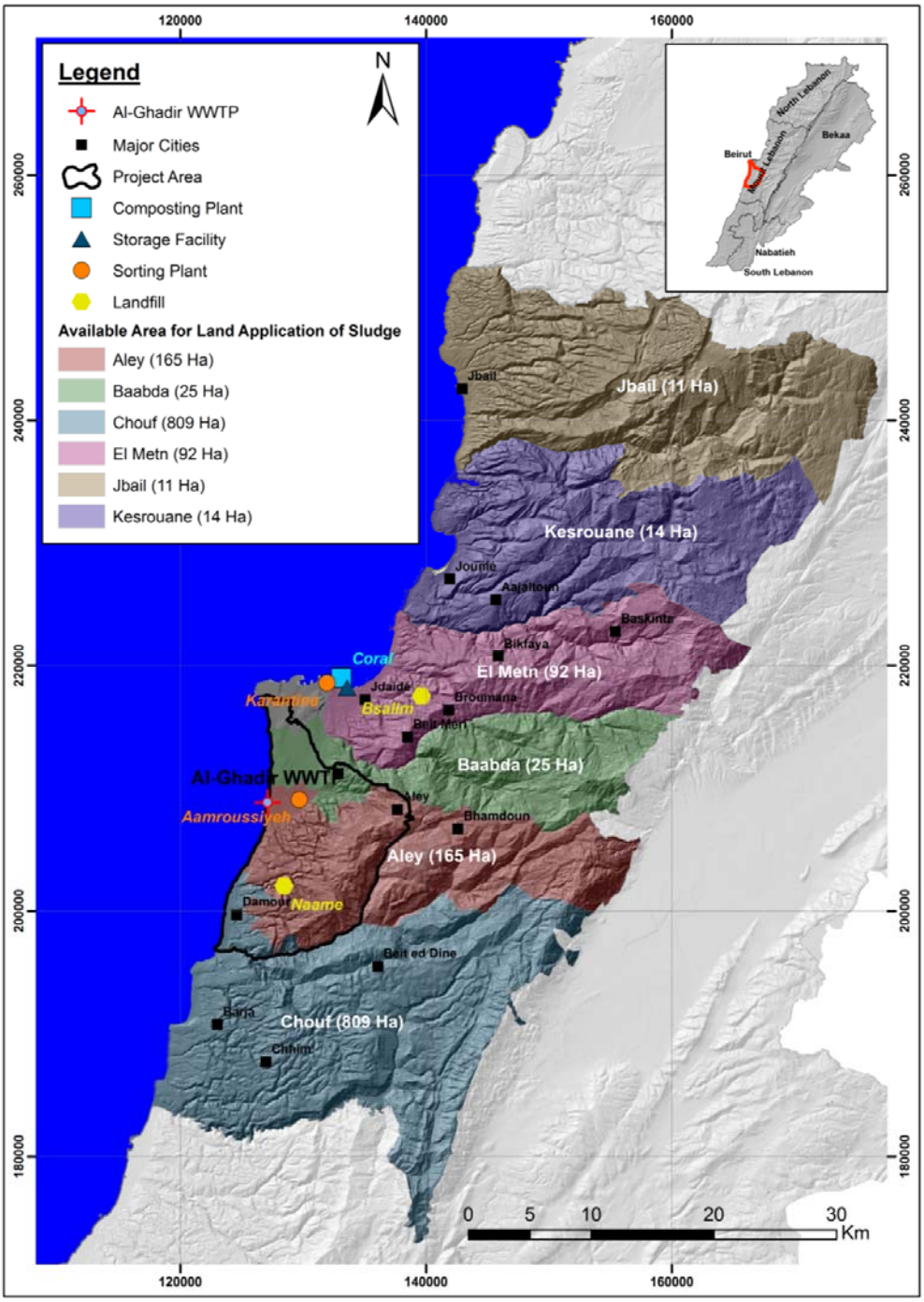


Figure 6.31 Solid waste management facilities & available area for sludge application per governorate[8]
(Source: Extension of Al-Ghadir WWTP Feasibility Study Part I : Project background and baseline data. 2012)

[8] Note: "Available Surface Area For Sludge Reuse" represents the sum of multiple areas/patches of land scattered over each District.

6.4.7.2 RECENT DEVELOPMENTS ON SOLID WASTE MANAGEMENT STRATEGY AT NATIONAL LEVEL

In June 2006, the CoM approved the Solid Waste Management Plan prepared by the CDR, whereby sites for solid waste treatment, composting and landfilling were selected covering all regions in Lebanon. The plan divided the country into four service areas (regions):

- Service area 1: Beirut - Mount Lebanon;
- Service area 2: North Lebanon;
- Service area 3: Bekaa; and
- Service area 4: South Lebanon.

Waste-to-energy plants (incinerators) for large cities, such as Beirut, Tripoli and Saida were introduced by decree of the CoM (September I, 2010). The 2006 plan remained favourable for other regions, without however restricting the possibility of studying the implementation of waste-to-energy technology for these regions.

The CDR has recently (end of 2010) launched a tender for consultancy service to integrate private international companies in solid waste management. The services consist of street cleansing, as well as collection, transportation, recycling and disposal of solid waste (including sludge) by integrating waste-to-energy through incineration.

A waste-to-energy feasibility study is currently being finalized by the CDR. The purpose of the study is to evaluate the feasibility of implementing waste-to-energy facilities as part of an integrated national solid waste master plan. The main rationale behind the need for such facilities is scarce land availability and the difficulty to identify suitable and socially acceptable sites for landfilling.

6.4.7.3 SLUDGE MANAGEMENT

There is no national sludge management strategy adopted. The feasibility of national "waste to energy" strategy is being assessed, as discussed above, and if found to be feasible, could accommodate the disposal of sludge from WWTPs.

7 ENVIRONMENTAL AND SOCIAL IMPACTS

Based on previous relevant and similar environmental studies and on concerns identified by technical experts and regulatory agencies; and in response to regulatory requirements and comments received from the stakeholders and project proponents during informal meetings and public consultation meetings, the following environmental and socio-economic aspects and impact categories were selected by the study team to be further studied as part of the ESIA study:

- Impacts on water quality;
- Impacts on air quality and the acoustic environment;
- Impacts on land use/landscape;
- Impacts on soil;
- Impacts on biodiversity;
- Socio-economic impacts;
- Impacts on archaeology and cultural heritage; and
- Impacts on public and occupational health and safety.

Potential impacts are identified and assessed **for both the construction and operation phases** of the Project (both components – WWTP upgrade and networks construction), based on the methodology described in the following sub-sections.

7.1 METHODOLOGY: IMPACT IDENTIFICATION AND ASSESSMENT

7.1.1 GENERAL APPROACH

The type, nature (positive, negative, direct, indirect), magnitude, timing (during design, operation), duration (short term/temporary, long term/permanent) and significance of impacts are assessed in this section. The evaluation approach is a **Receptor-Specific Analysis** approach addressing the various sources of impacts from the Project's construction and operation phases.

The general evaluation process will include the following stages:

- **Step 1:** Identification of project-related activities (sources) and environmental aspects;
- **Step 2:** Identification of potential impacts to the environment (physical, biological, human, cultural);
- **Step 3:** Evaluation and assessment of the related unmitigated impact significance;
- **Step 4:** Identification of Best Practicable Environmental Options (BPEO); and
- **Step 5:** Re-evaluation and assessment of the mitigated impact significance.

7.1.2 IMPACT IDENTIFICATION PRE-SCREENING LEVEL

The screening methodology that is adopted for the purpose of this EIA comprises a preliminary screening process followed by a more delicate and detailed secondary screening process.

The pre-screening process includes a thorough desk study review of wastewater treatment plants implemented in other parts of the world and Lebanon. This pre-screening stage highlighted some of the major impacts that might be coupled with normal operations based on the literature research and the nature of the surrounding environment.

The key issues identified were further investigated and evaluated based on planned project operations including proposed activities, time duration, national Lebanese regulations and the social and environmental baseline information collected. The team then channeled the results to a secondary screening process.

7.1.3 IMPACT EVALUATION SECONDARY SCREENING LEVEL

The purpose of a secondary screening level is to analytically screen the wide range of possible sources and potential impacts which were previously highlighted. This screening stage further assesses the impacts in terms of their significance, reversibility, likelihood of occurrence and geographical and temporal extents.

In the secondary screening level, impacts were classified based on the types outlined in Table 7.1, then ranked into six levels of significance detailed in Table 7.2. Then, the likelihood of the occurrence of the impact was rated according to the criteria outlined in Table 7.3.Impact rating scores were then assigned according to the Likelihood of Occurrence (A. High, B. Medium and C. Low) cross-tabulated with a Consequence Rating Criteria including the consequence and significance levels. The scale is illustrated in Table 7.4.

The assigned impact severity assessment was first considered assuming the absence of project control and mitigation measures. Following investigation and presentation of typical and commonly practiced project mitigations, the impact severities for the mitigated project activities were re-assessed.

Table 7.1 Impact Classification

Direct impacts	Those that arise from activities that form an integral part of the project (e.g. new infrastructure)
Indirect/ secondary impacts	Those that arise from activities not explicitly forming part of the Project (e.g. noise changes due to changes in road traffic flows on existing roads resulting from the operation of Project)
Cumulative impacts	Those that result from the incremental impact of an action added to other actions
Residual impacts	Those that will continue to occur even after the implementation of suitable mitigation measures (e.g., land scarring)
Temporary impacts	Those that persist for a limited period only (reversible), due for example to particular construction activities (e.g. noise from excavation works)
Permanent impacts	Those that result from an irreversible change to the baseline environment (e.g. land-take for facility operation) or which persist for the foreseeable future (e.g. air emissions from process units operation)
Positive impacts	Those that have a beneficial influence
Negative impacts	Those that have a minor, moderate or major negative influence

Table 7.2 Consequence Assessment Criteria

CRITERIA	CONSEQUENCE RATING
▪ Massive impact over a large area resulting in extensive, potentially irreparable damage to a receptor. ▪ Has a measurable effect on the livelihood of those using a resource over a period of years. ▪ Massive impact over a large area resulting in extensive, potentially irreparable damage to a site of social and/or cultural importance.	5. Catastrophic
▪ Long term or continuous impact resulting in substantial adverse changes in a receptor, well outside the range of natural variation. Unassisted recovery could be protracted. ▪ Area of effect is extensive and/or encompasses an area that supports a statistically significant proportion of a receptor population or ecosystem. ▪ Has a measurable effect on the livelihood of those using a resource over a period of months. ▪ Significant damage / impact to a site of social and/or cultural importance.	4. Major
▪ Moderate adverse changes in a receptor or area that supports a receptor population. Changes may exceed the range of natural variation though potential for recovery within a few years without intervention is good. ▪ Area of effect encompasses an area that supports either a moderate or minor proportion of a receptor population or ecosystem. ▪ Long term (> 5 years) changes over an area which is not considered to be a receptor. ▪ Has a measurable effect on the livelihood of those using a resource over a period of weeks. ▪ Moderate damage to a site of social and/or cultural importance.	3. Moderate
▪ Minor adverse changes in a receptor. Changes will be noticeable but fall within the range of normal variation and be typically short-lived, with unassisted recovery possible in the near term. However, it is recognised that a low level of impact may remain. ▪ Medium term impact (1-5 years) in an area that does not encompass a receptor or whose impact is highly localised within a RECEPTOR. ▪ Long term impact over a discrete, small area which does not support a receptor. ▪ May be noticed but does not affect the livelihood of those utilising a resource. ▪ Minor impact to a site of social and/or cultural importance.	2. Minor
▪ Short term changes in an ecosystem that are unlikely to be noticeable (i.e. fall within the scope of natural variation). Area of effect is restricted to the immediate vicinity of the source. ▪ Has no discernible effect on the environmental resource as a whole and is likely to go unnoticed by those who already use it. ▪ Negligible impact to a site of social and/or cultural importance.	1. Negligible
▪ Changes that result in a net positive impact to an ecosystem, environment or population.	Beneficial

Table 7.3 Likelihood Evaluation Criteria

LIKELIHOOD TO OCCUR	CATEGORY	SCORE
Impact is highly likely or certain to occur under normal operating/ construction conditions	High	C
Impact may possibly occur under normal operating/construction conditions	Medium	B
Impact is unlikely to occur under normal operating/construction conditions but may occur in exceptional circumstances	Low	A

Table 7.4 Environmental Impact Assessment Management Matrix *(Consequence and Significance versus Likelihood of Occurrence)*

CONSEQUENCE RATING	LIKELIHOOD RATING A	LIKELIHOOD RATING B	LIKELIHOOD RATING C
1	1A	1B	1C
2	2A	2B	2C
3	3A	3B	3C
4	4A	4B	4C
5	5A	5B	5C

LEGEND

Consequences		Likelihood	Acceptability
1 - Negligible	4 - Major	A – Low	Beneficial
2 - Minor	5 - Catastrophic	B – Medium	Negligible with minor mitigation
3 - Moderate	6 - Beneficial	C – High	Impacts need to be minimised
			Unacceptable

7.1.4 FORMAT OF IMPACT ASSESSMENT RESULTS

For each receptor, the different types of impacts are analyzed for both Project Components (referred to as "Networks" and "WWTP"), first for the Construction phase and then for the Operation Phase. Whenever applicable, impacts are analyzed separately for Phase I and Phase II of Component 2 (WWTP).

A single matrix was then developed to summarize all identified impacts during each phase for the WWTP and Networks, first assuming project execution without any mitigation measures (Table 7.18 and Table 7.16); then assuming the implementation of proposed mitigation measures (Table 7.19 and Table 7.17).

7.2 CURRENT SOURCES OF CUMULATIVE IMPACTS

Potential sources of cumulative impacts (*impacts caused by other past, present or reasonably foreseeable activities together with the project*) around the Project Site include, but are not limited to:

- Uncontrolled discharges of industrial and municipal wastewater uncontrolled discharges into the Ghadir River Basin and Ghadir WWTP Drainage Area and to the Mediterranean Sea near the Project Site;
- Air and noise emissions from airplanes and vehicular traffic around the Project Site;
- Air and noise emissions from vehicular traffic around networks construction sites; and
- The solid waste (rubble) dump located at the direct vicinity of the Project Site (mainly rubble).

7.3 IMPACTS ON WATER RESOURCES

Impacts on groundwater, surface water, and seawater quality are identified and assessed here.

7.3.1 CONSTRUCTION PHASE

Identified impacts on water resources during construction are mainly associated with the following:

- Possible groundwater and surface water pollution due to oil spills;
- Possible groundwater and surface water pollution from excavation and trenching works;
- Seawater pollution from land reclamation/dredging activities;
- Possible alteration of natural stormwater drainage; and
- Possible impact from water consumption.

These impacts are further described and assessed in the following sub-sections.

7.3.1.1 IMPACT FROM OIL SPILLS AND SOLID WASTE GENERATION

Networks Construction

The major potential sources of accidental spills during Construction of Project Component 1 and of Project Component 2 (Phase I and Phase II) include storage and re-fuelling of diesel supplies for power generation, lubricating oil as part of routine equipment operations, and equipment maintenance.

Fuel leakages contain BTEX such as benzene and toluene and methyl tertiary butyl ether (MTBE). These monocyclic aromatic hydrocarbons tend to readily evaporate from surface spills and biodegrade under aerobic and anaerobic conditions given their relatively good solubility and volatility, particularly MTBE and benzene. Whereas diesel spills consisting of BTEX; Poly Aromatic Hydrocarbons (PAH), chlorinated hydrocarbons, as well as heavy metals such as Nickel, Copper, Chromium and Zinc persist in the receiving environment, and when mixed with sediment, they tend to adhere and accumulate due to their low evaporation and biodegradability.

Construction activities are also likely to generate considerable volumes of solid waste including empty cement bags, piles of sand and dirt due to excavation, etc. Inappropriate waste handling and disposal practices may potentially result in soil, groundwater and surface water contamination due to leaching and runoffs.

Unlike the WWTP which is entirely located over one type of geological formation, the network pipelines are located along various geological formations outcropping in the study area, ranging from formations acting as aquiclude with low permeability (such as Chekka Formation and the Hammana Formation) to major national aquifers (such as the Kesrouane Formation and the Sannine Formation) (refer to Figure 6.9).

The Abeih (C2a), Hammana (C_3), and Chekka (C6) Formations act as aquicludes, causing limited direct infiltration to deep aquifers. They therefore do not pose major threats in case of oil spills or major solid waste depositions.

The Sannine-Maameltein (C4-C5), Kesrouane (J4), Mdairej (C2b) and Quaternary Deposits (Q), on the other hand, act as aquifers. These have high direct infiltration to aquifers, and thus pose a major threat in case of spills and leaching. The Chouf Sandstone Formation(C1) and Miocene Conglomerates (mcg) act as semi-aquifer, and pose medium-level threats.

Most caution should thus be taken during the construction of networks spanning areas where Sannine-Maameltein (C4-C5), Kesrouane (J4), Mdairej (C2b), Quaternary Deposits (Q), Chouf Sandstone (C1) and Miocene Conglomerates (mcg) Formations outcrop.

It is to be noted, however, that groundwater in the area closest to the coast has already been subject to considerable pressure (see Seawater intrusion boundary on Figure 6.9).

The impact of oil spills and solid waste generation on groundwater during networks construction is thus generally evaluated as **moderate, temporary** and of **medium likelihood of occurrence (3B).** The impact nevertheless depends on the location and on the sensitivity of outcropping geological formations, and is to be considered and mitigated accordingly once construction works start.

The occurrence of accidental spills and leaks could be minimized, if not prevented, by the following mitigation measures:

- Scheduling the works for the dry season if possible;
- Progressively carrying out rehabilitation of disturbed areas as soon as practicable following completion of work in each area. Rehabilitation will include reinstatement of soil, surface levelling, re-vegetation and mulching;
- Immediately remediating any localized erosion;
- Adopting and implementing IFC guidelines for the prevention and control of hydrocarbon / chemical releases (IFC, 2007);
- Conducting routine inspection procedures and maintenance of equipment for risk minimization;
- Ensuring availability of oil spill response kits on the work area;
- Use secondary containment basins for long term storage of lubricants and fuels possibly used on site; and
- Promoting "good housekeeping" practices during construction, operation and maintenance.

In order to decrease the likelihood of spills occurring and mitigate the potential impacts of such incidents in the Project area, the following requirements should be addressed:

- Fuel, oil and chemicals should be stored in specifically designated areas on site, particularly on an impermeable base within a suitability contained area. Any storage tanks should be positioned to minimize the risks of damage by impact, and should be of sufficient strength and structural integrity;
- Drip trays should be installed underneath equipment such as diesel generators to contain leakages. Drip trays should be well maintained and kept drained of rainwater;
- Employees should be trained to be capable of dealing with small scale spill hazards;
- Inspection should be thoroughly practiced; and
- Collect and reuse or dispose of accordingly all used oils generated on the construction site.

The Project Proponent should envisage the development of a spill contingency plan by the Contractor. In the case of an important spill (>100 L), the operator should request quick assistance from local or foreign companies specialized in soil remediation directly upon spill reporting by site engineers. In the case of a small spill (<10 L-100 L), containment of spill and contamination could be performed on site by adopting the following:

- Immediate reporting of spill to contractor representative;
- Stopping the source of spill (closing valve, seal pipe, seal hole or as appropriate);
- Checking for hazards, flammable matters on site;
- Immediate cleaning of the spill by removing affected top soil layer by trained employees;
- Treating the removed soil as hazardous waste;
- In-situ sampling of soil in the vicinity and underneath the spill for potential contamination;
- According to sampling results, proposing a disposal method to be approved by the MoE; and
- Adopting dry cleaning techniques (to the extent- possible) to decrease resultant wastewater, and to avoid flushing of spills to deeper soil layers.

An additional measure consists in installing drainage systems and erosion and sediment controls. In case of a cross over a river or a stream, at the crossover between the network and the river, prior to commencement of construction and earth clearing.

With mitigation measures in place, the potential oil leaks and spills and leaching from Solid Waste associated with construction activities over networks are expected to have **a low likelihood and minor effect (2A).**

WWTP Construction

Impacts resulting from oil spills and solid waste generation during WWTP construction are similar to those identified for the Networks' construction.

Should such spills occur over the WWTP on shore construction area, the contaminants would infiltrate the Quaternary deposits, and reach groundwater levels. If spilled on concrete/asphalt surfaces, the contaminants would be carried towards surface water bodies, mainly the sea water in this case, causing adverse impacts. Such events would cause changes in the water quality which would exceed the normal range of variation, but where there is potential for recovery within a few years even without intervention. Spills occurring off-shore during Phase II would directly impact seawater and marine sediment quality and should be handled with even greater care.

The impact of oil spills and solid waste generation on groundwater during construction of the WWTP (phase 1 &2) is thus evaluated as **moderate, temporary** and of **medium likelihood of occurrence (3B).**

Mitigation measures proposed to reduce the impact from oil spills and solid waste generation during WWTP's construction are similar to those identified for the Networks' construction. Additional mitigation measures aiming at preventing oil spills during Phase II (land reclamation and construction over reclaimed land) are to be investigated, if need be, in light of an updated Environmental Impact Assessment Study prior to the start of Phase II and once detailed information on planned dredging and land reclamation activities are made available.

With the above mitigation measures in place, the potential oil leaks and spills associated with construction activities of the WWTP (phase Ib)are expected to have **a low likelihood and minor effect (2A).** Impacts related to Phase II are to be further investigated as part of an updated EIA.

7.3.1.2 IMPACT FROM DREDGING ACTIVITIES

WWTP Construction – Phase II

The major environmental concern in relation to conventional dredging and reclamation activities includes the potential adverse impacts on the benthic environment (species and habitat) and seawater quality. Impacts on these receptors are associated with the disturbance to the seabed and categorized into direct impacts (substrate removal and/or alteration of bottom hydrography and topography and sediment composition) and indirect (enhanced turbidity and sedimentation rates, release of chemical substances and changes in hydrographic regime and land-use). The type and nature of the impact varies in terms of reversibility and severity according to the contamination type and load already existing in the sediments.

By breaking the cohesions of the sediment particles, dredging normally causes to some extent an increase of turbidity that may be regarded as an indicator for potential ecological impacts, as re-suspension of sediments may give rise to the following:

- Spread of sediments and associated contaminants in the surroundings of the dredging site;
- Transport of sediments, particularly of finer fractions, and possibly adsorbed contaminants from the dredging area to other (possibly more sensitive) areas, possibly resulting in an increase of contaminant concentrations there;
- Release of nutrients resulting in potential risk of eutrophication;
- Introduction of new species either from ballast water released by the dredger or by physical transport (wave movement…);
- Consumption of oxygen (oxygen depletion), generally limited to the direct surroundings of the dredging site. Substances, which consume oxygen, nutrients and harmful materials, bonded to the sediments, can relatively easily be released into the water and thus reduce its oxygen content or cause an increase in the concentration of nutrients or harmful materials.
- Impact on pelagic and benthic organisms such as decrease of primary production due to smothering from reduced transparency of the water column;
- Mixing of interstitial water with sea water. Turbidity plumes and re-suspension may change the physical/chemical equilibrium, with a potential to release contaminants into the water; and
- Bioaccumulation of heavy metals and other petroleum-based contamination released from contaminated sediments.

Given the localized nature of the project, the area of effect is restricted to the vicinity of the source, and any potentially released contaminants and sediments are likely to disperse within a relatively short time-frame.

Nevertheless, it is recommended that this impact be more duly analyzed as part of an updated EIA study specific to reclamation activities prior to the start of Phase II; once there is more information on planned dredging activities available.

It can be assumed that impacts associated with sea bed disturbance such as release and spread of pollutants trapped in sediments during dredging activities, have a **high** likelihood of occurrence and are considered of **moderate** effect **(3C)**.

Mitigation measures aiming at reducing re-suspension of sediments and increases in turbidity levels include:

- Using Silt Curtains and ensuring that lower end of 'skirt' is resting upon the seafloor, and ensuring that top of the 'skirt' is always above the surface of sea;
- Reducing velocity of dredging;
- Decreasing the time-frame over which the dredging operation is to take place; and
- Limiting dredging operations to calmer sea states;
- Ensuring proper disposal of dredged material; and
- Conducting a seawater quality analysis as part of an updated EIA prior to the start of works on Phase II.

With this in place, dredging activities are expected to have a **medium** likelihood of occurrence while still having **moderate** effects **(2B)**.

7.3.1.3 IMPACT FROM WATER CONSUMPTION

Networks Construction

Water needs during the construction of the networks component are also associated with consumption of drinking water by construction workers, and the use of water as a raw material and for pumping tests. These are also expected to be relatively limited, although more important in extent given the large area of coverage and the estimated total length of networks to be constructed (about 80 Km of primary networks and about 707 Km of secondary and tertiary sewers).

The impact on groundwater and surface water resources due to consumption during the Networks construction is thus evaluated as **temporary, minor**, and of **medium likelihood of occurrence (2B).**

It is advised that the contractor adopts water saving techniques and raises construction workers' awareness on the matter so as to avoid overconsumption.

With this in place, the impact on groundwater due to consumption during construction of the network is reduced to **negligible** of **medium likelihood of occurrence (1B).**

WWTP Construction

Water consumption constitutes a source of pressure on groundwater resources. Water needs during construction of the WWTP (phase 1 & 2) are mainly associated with:

- Consumption of drinking water by construction workers; and
- Use of water as a raw material in the construction process.

Water requirements during construction are estimated in Table 7.5.

Table 7.5 Estimated Water Needs during Construction

Type of Water Consuming Activity	Daily Estimated Consumption (m^3/day)	Total Estimated Need (m^3)
Construction workers	3	N/A
Concrete Batching – Phase I	N/A	5,200
Concrete Batching – Phase II	N/A	24,000

These relatively low consumption levels are expected to cause minor changes in water availability, which would be short-lived and likely to go unnoticed.

The impact on groundwater and surface water resources due to consumption during the WWTP construction is thus evaluated as **temporary, minor**, and of **low likelihood of occurrence (2A)**.

It is advised that the contractor adopts water saving techniques and raises construction workers' awareness on the matter so as to avoid overconsumption.

With this in place, the impact on groundwater due to consumption during construction of the WWTP is reduced to **negligible** with **low likelihood of occurrence (1A).**

7.3.2 OPERATION PHASE

Identified impacts on groundwater, surface water and seawater resources during WWTP and Network Operation are mainly associated with the following:

- An **overall improvement in groundwater, surface water and seawater quality** due to upgraded wastewater treatment and reduced uncontrolled discharges;
- Localized seawater pollution due to the use of the emergency outfall during plant failures and possible overflows (PS);
- Possible groundwater and surface water pollution due to oil spills;
- Possible groundwater and surface water pollution due to wastewater leakages; and
- Negligible reduction in groundwater and surface water availability due to consumption.

These impacts are further described and their significance evaluated in the following sub-sections.

7.3.2.1 OVERALL IMPACT ON GROUNDWATER, SURFACE WATER, AND SEAWATER QUALITY

Given the nature of the Project, which aims to improve wastewater treatment and extend network connections in the Study Area, an overall **positive** impact on surface water, groundwater, and sea water resources is expected to arise, mainly due to:

- Improved quality of discharged effluents;
- Reduced uncontrolled discharges into the sea; and
- Reduced uncontrolled discharges into the Ghadir River and other water courses in the Al-Ghadir WWTP drainage area.

Networks Operation

An overall positive impact is expected to result from the operation of the networks once completed, mainly due to:

- The termination of uncontrolled discharges of untreated sewage into the environment, currently frequently observed, thus reducing diffuse pollution of groundwater, surface water and seawater resources, while at the same time reducing the risk of proliferation of odors, negative visual impacts, and disease vectors;
- The elimination of pollution of stormwater drainage channels, currently also used as raw sewage recipients; and
- The elimination of the need for septic tanks (although not very frequently used in the Study Area) which typically cause water pollution due to leakages resulting from poor installation and maintenance.

It is important to note, however, that this positive impact is conditional upon 1) the construction of the networks and 2) their connection to the WWTP. If completed but not connected, only the type of pollution would change from diffuse to a point and much more intense source of pollution.

The completion of Network Connections over the entire Al-Ghadir Drainage Area is thus highly likely to result in a **long-term beneficial** impact (**6C**) on water quality in the Study Area.

WWTP Operation - Phase I

During Phase I.b of the project (2020-2030) the upgrade to primary treatment will result in BOD removal in the range of 25%-30%, r**epresenting a clear improvement on current preliminary treatment processes** achieving 5-10% BOD reduction. Expected effluent quality for different parameters when the treatment is upgraded from preliminary to primary level, and the long sea outfall is used, is described in Table 7.6.

Table 7.6 Expected Effluent Quality after Upgrade to Primary Treatment (Phase I.b) *(Source: Extension of Al-Ghadir WWTP - Feasibility Study Part II a: Development of Alternative Processes for the WWTP. 2012)*

Parameters	Expected quality after primary treatment
Flow (m^3/s) (wet weather average)	3.44
BOD_5 (mg/L)	257
TSS (mg/L)	203
NH_4-N (mg/L)	65
Total P (mg/L)	9
Total Coliforms (MPN/ 100 mL)	1.00E+07

When compared to required ELVs, the required dilution ratio for each of the parameters can be calculated. These are shown in Table 7.7, while near-field dilution factors for various current speeds are shown in Table 7.8.

Table 7.7 Required dilution factors to achieve ELVs *(Source: Extension of Al-Ghadir WWTP - Feasibility Study Part II a: Development of Alternative Processes for the WWTP. 2012)*

Parameters	Expected Effluent Quality (mg/l)	ELV (mg/l)	Required Dilution Ratio
BOD_5 (mg/L)	257	25	10.28
TSS (mg/L)	203	60	3.38
NH_4-N (mg/L)	65	30	2.17
Total P (mg/L)	9	5	1.80

Table 7.8 Near-field dilution factors for different current speeds *(Source: Extension of Al-Ghadir WWTP - Feasibility Study Part II a: Development of Alternative Processes for the WWTP. 2012)*

Current Speed (m/s)	Dilution Factor
0.01	42.47
0.02	84.94
0.03	127.41
0.04	169.88
0.05	212.35
0.06	254.82
0.07	297.29
0.08	339.76
0.09	382.23
0.1	424.70
0.11	467.17
0.12	509.64
0.13	552.11
0.136	577.59

As shown in Table 7.8, the lowest dilution is in the order of 42, well above the highest required dilution as presented in Table 7.7 (10.28 for BOD_5). It is thus highly likely that sufficient dilution will take place before any of the contaminants reach the surface.

Table 7.9 represents the expected far-field dilution factor for various current speeds and their respective effect on total coliforms potentially reaching the shore.

Table 7.9 Total Coliforms reaching bathing waters *(Source: Extension of Al-Ghadir WWTP - Feasibility Study Part II a: Development of Alternative Processes for the WWTP. 2012)*

CURRENT (m/s)	DILUTION	TRAVEL TIME (hr)	NUMBER OF COLONIES REACHING THE COAST/100ml
0.01	183.86	57.72	0
0.02	367.72	28.86	0
0.03	551.58	19.24	0
0.04	735.44	14.43	0
0.05	919.30	11.54	0
0.06	1,103.16	9.62	0
0.07	1,287.01	8.25	0
0.08	1,470.87	7.22	0
0.09	1,654.73	6.41	0
0.1	1,838.59	5.77	1
0.11	2,022.45	5.25	2
0.12	2,206.31	4.81	3
0.13	2,390.17	4.44	5
0.136	2,500.48	4.24	6

Observations from the previous table indicate that even for the highest current speeds, the discharge is distant enough to allow dilution to minimize if not eliminate Coliforms presence in bathing waters. Sea water quality at the level of the discharge is also expected to improve as a result of the upgrade of the treatment level from preliminary to primary.

As such, the upgrade of the WWTP to Primary Treatment under the Project's Phase I will result in a **long-term beneficial** impact (**6B**).

WWTP Operation - Phase II

Secondary wastewater treatment, and specifically under the Conventional Activated Sludge treatment system, produces a highly treated and well-nitrified effluent that meets secondary effluent quality standards. In addition, in designs where disinfection is incorporated, as in the case of the Ghadir WWTP, bacterial population in the discharged effluent is significantly suppressed.

Expected effluent quality after secondary treatment is described in Table 7.10.

Table 7.10 Expected Effluent Quality after Upgrade to Primary Treatment (Phase II)

PARAMETERS	EXPECTED QUALITY AFTER SECONDARY TREATMENT	ELV	BATHING WATER CRITERIA
Flow (m^3/s) (wet weather average)	3.99 (2050)	-	-
BOD_5 (mg/L)	25	25	-
TSS (mg/L)	35	60	-
NH_4-N (mg/L)	7	30	-
NO_3-N (mg/L)	20	30	-
Total P (mg/L)	7	5	-
Total Coliforms (MPN/ 100 mL)	500	-	500

All parameters are equal or below the ELV threshold and in line with EU limits. The slight exceedance of phosphate will easily be compensated by near-field dilution even at very low current. Total Coliforms are also in line with the bathing water criteria requirements. The effluent can thus be safely discharged using the short outfall with no negative impacts on seawater or on its potential users.

A significant improvement is expected to occur as a result in comparison with the current situation where the short outfall is being used as an emergency overflow, whereas wastewater is discharged directly into the sea after a simple preliminary treatment (if not with no treatment at all).

As such, the upgrade of the WWTP to Secondary Treatment under the Project's Phase II is **highly** likely to result in a **long-term beneficial** impact (**6C**) on seawater quality.

7.3.2.2 IMPACT FROM PLANT FAILURE CONDITIONS

WWTP Operation

Operational upsets potentially resulting in the use of the existing emergency short outfall are likely to occur, particularly due to incidental industrial discharges and stormwater overflows reaching the plant. Although temporary in nature and small in scale, such events can have negative impacts on seawater quality. In such cases, untreated treated wastewater is likely to be momentarily discharged directly into the sea (via the short sea outfall during Phase I and via the long outfall in Phase II), causing moderate to minor changes in seawater quality (especially if compared to the current situation) and which would be relatively confined in time and space.

During Phase II, the long sea outfall would be used as emergency outfall. In this case, the impact of plant failure conditions would be significantly less as compared to the current situation that the short outfall is used for excessive untreated wastewater discharges.

With no mitigation measures in place, the impact from plant failures are expected to be **minor, temporary**, and of **medium likelihood to occur** (**2B**).

Main recommendations aiming to reduce the likelihood of occurrence of operational upsets include:

- Proper management coupled with continuous and effective monitoring and maintenance;
- The preparation, implementation and monitoring of an industrial pollution abatement program in the Al-Ghadir drainage area;
- Ensuring redundancy in the WWTP design; and
- Ensuring adequate training of plant operators to minimize the risks and effects of abnormal conditions.

With such measures in place, the risk of plant upset is reduced both in frequency and in magnitude.

As a result, the impact on water resources from plant upset conditions after implementation of the proposed mitigation measures is expected to be **minor, temporary**, and of **low** likelihood of occurrence (**2A).**

7.3.2.3 IMPACT FROM OIL SPILLS

Networks Operation

Impacts resulting from oil spills during Networks operation, as well as mitigation measures proposed to reduce them, are in all ways similar to those identified for the WWTP's operation below.

WWTP Operation

Apart from minor spills or leakages from fuel storage for power generation at the WWTP during its operation, no major risks of spills can be anticipated. The impact and likelihood of such events is considered similar to that occurring during construction (refer to section 7.3.1.1).

The impact of oil spills on groundwater during operation of the WWTP (phase 1 &2) is thus evaluated as **moderate,** and of **low likelihood of occurrence (3A).**

Mitigation measures are also similar to those suggested to mitigate the risk of oil spills and leakages during construction.

With mitigation measures in place, the potential oil leaks and spills associated with operation activities of the WWTP (phase 1 & 2) are expected to have a **low** likelihood and **minor** effect (**2A**).

7.3.2.4 IMPACT FROM WASTEWATER LEAKAGES

Networks Operation

The failure of sanitary infrastructure components can be attributed to the failure of:

- Pumps;
- Pump Station Power;
- Force main;
- Complete Pump Station Failure; or
- Gravity Sewer.

The major potential source of network leakage during operation is due to breakage of a network pipeline or to flooding of lifting pumps as a result of power blackouts or failure. Force mains operate under pressure and are typically a smaller diameter conduit with relatively thin walls (potential for accidental failure during work on adjacent utilities), resulting in the likelihood or risk of a total force main failure being greater than that of a trunk gravity sewer. Although the failure of a force main is generally rare, a force main may fail by collapse because of poor construction practices like improper bedding / backfill and compaction or a material flaw. Another scenario would be accidental breakage during subsequent construction or geotechnical investigation activities. Force mains may also become blocked at an unknown location due to sedimentation and/or build-up of grease.

Power for the operation of pumping stations will be provided through EDL and the village's generator during blackouts. Complete pumping station failure is unlikely but can be catastrophic when it occurs. Such failure could be a combination of local power outage and failure of the backup diesel generator.

A gravity sewer may fail by collapse due to improper bedding / backfill and compaction or a material flaw. The cause can be improper installation or the removal of fine particles within the bedding by pipe infiltration. Gravity sewers may also become blocked at an unknown location due to build-up of debris, grease and/or roots intrusion. A gravity sewer will likely continue to convey flow after a partial failure occurs. The likelihood of a gravity sewer pipe failure is small, especially for total failure of a large diameter trunk sewer since some flow will usually continue to pass. However, corrosion problems resulting from H_2S generation can accelerate the possibility of failure in unprotected concrete pipe and manhole structures, especially on those sections near the discharge of a long forcemain.

The network pipelines are located along various geological formations outcropping in the study area, ranging from formations acting as aquiclude with low permeability (such as Chekka Formation and the Hammana Formation) to major national aquifers (such as the Kesrouane Formation and the Sannine Formation).

The ten (10) pumping stations are located South of the WTTP, where five (5) pumping stations are located on the Sannine Formation, two (2) pumping stations are located on the Quaternary Deposits, one (1) pumping station is located on the Chouf Sandstone, one (1) pumping station is

located on the Abieh Formation, and one (1) pumping station is located on the Hammana Formation (Figure 7.1).

The pumping stations and network pipes located on aquicludes (Abeih and Hammana Formations) have limited direct infiltration of wastewater to deep aquifers without posing major threats. On the other side, the pumping stations and network pipelines located on aquifers (Sannine Formation and Quaternary Deposits) or semi-aquifers (Chouf Sandstone Formation) have high direct infiltration of wastewater to aquifers, and pose a major threat in case of breakage or failure.

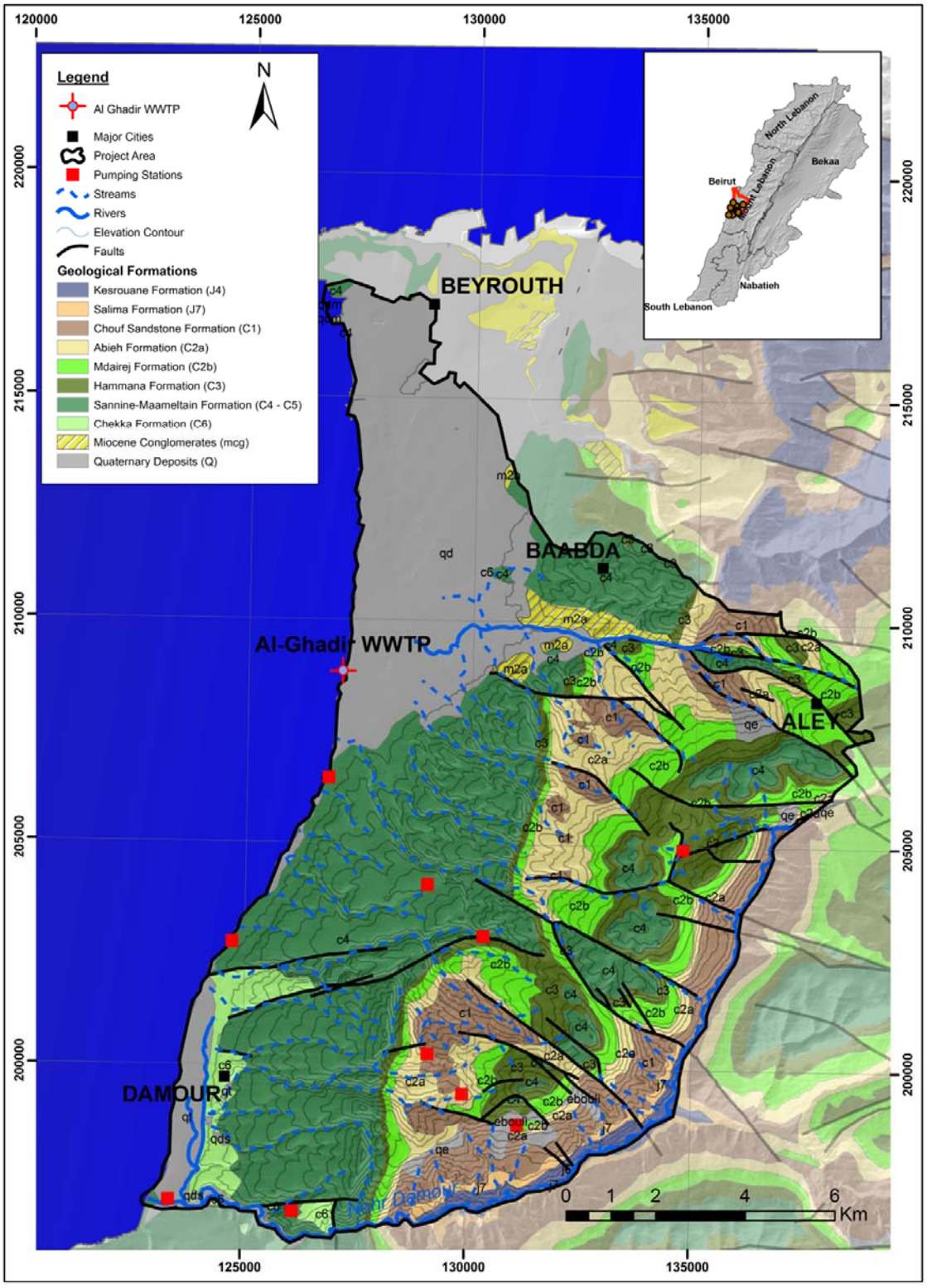


Figure 7.1 Geological Map showing Location of Pumping Stations in the Service Area

Leakage of wastewater that might occur at the river crossing is expected to cause relatively greater impact by contaminating the river locally underneath the crossing as well as downstream.

Despite the fact that the likelihood of network leakage is **low**, its effect is considered **moderate (3A)** when no mitigation measure is in place.

The Project Proponent shall envisage the development of a network leakage contingency plan by the Contractor. The following mitigation measures are recommended:

- Ensure proper bedding, backfilling and compaction of soil during the construction of the network;
- Network pipes should ideally be made of HDPE which is resistant and durable;
- Regular inspection and maintenance of electrical and mechanical components at pumping stations;
- The installation of pressure monitors on force mains allows the early detection of leaks in the network;
- Twinning of the force mains (dual force mains) provides a backup system in case repairs to the sewer are needed;
- The installation of an emergency flow line or bypass chambers also allows to divert sewage flow in case repairs to the sewer are needed;
- An emergency storage pond can be constructed near lifting stations for storage of wastewater in case of pump failure;
- In case of complete pump failure, wastewater storage within the collection system itself is a preferable solution to a discharge to the environment;
- A standby generator with sufficient capacity to start-up and maintain the firm capacity of the station is needed to ensure the continued operation of lifting stations in case of generator failure during power blackouts, and to avoid flooding in such cases;
- Regular testing (monthly) of back-up power (generator) at pumping stations;
- Establish a flow monitoring program to observe changes in flow patterns;
- Undertake an extensive monitoring program within the wastewater collection system to evaluate the levels of H_2S within the system and avoid corrosion;
- Carry out flushing and a CCTV program to observe gravity sewer condition and monitor changes every 5 years;
- Subject locations where sediment accumulation or other issues of concern have been noted to increased maintenance activities;
- Periodically swab force mains;
- Implement a comprehensive alarm system at the pump station, monitoring numerous parameters covering station operation and the status of standby generator system;
- Immediately report any leakages to municipal/governmental representative; and
- Stopping the source of leak (close valve, seal pipe, seal hole or as appropriate) as soon as possible.

With the above mitigation measures and contingency plan in place, the potential network losses associated with normal project operational activities are expected to have **a low likelihood and minor effect (2A).**

WWTP Operation

The major potential source of leakage during the operation of the WWTP (Phase I and II) is the breakage of a pipeline or leakage from all tanks.

The WWTP is located along geological formations with medium to high permeability and medium to high porosity, allowing direct infiltration of wastewater to underlying aquifers and/or migration towards neighbouring surface bodies. Such occurrences may heavily impact water quality since the wastewater would be leaking prior to receiving any treatment.

Despite the fact that the likelihood of piping and tanks leakage during operation of the WWTP (phase I & II) is **low,** its effect is considered **Significant (4A),** when no mitigation is in place.

The Project Proponent shall envisage the development of a network leakage contingency plan by the Contractor. In the case of a breakage in a network pipe, containment of spill and contamination could be performed on site by adopting the following:

- Ensuring the proper insulation of pipes and tanks during WWTP construction;
- Stopping the source of leak (close valve, seal pipe, seal hole or as appropriate); and
- Immediate cleaning of the spill by trained employees.

With the above mitigation measures and contingency plan in place, the potential network losses associated with construction activities of the WWTP (phase 1 & 2) are expected to have a **low** likelihood and **Minor effect (2A).**

7.3.2.5 IMPACT FROM WATER CONSUMPTION

Networks Operation

Water consumption for networks operation is likely to be insignificant. No impact is thus to be expected here.

WWTP Operation

The current water consumption at the Preliminary Treatment Facility is limited to water consumed by around four (4) people currently operating the plant, in addition to water used for laboratory purposes and maintenance. The potential "additional water consumption" for operating the plant once upgraded relates to the increased number of personnel (28 during Phase I and 32 during Phase II), in addition to increased volumes needed for general operation activities (mainly for the preparation of aquatic solutions), maintenance, cleaning and laboratory analyses. The estimated requirements are shown in Table 7.11.

Table 7.11 Estimated Water Requirements during Operation

UNIT	ESTIMATED DAILY CONSUMPTION (m^3/day)
PHASE I	
Personnel *(28 in total, 50L/person/day)*	1.4
General Operation	1,300
PHASE II	
Personnel *(32 in total, 50L/person/day)*	1.6
General Operation	2,400

While the water consumption by the personnel can be considered negligible, water consumed by the operation process will noticeably increase as compared to the current situation. Nevertheless, part of this amount of phase II can be replaced by reused water to save freshwater consumption.

The impact on groundwater resources and surface water due to consumption during operation of the WWTP (phase I & II) is thus evaluated as **long-term, moderate,** and of **high likelihood of occurrence (3C).**

It is advised that the operators adopt water saving techniques coupled with proper training and awareness raising among personnel so as to avoid overconsumption, especially in maintenance and cleaning.

By adopting the proposed mitigation measures, the impacts on groundwater resources due to consumption during operation of the WWTP (phase 1 & 2) would become **minor** with **a medium likelihood to occur (2B).**

7.4 IMPACTS ON AIR QUALITY

7.4.1 CONSTRUCTION PHASE

WWTP and Network Construction

Construction is a source of dust emissions and gases that can have temporary impacts on local air quality. The primary sources of air emissions during WWTP and networks construction include:

- Combustion and exhaust emissions from diesel-fuelled equipment, generators and transport vehicles; and
- Airborne particulates (dust) from soil excavation and transportation.

Dust emissions would vary from day to day depending on the level of activity and the prevailing weather. In addition to particulate emissions from earth moving, combustion emissions from fuel-powered construction equipment may create a temporary impact on local air quality. Diesel emissions count about 40 hazardous air pollutants (HAP) as reported by the EPA (2002). However, the main air pollutants likely to be associated with these emission sources include: Nitrogen Oxides

(NO_x), Sulfur Dioxide (SO_2), Carbon Dioxide (CO_2), Carbon Monoxide (CO), and Particulate Matter (PM).

Table7.12 summarizes the impacts associated with potential air emissions, while Table7.13 summarizes the impacts associated with dust generation.

Table7.12 Environmental Impacts of Major Air pollutants from Combustion Sources

EMISSION	ENVIRONMENTAL IMPACT
Oxides of Nitrogen – NOX	NO2 is a toxic gas, even at relatively low concentrations. NOX also contributes to the formation of acidic species, which can be deposited by wet and dry processes. NOX can also increase the formation of ozone at ground level when mixed with VOCs in the sunlight atmosphere. NO is a relatively innocuous species, but is of interest as a precursor for NO2.
Sulfur Dioxide – SO2	SO2 is a toxic gas, and is known to contribute to acid rain deposition (wet SO2 and dry), which may impact ecosystems (soil, water bodies…). Direct health effects potentially causing respiratory illness.
Particulates – PM10	Particulate matter is a complex mixture of organic and inorganic substances present in the atmosphere in either solid or liquid form. Particulate matter is inhaled and deposited within the respiratory pathways, leading to a variety of health effects. PM10 (i.e. particulate matter with a diameter of less than 10 µm) is able to penetrate deeply into the lungs. An association has been established between elevated concentrations of PM10 and excess short term mortality and morbidity rates.
Carbon Monoxide – CO	Carbon monoxide (CO) is a colorless, odorless gas that is slightly less dense than air. When inhaled, the gas is absorbed into the bloodstream and combines with hemoglobin in the blood to form carboxyhemoglobin (COHb). The affinity of hemoglobin for CO is more than 200 times greater than for oxygen. The result is that CO acts as a poison by reducing the amount of O2 that can combine with hemoglobin.
Carbon Dioxide – CO2	Carbon dioxide is a odorless and colorless gas of greenhouse effect known to contribute to global warming. Prolonged exposure to moderate concentrations to CO2 can cause acidosis and adverse effects on calcium phosphorus metabolism resulting in increased calcium deposits in soft tissue. Carbon dioxide is toxic to the heart and causes diminished contractile force.

Table7.13 Potential Impacts from Dust

TARGET	POTENTIAL IMPACT
Human Health	Asthma
	Nose and throat diseases
	Eyes irritation
	Skin irritation
Environment	Low visibility and haze formation
Infrastructure	Grime deposits
	Metal corrosion
	Material deterioration

Exhaust emissions are inevitable during normal operation of combustion sources. However, lack of maintenance, poor quality fuel, unnecessary idling periods, long operation period (especially for the power generators) and absence of exhaust emission control units will result in the increase of pollutants concentration emissions.

Main receptors that may be impacted by air and dust emissions around the WWTP include:

- Inhabitants of residential areas within a radius of 1 Km from the **WWTP** construction site;
- The neighbouring beach resorts;
- WWTP operating personnel;
- Local wild life; and
- Agricultural fields located within a radius of 1 Km from the WWTP construction site.

It is to be noted that these receptors are already subject to cumulative air pollution resulting from traffic over the secondary road and the existing rubble dump.

Main receptors that may be impacted by air and dust emissions around the **networks** construction sites include:

- Residents around the construction sites;
- Local wild life;
- Agricultural fields, forests and other ecologically sensitive areas around the construction sites.

Overall, given the scale and duration of the project, the impact of construction-related dust and emission generation (which is highly likely to occur) will result in minor adverse changes in the Study Area's ambient air quality. This change will be temporary and its effects can recover within a short period of time after the interruption of construction activities.

Accordingly, with no mitigation measures in place, this activity is likely to have a **minor** consequence level of **high** likelihood of occurrence **(2C)** on the overall air quality within the project area during construction.

It is recommended that various mitigation measures be adopted, including:

- Using continually well designed, maintained and operated equipment/ vehicles by the contractor. Precautionary control measures for atmospheric emissions reduction could include proper engine fuel mixtures, regularly serviced exhaust emission systems, suitable engine tuning, and purchase of diesel fuel with low sulfur content (5% sulfur content whenever available);
- Employing environmentally friendly equipment (whenever available) by the contractor such as machinery with higher fuel efficiency or those equipped with air pollution control devices to minimize exhaust emissions. Examples include vehicles equipped with two-or three-way catalytic converters;
- Installation of Diesel Particulate Filters on Construction Equipment;
- Avoiding idling vehicles and equipment engines that are left running unnecessarily;
- Watering-down work area/s particularly near sensitive receptors, at loading and unloading operations;
- Efficient scheduling of deliveries as well as establishing and enforcing appropriate speed limits over all paved and unpaved surfaces (< 40 km/h);

- Travelling on existing and paved tracks wherever possible;
- Maintaining stockpiles at minimum heights and forming long-term stockpiles into the optimum shape (i.e. stabilization) to reduce wind erosion; and
- Installing covers (manual and/or mechanical) on back loads of dump trucks and large vehicles before leaving a construction site to reduce as low as possible, if not prevent, fugitive dust emissions from being released during road transportation and vehicular movement.

The above-mentioned mitigation measures can reduce the adverse impacts on ambient air quality to a level that is noticeable but short-lived and of low significance.

Implementing the above mentioned mitigation measures is likely to reduce construction-related air emissions and consequently minimize the project impacts on overall air quality within the project area during construction to **negligible** with **medium** likelihood of occurrence **(1B)**.

7.4.2 OPERATION PHASE

Main sources of impact on air quality during the WWTP operation mainly consist of:

- Odour generations from the WWTP and from the networks and pumping stations ;
- Greenhouse gas emissions from power generation *(at the WWTP level only)*; and
- Emissions from sludge treatment and disposal *(at the WWTP level only).*

7.4.2.1 IMPACT FROM ODOR GENERATION

Network's Operation

Impacts from networks and pumping stations operation are mainly related to possible leaks and overflows in the pumping stations, which could generate slight odours. These can be prevented through proper engineering and adequate preventive measures part of a Spill Prevention and Response Plan.

WWTP Operation

Inlet works, grit channels, screening and grit handling, and sludge treatment units (storage, thickening, dewatering) are the main sources of odor. However, in many instances, odors can be reduced or prevented through normal housekeeping, improved operation, and maintenance procedures along with proper management. When kept clean, sludge transfer systems, such as conveyors, screw pumps, and conduits, will not generate odors.

Additionally, the plant will be equipped with an odour control system, which will abate odour emissions. The odour control system will be using NaOCl solution scrubbers for the oxidation of volatile odorous substances in the off-gases from the following units:

- Preliminary Treatment Unit: All existing and new works (lifting pumps, screens, grit chambers and auxiliaries) will be enclosed and connected to the odour control system.
- Primary Settling Tanks: The tanks will be covered and connected to the system.
- Gravity Thickeners: The tanks will be covered and connected to the system.
- Anaerobic Digesters

- Sludge Screens
- Buffer tanks (prior to mechanical thickening, to digestion and to dewatering)
- Mechanical drum thickeners
- Mechanical Dewatering Unit
- Dewatered sludge silos

The storage of all malodorous solid waste (screenings, grit etc) will be in closed units so as to minimize and control the risk of residual odours.

It is to be noted that persistent odours are currently observed inside and around the existing Preliminary Treatment Plant. These mainly result from the lack of well-maintained odour control units, and the storage of screenings, grits, and sludge on-site and in the open air. The Project is thus expected to result in an overall reduction in odour emissions, thus producing a **positive** impact compared to the actual baseline situation.

The predominant wind direction in the WWTP's area is South West (Figure 6.5). It is thus expected to normally draw potential residual odours towards the sea, thus sparing residential areas. Winds also blow, although less frequently, towards the North, North East and South. Under such circumstances, the closest residential areas, airport users, and vehicles crossing roads near the site, may be slightly affected. Nevertheless, such occurrences are expected to be low in frequency and temporary in nature.

With reference to the above, and due to envisaged control measures coupled with a South-Westerly predominant wind direction observed on-site, the impact on air quality from odour generations during plant operation is anticipated to be **minor** and of **medium** likelihood of occurrence (**2B**).

Activated sludge tanks do not normally emit an objectionable odor when a dissolved oxygen level of ≥ 2 mg/L is maintained in the mixed liquor. Thus, it is essential to

- Conduct odor simulation studies for pumping stations and the WWTP during the detailed design phase of the project to confirm that emissions thresholds are met and that concentrations of odorous compounds (mainly H_2S and NH_3) remain below threshold values at the nearest receptors;
- Execute a regular program of maintenance to prevent the clogging of the fine-diffusers or diffuser plates to maintain adequate dissolved oxygen levels in the aeration tanks, which in turn minimizes the chances for the production of odorous compounds that might be generated in case of incomplete aeration.
- Execute regular cleaning of aeration tank walls and floors, washing weirs, and removing scum regularly;
- increasing the pumping rate of the thickened sludge, monitoring a low sludge blanket level, and increasing the influent flow rate to the sludge-holding tank without losing thickening, to reduce odors from final settlement tanks and sludge holding tanks;
- Tank mixing during off-shifts to minimize the release of trapped gas during the day;
- Provide flow regulating chambers, drainage valves, standby pumps, as well as electric standby generators to reduce the possibility of wastewater flooding. The presence of multiple aeration basins in the plant also reduces overflowing problems; and

- Proper landscaping around the facility along with the existing landscape may serve as a natural windbreaker and minimize potential odor dispersions.

The impact on air quality from odour generations during plant operation can be reduced to **negligible** and of **medium** likelihood of occurrence (**1B**) if additional mitigation measures are implemented.

7.4.2.2 IMPACT FROM POWER GENERATION AND SLUDGE TREATMENT

WWTP Operation

The daily consumption of electric power at the WWTP at full load operation during Phase I.b is estimated at 82,983 kWh, while the respective value for Phase II is 117,152 kWh. This power demand is calculated after excluding the power generated onsite by the CHP engines and refers to the full inflow of wastewater which is 286,912 m^3/day for Phase I and 345,044 m^3/day for Phase II.

However, energy will be recovered from sludge during both Phase I and Phase II. The recovered energy will reduce the plant's overall power demand and energy footprint, thus reducing related GHG emissions. The biogas produced from the anaerobic process will be utilised by Combined Heat-Power (CHP) engines. For this purpose, biogas from the spherical storage tank will be fed to 3 CHP engines (2 in Phase I.b and 1 in Phase II), each rated at an electrical output power of 888 kW.

A gas flaring station will be installed in addition to the CHP engines for safety reasons (Phase I.b), so as to burn the biogas in situations when the CHP engines are out of operation (malfunction, maintenance etc). In Phase II, an additional gas flaring station will be installed. Moreover, for the initiation of the anaerobic digestion process auxiliary boilers will be used to heat up the sludge.

While flaring can result in harmful air emissions, it is to be noted that it will be used for emergency cases only. Impact would thus be temporary and short.-termed. It is to be noted that if residual sludge is to be incinerated, additional air emissions are expected to arise, resulting in an off-site impact. In addition to NOx, CO_2, and CO, emissions from flaring and incineration can include unburned hydrocarbons, particulate matter, and volatile organic compounds (VOC). If the natural gas contains H_2S, emissions can include sulphur dioxide (SO_2), carbon disulphide (CS_2) and carbonyl sulphide (COS); all of which can significantly alter air quality if they reach high concentrations.

The impact on air quality from power generation during operation is evaluated as **moderate** and of **medium** likelihood of occurrence (**3B)** given the small-scale nature of the power generation plant and given the energy reuse potential**.**

Maximizing the energy recovery potential would ensure a reduced Project contribution to air pollution and to climate change. Other important mitigation measures relate to reducing emissions from flaring, and include:

- Choosing efficient and low-emission equipment ; and
- Monitoring the heating value of the gas to maintain a stable flare.

After the implementation of mitigation measures, the impact is evaluated as **minor**, and of **low** likelihood of occurrence (**2B**).

7.5 IMPACTS ON THE ACOUSTIC ENVIRONMENT

7.5.1 CONSTRUCTION PHASE

Networks Construction

Noise generation during construction is mainly associated with:

- Construction activities, including the transportation/delivery of raw materials; and
- The operation of heavy equipment, notably excavators.

Both sources of impacts are temporary in nature as they would be interrupted as soon as construction activities are over.

Typical noise levels associated with trucks movement are reported at 74 dB(A) according to the British Standard for Noise and Vibration Control on Construction and Operation Sites (BS5228:1997). These levels are normal in general construction sites (and can go up to 85-90 dB(A)).

Most construction activities would generate average noise levels of about 10 to 19 $dBAL_{eq\ (h)}$ above ambient daytime or nighttime traffic noise when these activities occurred within about 20 meters of an adjacent land use. Maximum instantaneous noise levels generated by construction activities are typically 5 to 10 dBA above existing maximum noise levels generated by traffic, with the exception of activities such as the use of a hoe ram or impact pile driver where maximum instantaneous noise levels can exceed existing conditions by up to 20 or 25 dBA, which will not be used in this project.

Table 7.14 enumerates the different noise levels for various types of construction equipment.

Table 7.14 Typical Sound Pressure Levels Reported from Construction Equipment (BS5228:1997)

CONSTRUCTION TYPE	MACHINES	NOISE LEVEL (DBA)*
Earth Moving	Compactors	78
	Front Loaders / Bulldozers	88
	Backhoes	76
	Tractors	71
	Scrapers	82
	Caterpillar Graders	84
	Pavers	74
	Dump Trucks	74
	Excavators	78
Material Handling	Concrete Mixer	76
	Concrete Pumps	81
	Cranes	81
Stationary	Pumps	82
	Generators	82
	Compressors	85

Given that the Networks area extends over a heterogeneous zone with disparate baseline noise levels, it is expected that baseline sound pressures especially in those quieter areas would rise by levels that would be noticed without however considerably affecting the livelihood of those using or residing close to the construction sites.

With reference to the above, and due to the short duration of the construction period, the impact on Sound Quality during construction is anticipated to be **moderate** and **highly** likely to occur (**3C**).

To reduce the significance of noise impacts resulting from project construction, the following measures should be implemented during project construction. The proposed measures should adequately mitigate the noise impact to a less-than significant level to receptors, particularly workers:

- Equip all internal combustion engine driven equipment with intake and exhaust mufflers that are in good condition and appropriate for the equipment;
- All vehicles and machinery to be fitted with effective exhaust silencers;
- All vehicles and machinery should be maintained in good repair and in accordance with the manufacturer's instructions;
- Any machinery, which is intermittent in use, should be shut off in periods of non-use or, where this is impracticable to be throttled back to a minimum; and
- Establish a noise complaint grievance mechanism as a measure to allow implementation of timely and effective actions to minimize impacts from noise.

With the proposed mitigation measures in place, the impact on sound quality is reduced to **minor** with a **high** likelihood of occurrence **(2C)**.

WWTP Construction

Considering that the WWTP is located close to the Airport, noise levels are generally high. Although construction activities are likely to temporarily raise baseline sound pressures, it is expected that they would be barely noticed.

Impacts on the acoustic environment resulting WWTP construction, as well as mitigation measures proposed to reduce them, are in all ways similar to those identified for the Networks' construction.

7.5.2 OPERATION PHASE

Network Operation

Noise from the network component operation is expected to arise mainly from the operation of pumping stations. Properly enclosing the stations and keeping them maintained at all times would help reduce any such impacts.

The impact on Sound Quality during operation is anticipated to be **negligible** and of a **low** likelihood to occur (**1A**).

WWTP Operation

Noise during WWTP operation is mainly expected to arise from heavy machinery and equipment.

The impact on Sound Quality during operation is anticipated to be **negligible** and of a **low** likelihood to occur (**1A**), given that the project is located close to the Airport where noise pollution levels are already high.

Proposed noise mitigation measures include:

- Selecting new equipment that conforms with international standards;
- Placing air blowers and other noisy equipment in isolated rooms would ensure that noise levels comply with national standards;
- Equipping all internal combustion engine driven equipment with intake and exhaust mufflers that are in good condition and appropriate for the equipment;
- Keeping equipment maintained in good repair and in accordance with the manufacturer's instructions; and
- Fencing and screening the site with a green belt to muffle any residual noise generation.

7.6 IMPACTS ON LANDSCAPE AND LAND USE

7.6.1 CONSTRUCTION PHASE

7.6.1.1 IMPACT ON VISUAL AMENITY

WWTP and Networks Construction

No major impacts are expected to result from construction activities related to the WWTP upgrade or those related to the networks, apart from temporary decreased visual amenity and aesthetics due to the temporary storage of construction material and machinery on-site. The impacts are likely to be noticed by inhabitants and users of the area, without however considerably affecting their livelihoods.WWTP Construction works (phase Ib and phase II), however, will be additionally visible by air plane travelers, and may constitute a greater visual impact.

While the impact of the project's Construction on the landscape is **highly** likely to occur, it is expected to be **minor** and **temporary** (**2C**).

Impacts during construction can be mitigated through hoarding or boundary fencing around construction sites, sensitively designed to fit into the existing environment when looking from outside.

With mitigation measures in place, the **temporary** impact on the landscape from construction activities can be reduced to **negligible** levels with a **high** likelihood of occurrence (**1C).**

7.6.1.2 IMPACT ON LAND USE

Networks Construction

Networks may cross agricultural land, potentially requiring the removal of trees or affecting agricultural areas. Consequently, the land will lose its agricultural value. This impact would be irreversible, but it is not highly likely to occur given that the routing can always be moderately modified to avoid any significantly sensitive areas. Additionally, secondary and tertiary networks will, to the extent possible, follow existing road routes.

The consequence of the Project's impact on land use during the construction phase is considered to be **moderate** and of **medium** likelihood of occurrence **(3B).**

However, appropriate measures can be taken to reduce the impacts on land use, mainly through the avoidance of sensitive areas. Recommended mitigation measures related to tree relocation include:

- Relocating the trees to a different land with the same specification; the neighbouring farmers would take in these trees;
- Preserving any removed roots and avoiding damaging them to the extent possible; and
- Avoiding the use fertilizers for a period of time exceeding one year to avoid damaging the vulnerable roots.

With the proposed measures in place, the consequence of the impact on land use can be reduced to **minor** and its likelihood of occurrence to **low (2A).**

7.6.2 OPERATION PHASE

Networks and WWTP's Phase I and Operation

No major impacts are expected to result from the WWTP in its first phase and from the networks during Operation.

WWTP Operation – Phase II

Necessary land reclamation for upgrading to secondary treatment (Phase II) will result in a permanent but localized disturbance of the coastline. Due to the limitation on maximum facility height imposed by the proximity to the airport, it is expected that the facility would not significantly obstruct the sea view. Nevertheless, the plant is expected to be highly visible from air planes, from the beach resorts located south of the Plant and from residential areas north of it, thus irreversibly impacting the coastline view. Given the plant's crucial environmental function, combining a progressive and well-thought architectural design with awareness campaigns would improve the general public's perception and acceptability towards it, hence reducing the visual disturbance.

Nevertheless, it is recommended that this impact be more duly analyzed as part of an updated EIA study specific to reclamation activities prior to the start of Phase II in 2030 according to the project implementation plan.

It is thus expected that the impact from the WWTP in its phase II will have a **moderate** and **long-term** impact on the landscape (**3C**).

To mitigate negative impacts resulting from the existence of wastewater treatment facilities on the landscape, the following steps are recommended:

- Maintaining cleanliness within the treatment plant (preventing spillovers, cleaning roads and ground, etc.);
- Appropriate landscaping of the plant grounds with planting of suitable trees, grass, and flowers;
- Fencing and screening the site with appropriate trees to obstruct the plant components from onlookers and area inhabitants (all along with some noise reduction); and
- Analyzing the land reclamation's impact on the landscape as part of an updated EIA prior to the start of works on Phase II.

With this in place, the **long-term** impact would be reduced to a **minor** level of significance with a **medium** likelihood to occur (**2C**).

7.7 IMPACTS ON SOIL AND SEDIMENTS

7.7.1 CONSTRUCTION PHASE

Impacts on soil and sediments resulting from the WWTP's and Networks construction include:

- Soil pollution from excavation and trenching works, oil spills, and solid and liquid waste generated during construction; and

- Sediments contamination from land reclamation/dredging activities (Phase II of component 2 only).

7.7.1.1 IMPACT FROM EXCAVATION AND TRENCHING WORKS, OIL SPILLS, AND SOLID AND LIQUID WASTE GENERATION

Networks and WWTP (Phase I) Construction

The Project's disturbance to soil resulting from excavation and trenching works is restricted to construction areas and limited to pipeline corridors and tunnel alignments. Additional civil works may be required for the construction and/or upgrade of access roads to the construction sites.

The major potential sources of accidental spills during construction include storage and re-fuelling of diesel supplies for power generation, lubricating oil as part of routine equipment operations, and equipment maintenance. Fuel leakages contain BTEX such as benzene and toluene and methyl tertiary butyl ether (MTBE). These monocyclic aromatic hydrocarbons tend to readily evaporate from surface spills and biodegrade under aerobic and anaerobic conditions given their relatively good solubility and volatility, particularly MTBE and benzene. Whereas diesel spills consisting of BTEX; Poly Aromatic Hydrocarbons (PAH), chlorinated hydrocarbons, as well as heavy metals such as Nickel, Copper, Chromium and Zinc persist in the receiving environment, and when mixed with sediment, they tend to adhere and accumulate due to their low evaporation and biodegradability.

Should such leakages occur, significant long term changes in soil quality are likely to be observed. However these impacts would be localized given the relatively small volume of oil to be stored on-site.

Additionally, waste handling and disposal practices throughout the course of the site preparation activities and construction works pose potential risks of soil contamination either through direct contamination (if hazardous) or through the generation of contaminated leachate. The main waste streams expected to be generated include:

- Inert solid waste stream (construction waste (concrete, wood, steel, rock spoil), domestic / putrescibles and packaging and green/organic waste);
- Liquid waste streams (grey water, sanitary wastewater and hydrotest water); and
- Non-inert waste streams (recovered solvents / chemicals, acids, paints, fuel and oils, hydrotest water-if mixed with additives).

If not mitigated, the impact on soil from physical disturbance, from potential oil spills, and from solid and liquid waste generated is expected to be **moderate, temporary,** and of **medium likelihood** to occur (**3B**); as any changes in soil quality would be of small-scale and relatively confined nature.

Mitigation measures proposed include:

- Adopting minimum safe operating widths and using existing tracks whenever possible to minimize the size of the area impacted by trenching and excavation works;
- Adhering to proper waste management practices to reduce the risk of soil contamination through leaching; and
- Keeping all equipment well maintained and adopting a Spill Prevention and Response Plan to reduce the risks of leaks happening.

When mitigation measures are applied, the impact on soil during construction can be reduced to **minor, temporary,** and **low** likelihood of occurrence (**2A**).

7.7.1.2 IMPACT FROM LAND RECLAMATION/DREDGING ACTIVITIES

WWTP Construction - Phase II

As mentioned in 7.3.1.2, dredging activities for land reclamation are likely to result in substrate removal and/or alteration of bottom hydrography and topography and sediment composition; indirectly causing changes in turbidity and sedimentation rates, release of chemical substances, and changes in hydrographic regime and land-use.

Breaking the cohesion of the sediment particles may give rise to the following:

- Re-suspension of sediments;
- Spread of sediments and associated contaminants in the surroundings of the dredging site; and
- Transport of sediments, particularly of finer fractions to other (possibly more sensitive) areas.

Nevertheless, it is recommended that this impact be more duly analyzed as part of an updated EIA study specific to reclamation activities prior to the start of Phase II.

If not mitigated, impacts from dredging activities on sediments are **highly** likely to occur. They would, however, be **localized, temporary,** and of **moderate** severity (**3C**).

Mitigation measures aiming at reducing re-suspension of sediments are similar to those suggested under 7.3.1.2, and include:

- Coordinating with the Directorate General of Land and Maritime Transport;
- Using Silt Curtains and ensuring that lower end of 'skirt' is resting upon the seafloor, and ensuring that top of the 'skirt' is always above the surface of sea;
- Reducing velocity of dredging;
- Decreasing the time-frame over which the dredging operation is to take place;
- Confining dredging operations to calmer sea states; and
- Conducting a sediment analysis over the dredging locations as part of an updated EIA prior to the start of works on Phase II.

The above mitigation measures would reduce the likelihood of re-sedimentation to **medium** levels, and its impact to **minor** and **temporary** (**2B**).

7.7.2 OPERATION PHASE

Networks Operation

The networks operation is expected to have an overall **positive** impact on soil quality mainly as a result of the reduction of uncontrolled wastewater discharges in the Study Area.

Nevertheless, localized negative impacts of limited intensity may result from leaks in networks, if not well managed and maintained. Proper engineering and adequate preventive measures, in addition to the adoption of a Spill Prevention and Response Plan, can reduce the related risks.

As such, the Project is **likely** to have a **long term, beneficial** impact on soil quality in the Study Area once fully operational (**6B**).

WWTP Operation

Impacts on soil during operation are expected to result mainly from:

- Solid waste streams and sludge generated at the Plant; and
- Localized modified hydrodynamic regime due to reclaimed land offshore.

Solid waste streams will mainly be limited to office domestic waste, laboratory waste, sanitary wastewater, chemicals, fuel oil and sludge. Given that the WWTP will be operated by 28 to 32 staff (during Phase I and Phase II, respectively), it is anticipated that around 15 kg of domestic solid waste and around 1.6 m^3 of sanitary wastewater will be generated daily. The daily sludge production at full load operation of the WWTP during Phase I is calculated at 162 m^3/day, while the respective value for Phase II is about 324 m^3/day.

Sludge generated at the WWTP may cause a negative off-site impact on soil if not properly treated and disposed of. However, sludge dewatering and stabilization will be applied on-site, rendering it suitable and safe for transport and disposal in landfills or energy recovery facilities. Application of the pre-treated sludge on agricultural lands is not considered at the moment due to industrial discharges to the receiving network which may considerably affect sludge composition and quality.

During Phase II, localized modified hydrodynamic regime due to the newly reclaimed land offshore may affect sediment transport processes and coastal erosion**. It is recommended that this impact be more duly analysed as part of an updated EIA study prior to the start of Phase II**.

The impact on soil during plant operation is thus expected to be **negligible** and of **low** likelihood to occur (**1A**).

7.8 IMPACTS ON BIODIVERSITY

Main identified impacts on biodiversity during the construction phase are associated with the following:

- Habitat loss or destruction and vegetation loss due to physical damage from clearance activities and vehicular transport during construction; and
- Altered abiotic/site factors due to wastewater leakages and oil spills during operation.

These impacts are further described and their significance evaluated in the following sub-sections.

Additional potential impacts are summarized in Table 7.15.

Table 7.15 Potential Negative Impacts on Biodiversity

POTENTIAL IMPACT	CAUSE
Habitat loss or destruction	Construction works
Altered abiotic/site factors	Soil compaction, erosion
Mortality of individuals	Destruction of vegetation (Planted fruit trees)
Loss of individuals through emigration	Following disturbance or loss of habitat
Habitat fragmentation	Habitat removal and/or introduction of barriers
Disturbance	Due to construction noise, traffic, or presence of people
Altered species composition	Changes in abiotic conditions, habitats (not present in this case)
Vegetation loss	Soil contamination due to disposal of oils and waste material

7.8.1 CONSTRUCTION PHASE

Networks Construction

As mentioned in the biological environment baseline chapter (6.3), the networks area contains different types of lands (i.e agricultural lands, artificialized lands, herbaceous vegetation, permanent streams, unproductive land and wooded land), represented in Figure 6.24.

The main impacts from site clearance and civil works related to networks construction involve the loss of vegetative cover that supports natural habitats of the site fauna. Any significant damage to vegetation cover or flora will result in further loss of vulnerable feeding sources for local fauna. Construction activities will have a direct local impact on invertebrates such as snails, scorpions, spiders, beetles also ants; crickets and locusts along with small vertebrates (lizards, small mammals) present on the site area on soil cover and within the top soil layer. Any significant loss or disturbance of the fragile ecosystem of the listed above species could have negative impacts on the other animals feeding sources although this impact expected to be minor in general.

Most sensitive areas identified in the Study Area are as follows:

- Areas covered by herbaceous vegetation, highly important in terms of ecological value. Although these only constitute 0.16% of the Study Area, they need to be dealt with carefully if crossed by networks, through the preservation of excavated top soil and re-vegetation of the disturbed areas with common local species.
- Agricultural lands, covering 23, 43% of the Study Area. Besides their importance in terms of coverage, these lands will see the removal of trees and crops, affecting both the vegetation cover and the livelihoods of farmers. Any affected trees should be re-planted in neighbouring lands so as to minimize vegetation loss.
- Wooded lands, mainly consisting of Pinus and Quercus forests, and covering around 31% of the network area. These have been heavily degraded during the last 10 to 20 years. Caution should thus be observed in such lands to avoid further degradation and habitat destruction.
- Vegetation close to permanent streams, representing an ecosystem which is already under pressure in Lebanon due to pollution and misuse of water streams. Construction of networks close or through permanent streams should be avoided or minimized to the extent possible.

It is advised that a more detailed study over the networks area be undertaken prior to the start of works and as they proceed, in order to identify additional ecological sensitivities along chosen routes.

The impacts from networks construction on local fauna and flora are thus expected to be **significant** if not mitigated, and of **medium** likelihood of occurrence (**3B**).

Mitigation measures to minimize the impacts on the local flora and fauna include:

- Confining vehicular movements to defined roads;
- Keeping with minimum safe operating width and using existing tracks whenever possible to minimize impacted area size;
- Preserving excavated top soil and re-vegetating disturbed areas by seeding common species such as herbs and shrubs;
- Supervising the implementation of the proposed Waste Management and Spill Contingency plans;
- Raising the awareness of workers on the respect and preservation of wildlife during construction and operation phases;
- Spreading excavated topsoil containing pollen and roots of the original vegetation at the peripheries around the WWTP upon completion of construction works in order to regenerate and reintroduce some of the native flora species present in the area; and
- Conducting a biodiversity assessment over the network routes prior to the start of works on networks.

The impacts from networks construction on local fauna and flora are thus expected to be **minor, short-term**, and of **low** likelihood of occurrence (**2A**).

WWTP Construction

As noted in the baseline study (section 6.3), vegetation is well distributed along the WWTP's area, even over the rubble dump facing the plant. This vegetative cover is expected to have developed partly owing to the presence of the WWTP, feeding on biological matter made available by discharges through the emergency outfall.

This flora component expected to be affected during the construction phase as a result of the removal of top soil layers.. Additionally, construction activities are expected to directly and indirectly impact fauna components. Direct impacts are related to physical injuries from accidents or human activities (hunting, nest robbing, poisoning, trading, etc...). Indirect impacts are related to habitat loss and reduction in food resources due to damages inflicted on the vegetation cover.

It is to be noted that no sensitive or endangered floral species were identified on-site. No endangered or protected faunal species were observed either. However, animals documented in the baseline survey are generally mobile and tend to move away from sources of disturbance.

Direct and indirect impacts on fauna and flora would be permanent and irreversible. They will be, nevertheless, very limited in terms of geographical extension.

Construction activities are thus **highly** likely to have **permanent** but **moderate** effects on biodiversity if no mitigation measures are applied **(3C).**

Mitigation measures to minimize the impacts on the local flora and fauna include:

- Confining vehicular movements to defined roads;
- Keeping with minimum safe operating width and using existing tracks whenever possible to minimize impacted area size;
- Preserving excavated top soil and re-vegetating disturbed areas by seeding common species such as herbs and shrubs;
- Supervising the implementation of the proposed Waste Management and Spill Contingency plans;
- Raising the awareness of workers on the respect and preservation of wildlife during construction and operation phases; and
- Spreading excavated topsoil containing pollen and roots of the original vegetation at the peripheries around the WWTP upon completion of construction works in order to regenerate and reintroduce some of the native flora species present in the area.

Such practices are likely to reduce the impact on biodiversity during construction to a **minor** level with **negligible** likelihood of occurrence **(1A).**

7.8.2 OPERATION PHASE

Network operation

The networks operation is expected to have an overall **positive** impact on biodiversity mainly as a result of the reduction of uncontrolled wastewater discharges in the Study Area.

Nevertheless, localized negative impacts of limited intensity may result from leaks in networks (discussed under section 7.3.2.4.), if not well managed and maintained. Proper engineering and adequate preventive measures, in addition to the adoption of a Spill Prevention and Response Plan, can reduce the related risks.

As such, the Project is **likely** to have **a long term, beneficial** impact on soil quality in the Study Area once fully operational (**6B**).

WWTP Operation

The improvement in surface water and seawater quality expected to result from the Project's operation is likely to **positively** impact fluvial, riparian, coastal and marine fauna and flora due to improved quality of discharges.

As such, the Project is **likely** to have **a long term, beneficial** impact on biodiversity in the WWTP's Area once fully operational (**6B**).

7.9 SOCIO-ECONOMIC IMPACTS

Given the nature of the project which will result in an overall improvement in water quality in Al Ghadir area and will gather waste water discharge in one network, it is generally envisaged that the overall social and economic impact will be positive.

However, the project is likely to generate social and economic alterations during both construction and operational phases. These are presented and discussed in the sub-sections below.

7.9.1 CONSTRUCTION PHASE

During the construction phase, negative impacts on the socio-economic characteristics of the Study Area are expected to arise from:

- The creation of temporary job opportunities;
- Permanent expropriation of land (land take); and
- Temporary traffic and disturbance of public rights-of-way and access to community resources and services around construction sites.

Nevertheless, the proximity of the site to the airport implies the need to comply with airport regulations. Close coordination with airport authorities and authorisation and/or approval of the construction plan will take place prior at all stages of the design process to ensure that maximum safety conditions are met.

7.9.1.1 IMPACT FROM JOB CREATION

Networks and WWTP Construction

During the construction phase for the WWTP and the network, the creation of job opportunities will result in direct positive impacts. These anticipated impacts would be considered beneficial and of high likelihood of occurrence yet temporary.

A **positive temporary** impact from job creation is thus to be expected on the socio-economic context during construction (**6C**).

7.9.1.2 IMPACTS FROM LAND EXPROPRIATION

Networks Construction

The main impacts expected to arise from necessary partial expropriations of land include some restrictions on land use (such as depth of excavation, planting trees, etc.). This applies to the number of plots of land where the network will cross, according to the Contractor.

The impact from partial land expropriation is thus considered **minor** and **permanent** with a **low** likelihood of occurrence **(2C).**

Recommended mitigation measures to minimize the impacts include the following:

- Consultation with potentially affected families prior to expropriation procedures;
- Fair and full compensation for land expropriated for the project in the public interest as stated in the Lebanese expropriation law.

Such measures would reduce the effect of expropriations on the livelihood of land owners, thus reducing the impact consequence to a moderate level.

By applying the above recommended measures, the impacts are reduced to **negligible** with **low** likelihood of occurrence (**1C**).

7.9.1.3 IMPACT ON TRAFFIC

Construction of theWWTP extension as well as the network activities will involve an impact on traffic due to increased traffic loads (machinery, equipment, labor…) and obstruction of access roads.

If not mitigated, obstructions during construction can have a **significant, temporary** impact on traffic. Nevertheless, the impact has a **low** likelihood of occurrence especially around the WWTP given the low traffic flows around it (**4A**).

The following measures can be put in place in order to minimize the adverse effects:

- Consultation with any potentially affected communities (if any) prior to expropriation procedures and ensuring proper compensation as per the Lebanese expropriation law;
- Developing a Traffic Management Plan (TMP);
- Continuously liaising with local and the governmental authorities; and
- Allowing only certified and trained drivers to carry out transportation related activities.

By applying the above recommended measures, the impacts are reduced to a **minor** level of significance with **low** likelihood of occurrence **(2A)**.

7.9.2 OPERATION PHASE

The project is expected to bring overall **benefits** to the public through ensuring better public health conditions, reduced impacts on cultural heritage, and the creation of job opportunities.

It is to be noted that the government has already started imposing a minimal tariff in fully served areas, which paves the way to the introduction of wastewater tariffs on top of the current water tariffs. These additional tariffs have been designed on the basis of numerous studies conducted to assess the ability to pay of the population served, the costs that need to be covered and the benefits that will be realised for the general public.

7.9.2.1 IMPACT ON LOCAL PUBLIC HEALTH

It is expected that the project will result in the following positive impacts during its operation:

- Reduction in uncontrolled wastewater discharges, thus reducing risks of microbiological and organic contamination;
- The provision of proper sanitary services to the area;
- An overall improvement in environmental conditions resulting in improved health conditions; and
- Properly treatment of discharged effluents, decreasing seawater pollution levels and odours thus ensuring an added value to the neighboring resorts.

The Project's impact on local public health is thus considered as **beneficial**, of **long-term** nature**,** and with **high** likelihood of occurrence **(6C).**

7.9.2.2 IMPACT FROM JOB CREATION

Another direct **positive** impact which can be anticipated from the WWTP's operation consists in employment of skilled technicians and professionals needed for the daily operation of the upgraded WWTP in addition to impacts on cultural heritage and socio-cultural sites, public health, and land use as described below.

The Project's impact on the local economy is thus considered as **beneficial**, of **long-term** nature**,** and with **high** likelihood of occurrence **(6C).**

7.10 IMPACTS ON OCCUPATIONAL HEALTH AND SAFETY

7.10.1 CONSTRUCTION PHASE

Networks Construction

The main sources of impact on occupational health and safety are from the site preparation and construction phase of the Project.

Working on a construction project entails several health and safety risk factors that need to be addressed ahead of the influx of the construction workers. The main sources of health and safety risks include physical injuries (potentially leading to fatalities, if not properly prevented and mitigated) and exposure to dust and noise.

With no mitigation measures in place, the impacts on the occupational health and safety from the construction phase are of **short term, reversible** nature, **moderate** effect and **medium** likelihood of occurrence (**3B**).

In order to avoid adverse impacts on workers' health and safety, the following measures are recommended:

- Identification and provision of appropriate PPE that offers adequate protection to the workers (goggles, dust masks, helmets, hearing protection equipment, proper clothing, safety boots…);
- Proper maintenance of PPE, including cleaning when dirty and replacement when damaged or worn out. Proper use of PPE should be part of the recurrent training programs for employees;
- Warning of staff about potential construction hazards during regular toolbox meetings;
- Availability of adequate loading and off-loading space;
- Prohibition of smoking as well as litter or weed build up in the area;
- A fire protection and prevention program approved by the Government is in place;
- Fire-fighting equipment is available within the premises;
- Inspection and maintenance of portable fire protection equipment;
- Investigation of fire incidents;
- Emergency action plan and fire hazard inspection procedures are available on-site at all times for all employees;
- The contractor should ensure that qualified first-aid can be provided at all times. Appropriately equipped first-aid stations should be easily accessible throughout the place of work; and
- Adequate signs should be posted throughout the Construction Area, especially at visible locations, indicating type of operation and other information and appropriate medical / emergency action response;
- Staff training about the fundamentals of occupational health and safety procedures, and about handling hazardous material containers and related wastes;
- CDR guidelines for health and safety should be properly implemented;
- Implementation of speed limits for trucks arriving to and leaving the site.

By adopting the above proposed mitigation measures, impacts on occupational health and safety are predicted to become **minor** with **low** likelihood of occurrence (**2A**).

WWTP Construction

Impacts on occupational health and safety during WWTP construction, as well as mitigation measures proposed to reduce them, are in all ways similar to those identified for the Networks' construction.

7.10.2 OPERATION PHASE

Networks Operation

Workers who will be in charge of the maintenance of the network will have to regularly inspect lifting stations where they will be exposed to gases, odors, insufficient ventilation, and microbiological hazards as well as potential fall or injury.

Mitigation measures are similar to those suggested for the WWTP operation below.

WWTP Operation

The WWTP will require 25 operating personnel under Phase I, and 29 under Phase II, in addition to 3 administrative/management personnel.

Wastewater treatment plant operators are typically exposed to a variety of hazardous chemical agents contained within the effluents and the reagents used in the wastewater processing or generated during the wastewaters treatment. These chemical agents may cause acute poisoning, chemical accidents (e.g., skin burns, injury to the eyes, etc.) damage to the respiratory system, allergies, dermatitis and chronic diseases. In addition, operators may be injured by slips, trips and falls on wet floors; falls into treatment ponds, pits, clarifiers or vats or splashes of hazardous liquids; they may also suffer cuts and pricks from sharp tools. Other common hazards include electric shock, explosions, entanglement in moving machinery, etc.

Accordingly, in the absence of mitigation measures at the operation phase, impacts on occupational health and safety can be **significant** in magnitude, and have **medium** likelihood of occurrence (**4B**).

The likelihood of impacts on public and occupational safety operation during operation can be significantly suppressed by the following mitigation measures:

- Restricting unattended public access to the wastewater treatment plants by proper fencing and guarding;
- Controlling movement of equipment and vehicles to and from the site;
- Properly labeling and storing chemicals (Chlorine gas or powder), oils, and fuel to be used on-sites;
- Emphasizing safety education and training for system staff and enforcing adherence to safety procedures set in and around the plant facility;
- Providing appropriate safety equipment, fire protection measures, and monitoring instruments;

- Providing hand railing at all access corridors above and around all open treatment units (except where sidewalls extend ≥1.1 meters above ground level);
- Properly rating electrical installations and equipment and, where applicable, protecting them for use in flammable atmosphere; and
- Providing sufficient lighting that should comply with zoning requirements.

As a conclusion, proper supervision, high workmanship performance, and provision of adequate safety measures will alleviate public and occupational risks.

By adopting the above proposed mitigation measures, impacts on occupational health and safety during operation are predicted to become **minor** with **medium** likelihood of occurrence (**2B**).

7.11 SUMMARY OF ENVIRONMENTAL IMPACTS BEFORE AND AFTER IMPLEMENTATION OF MITIGATION MEASURES

Identified and ranked impacts are summarized here. The Environmental Impact Assessment Matrix is provided in Table 7.4, under section 7.1.3 (page 166).

7.11.1 SUMMARY OF IMPACTS FROM NETWORKS' CONSTRUCTION AND OPERATION

Table 7.16 Summary of Networks' Construction and Operation Impacts Without Mitigation Measures in Place

Impact/Pathway	Water Resources	Air Quality	Acoustic Environment	Landscape	Land Use	Soil & Sediment	Biodiversity	Socio-Economic	Occupational H&S
Construction Phase									
General Construction Activities		2C	3C	2C	3B		3B		3B
Water Consumption	2B								
Oil Spills & Solid Waste Generation *(incl. sludge)*	3B								
Excavation and Trenching						3B			
Job Creation								6C	
Land Expropriation								2C	
Traffic Generation								4A	
Operation Phase									
General Operation	6C		1A			6B	6B		4B
Oil Spills	3B								
Wastewater Leakages	3A								
Public Health								6C	

Table 7.17 Summary of Networks Construction and Operation Impacts With Mitigation Measures

Impact/Pathway	Water Resources	Air Quality	Acoustic Environment	Landscape	Land Use	Soil & Sediment	Biodiversity	Socio-Economic	Occupational H&S
Construction Phase									
General Construction Activities		1B	2C	1C	2A		2A		2A
Water Consumption	1B								
Oil Spills & Solid Waste Generation	2A								
Excavation and Trenching						2A			
Job Creation								6C	
Land Expropriation								1C	
Traffic Generation								2A	
Operation Phase									
General Operation						6B	6B		2B
Oil Spills	2A								
Wastewater Leakages	2A								
Public Health								6C	
Cultural Heritage								6C	

7.11.2 SUMMARY OF IMPACTS FROM WWTP'S CONSTRUCTION AND OPERATION

Table 7.18 Summary of WWTP Construction and Operation Impacts Without Mitigation Measures

Impact/Pathway	Water Resources	Air Quality	Acoustic Environment	Landscape	Land Use	Soil & Sediment	Biodiversity	Socio-Economic	Occupational H&S
Construction Phase									
General Construction Activities		2C	3C	2C			3C		3B
Water Consumption	2A								
Oil Spills & Solid Waste Generation	3B					3B			
Excavation and Trenching						3B			
Dredging Works (Phase II)	3C					3C			
Job Creation								6C	
Traffic Generation								4A	
Operation Phase									
General Operation (Phase I)	6B		1A				6B		4B
General Operation (Phase II)	6C		1A	3C			6B		4B
Plant Failure Conditions	2B								
Water Consumption	3C								
Oil Spills	3A								
Wastewater Leakages	4A								
Odor Generation		2B							
Solid Waste/Sludge Generation						1A			
Power Generation & Sludge Treatment		3B							
Public Health								6C	
Job Creation								6C	

Table 7.19 Summary of WWTP Construction and Operation Impacts With Mitigation Measures

Impact/Pathway	Water Resources	Air Quality	Acoustic Environment	Landscape	Land Use	Soil & Sediments	Biodiversity	Socio-Economic	Occupational H&S
Construction Phase									
General Construction Activities		1B	2C	1C			1A		2A
Water Consumption	1A								
Oil Spills & Solid Waste Generation *(incl. sludge)*	2A					2A			
Excavation and Trenching						2A			
Dredging Works (Phase II)	2B					2B			
Job Creation								6C	
Land Expropriation									
Traffic Generation								2A	
Operation Phase									
General Operation (Phase I)	6B		1A				6B		2B
General Operation (Phase II)	6C		1A	2C			6B		2B
Plant Failure Conditions	2A								
Water Consumption	2B								
Oil Spills	2A								
Wastewater Leakages	2A								
Solid Waste/ Sludge Generation						1A			
Odor Generation		1B							
Power Generation & Sludge Treatment		2B							
Public Health								6C	
Job Creation								6C	

7.12 POTENTIAL IMPACTS ON THE PROJECT

7.12.1 IMPACTS FROM CLIMATE CHANGE

The Project, especially under Phase II of the WWTP upgrade component, may be impacted by climate change-induced sea level rise. Impacts would mainly relate to interferences with the sea outfalls and increased coastal erosion.

Adaptive measures include structural interventions such as dikes, breakwaters, flap gates, etc.; and the continuous monitoring of the long sea outfall while it is being used.

It is recommended that this impact be more duly analyzed as part of an updated EIA study specific to reclamation activities prior to the start of Phase II.

7.12.2 IMPACTS FROM AIRPORT EXTENSION

As previously mentioned, the land surrounding the plant (on shore) has been expropriated by the Airport Authorities for security reasons and for possible future extension of airport facilities. Nevertheless, the ongoing Feasibility Study has confirmed that this area is not planned for the development of any specific facilities under the official Master Plan for airport extension. Nevertheless, continuous coordination with local authorities and the Civil Aviation Authority is needed to avoid conflicting plans, also when planning for land reclamation.

8 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

This Environmental and Social Management Plan (ESMP) addresses the framework for the mitigation of impacts identified in the Impact Assessment, and proposes the following:

- Mitigation measures to be implemented during the project's construction and operation phases;
- References to control guidelines and standards;
- Responsibilities for the implementation of the plan;
- Verification, monitoring and training requirements;
- Reporting requirements; and
- Overall cost estimates for mitigation measures and monitoring, whenever possible/applicable.

The overall objectives of the ESMP are to ensure Project compliance with environmental legislation, EU standards and proponent's requirements, and to provide the client and the contractors with clear and specific guidelines to undertake the appropriate monitoring activities and compliance inspection programs. The ESMP may be subject to updates and modifications by the project proponent throughout the Project lifetime.

8.1 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

Mitigation measures identified in the impact analysis are summarized in this section. They are presented under separate tables for the Networks Construction (Table 8.1), the WWTP Construction (Table 8.2), the Networks Operation (Table 8.3), and the WWTP Operation (Table 8.4).

Table 8.1 Construction Environmental and Social Management Plan (CESMP) – **Networks**

IMPACTED VEC	PROJECT ACTIVITY (IMPACT/ PATHWAY)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Water resources	Water consumption	▪ Adopting Water Saving Techniques ▪ Raising Construction Workers' Awareness	Implementation: Contractor / Supervision: Supervision Consultant	Included in contractor cost
	Oil spills and solid waste generation	▪ Carrying out rehabilitation (reinstatement of soil, surface leveling, re-vegetation and mulching) of disturbed areas as soon as practicable and mmediately remediating any localized erosion ▪ Adopting and implementing IFC guidelines for the prevention and control of hydrocarbon / chemical releases ▪ Promoting "good housekeeping" practices ▪ Storing fuel, oil and chemicals in specifically designed areas on site, on an impermeable base within a suitability contained area ▪ Ensuring availability of oil spill response kits on the work area ▪ Installing drip trays underneath equipment to contain leakages ▪ Developing a spill contingency plan ▪ Installing drainage systems and erosion and sediment controls in case of a cross over a river or a stream, at the crossover between the network and the river, prior to commencement of construction and earth clearing ▪ Collecting and reusing or disposing of appropriately all used oils generated on the construction site.	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Air quality	General construction	▪ Using well designed, well maintained and well operated equipment/vehicles ▪ Employing environmentally friendly equipment (higher fuel efficiency, air pollution control devices …). ▪ Installing diesel particulate filters on construction equipment ▪ Watering-down work area/s particularly near sensitive receptors ▪ Efficiently scheduling deliveries and enforcing appropriate speed limits (< 40 km/h) ▪ Travelling on existing and paved tracks wherever possible ▪ Maintaining stockpiles at minimum heights and in the optimum shape (i.e.	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost

IMPACTED VEC	PROJECT ACTIVITY (IMPACT/ PATHWAY)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
		Stabilization) to reduce wind erosion. ▪ Installing covers on back loads of dump trucks and large vehicles		
Acoustic environment	General construction	▪ Equipping all equipment with intake and exhaust mufflers ▪ All vehicles and machinery should be maintained in good repair ▪ Any machinery, which is intermittent in use, should be shut off in periods of non-use	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Landscape and land use	General construction	▪ Relocating any affected trees to a different land with the same specification ▪ Preserving removed roots and avoiding damaging them	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Soil and sediments	Excavation and trenching works, oil spills, and solid liquid waste generation	▪ Adopting minimum safe operating widths and using existing tracks whenever possible ▪ Adhering to proper waste management practices ▪ Keeping all equipment well maintained and adopting a Spill Prevention and Response Plan	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Biodiversity	General construction	▪ Preserving excavated top soil and re-vegetating disturbed areas ▪ Raising the awareness of workers on the respect and preservation of wildlife ▪ Spreading excavated topsoil containing pollen and roots of the original vegetation upon completion of construction works ▪ Conducting a biodiversity assessment over the network routes prior to the start of works on networks	Implementation: Contractor Supervision: Supervision Consultant CDR	Biodiversity assessment: 30,000 USD *(assuming 2 field visit rounds - wet and dry season)*
Socio-economic	Land expropriation and general construction activities	▪ Establishing a consultative process with potential affected families (if any) ▪ Ensuring fair and full compensation as per the Lebanese expropriation law ▪ Developing and "Archaeological Intervention Plan" in coordination with the DGA	CDR, DGA	To be determined
Occupational health and safety	General construction	▪ Provision and maintenance of appropriate Personal Protective Equipment (PPE) ▪ Warning staff about potential construction hazards ▪ Ensuring that qualified and accessible first-aid is provided at all times ▪ Posting signs throughout the construction area	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost

Table 8.2 Construction Environmental and Social Management Plan (CESMP) – **WWTP**

IMPACTED VEC	PROJECT ACTIVITY (IMPACT/ PATHWAY)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Water resources	Water consumption	▪ Adopting Water Saving Techniques ▪ Raising Construction Workers' Awareness	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
	Oil spills and solid waste generation	▪ Carrying out rehabilitation (reinstatement of soil, surface leveling, re-vegetation and mulching) of disturbed areas as soon as practicable and immediately remediating any localized erosion ▪ Adopting and implementing IFC guidelines for the prevention and control of hydrocarbon / chemical releases *(International Finance Corporation's Environmental, Health, and Safety General Guidelines)* ▪ Promoting "good housekeeping" practices ▪ Storing fuel, oil and chemicals in specifically designed areas on site, on an impermeable base within a suitability contained area ▪ Ensuring availability of oil spill response kits on the work area ▪ Installing drip trays underneath equipment to contain leakages ▪ Developing a spill contingency plan ▪ Installing drainage systems and erosion and sediment controls in case of a cross over a river or a stream, at the crossover between the network and the river, prior to commencement of construction and earth clearing ▪ Collecting and reusing or disposing of appropriately all used oils generated on the construction site.	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
	Dredging activities	▪ Using Silt Curtains ▪ Reducing velocity of dredging ▪ Decreasing the time-frame over which the dredging operation is to take place ▪ Limiting dredging operations to calmer sea states ▪ Ensuring proper disposal of dredged material	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost

IMPACTED VEC	PROJECT ACTIVITY (IMPACT/ PATHWAY)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Air quality	General construction activities	Same mitigation measures as the ones suggested for the construction of the Networks: ▪ Using well designed, well maintained and well operated equipment/vehicles ▪ Employing environmentally friendly equipment (higher fuel efficiency, air pollution control devices ...). ▪ Installing diesel particulate filters on construction equipment ▪ Watering-down work area/s particularly near sensitive receptors ▪ Efficiently scheduling deliveries and enforcing appropriate speed limits (< 40 km/h) ▪ Travelling on existing and paved tracks wherever possible ▪ Maintaining stockpiles at minimum heights and in the optimum shape (i.e. Stabilization) to reduce wind erosion. ▪ Installing covers on back loads of dump trucks and large vehicles	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Acoustic environment	General construction activities	Same mitigation measures as the ones suggested for the construction of the Networks: ▪ Equipping all equipment with intake and exhaust mufflers ▪ All vehicles and machinery should be maintained in good repair ▪ Any machinery, which is intermittent in use, should be shut off in periods of non-use	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Landscape and land use	General construction activities	▪ Hoarding or boundary fencing around construction site ▪ Coordinating with the Directorate General of Land and Maritime Transport	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Soil and sediments	Land excavation and trenching works, oil spills, and solid and liquid waste generation	▪ Adhering to proper waste management practices ▪ Keeping all equipment well maintained and adopting a #	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
	Land reclamation/ dredging activities	▪ Using silt curtains ▪ Reducing velocity of dredging ▪ Decreasing the time-frame over which the dredging operation is to take place ▪ Confining dredging operations to calmer sea states	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost

IMPACTED VEC	PROJECT ACTIVITY (IMPACT/ PATHWAY)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Biodiversity	General construction	Same mitigation measures as the ones suggested for the construction of the Networks: ▪ Preserving excavated top soil and re-vegetating disturbed areas ▪ Raising the awareness of workers on the respect and preservation of wildlife ▪ Spreading excavated topsoil containing pollen and roots of the original vegetation upon completion of construction works ▪ Conducting a biodiversity assessment over the network routes prior to the start of works on networks	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost
Socio-economic context	Traffic generation and general construction activities	▪ Developing a traffic management plan ▪ Continuously liaising with local and the governmental authorities ▪ Allowing only certified and trained drivers to carry out transportation related activities ▪ Developing an "Archaeological Intervention Plan" in coordination with the DGA	Contactor Supervision consultant Municipalities Local committee	Included in contractor cost
Occupational health and safety	General construction	Same mitigation measures as the ones suggested for the construction of the Networks: ▪ Provision and maintenance of appropriate Personal Protective Equipment (PPE) ▪ Warning staff about potential construction hazards ▪ Ensuring that qualified and accessible first-aid is provided at all times ▪ Posting signs throughout the construction area	Implementation: Contractor Supervision: Supervision Consultant	Included in contractor cost

Table 8.3 Operation Environmental and Social Management Plan (OESMP) – **Networks**

Impacted VEC	PROJECT ACTIVITY (Impact/ Pathway)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Water resources	Wastewater leakages	▪ Installing pressure monitors on force mains to allow the early detection of leaks ▪ Conducting regular inspection and maintenance of electrical and mechanical components at pumping stations – Regular testing (monthly) of back-up power (generator) at pumping stations ▪ Installing an emergency flow line or bypass chambers to divert sewage flow in case repairs to the sewer are needed and the construction of emergency storage pond near lifting stations for storage of wastewater in case of pump failure ▪ Carrying out flushing and a CCTV program to observe gravity sewer condition and monitor changes every 5 years ▪ Implementing a comprehensive alarm system at the pump station, monitoring numerous parameters covering station operation and the status of standby generator system ▪ Immediately reporting any leakages to municipal/governmental representative and stopping the source of leak (close valve, seal pipe, seal hole or as appropriate)	Networks operator(s)	Quotations for standby generator, flow meters, H2S and wastewater quality monitoring and alarm system to be requested Regular maintenance activities: USD1,000/year
Occupational health and safety	Operation	▪ Providing appropriate safety equipment, fire protection measures, and monitoring instruments on-site ▪ Providing sufficient lighting that should comply with zoning requirements.	Networks operator(s)	Included in contractor cost

Table 8.4 Operation Environmental and Social Management Plan (OESMP) – **WWTP**

Impacted VEC	PROJECT ACTIVITY (Impact/ Pathway)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
Water resources	Plant failure conditions	▪ Proper management coupled with continuous and effective monitoring and maintenance ▪ The preparation, implementation and monitoring of an industrial pollution abatement	Plant operator(s)	Industrial pollution abatement plan: Preliminary survey:

Impacted VEC	PROJECT ACTIVITY (Impact/ Pathway)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
		program in the Al-Ghadir drainage area ▪ Ensuring redundancy in the WWTP design ▪ Ensuring adequate training of plant operators		~300,000 USD Implementation: to be determined
	Water consumption	▪ Adopting water saving techniques ▪ Proper training and awareness raising among personnel (especially in maintenance and cleaning)	Plant operator(s)	Included in operator cost
	Oil spills	▪ Same mitigation measures suggested to mitigate the risk of oil spills and leakages during construction ▪ Using secondary containment basins for long term storage of lubricants and fuels used on site	Plant operator(s)	To be determined
	Wastewater leakages	▪ Immediate reporting of leakage to municipal/governmental representative ▪ Stopping the source of leak (close valve, seal pipe, seal hole or as appropriate) ▪ Immediate cleaning of the spill by removing affected topsoil layer by trained employee	Plant operator(s)	Included in operator cost
Air quality	Odor generation	▪ Conducting odor simulation studies for pumping stations and the WWTP during the detailed design phase to confirm that emissions thresholds are met and that concentrations of odorous compounds (mainly H_2S and NH_3) remain below threshold values at the nearest receptors ▪ Executing a regular program of maintenance to prevent the clogging of the fine-diffusers or diffuser plates to maintain adequate dissolved oxygen levels in the aeration tanks ▪ Executing regular cleaning of aeration tank walls and floors, washing weirs, and removing scum regularly ▪ Increasing the pumping rate of the thickened sludge, monitoring a low sludge blanket level, and increasing the influent flow rate to the sludge-holding tank without losing thickening to reduce odors from final settlement tanks and sludge holding tanks ▪ Providing flow regulating chambers, drainage valves, standby pumps, as well as electric standby generators to reduce the possibility of wastewater flooding	Plant operator(s)	Odor simulation study: 10,000 USD
	Air pollution from power generation and sludge	▪ Maximizing the energy recovery potential to reduce project contribution to air pollution and to climate change	Plant operator(s)	Included in operator cost

Impacted VEC	PROJECT ACTIVITY (Impact/ Pathway)	MITIGATION MEASURES	INSTITUTIONAL RESPONSIBILITIES	COST ESTIMATE
	treatment	▪ Choosing efficient and low-emission equipment ▪ Monitoring the heating value of the gas to maintain a stable flare		
Acoustic environment	General Operation	▪ Placing possibly noisy equipment in isolated units ▪ Equipping all equipment with intake and exhaust mufflers ▪ Fencing and screening the site with a green belt to muffle any residual noise generation.	Plant operator(s)	To be determined
Occupational health and safety	General Operation	▪ Restricting unattended public access by proper fencing and guarding ▪ Properly labeling and storing chemicals (NaOCl, $NaHSO_3$), oils, and fuel to be used on-sites ▪ Providing hand railing at all access corridors above and around all open treatment units, (except where sidewalls extend ?1.1 meters above ground level); ▪ Providing appropriate safety equipment, fire protection measures, and monitoring instruments ▪ Providing sufficient lighting that should comply with zoning requirements. ▪ Preparing a fire protection and prevention program to be approved by the Government ▪ Ensuring that emergency action plan and fire hazard inspection procedures are available on-site at all times for all employees ▪ Training staff about the fundamentals of occupational health and safety procedures, and about handling hazardous material containers and related wastes.	Plant operator(s)	Included in operator cost

8.2 ENVIRONMENTAL AND SOCIAL IMPLEMENTATION PLAN

8.2.1 ROLES AND RESPONSIBILITIES

Specific roles and responsibilities are defined in this section and outlined under an ESMP Implementation Plan (Table 8.5).

Table 8.5 ESMP Implementation Plan

INSTITUTION/BODY	ROLES AND RESPONSIBILITIES
Council for Development and Reconstruction (CDR)	Overall responsibility over the implementation of the EMP during construction
Beirut and Mount Lebanon Water and Wastewater Establishment (BMLWWE)	▪ Supervision and support in the WWTP operation ▪ Ensuring regular monitoring of treated effluent, keeping record of analysis results, and intervening when needed ▪ Overall responsibility for the WWTP operation and networks operation
Municipality of Mreijeh - Tahouitat Al Ghadir - Laylakeh and other municipalities within the drainage area	Monitoring of ESMP implementation during construction and operation
Ministry of environment (MoE)	▪ Ultimately approving EMP reports ▪ Informing supervision consultants in case of additional environmental requirements to be followed ▪ Conducting site audits as needed to check implementation of EMP
Ministry of Transportation (MoT)	Monitoring and coordinating the implementation of a Traffic Management Plan
Lebanese Civil Aviation Authority (LCAA)	▪ Ensuring safety procedures are met during construction and operation ▪ Coordinating and approving of extension plans
Directorate General of Antiquities (DGA)	Coordinating and supervising “Archaeological Intervention Plan”
Engineering consultant(s)	Ensuring EIA findings and EMP considerations are properly taken into consideration in the detailed engineering design and properly integrated in the tender documents for contractors
Contractor	▪ Preparing a Construction Environmental Management Plan (CEMP) that details how the contractor shall implement the provisions of the EMP ▪ Providing a field HSE officer to ensure implementation of the CEMP ▪ Liaising with supervision consultant and regularly reporting on EMP implementation ▪ Immediately reporting to supervision consultant in case of accidents, spills or other events which have health, safety or environmental implications ▪ In case of incidents, contractors should fill an incident records form, including how the incident is planned to be addressed
Supervision consultant(s)	▪ Supervising the contractor's implementation of the CEMP ▪ Preparing a checklist to be used to supervise contractor’s works ▪ Reviewing and approving contractor’s CEMP ▪ Coordinating with the MoE to ensure appropriate reporting of EMP implementation

INSTITUTION/BODY	ROLES AND RESPONSIBILITIES
	▪ Identifying training needs of concerned parties to ensure EMP requirements are well-understood and can be implemented
Local committee	▪ Following up on the project implementation ▪ Liaising between the local community and the project proponent (through engineering consultant and/or supervision consultant) regarding EMP implementation ▪ Following up on any complaints and responding to them/ seeking prompt solutions in coordination with the municipalities and the BMLWWE

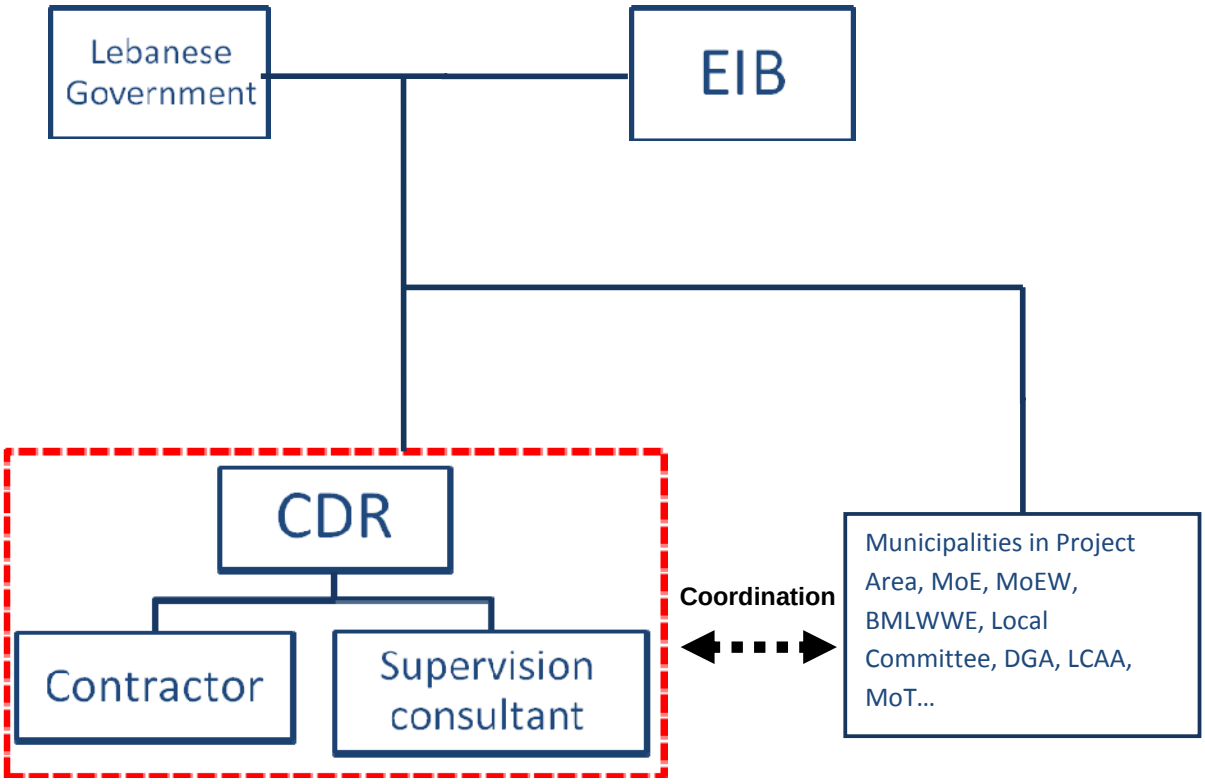


Figure 8–1 Institutional Setup for EMP Implementation

8.2.2 CAPACITY BUILDING NEEDS

8.2.2.1 TRAINING NEEDS DURING THE CONSTRUCTION PHASE

In order to ensure a proper and effective implementation of the CEMP, it is particularly important to undertake a training program for the contractor regarding its preparation and implementation. Training sessions for the contractor should be conducted prior to the commencement of the construction works and shall focus on the following topics:

- Preparation and implementation of CESMP;
- Implementation of CDR's HSE guidelines;
- Air pollution control;
- Control of leakages;
- Water Consumption;
- Solid Waste Management;
- Traffic Management Plan; and
- Emergency plan.

8.2.2.2 TRAINING NEEDS DURING OPERATION PHASE

It is recommended to train the WWTP's operation and maintenance personnel on:

- The WWTP components and operation process;
- Odor control/management;
- Operation and maintenance requirements;
- Types of hazards associated with its operation and measures to be taken;
- How to act in case of Emergency (overflow/ network leakage/ shutdown/ health and security emergencies…);
- Management of solid waste generated (sludge, harvested reeds, and waste from the screen cleaning);
- Oil spill and wastewater leakages prevention and control; and
- Chemicals handling and storage.

8.2.3 ENVIRONMENTAL MONITORING PLAN

The monitoring component is of particular importance in identifying successfulness of mitigation measures formulated for the significant impacts identified. A Construction and Operation Monitoring Plan shall thus be developed to include parameters to be monitored, frequency of monitoring, and responsibilities, in a format similar to that of Table 8.6.

Table 8.6 Construction and Operation Monitoring Plan

ENVIRONMENTAL COMPONENT	PARAMETERS	FREQUENCY	LOCATION	RESPONSIBILITY	ESTIMATED UNIT COST (USD)	ESTIMATED TOTAL COST(USD)
DURING CONSTRUCTION						
Traffic Flow	Number of days of road diversions due to the construction of networks on major and minor roads	Monthly	All roads to be crossed by wastewater networks		N.A.	N.A
Ambient Air Quality	Dust emissions: TSP + PM10 and PM2.5	Continuous	Construction Site	Site HSE officer		Depending on length of construction period
Noise Levels	Leq, Lmax, Lmin (dBA)	Spot monitoring near sensitive receptors, and upon receiving complaints	Construction Site	Site HSE officer	USD 1,250/month	Depending on length of construction period
Solid waste	Waste Type Quantity of generated waste (kg/tons) Methods of disposal Waste transported for offsite reuse/recycle	Daily	Construction Site	Site HSE officer	N.A.	N.A
Health safety environment and Hygiene	Proper PPE use Good housekeeping practices	Continuous	Construction site	Site HSE officer	N.A.	N.A
DURING OPERATION						
Ambient Air Quality	Number of complaints about odors	Daily/monthly during operation	Ghadir area Pumping stations	Local Committee	N.A.	N.A

ENVIRONMENTAL COMPONENT	PARAMETERS	FREQUENCY	LOCATION	RESPONSIBILITY	ESTIMATED UNIT COST (USD)	ESTIMATED TOTAL COST(USD)
Noise Levels	Leq, Lmax, Lmin (dBA)	Monthly	WWTP area		USD 1,250/month	
Treated Effluent Quality	pH, Temperature, color, Dissolved Oxygen, Suspended Solids	Daily	Treated effluent at the outlet	BMLWWE Plant Operator(s)	Included in operational costs (laboratory on-site)	Included in operational costs (laboratory on-site)
	COD, BOD, Ammonia, Phosphate, Alkalinity	Weekly	Treated effluent at the outlet	BMLWWE Plant Operator(s)		
	Nitrates, Sulphates, Surfactants, Phenols, Cyanides, Tannins	Monthly	Treated effluent at the outlet	BMLWWE Plant Operator(s)		
	E.Coli/100ml Fecal coli/100ml Helminth eggs/l	Twice/month	Treated effluent at the outlet	BMLWWE Plant Operator(s)		
	Metals (Al, Bo, Cd, Cr, Cu, Fe, Pb, K, Si, Mn, Mo, Ni, Se, Va, Zn, Hg)	Twice/year	Treated effluent at the outlet	BMLWWE Plant Operator(s)		
Sludge Quality	Dry and organic matter	Four times/year	Sludge produced at the WWTP	BMLWWE Plant Operator(s)		
	Heavy metals (As, Cd, Cr, Cu, Pb, Hg, Zn)	Four times/year	Sludge produced at the WWTP	BMLWWE Plant Operator(s)	Included in operational costs (laboratory on-site)	Included in operational costs (laboratory on-site)
	Primary nutrients (N, NH4-N, P, K) and secondary nutrients (Ca, Mg, S, Na and oligoelements)	Four times/year	Sludge produced at the WWTP	BMLWWE Plant Operator(s)		
	Organic compounds (AOX, PAH, PCB, PCDD/F)	Yearly	Sludge produced at the WWTP	BMLWWE Plant Operator(s)		
	Pathogen microorganisms (Fecal coliforms, E. Coli…)	Four times/year	Sludge produced at the WWTP			

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10 ANNEXES

ANNEX 1 - MAP OF EXISTING AND PLANNED NETWORKS-IN THE GHADIR DRAINAGE AREA

ANNEX 2 - PROPOSED WWTP LAYOUT

ANNEX 3 - SECTION DRAWING OF RECLAMATION WORKS

ANNEX 4 - PUBLIC CONSULTATION MEETINGS: INVITATION LETTERS AND FLYERS

ANNEX 5 - PUBLIC CONSULTATION MEETINGS - LIST OF INVITEES

ANNEX 6 - PUBLIC CONSULTATION MEETINGS: PRESENTATIONS IN ARABIC AND ENGLISH

ANNEX 7 - LIST OF ESIA PREPARERS

Ramez KAYAL	Senior Peer Reviewer Senior Geologist / Hydrogeologist
Ricardo KHOURY	Senior Peer Reviewer Senior Environmental Engineer
Manal KAHI	ESIA Coordinator Environmental Specialist
Nathalie MEDAWAR	Environmental Specialist
Cady NASR	Environmental Specialist
Rachad GHANEM	Senior Geologist / Hydrogeologist
Basma SHAMAS	Geologist
Bilal IDRIS	Hydrogeologist
Wafa HALABI	Socio-economist / Ecologist

EXPANSION AND UPGRADE OF AL-GHADIR WASTEWATER TREATMENT PLANT PROJECT – PHASE I: DESIGN, BUILD AND OPERATE, INCLUDING TWO NEW SEA OUTFALLS AND INSPECTION & ASSESSMENT OF EXISTING SEA OUTFALLS

PART 5 – OTHER INFORMATION

BOOK 1/2

SECTION XIII – DESIGN REPORT FOR WWTP

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

REPUBLIC OF LEBANON

COUNCIL FOR DEVELOPMENT AND RECONSTRUCTION

CONSULTANCY SERVICES FOR PRELIMINARY DESIGN, PREPARATION OF DESIGN-BUILD TENDER DOCUMENTS AND CONSTRUCTION SUPERVISION SERVICES OF

"EXPANSION AND UPGRADE OF AL-GHADIR WASTEWATER TREATMENT PLANT PROJECT"



DESIGN REPORT

MARCH 2025

DAR AL HANDASAH NAZIH TALEB & PARTNERS
دار الهندسة نزيه طالب وشركاه
Founded 1956

ARTELIA

TABLE OF CONTENT

CHAPTER 1 INTRODUCTION

CHAPTER 2 DATA COLLECTION

CHAPTER 3 TOPOGRAPHIC SURVEY

CHAPTER 4 GEOTECHNICAL INVESTIGATION

CHAPTER 5 WASTEWATER SAMPLING AND TESTING

CHAPTER 6 REVIEW OF THE FEASIBILITY STUDY

CHAPTER 7 DESIGN CRITERIA AND PROCESS DESCRIPTION

CHAPTER 8 PROCESS CALCULATION

CHAPTER 9 SOIL TREATMENT

CHAPTER 10 REHABILITATION OF THE EXISTING WWTP (CIVIL WORKS)

CHAPTER 11 ACCESS AND CONNECTION OF THE TWO SITES OF THE WASTEWATER TREATMENT PLANT

CHAPTER 12 POW OF THE EXECUTION OF THE FIRST PHASE (INCLUDING O & M)

QC	Ref: L2401DS / 3952	
	Revision: (00)	Date: March 5, 2025
	Signature:	

CHAPTER 1 INTRODUCTION

Chapter 1 – Introduction

Table of Content

Chapter 1 Introduction 1

1.1 Project Background 1

1.2 Location, General Geography and Access to Site 1

1.3 Drainage Area and Population Served 2

1.4 Scope of Work and Project Phasing 3

1.5 General Consultant Scope of Work and Deliverables schedules 7

1.6 Draft Tender Documents Objectives 8

List of Figures

Figure 1.1 Aerial View of the Ghadir Preliminary Treatment Facility and Project Location 1

Figure 1.2 Ghadir WWTP Drainage Area 2

Figure 1.3 Ghadir Preliminary Treatment Facilities 4

Figure 1.4 Construction Phases for Ghadir WWTP 6

Figure 1.5 Backfill Progress in the Ghadir WWTP reclaimed area 7

List of Tables

Table 1.1 Deliverables Schedule 8

Chapter 1 Introduction

1.1 Project Background

The Ghadir Wastewater Treatment Plant (GWWTP) has had a preliminary facility and sea outfall operational since 1990's. However, it has been out of service since July 2022 due to insufficient maintenance since 2018. Critical civil and electromechanical repairs are currently underway to restore the plant to minimum operational capacity. The existing facility covers about 21,500 m², with public land area of 31,300 m².

This wastewater treatment plant processes wastewater from a drainage area of 175 km², serving 44 municipalities across parts of Beirut, Baabda, and Aley Cazas (Refer to Figure 1.2).

In order to cater for planned increase flows due to network construction as well as to meet the stringent requirements of the Mediterranean Hot Spot Investment Program (MeHSIP), CDR has planned for an upgrade and capacity extension of the said GWWTP, in 2 phases:

- First phase consisting of capacity extension from 140,000 m^3/d up to 282,459 m^3/d (design year 2050) and upgrade of treatment level from preliminary to primary in addition to sludge treatment, power generation and odor control,
- Second phase consisting of the treatment level upgrade from primary to secondary.

It is important to note that the existing site is insufficient for the full expansion and upgrade of the wastewater treatment plant. Therefore, a newly reclaimed area of approximately 131,850m², located on the opposite side near the landfill, will be utilized for constructing the additional plant components (see Figure1.4). This area was reserved during the 2013 feasibility study and doesn't require any expropriation.

For this, the Government of Lebanon has received financing for the first phase from Islamic Development Bank (IsDB) and will be calling for internal bid from reputable contractor to submit their offer for the extension and upgrade of Ghadir Wastewater Treatment Plant.

1.2 Location, General Geography and Access to Site

Al-Ghadir preliminary wastewater treatment facility is located about 7 Km south of Beirut, at the direct proximity of the Beirut International Airport. The approximate stereographic coordinates at the center of the WWTP are X: -339421.906 and Y: - 36805.945 (Figure 1.1).



Figure 1.1 Aerial View of the Ghadir Preliminary Treatment Facility and Project Location

The preliminary WWTP was considered suitably distant from residential areas at the time of construction. However, the proximity to the Airport has entailed certain limitations on extension due to limited land availability and to airport security issues.

The site is accessible via Ouzaii main coastal Highway that connects Beirut to the southern regions of the country. The proximity to the highway allows convenient access for construction, maintenance, and operational personnel. Additionally, the plant's location near the coastline facilitates the discharge of treated wastewater into the sea through its sea outfall system.

1.3 Drainage Area and Population Served

The drainage area served by Ghadir WWTP is shown in the below figure:

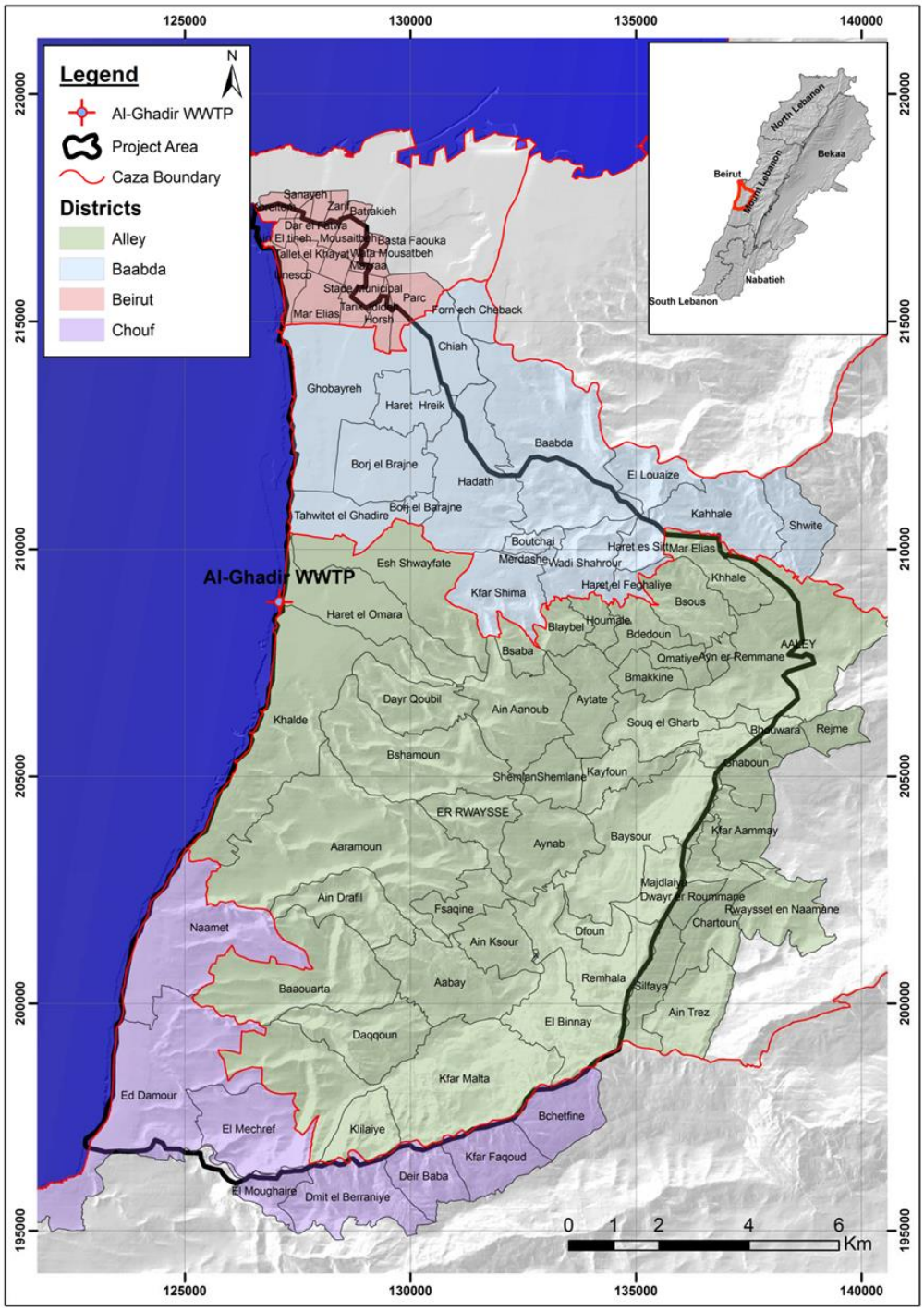


Figure 1.2 Ghadir WWTP Drainage Area

The WWTP parameters are presented hereafter:

Parameter	Ghadir WWTP
Equivalent Population served by the WWTP (Horizon year 2050)	1,722,312
Average Dry Daily Flow	282, 459m^3/day
Peak Hourly Dry Flow	16,316 m^3/h
Biochemical Oxygen Demand BOD_5(Influent)	360 mg/L
Chemical Oxygen Demand COD (Influent)	700 mg/L
Total Suspended Solids TSS (Influent)	450 mg/L
Total Kjeldhal Nitrogen	72 mg/L

1.4 Scope of Work and Project Phasing

The Project includes expanding the capacity of the existing preliminary WWTP from 140,000m^3/day to approximately 282,459m^3/day, and upgrading the treatment process from preliminary to primary level in phase I and to secondary level in phase II of the project. Additionally, the project will incorporate sludge treatment, power generation, and odor control measures.

The existing Ghadir plant consists of preliminary treatment works which include the following units:

- Inlet works of the incoming wastewater from the sewage networks and the tanker trucks
- Lifting station (Archimedean Screw Pumps)
- Automatic Coarse Screens with screenings compactor
- Grit and scum removal with grit classifiers
- Pumping station for the sea outfall equipped with three pumps: one in operation and two on standby to accommodate low flow conditions. It also includes space for a fourth pump to be added in the future to handle increased flow.
- Main sea outfall for discharging preliminarily treated wastewater into the sea, (DN 1200 extending 2,500 meters into the sea).
- Emergency sea outfall, for the discharge of untreated wastewater (DN 1500 extending 500 m into the sea); and
- Bypass/Overflow Facilities.
- Transformers/Generators



Lifting Station Unit Screw Pumps



Screening unit



Screening unit



De-gritting Unit (a) Grit classifier



Outfall Pumping Station



De-gritting Unit's aeration blowers

Figure 1.3 Ghadir Preliminary Treatment Facilities

In order to comply with the future flows and discharge requirements, set by Lebanese legislation and EU standards, the treatment scheme of this project will include the following components (Figure 1.4):

- **Phase 1**
  - Preliminary Treatment Unit, to include:
  - Refurbishment, capacity extension and upgrade of Initial Lifting Station;
  - Refurbishment, capacity extension and upgrade of Screening system to include additional fine screens and their ancillaries
  - Refurbishment, capacity extension and upgrade of Aerated De-gritting Chambers and their ancillaries
  - New Primary Treatment Unit (lamella settling tanks);
  - Primary Sludge Treatment Facilities, including:
  - Gravity Thickeners, for primary sludge (PS);
  - Sludge Screening, for primary sludge;
  - Buffering-Mixing tanks, for PS and SAS;
  - Anaerobic Digestion Treatment, for mixed sludge;
  - Mechanical Dewatering of digested sludge;
  - Storage of dewatered sludge.
  - Biogas Utilization Unit, including:
  - Biogas Collection and Storage;
  - Combined Heat - Power (CHP) Engines, for power production;
  - Emergency Flaring Station.
  - Odor control
  - SCADA
  - Electrical System

- **Phase 2**
  - Secondary Treatment Unit, including:
    - Anoxic tanks and their ancillaries;
    - Aeration tanks and their ancillaries;
    - Secondary Settling Tanks and their ancillaries;
    - Chlorination/de-chlorination tanks and their ancillaries.
  - Secondary Sludge Treatment consisting of:
    - Mechanical Thickening, for surplus activated sludge (SAS);
    - Buffering-Mixing tanks, for PS and SAS (extension of phase 1);
    - Anaerobic Digestion Treatment, for mixed sludge (extension of phase 1);
    - Mechanical Dewatering of digested sludge (extension of phase 1);
    - Storage of dewatered sludge (extension of phase 1)
  - Upgrade of Biogas Utilization Unit, including:
    - Biogas Collection and Storage (extension of phase 1);
    - Combined Heat - Power (CHP) Engines, for power production (extension of phase 1);
    - Emergency Flaring Station (extension of phase 1).
  - Odor control (extension of phase 1)
  - SCADA (extension of phase 1)
  - Electrical system (extension of phase 1)

The WWTP will use the Conventional Activated Sludge Process with sludge treatment and anaerobic digestion and power generation. In addition to the process equipment mentioned earlier, the following service buildings shall be included as a minimum:

- Influent lifting station building extension
- Treated Sewage Effluent pumping building refurbishment
- Intermediate pumping station (the transfer of the primary effluent to the biological treatment)
- RAS/SAS pumping stations
- Air blowers building
- Influent/effluent distribution chambers, Flow Measurement systems
- Sludge Dewatering building
- Sludge Stocking silos
- Services Building: administration, workshop, guardhouse, accommodation, chlorination, etc.
- Standby Power Generation Facilities, Transformer Room (medium/low voltage), connection to the Public Power Grid
- Supervisory Control and Data Acquisition (SCADA) system
- Landscaping, access roads inside and outside the site, mainly access road between the existing plant location and secondary treatment site.
- Works return pumping station.

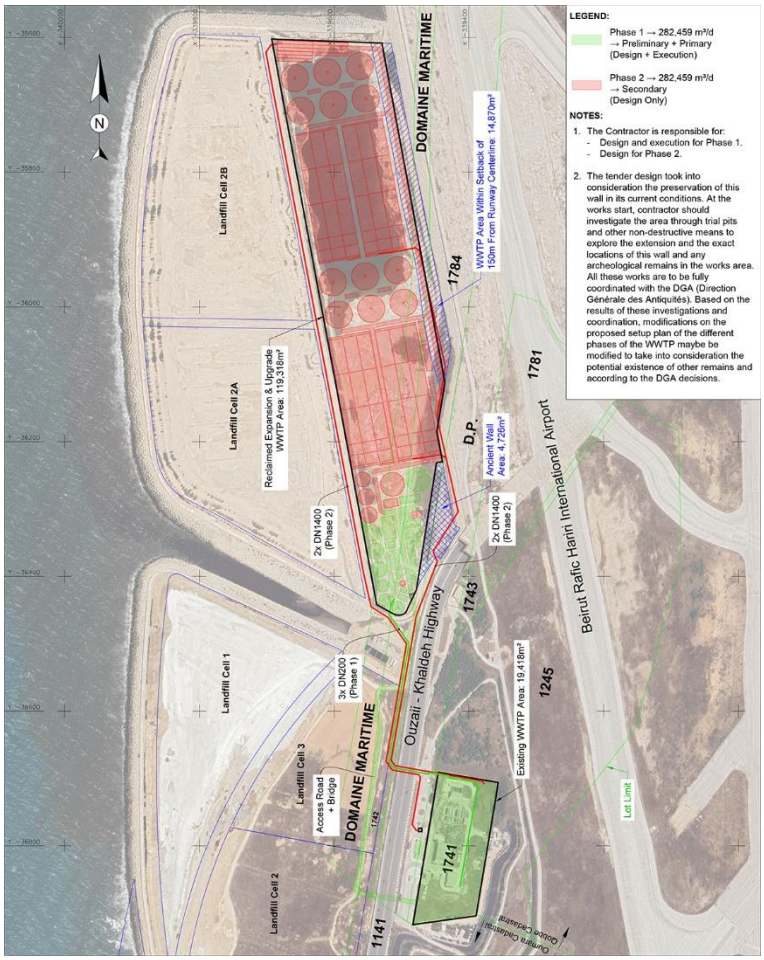


Figure 1.4 Construction Phases for Ghadir WWTP

Backfilling and Soil Treatment Phasing:

In the Terms of Reference (TOR), it was expected that the solid waste contractor would complete backfilling of the reclaimed land to a level of +2m. However, progress has been delayed due to financial issues, as illustrated in Figure 1.5below. Consequently, discussions were held with the client and funder to consider the option of bringing in an intermediate contractor for backfilling the entire area to +2m and for soil treatment for Phase 1 (or phase 1 and 2) of the reclaimed area. The wastewater treatment plant (WWTP) contractor will then focus exclusively on tasks related to the WWTP. To support this, the consultant has provided the relevant tender documents, including a cost estimate for the earthworks, to aid in decision-making process. Following CDR's review of these documents, the general approach is to proceed with a single tender and one contractor for both the Earthworks and the WWTP, as stated by CDR in the meeting on November 12, 2024. This approach takes into account that the current landfill contractor will hand over the WWTP reclaimed land at a level of +2m, as specified in his scope of work.

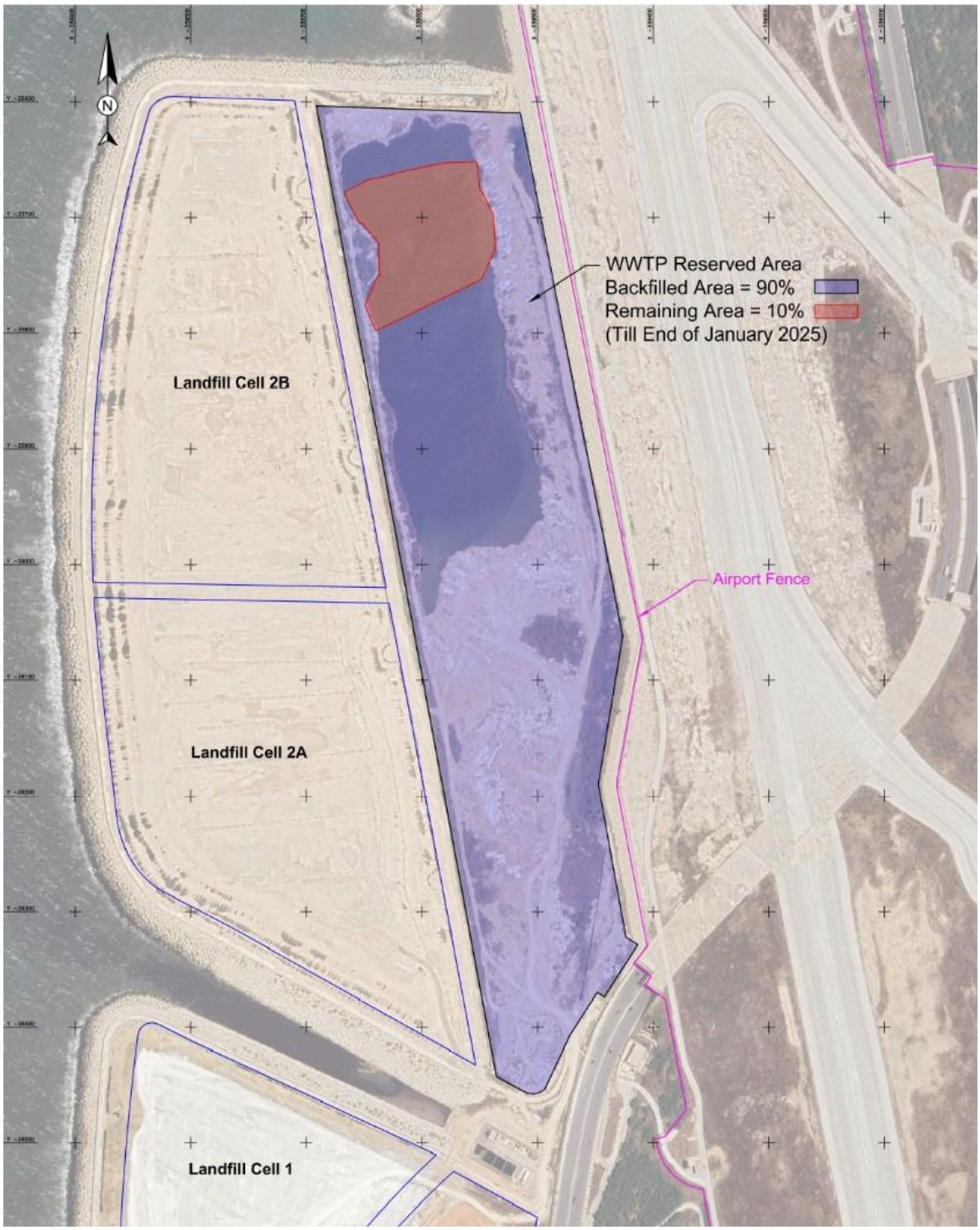


Figure 1.5 Backfill Progress in the Ghadir WWTP reclaimed area (End of Jan. 2025)

1.5 General Consultant Scope of Work and Deliverables schedules

According to TOR sections I.2 and II, the scope of works for "Expansion and Upgrade of Al-Ghadir WTTP Project" can be divided into three main parts:

- Preliminary Design.
- Design-Build Tender Documents.
- Supervision of the project, including assisting CDR during tendering for construction works.

The deliverables schedule shall be submitted as outlined in the signed TOR and as confirmed during the negotiation meeting on May 16, 2022:

Table 1.1 Deliverables Schedule

Deliverables	% of man/month	Schedule
1- Preliminary Design Report	10%	ND* + 2 months
2-Draft Final Design Report, Field Topographical Survey and Expropriation Documents	20%	ND* + 3 months
3-Draft Tender Documents	20%	ND* + 6 months
4-Final Tender Documents	30%	ND* + 8 months
5-Final Design Report	10%	ND* + 12 months
6-Assistance During Tendering	10%	

*ND = Effective Notification Date (6 September 2024)

1.6 Draft Tender Documents Objectives

The tender documents, shall comply with the requirements of the FIDIC conditions of contract, relevant funding agency guidelines, and CDR requirements. The documents will be organized into five main volumes:

- Vol 0: Tender Procedure
- Vol 1: Conditions of Contract and Contract Forms
- Vol 2: Employer's Requirements
- Vol 3: Drawings
- Vol 4: Other Information

As outlined in the terms of Reference (TOR), the objectives of the draft Tender Documents are as follows:

- Provide clear instructions for Tendering Process.
- Setting out the obligations and responsibilities of the contractor.
- Enable the contractor to:
    - Produce shop drawings for all parts of the works.
    - Construct the entire scope of the works.

CHAPTER 2 DATA COLLECTION

Chapter 2 – Data Collection

Table of Content

Chapter 2 Data Collection 1

2.1 List of Data Collection Resources 1

2.1.1 Tender Documents for outfall pipes Rehabilitation for South Beirut Sea Outfall at Ghadir 2

2.1.2 Feasibility Study on Ghadir WWTP – Inception & Conception Reports – Final Version by CES & BTD, July 1998 2

2.1.3 Feasibility Study Report for the Extension of Al-Ghadir WWTP – Phase II: Part III Analysis of the selected scenario 2

2.1.4 Ghadir Outfall pretreatment Plant – Operation and Maintenance yearly Reports (24/11/97-23/11/2000) & (24/11/2000 to 22/8/2001) 4

2.1.5 As-Built Ouzai Road / Highway Wet and Dry Infrastructure Drawings 4

2.1.6 On Going Critical Civil and Electro-Mechanical rehabilitation works for the existing WTTP 4

2.1.7 Daily Inlet Flows to the WWTP measured by BMLWE for years 2017-2021 4

2.1.8 Wastewater testing results for year 2018 received from Beirut and Mount-Lebanon Water Establishment (BMLWE) in PDF files format 5

2.1.9 Landfill progress plans for proposed reclaimed land and solid waste landfills 5

2.1.10 Etude de l'impact des rejets de la station de traitement des eaux usées de Ghadir sur l'environnement marin 5

2.1.11 Cadastral Situation 6

2.1.12 Dar Site Visits & Water Operators Data 6

2.1.13 Laws about the airport nearby construction 6

List of Figures

Figure 2.1 Sketch of allowable heights for proposed WWTP structures in relation to the Airport. 6

List of Tables

Table 2.1 Project Phasing and Cost as per FS 3

Chapter 2 Data Collection

2.1 List of Data Collection Resources

Many documents and studies have been provided through Beirut and Mount Lebanon Water Establishment (BMLWE), Council for Development and Reconstruction and other associated parties (such as consultants…) regarding the Ghadir Wastewater Treatment Plant (WWTP). Below is a list of the documents and studies received in either soft copies (by email/CD) or hard copies:

- Tender Documents for outfall pipes Rehabilitation for South Beirut Sea Outfall at Ghadir – May 1996, developed by ACE.
- "Feasibility Study on Ghadir WWTP – Conceptual Study – Annex – Final Version" by CES & BTD, July 1998, in PDF format.
- "Feasibility Study on Ghadir WWTP – Inception Report – Final Version" by CES & BTD, July 1998, in PDF format.
- "Feasibility Study Report for the Extension of Al-Ghadir WWTP – Phase II: Part III Analysis of the selected scenario" by Atkins, April 2013, obtained from the Council for Development and Reconstruction (CDR) in PDF format.
- "Ghadir Outfall Pretreatment Plant - Operation & Maintenance Yearly Reports (24/11/97-23/11/2000) & (24/11/2000 to 22/8/2001)" provided to us by the Contractor, Subal Engineering, under the supervision of ACE, in pdf format.
- As-Built Ouzai Road / Highway wet and dry Infrastructure drawings, completed by Dar Shair on behalf of CDR, were provided to us through CDR in image file format.
- On going critical Civil and Electro-Mechanical rehabilitation works for the existing WWTP delivered to us by Beirut and Mount-Lebanon Water Establishment (BMLWE) in excel BOQ format.
- Daily Inlet Flows to the WWTP measured by BMLWE for years 2017-2021.
- Wastewater testing results for year 2018 received from Beirut and Mount-Lebanon Water Establishment (BMLWE) in PDF files format.
- Landfill progress plans and files obtained from the contractor of Ghadir Sanitary Landfill "Jihad El Aarab," primarily for the proposed reclaimed land (approximately 131,850m²) designated for the expansion and upgrade of the Ghadir WWTP, as well as for solid waste landfills, provided in ACAD, PDF, and Excel formats.
- "Etude de l'impact des rejets de la station de traitement des eaux usées de Ghadir sur l'environnement marin" received from CDR in PDF format.
- Cadastral Situation,
- Dar Site Visits and Data Collected from water operator (General Layout for Ghadir Pretreatment Plant received on site as hard copy, Catalogs for some equipment, General data on buildings, pumps and generators…),
- Laws about the airport nearby construction.

2.1.1 Tender Documents for outfall pipes Rehabilitation for South Beirut Sea Outfall at Ghadir

The tender documents for the CCTV investigation and rehabilitation of outfall and overflow pipes at the South Beirut Sea outfall in Ghadir were prepared by ACE in May 1996. These documents primarily include all the necessary remedial works for the sea outfall pipes, including:

- Contract conditions, along with Safety, Health, and Environmental Regulations
- General and specific specifications
- Bill of Quantities and Dayworks schedule.

2.1.2 Feasibility Study on Ghadir WWTP – Inception & Conception Reports – Final Version by CES & BTD, July 1998

Inception Report:

An inception report on Ghadir WTTP was prepared by CES & BTD in July 1998 including the following chapters or sections:

- Introduction,
- Previous Studies and information,
- Characteristics of the project area (Bathymetric, geological, hydrogeology, socio-economy…)
- Existing and proposed urban drainage, sewer and sea outfall treatment systems
- Analysis of urban drainage systems and treatment systems,
- Financial performance of water and sewer sectors,
- Recommendations for future concept alternatives.

Conceptual Study:

Based on the above inception report, a conceptual study on Ghadir WTTP was prepared by CES & BTD in July 1998 and includes the following chapters or sections:

- Environmental assessment and ecological survey,
- Socio-Economical Study
- Urban Development till year 2040
- Wastewater measurement and analysis
- Sea Outfall survey and modelling
- Cost (Investment, operation and maintenance),
- Industrial Wastewater,
- Sludge disposal and use,
- Maps.

2.1.3 Feasibility Study Report for the Extension of Al-Ghadir WWTP – Phase II: Part III Analysis of the selected scenario

A feasibility study for Ghadir WTP extension / upgrading and development of sewer networks inside Ghadir WTP drainage area was financed by EIB (in 2013), in collaboration with CDR & MOEW. Here below the main findings of this concerned study:

- Ghadir Drainage Area (44 zones) Population and Needs:

year	Equivalent Population	Average Needs (m^3/s)	Peak Needs (m^3/s)
2050	1,913,680	Dry: 3.27m^3/s & Wet: 3.87m^3/s	Dry: 4.53m^3/s & Wet: 5.13m^3/s

  - The layout of the plant, for its expansion and upgrade, will be limited to the existing plot along with the newly reclaimed area of approximately 130,000 m². Currently, the plant consists solely of preliminary treatment facilities.
  - For the existing WWTP, a visual inspection of the electromechanical works indicates signs of aging such as corrosion, fatigue, and erosion. Specific items, including the SCADA System and electrical control panels, require replacement or intensive maintenance. Lack of emergency stop switches and spare parts has also been observed.
  - CAS (Conventional Activated Sludge with primary settling tanks) technology was selected as the best treatment option for Ghadir WWTP secondary upgrade out of 6 analyzed processes.
  - The WWTP will discharge the drainage area sewer flow of year 2050, assuming industrial compliance with ELVs, necessitating on-site pre-treatment by industries.
  - The sea outfalls system assessment should be done by CDR prior to the project and may cause delays in project planning and budget.
  - The annual operation cost for CAS WTP treatment ranges from 1.5MUSD (2017) to 19.6MUSD (2050).

- Ghadir Phasing and cost (Table 2.1):

Table 2.1 Project Phasing and Cost as per FS

Phases	Tendering Design, Construction	Year in Operation	Description of Tasks	Estimated Cost (USD)
Phase Ia	2014 - 2017	2017	Immediate priority networks and similar works (connect existing mains with Ghadir plant, separate stormwater flows, details given in the report "Preliminary assessment of sewer and stormwater networks of the area in relation with Carlton – Ghadir, Ghadir river, and Qassis conveyors" submitted as part of the survey)	32 Million
	2015 – 2017 2017 – 2018 (DLP)	2018	Extend the capacity of the existing preliminary work at the al-Ghadir wastewater treatment plant	16 Million
			Total estimated budget for Phase Ia	48 Million
Phase Ib	2015 – 2019	2019	Complete priority networks to cover 80% of the Ghadir drainage basin population (including the area to be served by KfW funded network)	49 Million
	2016 – 2019 2019- 2020 (DLP)	2020	Upgrade the wastewater treatment plant to primary treatment by the year 2020	66 Million
			Total estimated budget for Phase Ib	115 Million
			Total estimated budget for Phase I	163 Million
Phase II	2026 - 2030	2030	Upgrade the WTTP to secondary level of treatment	160 Million
	2025 - 2035	2035	Complete the remaining network to serve the total population of Ghadir WTTP drainage area	83 Million
			Total estimated budget for Phase II	243 Million
Total in Investment for the networks				164 Million
Total in Investment for the wastewater treatment plant				242 Million
Grand Total for Ghadir Drainage Area				406 Million

To be noted that this feasibility study was used as base for our project with some changes as will be described in Chapter 6.

2.1.4 Ghadir Outfall pretreatment Plant – Operation and Maintenance yearly Reports (24/11/97-23/11/2000) & (24/11/2000 to 22/8/2001)

Operation and maintenance yearly reports covering the period from November 1997 to August 2001 was prepared by the Operator, Subal, under the supervision of the Consultant, ACE. These reports primarily include:

- A description of the Plant and its operational procedures (both normal operations and shutdown of the WTTP during overflow).
- Observation and tests, which encompass:
  a. Min, Average and Max daily variation of flow for every month within this period,
  b. Maintenance activities conducted during the period,
  c. Results and analyses of Wastewater tests with min, average and max (Temp, PH, COD, BOD5, FOG, Heavy metals…),
  d. Seawater tests with min, max and average, …
  e. Screening and Sand Removal,
  f. Fuel and Power Consumption,
  g. Personnel.

2.1.5 As-Built Ouzai Road / Highway Wet and Dry Infrastructure Drawings

As-built drawings for Ouzaii Road/Highway were provided to us by CDR through the consultant, Dar Chair. These drawings include mainly:

- Potable Water Main Lines,
- Sewer Trunk and lines,
- Stormwater Drainage system and details,
- Drainage Plan,
- Electrical Layout,
- Street Lighting and Telephone Network,
- Road Sections and corridors.

2.1.6 On Going Critical Civil and Electro-Mechanical rehabilitation works for the existing WTTP

A BOQ file was received via BMLWE for the ongoing civil and electro-mechanical rehabilitation of existing structures and equipment, primarily focusing on the coarse screening and degritting facility, pumping facility, guardhouse, laboratory, 4 WCs and kitchen, and generator room. The project was prepared by the consultant, WET and funded by UNICEF. It is important to note that these works are minor or complementary works, aiming only to put the existing WWTP into preliminary basic service, rather than a major or full rehabilitation. It's worth noting that these minor rehabilitation works were affected and stopped due to the conflict in the country between September and November 2024.Daily Inlet Flows to the WWTP measured by BMLWE for years 2017-2021

2.1.7 Daily Inlet Flows to the WWTP measured by BMLWE for years 2017-2021

BMLWE provided the daily flow measurements recorded at the inlet of the WWTP (basing on the varying operation hours of screw pumps) for the years 2017-2021 in PDF format. The main findings are as follows:

- **Maximum recorded daily flow:** 116,580 m^3/d (January 17, 2021)

- **Minimum recorded daily flow:** 49,996 m^3/d (August 12, 2021)
- **Maximum monthly flow:** 2,588,134 m^3 (December 2021) ➔83,488 m^3/d
- **Minimum monthly flow:** 1,692,254 m^3 (August 2021)) ➔54,589 m^3/d
- **Yearly flow:** 24,447,545 m^3 ➔66,980 m^3/d

2.1.8 Wastewater testing results for year 2018 received from Beirut and Mount-Lebanon Water Establishment (BMLWE) in PDF files format

BMLWE supplied all available wastewater testing results for the Ghadir existing WWTP from the year 2018 in PDF format showing the evolution of each parameter over various time intervals as follows:

- **Daily Analysis Parameters** (at the inlet after lift station and at the outlet after the grit removal system): Temperature (OC), PH, Dissolved Oxygen DO (mg/l), Total Suspended TSS (mg/l). We observed that the TSS measured after the lifting station (IN) is not significantly different from the TSS measured after the grit removal system (OUT). This indicates that the screenings and grit removal system may not be operating efficiently or could be bypassed.
- **Weekly Analysis Parameters**: Chemical Oxygen Demand COD (mg/l), Biochemical Oxygen Demand BOD (mg/l), Ammonia (mg/l), Phosphates (mg/l), Alkalinity (mg/l) & Iron (mg/l).
- **Monthly Analysis Parameters**: Heavy metals (mg/l), Electrical Conductivity ((µS/cm).

2.1.9 Landfill progress plans for proposed reclaimed land and solid waste landfills

A variety of documents and drawings have been provided by the solid waste contractor, Jihad El Arab, under the supervision of the consultant Dar Taleb, available in ACAD, Excel, and PDF formats. These materials primarily include:

a. Monthly Progress reports, site pictures, drawings and excel files showing the progress of solid waste landfills, particularly in the reclaimed area up to a level of +2m, as of the end of January 2025. It's worth noting that these backfilling works were affected and stopped due to the conflict in the country between September and November 2024.

b. As built drawings for solid waste cells 2A and 2B (facing the reclaimed land) and Cells 2 & 3 (facing the existing WWTP), which are currently in the temporary hand-over phase.

c. Survey files related to the solid waste project, including the gas flare, the structures and existing facilities (military caserne, rooms, ancient walls…) inside the reclaimed land of Ghadir WWTP.

d. Information on the Materials used for backfilling in the solid waste operations.

2.1.10 Etude de l'impact des rejets de la station de traitement des eaux usées de Ghadir sur l'environnement marin

This master's project, prepared at the Faculty of Agronomy during the academic year 2005-2006, focuses on the current impact of treated wastewater discharge from the Ghadir preliminary treatment plant on the Mediterranean Sea. The study assesses this impact through the analysis of various water quality parameters measured from end of September 2001 to Mid-July 2006.

The key recommendations of this study for the Ghadir preliminary WWTP to reduce the high concentrations of effluent discharged into the sea are as follows:

- A secondary treatment at least will remove most of the biological pollution from the wastewater, which improves the oxygenation of the water and, consequently, the

living conditions for marine fauna and flora, including the concentration of dissolved oxygen in the sea.

- Wastewater disinfection will help eliminate microbiological pollution, particularly Total Coliforms (TC).

2.1.11 Cadastral Situation

From a cadastral and legal perspective, the existing plant and the proposed reclaimed land are situated within the Oumara cadastral area. All plots adjacent to these sites are designated as public domain, maritime domain, or are already expropriated or owned by the CDR / Lebanese government for public interest (Solid waste, extension of International Beirut Airport, Extension of Ghadir WTTP…). This has been verified through cadastral documents, indicating that no expropriation is necessary at this stage.

2.1.12 Dar Site Visits & Water Operators Data

Dar conducted several site visits, engaging in discussions with water operators and consultants to gather information about the WWTP. These visits focused mainly on the operational scheme, existing equipment data, necessary rehabilitation works, potential for expansion, access roads, and the connection between the reclaimed land and the existing WWTP site, all aimed at achieving a comprehensive understanding of the WWTP project. It's important to note that the existing WTTP has been out of service from July 2022 due to lack of maintenance since 2018. As mentioned earlier in section 2.1.7, ongoing civil and electro-mechanical rehabilitation works are being carried out to restore the WTTP to operational status.

2.1.13 Laws about the airport nearby construction

Given the critical location and its proximity to the Beirut International Airport, the client CDR has requested a coordination meeting with the airport authority to introduce the project and understand the necessary design constraints. These include height restrictions, setbacks, road access, pipe trenches, permissible gas emissions, and other relevant factors to ensure compliance with aviation regulations and safety standards.

Eng. Joumana Aarabi, the Director of the Airports Design & Planning Department, provided a sketch via email outlining the allowable heights for the proposed WTTP structures and the offsets from the runway centerline. She also requested clarifications on other issues such as thermal effects and gas emissions.

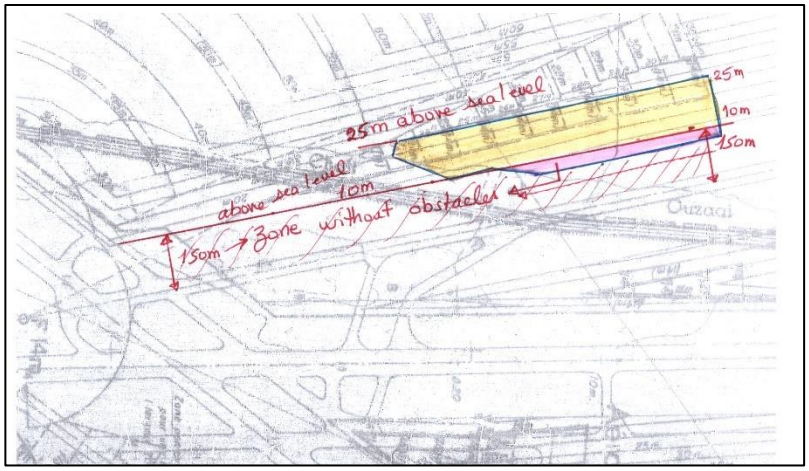


Figure 2.1 Sketch of allowable heights for proposed WWTP structures in relation to the Airport

In response, the consultant submitted an official letter addressing the required clarifications and is currently awaiting an official reply from the airport authority.

CHAPTER 3 TOPOGRAPHIC SURVEY

Chapter 3 – Topographic Survey

Table of Content

Chapter 3 Topographic Survey 1

3.1 Introduction 1

3.2 Surveyed Area 1

3.3 Topographical Survey Methodology, Equipment and Personnel 2

3.4 Site Pictures 3

3.5 Topographical Drawings 3

List of Figures

Figure 3.1 "Geodezya Group-Delta Surveying Studies" Company Profile 1

Figure 3.2 Ghadir WWTP Surveyed Area (Within Blue Polygon) 2

List of Appendices

Appendix 3.1 Existing WWTP Survey

Appendix 3.2 Reclaimed Land Survey

Chapter 3 Topographic Survey

3.1 Introduction

This chapter presents an overview of the topographic survey conducted for the Ghadir WWTP, which will form the basis for our design drawings. To undertake this task, the consultant has appointed "Geodezya Group-Delta Surveying Studies" (Figure 3.1) to conduct a physical survey of the existing sewers and structures at the WWTP. This includes mapping the location, building boundaries, manhole cover and invert levels, pipe diameters, and the available equipment within the WWTP, …



Figure 3.1 "Geodezya Group-Delta Surveying Studies" Company Profile

3.2 Surveyed Area

The surveyed area primarily lies within the Haret El Oumara Cadastral in Aaley Caza, Mount Lebanon, and falls under the jurisdiction of Choueifat Municipality (Refer to Figure 3.2).

The location of the project area is limited by the following points coordinates:

- Point A : X = -339,567.34, Y = -36,929.33
- Point B : X = -339,389.44, Y = -36,903.82
- Point C : X = -339,356.44, Y = -36,706.06
- Point D : X = -339,462.10, Y = -36,602.75
- Point E : X = -339,408.50 , Y = -36,338.47
- Point F : X = -339,424.99 , Y = -36,053.97
- Point G : X = -339,517.01 , Y = -35,605.16
- Point H : X = -339,703.63 , Y = -35,594.07
- Point I : X = -339,544.44 , Y = -36,445.68
- Point J : X = -339,494.24 , Y = -36,480.60

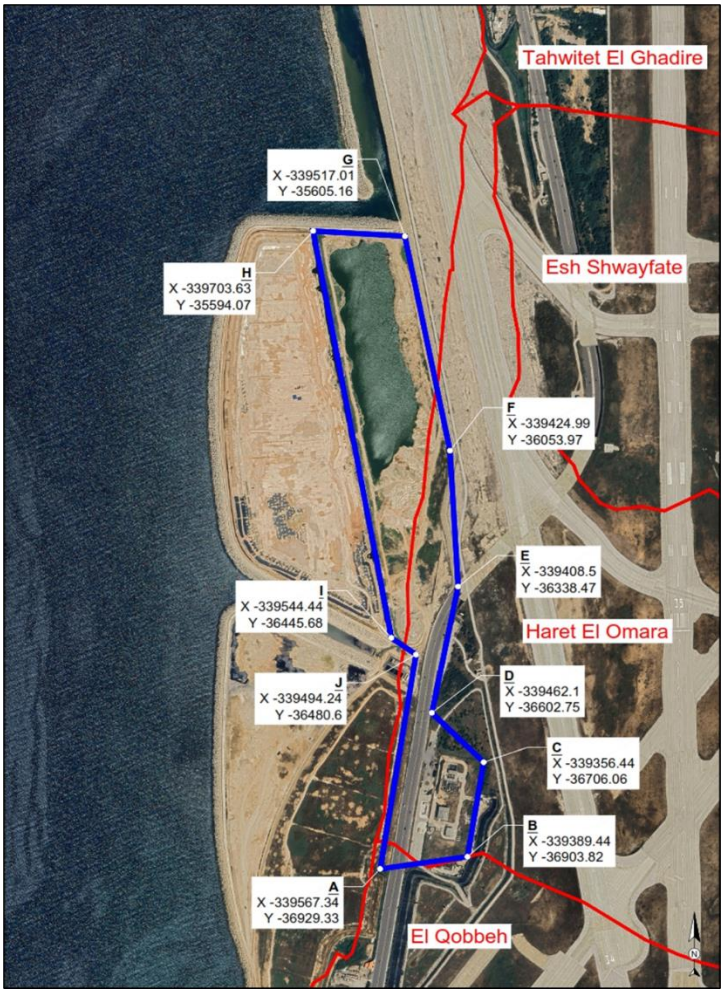


Figure 3.2 Ghadir WWTP Surveyed Area (Within Blue Polygon)

3.3 Topographical Survey Methodology, Equipment and Personnel

Following the agreement on the scope of work, Geodezya Group launched the project with a dedicated team that approached the task with expertise and commitment. It's worth mentioning that the related survey works was carried out by a highly skilled group of surveyors and engineers, including Rawan Ghali, Joseph Ibrahim, Mehdi Hammoud, Hassan Chehadeh, Anthony Bitar, Omar Daffe, and Mounah Abou Hamdan, all experienced in similar projects and utilizing advanced equipment. This effort has significantly enhanced their technical expertise, complementing the knowledge gained from previous onshore and offshore surveys for other Projects.

The project was surveyed by the following machines:

1. Total Station: Topcon ES 105
2. GPS: Sino GNSS Mars Pro RTK
3. GPS: Sino GNSS T300 Plus

The GPS base machine was fixed on the main army benchmark. Office work was prepared previously by our technical department to survey all the existing facilities within the WTTP, including nearby Ouzaii highway and manholes and inside the reclaimed land, utilizing a total station where necessary.

All these data were uploaded on the data collector or the total station memory card. This data was then analyzed using specialized software to generate three-dimensional coordinate points.

3.4 Site Pictures





3.5 Topographical Drawings

In accordance with the outlined methodology, the topographical survey drawings for the existing WWTP and the proposed reclaimed land (approximately 131,850m²) designated for the expansion and upgrade of the Ghadir WWTP are included in Appendices 3.1 and 3.2.

CHAPTER 4 GEOTECHNICAL INVESTIGATION

Chapter 4 – Geotechnical Investigation

Table of Content

Chapter 4 Geotechnical Investigations 1

4.1 Introduction 1
4.2 Project Description 2
4.3 Site Description 2
4.4 Scope of Works 4
4.5 Surficial Geology & Geological Structures 6
4.6 Subsurface Geology & Hydrogeology 6
4.7 Seismology 8
4.8 Landforming 9
4.9 Bearing Strata 9
4.10 Interpretations 9
4.11 Closure 10

List of Figures

Figure 4.1 Expansion and Upgrade of Al-Ghadir Wastewater Treatment Plant 1
Figure 4.2 Ghadir WWTP Overall Hydraulic Profile 2
Figure 4.3 Land Reclamation Topography (October 2024) 3
Figure 4.4 Truck mounted rotary drill rig Mack MD7 (BH2/Ghadir - 2024) 4
Figure 4.5 Beyrouth Leaf, by M. Louis Dubertret 6
Figure 4.6 Contour map of PGA with a 10% probability of exceedance in 50 years 8

List of Tables

Table 4.1 Continuous core drilling in soil and rock 5
Table 4.2 Piezometric survey (September 17, 2024) 8

List of Appendices

Appendix 4.1 Borehole Locations
Appendix 4.2 Logs of Borings
Appendix 4.3 Photos of Core Boxes
Appendix 4.4 Laboratory Test Results
Appendix 4.5 Overall Hydraulic Profile

Chapter 4 Geotechnical Investigations

4.1 Introduction

As requested in the ToR, DAR-TALEB carried out a geotechnical investigation campaign at the location of the Expansion and Upgrade of Al-Ghadir Wastewater Treatment Plant, Aley Caza – Mount Lebanon (see below Figure 4.1).

The purpose of the investigation is to reveal the geological/hydrogeological stratigraphy and to determine/estimate the geomechanical parameters of the subsurface soil and rock stratums, at the area of interest (down to an influence depth of 18m), to aid in the design of Expansion and Upgrade of Al-Ghadir Wastewater Treatment Plant.

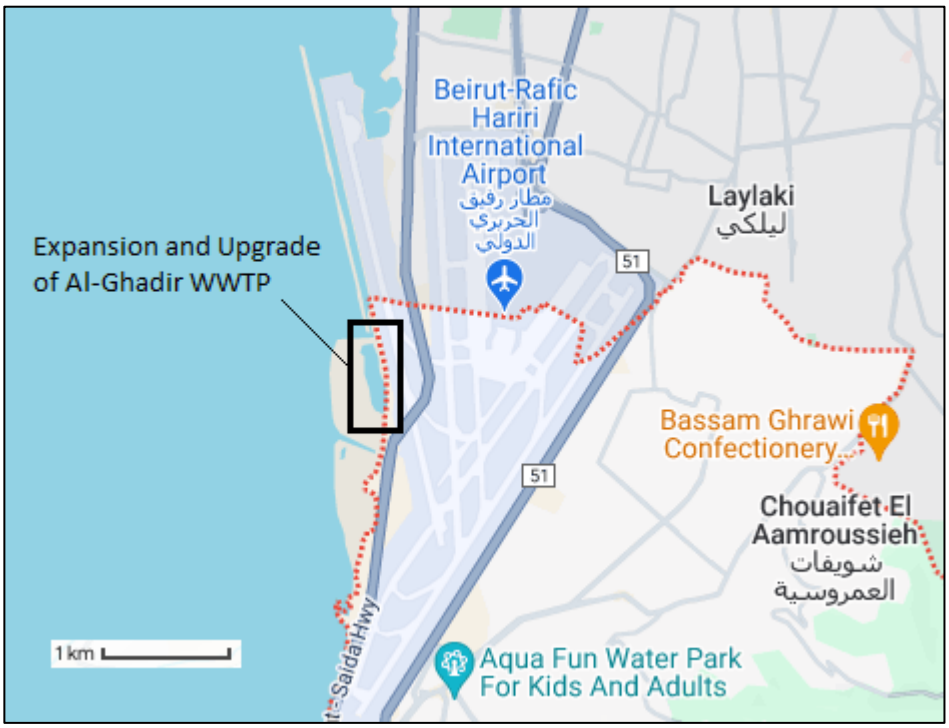


Figure 4.1 Expansion and Upgrade of Al-Ghadir Wastewater Treatment Plant

4.2 Project Description

The project involves expansion and upgrade of Ghadir Wastewater Treatment Plant (WWTP) as shown in below Figure 4.2. (refer to Appendix 4.5).

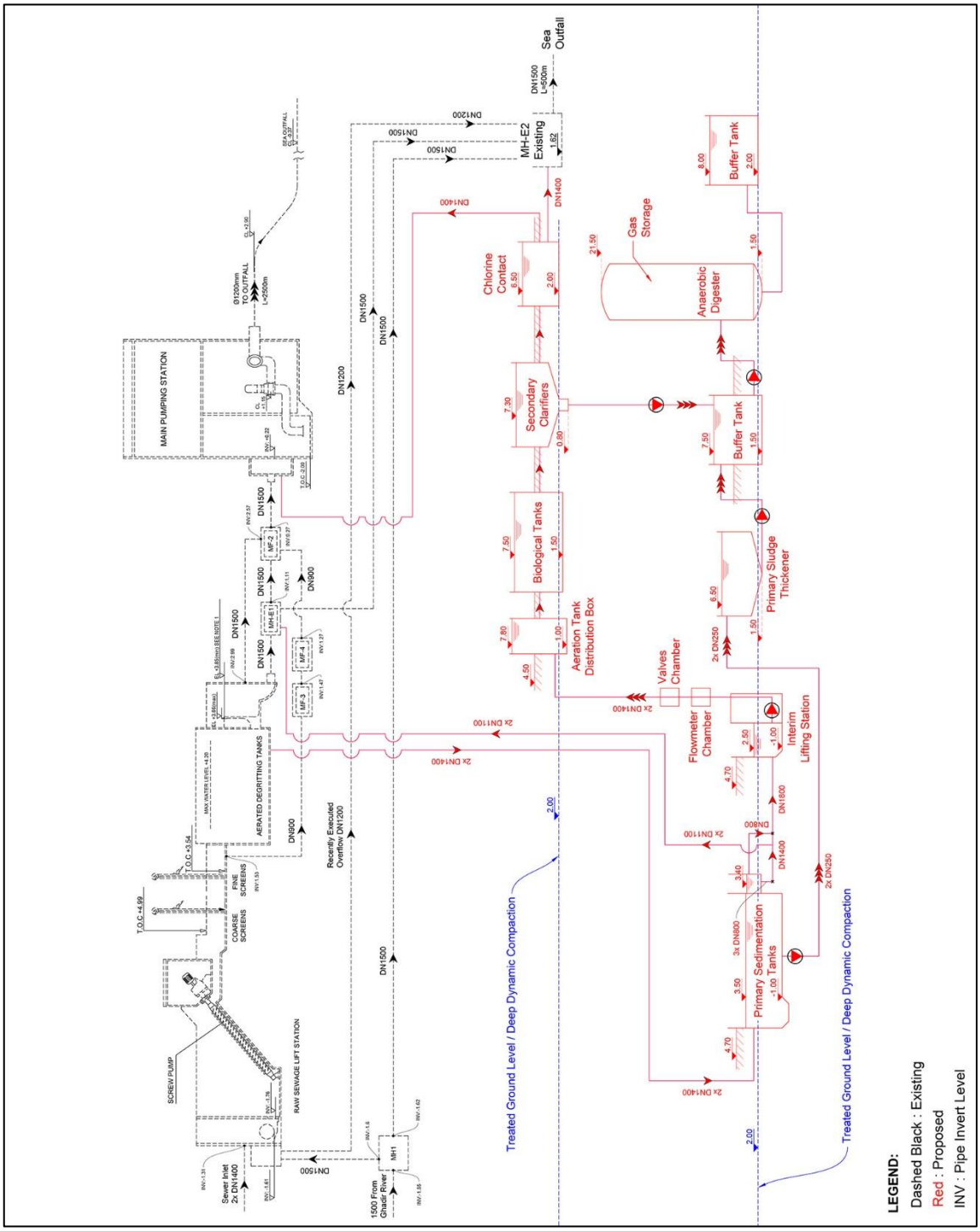


Figure 4.2 Ghadir WWTP Overall Hydraulic Profile

4.3 Site Description

The expansion and upgrade of Ghadir WWTP is located on a Land Reclamation (ongoing). The Land Reclamation topography increases in elevation southeastward, its lowest point is sea level (0.00), and reaches a mean elevation of 2.97 above the sea level (asl, see below Figure 4.3). The WWTP area is about 12ha.

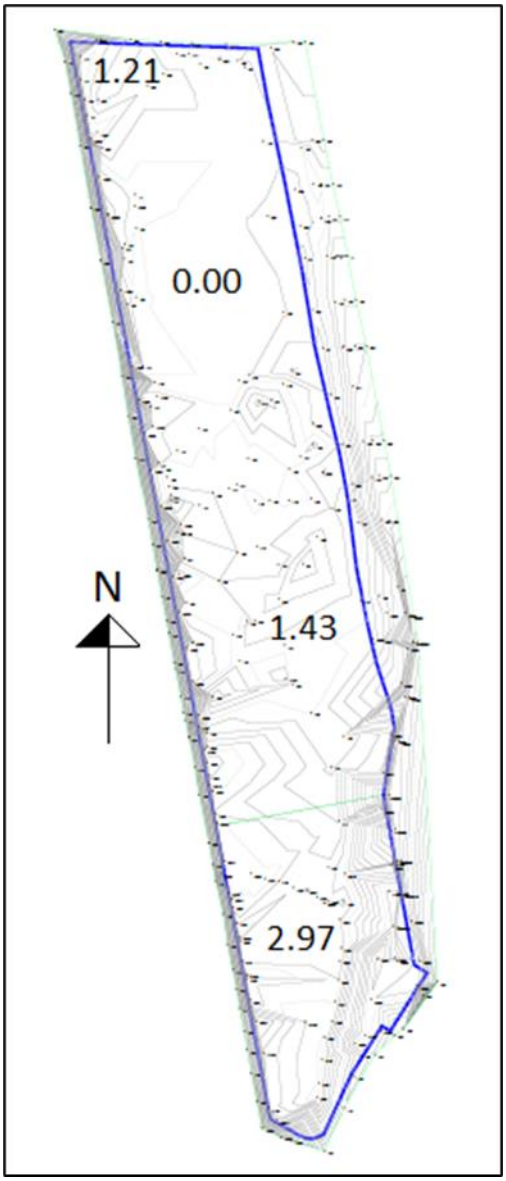


Figure 4.3 Land Reclamation Topography (October 2024)

4.4 Scope of Works

Four (4) nos. of boreholes 18m deep each were drilled between the dates of September 14 and 17, 2024 at locations shown on attached drawing (Appendix 4.1), to reveal the geological/hydrogeological stratigraphy of the site, and to determine/estimate the geomechanical parameters of the subsurface soil and rock stratums.

Open standpipe piezometers were installed into the drilled boreholes for measuring the depth and fluctuations of the groundwater table (seawater-level).

A truck mounted rotary drill rig Mack MD7 (see below Figure 4.4) was used in geotechnical investigation campaign.



Figure 4.4 Truck mounted rotary drill rig Mack MD7 (BH2/Ghadir - 2024)

The scope of works of this geotechnical investigation consisted of the followings:

- Continuous core drilling in soil and rock (see below Table 4.1),
- Performing Standard Penetration Test (SPT) in soil and obtaining disturbed samples,
- Performing Dynamic Cone Penetration Test (DCPT) in soil contains coarse gravel and cobbles,
- Installing open standpipe piezometers into the drilled boreholes and measuring the depth and fluctuations of the groundwater table/seawater-level (piezometric survey after airlifting/bailing out) by using a water level meter (PLS 200 / Denmark, EU), and
- Performing laboratory tests on representative soil and rock samples taken from the boreholes.

Table 4.1 Continuous core drilling in soil and rock

Borehole Identity	X	Y	Z	Depth of Borehole (m)
BH1/Ghadir-2024	-339492.5	-36374.5	2.60asl	18
BH2/Ghadir-2024	-339516.4	-36185.1	1.50asl	18
BH3/Ghadir-2024	-339557.5	-36025.3	1.00asl	18
BH4/Ghadir-2024	-339529.3	-35899.5	1.25asl	18

86mm diameter (bit set OD) double tube core barrel (T2 86) equipped with tungsten carbide core bit was used in continuous core drilling with NW drill rods and 128mm diameter (OD) metric casings.

Core drilling was performed by using as minimum as possible amount of circulation water in a manner to increase the Total Core Recovery (TCR). TCR, Solid Core Recovery (SCR), Rock Quality Designation (RQD), Fracture Frequency, cavity detection and detailed logging were carried out during the core drilling and indicated in logs of borings. The logs of borings are presented in Appendix 4.2.

Cores taken from the boreholes were wrapped with plastic wrap to prevent the soil samples from drying out, and stored in standard plastic core boxes. All the necessary information related to the runs of coring and boreholes were indicated on the boxes and photos of core boxes were taken upon completion of each borehole. The photos of core boxes are presented in Appendix 4.3.

In soil, Standard Penetration Test (SPT) was performed by using Split-Spoon SPT sampler in 2 inches outside diameter with SPT hammer.

In soil/manmade fill and soil-like rockmass contain coarse gravels and cobbles; Dynamic Cone Penetration Test (DCPT) was performed by using a solid cone (apex angle of 60 degrees and end diameter of 62.5mm) with SPT hammer.

The penetration tests were performed to evaluate the relative densities of the subsurface soil/manmade fill and soil-like rockmass stratums. However, SPTs and DCPTs were mainly ended with refusal, due to boulders.

Perforated (one third of the standpipe) UPVC pipes, 42mm diameter (OD) and 2.2mm thick, wrapped with geotextile (PP, 150 gr/m2) were installed into the drilled borehole as open standpipe piezometer with concrete heading and steel pipe protection, to measure the depth and fluctuations of the groundwater table/seawater-level by using a water level meter (PLS 200 / Denmark, EU).

All above mentioned works were performed according to ASTM and IS standards, and were supervised by an engineering geologist.

- ASTM D6640: Core drilling in soil and rock,
- ASTM D1586: Standard Penetration Test,
- IS 4968: Dynamic Cone Penetration Test, and
- ASTM D4750: Determining subsurface liquid level in a borehole.

Representative soil and rock sample from the boreholes were selected and tested in the laboratory to determine the geomechanical parameters of the subsurface soil and rock stratums. The laboratory test results are presented in Appendix 4.4.