



# Lebanon

## Post-Conflict Environmental Assessment



United Nations Environment Programme

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## Foreword

The recent conflict in Lebanon and in Israel, which began in July 2006 and lasted for more than a month led to nearly one million Lebanese – over to a quarter of the total population – fleeing their homes.

This massive human displacement and destruction or severe damage of approximately 30, 000 housing units clearly had a very deep impact on the civilian population.

Within hours of the ceasefire on 14 August, large numbers began returning home—a measure of the resilience of the Lebanese people but also representing a huge challenge for the aid workers trying to deal with the flood of returnees.

Removal of the huge amount of rubble generated by the conflict represented a further challenge but one that got underway surprisingly quickly and, as part of the reconstruction work, is on-going.

One of the most high profile issues of the conflict was the bombing of the Jiyeh power plant which resulted in the spillage of thousands of tones of oil into the Mediterranean Sea. On 5 August, the Minister of Environment of the Lebanon formally requested UNEP to conduct a post-conflict environmental assessment of his country. The scope of UNEP's assessment work was geographically limited to Lebanon.

The findings are presented in this report. Coastal communities have been severely affected by the oil pollution washed onto their shores. During and in the immediate aftermath of the conflict, the international community (including governments and regional organizations) and the Lebanese



government worked tirelessly alongside local civil society organizations in a massive effort to contain the oil spill and implement clean-up measures along the Lebanese coast.

One of the outstanding issues of the clean-up work is the urgent need to dispose of large quantities of oil contaminated waste. This is a continuing challenge for those involved in the clean-up efforts and requires the financial and technical support of the international community.

The type of oil that leaked from the power plant's tanks was heavy and not very mobile. It therefore sank quickly, thus limiting the amount of oil that washed up on beaches. The oil currently on the seabed remains of concern and should be cleaned up to prevent any possibility of re-suspension.

However, due to its low mobility petroleum hydrocarbon concentrations found in sediment outside of the immediate vicinity of the power plant were only marginally higher than normal and the petroleum hydrocarbon concentrations in oysters and fish are as expected for that part of the Mediterranean. This does indeed bode well for the long-term recovery of livelihoods and the environment of the area.

In the context of weapons used, UNEP examined specifically the possible use of munitions containing Depleted Uranium. Thirty-two sites were visited south and north of the Litani river and more than fifty samples taken for laboratory analysis. The dust, soil and smear samples were analyzed using modern, highly sensitive equipment.

I hope it is a measure of comfort for the local populations that no evidence of the use of depleted or natural uranium-containing weapons was found. However, the large numbers of cluster bombs, which lie unexploded throughout much of southern Lebanon, do constitute a severe impediment to post-conflict recovery. With large tracts of agricultural land contaminated with unexploded ordnance, this affects the economic and physical well-being of civilian populations and continued international assistance is needed to help them address this serious issue.

In addition, UNEP investigated concerns relating to land contamination, ground and surface water, as well as solid and hazardous waste, including asbestos. Where environmental impacts were found, appropriate recommendations for remediation were made.

In times of political turmoil, conflict and human suffering, the environment can often be overlooked. However, the sustainable management of natural resources can provide the basis for long-term sustainable livelihoods, development and stability. By conducting this assessment, we hope to raise warnings where urgent measures are needed, provide practical recommendations to avert future

damage to the environment and strengthen the common resource base essential to the well-being of all Lebanese people.

We sincerely thank the Governments of Germany, Norway and Switzerland, who have funded UNEP's assessment activities. We also thank the Joint UNEP/OCHA Environment Unit, which started the monitoring of conflict impacts on the environment while the conflict was on-going, and played an important role in the coordination of the oil spill response.

This assessment was able to build on the sound work of the Joint Unit. In addition, the post-conflict environmental assessment would not have been possible without the support of our colleagues at UNDP, UNDSS and UNMACC. The Ministry of Environment of Lebanon has been an active and open partner in the assessment process, providing information and logistical support wherever required. UNEP is already in contact with key donors and the Ministry of Environment regarding projects to implement some of the recommendations of this assessment. We hope that UNEP can remain a long-term partner of the Lebanese government and people as they continue to reconstruct and restore their infrastructural and environmental assets.



Achim Steiner  
United Nations Under-Secretary-General  
Executive Director of the  
United Nations Environment Programme

# Introduction

*French navy experts on an oil polluted beach in Beirut, 1 September 2006. The bombing of the Jiyeh power plant on 13 and 15 July caused an oil spill that affected approximately 150 kilometers of Lebanon's coast.*

© AP Photo





## Introduction

The conflict in Lebanon and in Israel, which began on 12 July 2006 and ended on 14 August with a ceasefire under UN Security Council Resolution 1701, was relatively short – lasting 34 days. However, the impact on Lebanon’s civilian population was significant, with 1,191 people reportedly killed and 4,405 injured. In addition, more than 900,000 Lebanese fled their homes. Severe damage was caused to infrastructure, with wide-spread destruction of arterial roads and more than 100 bridges or overpasses. Beirut airport and sea ports were bombed, and approximately 30,000 housing units were destroyed or badly damaged<sup>1</sup>. UNEP’s post-conflict environmental assessment was conducted within the geographical area of Lebanon, which is the focus of this report.

The environmental impact of the conflict was brought to the fore by the bombing of fuel storage tanks at the Jiyeh thermal power plant on 13 and 15 July 2006, which resulted in some 10,000 – 15,000 tons of heavy fuel oil spilling into the sea, affecting approximately 150 km of Lebanese coastline, as well as part of Syria’s coast. As early as the day of the ceasefire, the Joint UNEP/OCHA Environment Unit established a presence in Beirut

to assist the coordination of the oil spill response along the Lebanese coast. The Joint Unit worked closely with the Ministry of Environment and international actors, such as the European Union and IUCN, to establish an Oil Spill Operations and Coordination Centre. The Centre played an important role in coordinating the large amount of aid that was delivered in the form of equipment, monetary contributions and secondment of staff by the international community in the aftermath of the spill. The Joint Unit also monitored public sources to gather information on environmental impacts aside from the oil spill.

With concerns regarding the extent of environmental damage caused by the oil spill and potential contamination of land, air, water and biota as a result of the conflict, the Lebanese Minister of Environment requested UNEP on 5 August 2006 to conduct a post-conflict environmental assessment of Lebanon. This activity was included in the Government of Lebanon’s National Early Recovery Plan, released on 31 August 2006. UNEP accordingly sent a team of twelve international environmental experts to Lebanon from 30 September to 21 October to carry out a field assessment. The team included experts in the areas of solid and hazardous waste management, fresh water resources, land-based contamination, marine and coastal management and military



*Promenade in central Beirut*



*UNEP expert assessing damaged fuel storage tanks at Jiyeh power plant*

expertise. The experts were joined by a national team of consultants that had been established by UNDP and had conducted important preparatory work, including reconnaissance visits to sites, in the ten days prior to the assessment. The UNEP team visited over 100 sites throughout the country and took close to 200 samples of soil, surface and groundwater, dust, ash, seawater, sediment and marine animals. Samples were sent twice weekly to laboratories for analysis. Duplicate samples were made available to the Ministry of Environment for comparative analysis. Fifteen Ministry of Environment staff members and volunteers and a scientist from the Lebanese Atomic Energy Agency, accompanied the assessment team in the field. The Joint Unit remained on standby throughout the assessment to assist in the event that acute environmental impacts requiring immediate attention were discovered.

UNEP visited 29 potentially contaminated industrial and urban sites, where samples were collected and field observations made. The findings and detailed laboratory test results, together with appropriate short-, medium- and long-term recommendations, are discussed in the chapter titled 'Industrial and Urban Contamination'. In addition, broader concerns were investigated in sectors such as solid and hazardous waste management and fresh water resources. UNEP's findings regarding these sectors are contained in 'Solid and Hazardous Waste' and 'Water

Resources', respectively. The 'Coastal and Marine Environment' chapter focuses on the medium- to long-term environmental impacts of the oil spill at the Jiyeh power plant, while the section titled 'Weapons' contains UNEP's findings on the environmental consequences of weapons used during the conflict. The main findings and recommendations of the assessment are provided in the final chapter. In order to distribute the findings of this report widely, a comprehensive executive summary has been produced as a stand-alone publication in French and Arabic.

One of the aims of post-conflict environmental assessments is to obtain baseline data on the environment following a conflict, which could form the basis for further monitoring work and assist the government in formulating environmental management policies, as well as remediation priorities. The data collected will also add to the global body of knowledge on the environmental impacts of conflict. As part of the Lebanon assessment, UNEP will consolidate all the gathered data into a central information system, which will be handed over to the Lebanese Ministry of Environment.

UNEP is ready to continue its work with the Ministry of Environment to support the post-conflict reconstruction process in Lebanon and establish a sustainable path towards environmental recovery.

# Country Context

*A scene from the southern suburbs of Beirut, which were heavily bombed. An estimated 30,000 housing units were destroyed or badly damaged in the conflict.*



## Country context

### Introduction

Lebanon's mountainous terrain, proximity to the sea and strategic location were decisive factors in shaping its history. In recent years, the country's varied geographical features – which include alpine regions, coastal plains and fertile plateaus – its temperate climate, as well as its archeological and cultural wealth, have combined to attract a rapidly growing number of tourists. The impact of the July-August 2006 conflict on the country's natural resources was therefore of particular concern to the Lebanese and international community alike.

This chapter presents a brief overview of Lebanon's geography, climate, land cover, ecology and economy. The information is drawn from existing sources and is intended to provide a contextual framework for UNEP's assessment work, rather than represent an exhaustive study of Lebanon's natural and economic environment.

### Geography

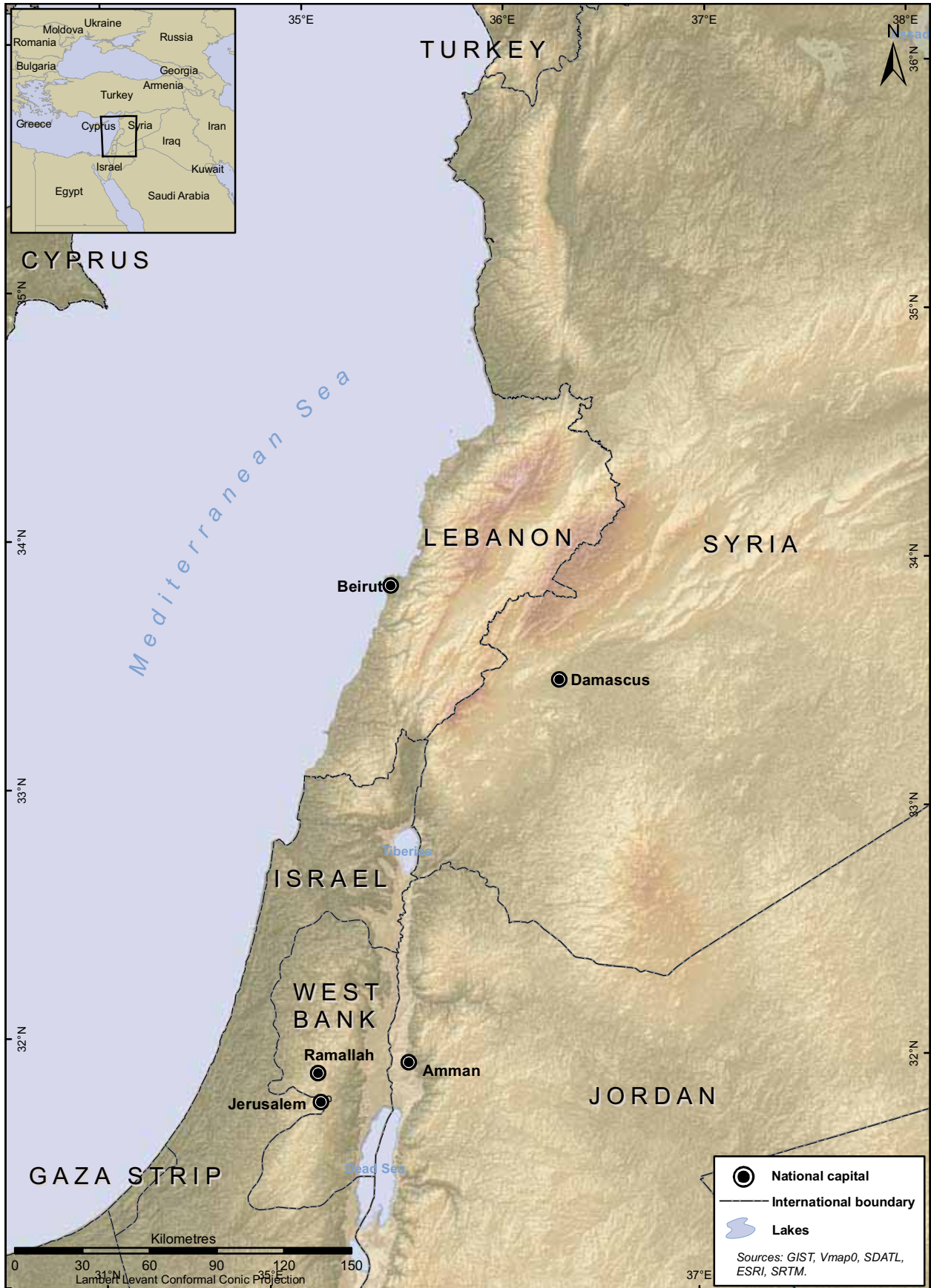
Lebanon, officially the Lebanese Republic, is a small, largely mountainous country located on the eastern shore of the Mediterranean Sea. It is bordered by Syria to the north and east, and by Israel to the south.



*A fuel tank burns at Rafik Hariri International Airport in Beirut, 14 July 2006*

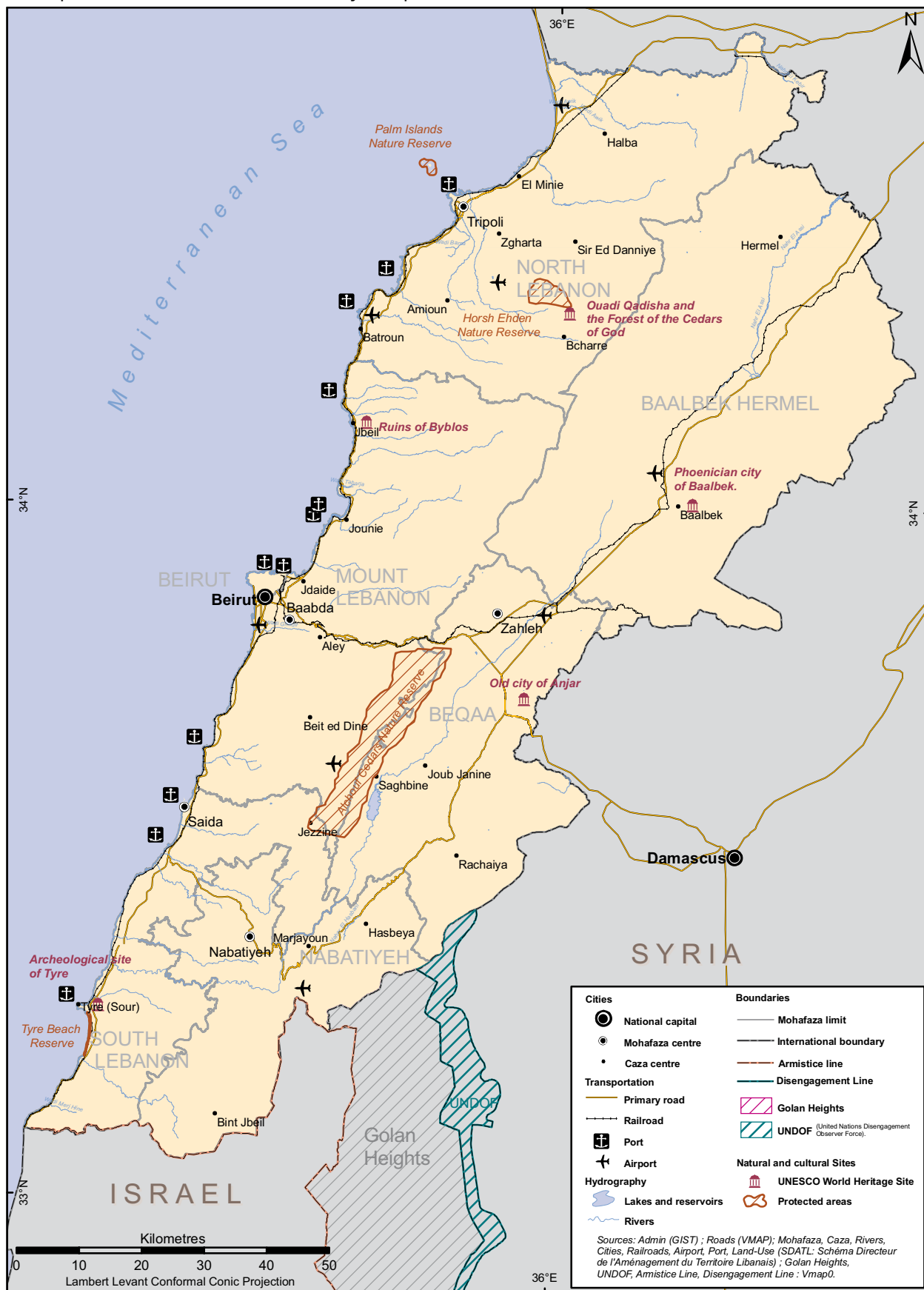
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Map 1. Lebanon – Regional map



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Map 2. Lebanon – Country map



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.





*UNEP and local experts inspect a damaged glass factory in Zahleh*

Lebanon's total area is approximately 10,452 km<sup>2</sup>. The physical geography of Lebanon is influenced by natural systems that extend outside the country. Thus, the Beqaa Valley is part of the Great Rift system, which stretches from southern Turkey to Mozambique. Because of its mountainous terrain, Lebanon's physical geography is complex and varied. Land forms, climate, soil, and vegetation change markedly within short distances.

Lebanon can be divided into four distinct physiographic regions<sup>1</sup>:

**1. The coastal plain**, which runs along the Mediterranean shore, is a narrow and discontinuous strip formed of river-deposited alluvium and marine sediments which alternate with rocky beaches and sandy bays. Hemmed in between sea and mountain, the *sabil* is widest near Tripoli, where it is 6.5 km wide. The shoreline is regular, with no deep estuary, gulf, or natural harbor. Generally quite fertile, the maritime plain is especially productive of fruits and vegetables.

**2. The Lebanon Mountains** form the country's second geographic region. They are the highest and most rugged of the whole maritime range of mountains and plateaus that start with the

Amanus or Nur Mountains in northern Syria and end with the Sinai. The mountain range, which is approximately 169 km long, is a clearly defined unit with natural boundaries on all four sides: in the north it is separated from the Nusayriyah Mountains of Syria by the An Nahr al Kabir River; to the south it is bounded by the Al Qasmiyah River. Its width varies from about 56.5 km near Tripoli to 9.5 km on the southern end. It rises to alpine heights southeast of Tripoli, where Al Qurnat as Sawda reaches 3 088 m. At the southern end, the Lebanon Mountains give way to the hills of Galilee, which are lower. Although the limestone composition of the mountains provides relatively poor topsoil, the lower and middle slopes are intensely cultivated.

**3. The Beqaa Valley** – a central highland separating the Lebanon and the Anti-Lebanon mountain ranges – is about 177 km in length and 9.6 to 16 km wide, with an average elevation of 762 m. Geologically, the Beqaa is the medial part of a depression that extends north to the western bend of the Orontes River in Syria and south to Jordan through Al Arabah to Al Aqabah, the eastern arm of the Red Sea. The Beqaa, whose soil is fertile due to alluvial deposits from mountains on either side, is the country's chief agricultural area.



*The Wazzani springs are the main source of water for the Hasbani River during the dry summer season*

**4. The Anti-Lebanon Mountains**, the eastern range that forms the border with Syria, are almost equal in length and height to the Lebanon Mountains. This fourth geographical region falls swiftly from Mount Hermon to the Hawran Plateau and continues through Jordan south to the Dead Sea. The Barada Gorge divides the range. The Anti-Lebanon are more arid, especially in their northern parts, than the Lebanon Mountains, and are consequently less productive and more thinly populated.

Finally, South Lebanon comprises an elevated plateau that extends a short distance inland from the shore of the Mediterranean to the Mount Hermon foothills in the east.

### **Water resources**

Although the country is well watered by many rivers and streams, there are no navigable rivers, nor is any one river the sole source of irrigation water. Most rivers in Lebanon have their origin in springs, which are often quite large. These springs emerge from the permeable limestone strata cropping out at the 915- to 1,524-metre level in

the Lebanon Mountains. Other springs emerge from alluvial soil and join to form streams which serve as tributaries to the principal rivers.

The Beqaa Valley is watered by two rivers that rise in the watershed near Baalbek: the Orontes, which flows north, and the Litani, which flows south into the hill region of the southern Beqaa Valley, where it turns to the west and is thereafter called the Al Qasmiyah River. The Orontes continues to flow north into Syria and eventually reaches the Mediterranean in Turkey. For much of its course, its waters flow through a channel considerably lower than ground surface.

The only permanent lake is Buhayrat al Qirawn, about 10 km east of Jezzine. There is one seasonal lake, fed by springs, on the eastern slopes of the Lebanon Mountains near Yammunah, about 40 km southeast of Tripoli.

### **Climate**

Lebanon falls in the Mediterranean climatic region, which is characterized by a hot, dry summer and a cool, rainy winter; the spring and

autumn seasons are short. Topographical variation, however, causes local modifications of the basic climatic pattern, resulting in a number of micro-climates within the country, with contrasting temperatures and rainfall distribution. Conditions vary from a typical Mediterranean climate along the coastal plain and in the Lebanon mountain range to a sub-alpine or mountain Mediterranean climate on the highest peaks, which are covered in snow for most of the year. In some of the northern plains, the climate is sub-desert in character.

Along the coast, summers are hot and humid, with little or no rain. The daily range of temperature is generally not wide, although temperatures may at times reach above 38°C in the daytime and below 16°C at night. Winter is the rainy season, with major precipitation occurring from November to April. The amount of annual rainfall on the coast varies from year to year, from 600 to 900 mm.

In the Lebanon Mountains, the gradual increase in altitude produces colder winters with more precipitation and snow. In summer, the daily range of temperatures is wider and humidity is lower than on the coast.

The Beqaa Valley, which is shielded from the influence of the sea by the Lebanon Mountains, has

a wider variation in daily and yearly temperatures, considerably less precipitation and lower humidity. Rainfall ranges from 800 mm in the south to 250 mm in the northeast, where it causes the climate to turn nearly dry.

Despite their remoteness from maritime influences, the Anti-Lebanon Mountains receive more precipitation than the Beqaa Valley because of their altitude. Like those of the Lebanon range, the peaks of the Anti-Lebanon are covered in snow for most of the year.

### Land cover and ecology

The biological wealth of Lebanon is intricately linked to its diverse topography. The country's different geomorphological regions give rise to at least 22 bioclimatic zones<sup>2</sup> and several types of habitats, including several distinct semi-natural habitats that have evolved and adapted to human activities and pressures.

In the last decade special attention has been paid to protecting endangered plant and animal species and conserving their habitats in specific parts of the country. In addition to eight nature reserves<sup>3</sup>, there are numerous legally protected areas in Lebanon, as well as hundreds of cultural and natural heritage sites, UNESCO world heritage sites, and areas protected through private initiatives.



*Harbour of the archeologically important town of Byblos*

Map 3. Land use in Lebanon



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

## Vegetation

Relative to its size, Lebanon has one of the highest densities of floral diversity in the Mediterranean basin<sup>4</sup> and boasts a high percentage of endemic plant species. Vegetation types range from subtropical and desert to alpine. Olive trees, fig trees and grapevines are abundant on lower ground, while cedar, maple, juniper, fir, cypress, oak, and pine trees are found at higher altitudes.

There is evidence that Lebanon was heavily forested in ancient and medieval times, but most natural vegetation has been grazed, burnt or cut, and little has regenerated. At present, forests and woodlands cover only approximately 13 per cent of the overall area of Lebanon (4.89 per cent dense woodlands and 8.43 per cent clear woodlands)<sup>5</sup>. Excessive felling, over-grazing, urban development, fires, and pests currently threaten Lebanese forests<sup>6</sup>. In 2001, the Ministry of Environment initiated a National Reforestation Plan aimed at restoring the country's green cover to a target of 20 per cent<sup>7</sup>.

## Fauna

Lebanon is host to nearly 4,500 known fauna species, of which insects make up 27 per cent<sup>8</sup>. Although

excessive hunting has killed off most wild mammals, jackals are still found in the wilder rural regions, and gazelles and rabbits are numerous in the south. Many varieties of rodents, including mice and gerbils, and many types of reptiles, such as lizards and snakes, may be found. Approximately one third of existing mammals are rare, and another 39 per cent are vulnerable species. The wolf, wildcat, mongoose and squirrel are close to extinction<sup>9</sup>. Deforestation, urban encroachment, new roads, drainage of wetlands, bio-accumulation of agro-chemical residues, and hunting are the major sources of pressure on the mammalian fauna of Lebanon<sup>10</sup>.

In addition, at least 372 species of birds have been recorded on Lebanese territory<sup>11</sup>: thrushes, nightingales, and other songbirds are native to Lebanon, but partridges, pigeons, vultures, and eagles, for example, can also be found. A number of bird species are endangered and the overall population is declining, due to the excessive and inappropriate use of pesticides, the disappearance of natural biotopes, urban expansion, and hunting<sup>12</sup>.

Finally, over 200 marine fish species from 140 genera have been identified, and an additional 25 species are confirmed to exist in Lebanese freshwater systems<sup>13</sup>.

However, the general deterioration of the coast – due to the combined effects of concentrated residential, industrial, and tourism development, infrastructure and activities – is exerting increasing pressure on marine habitats and coastal ecosystems. Indeed, Lebanon's population and economic activity are concentrated in the coastal zone, which extends over approximately 162,000 ha of coastal plains and mountains (16 per cent of Lebanon's surface area), is inhabited by an estimated 2.5 million people, and contributes over 70 per cent of Lebanon's GDP<sup>14</sup>.



Stone pines

## Soil

Lebanese soil, which is typically Mediterranean in character, varies widely in quality and productivity. Because Lebanon is predominantly mountainous, its soil is generally very shallow, fragile and prone to erosion. Even in the Beqaa plain, it is rarely more than a few metres deep. The region's lithology has contributed to the diversification of soil resources, most of which is base-saturated calcareous soil, except for the sandy soil formed on the basal cretaceous strata. The most widely represented types of soil are the Terra-Rossa (red Mediterranean soil) and Rendzinas, which represent about 70 per cent of Lebanese soil<sup>15</sup>.

## Economy

The Lebanese economy is chiefly based on the services sector. Tourism, trade and banking constitute the principal sources of both income and foreign earnings, with smaller contributions coming from the industrial and agricultural sectors. While its competitive and free market regime have

long made the country a banking and trading hub among Arab countries, its pleasant climate and many historic landmarks have continually attracted large numbers of tourists. Tourism is particularly important, as many other areas of the economy also depend on it, including the construction and real estate sectors. The services sector employs the majority of the Lebanese workforce and contributes over 70 per cent of the annual gross domestic product<sup>16</sup>.

The industrial sector ranks second in both workforce and GDP contribution, with 12,03 per cent of Lebanon's GDP in 2000<sup>17</sup>. Most industries in Lebanon are light manufacturing plants (more than 90 per cent employ less than ten people). While there are 23 industrial branches in Lebanon (not including water, power and construction activities), the vast majority belong to the following eight<sup>18</sup>: food and beverages, fabricated metal products, non-metallic mineral products, furniture, clothing, wood products, leather products, and textiles. In 2005, Lebanon's principal exports were machinery, jewellery, metals, foodstuffs and chemicals.



*Street vendor in South Beirut*



*Everyday life in the heavily bombed southern suburbs of Beirut*

Lebanon produces crops in five major categories: cereals, fruit, olives, industrial crops (such as tobacco and sugar beets) and vegetables. Agricultural production is concentrated in the Beqaa plain, which accounts for 42 per cent of the total cultivated land<sup>19</sup>. Livestock production is also an important activity, particularly in the mountains and in the Baalbeck-Hermel area on the eastern mountain chain, where soil fertility is relatively low<sup>20</sup>.

The 1975-1990 civil war seriously damaged Lebanon's economic infrastructure, but the economy witnessed its strongest period of sustained growth since 1995 in the first half of 2006, before the July – August war. Based largely on the tourism sector, the growth was reversed by the conflict, which damaged infrastructure and trade.

A number of international donors agreed to provide aid and assist reconstruction in the wake of the July-August conflict. During the conflict itself, Saudi Arabia and Kuwait pledged funds for humanitarian assistance and reconstruction and offered the Banque du Liban (the central bank) low-interest loans to shore up the currency. Significant aid continued to arrive from other Arab countries in the months after the war, covering a large portion of total reconstruction costs<sup>21</sup>. On 31 August 2006, a donor conference held in Stockholm and attended by ministers from over 60 countries, as well as UN, World Bank, International Monetary Fund and Red Cross officials, raised USD 940 million for the reconstruction of Lebanon. Major contributors at the conference included Qatar, the United States, the Arab Fund for Economic and Social Development, Saudi Arabia, the European Commission, the United Arab Emirates, the United Kingdom, Italy, Spain and Sweden<sup>22</sup>.

# Environmental Assessment

*UNEP expert collecting a soil sample  
in South Beirut. A number of sites visited  
require treatment and appropriate disposal  
of hydrocarbon-contaminated soil.*





## Environmental assessment

Post-conflict environmental assessments seek to provide an objective scientific assessment of the environmental situation in a country immediately following a conflict. They aim to inform the general public on environmental risks associated with the conflict, and to provide guidance to local government on priority issues to be addressed. They also help the international community to channel funding and technical assistance to the key areas of environmental management.

### Objectives and scope

UNEP's post-conflict environmental assessment in Lebanon had three main objectives:

1) To obtain baseline data on the environment in Lebanon after the conflict;

- 2) To identify issues of concern constituting a threat to public health and requiring urgent remediation measures, for which the Joint Unit remained on standby; and
- 3) To identify other issues of concern that, while not requiring urgent remediation, should be taken into consideration during the post-conflict reconstruction process, and to develop recommendations for addressing those issues in a sustainable way.

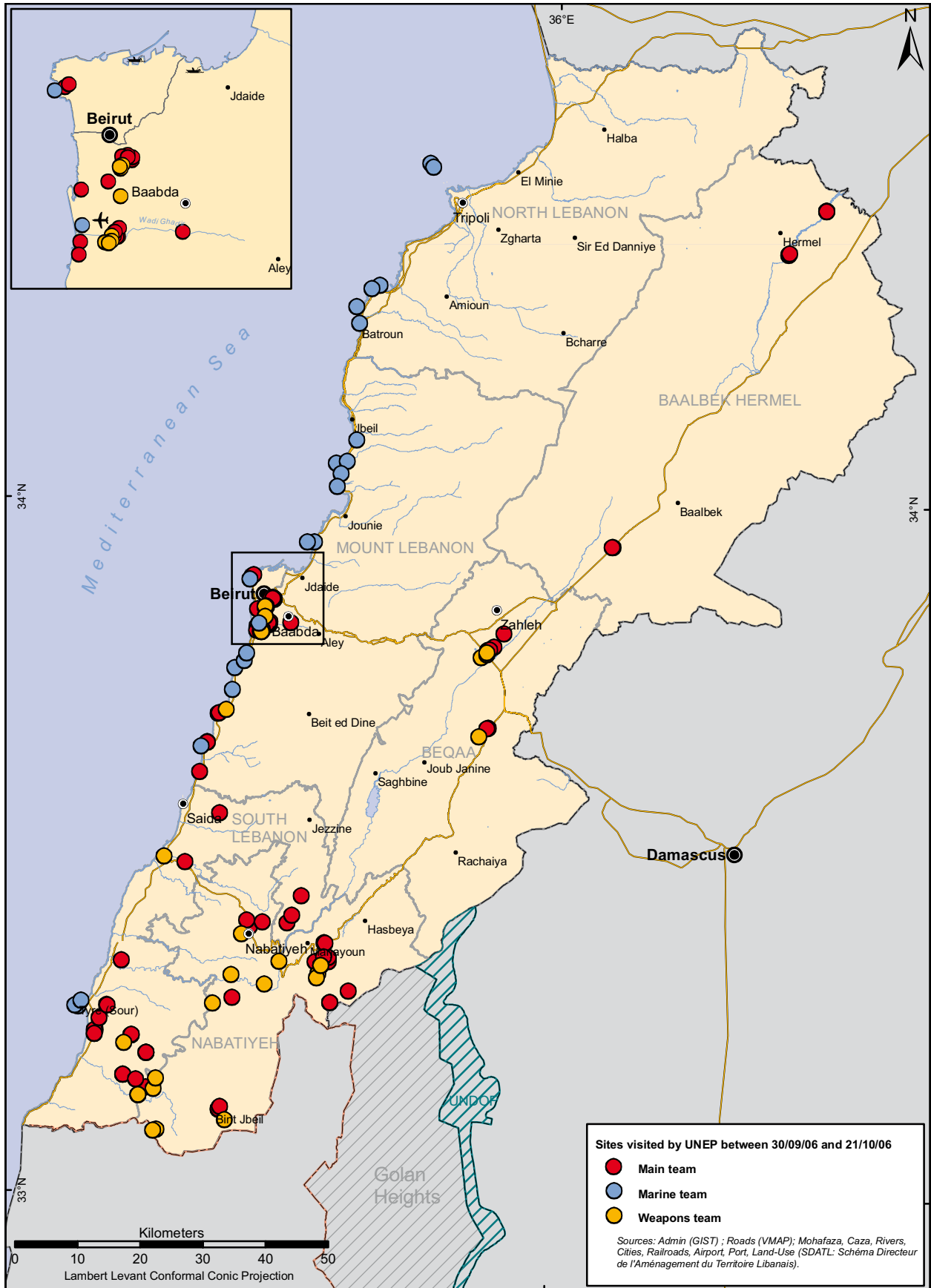
The geographical scope of the assessment was restricted to Lebanon, though the impacts of the conflict may reach beyond its borders. The scientific areas covered by the UNEP team included:

- surface and groundwater;
- solid and hazardous waste (including asbestos);
- contamination of land;
- marine and coastal contamination; and
- issues relating to weapons used.



*UNEP team in discussion with site manager of the Maliban glass factory, Zahleh*

Map 4. Sites visited during the UNEP assessment



During the conflict, UNEP's Post-Conflict Branch tracked the course of hostilities and evaluated the significance of various events from an environmental point of view. These activities and an inventory compiled in collaboration with the Joint Unit were at the basis of defining the broad scope of the assessment and identifying potential areas of interest. A preliminary list of sites of possible environmental concern was compiled based on government reports, press articles and anecdotal information. The list was then narrowed down through reconnaissance visits conducted by Elard s.a.r.l., a local environmental consulting firm involved in a post-conflict rapid environmental assessment project with UNDP and the Lebanese Ministry of Environment since September 2006. In the ten days preceding the UNEP mission, Elard visited 75 sites, comprising those identified by UNEP and additional sites the consultants recommended based on local information. On the basis of these visual inspections and background knowledge, an initial screening was performed and the sites were categorized according to the following criteria:

- the degree of visible site contamination;
- industrial activities conducted at the site;
- the environmental sensitivity of the area; and
- the extent of clean-up measures taken.

Of the 75 locations that were visited, 16 were classified as high priority due to heavy damage sustained during the conflict, while 42 were partially damaged, and the remaining 17 had no apparent conflict-related damage. This initial classification allowed the UNEP team to focus the field component of its work on sites that were damaged in the 2006 conflict. Additional information was obtained from local sources during the fieldwork and other site visits were scheduled as necessary.

## Fieldwork

For logistical reasons, the 12 environmental experts on the UNEP mission were divided into three teams:

- 1) The main team was constituted of experts in the areas of waste management, freshwater resources and land-based contamination;
- 2) The weapons team, which provided military expertise, initially accompanied the main team, but subsequently conducted separate field visits, focusing on areas south of the Litani River; and

- 3) The marine and coastal team consisted of marine biologists and coastal environment experts, who visited 27 sites along the coast between Tyre and Tripoli.

The teams were based in Beirut and traveled from the capital to sites across Lebanon. This arrangement allowed the collected water and soil samples to be kept cool or frozen, and to be shipped twice weekly to laboratories in Europe.

In addition, the Lebanese Ministry of Environment nominated 15 of its staff members and volunteers (environmental science students from local academic institutions) to accompany the assessment team, while a scientist from the Lebanese Atomic Energy Commission accompanied the weapons team. Ministry staff members and volunteers, who were with the different UNEP sub-teams throughout the field phase, observed the work of the international experts. They assisted the team by ensuring access to sites – including arranging for permission to be granted to visit restricted areas – and facilitated contact with local municipalities.

All samples were taken in duplicate; one set was sent for laboratory analysis by UNEP and another was made available to the Lebanese Ministry of Environment for its own comparative analysis.

In total, the different assessment teams visited more than one hundred sites throughout Lebanon.

## Remote sensing analysis

To prepare and assist the teams in the field, it was necessary to obtain as much information as possible on sites of interest prior to the mission, regarding:

- the location of impacted areas (e.g. industrial sites, water networks, nature reserves, forests, cultivated land and residential areas); and
- the damage to infrastructure (e.g. roads, bridges, airports and ports).

On the basis of this preliminary information, a set of maps was drawn to help experts navigate efficiently and safely between sites in Lebanon, as well as within the sites themselves. The process is described in detail below.



UNEP used remote sensing analysis to assist with identification of pollution hot-spots

### Stage 1: Satellite data collection

An overview of the most severely damaged areas in Lebanon was obtained from a range of public sources, including:

- the UN community (e.g. ReliefWeb, OCHA, HIC, and UNEP);
- the US Department of Homeland Security;

- the European Union (e.g. the European Union Satellite Centre and Joint Research Centre); and
- various media sources.

Based on this information, very high resolution images of the most severely impacted areas were acquired. The information was cross-checked and a list of priority areas was defined, for which pre- and post-conflict images were procured. The pre-conflict images were taken as close as possible to the start of the conflict, while post-conflict images were taken as close as possible to the ceasefire on 14 August 2006. Pre-conflict imagery was not, however, available for all impacted areas.

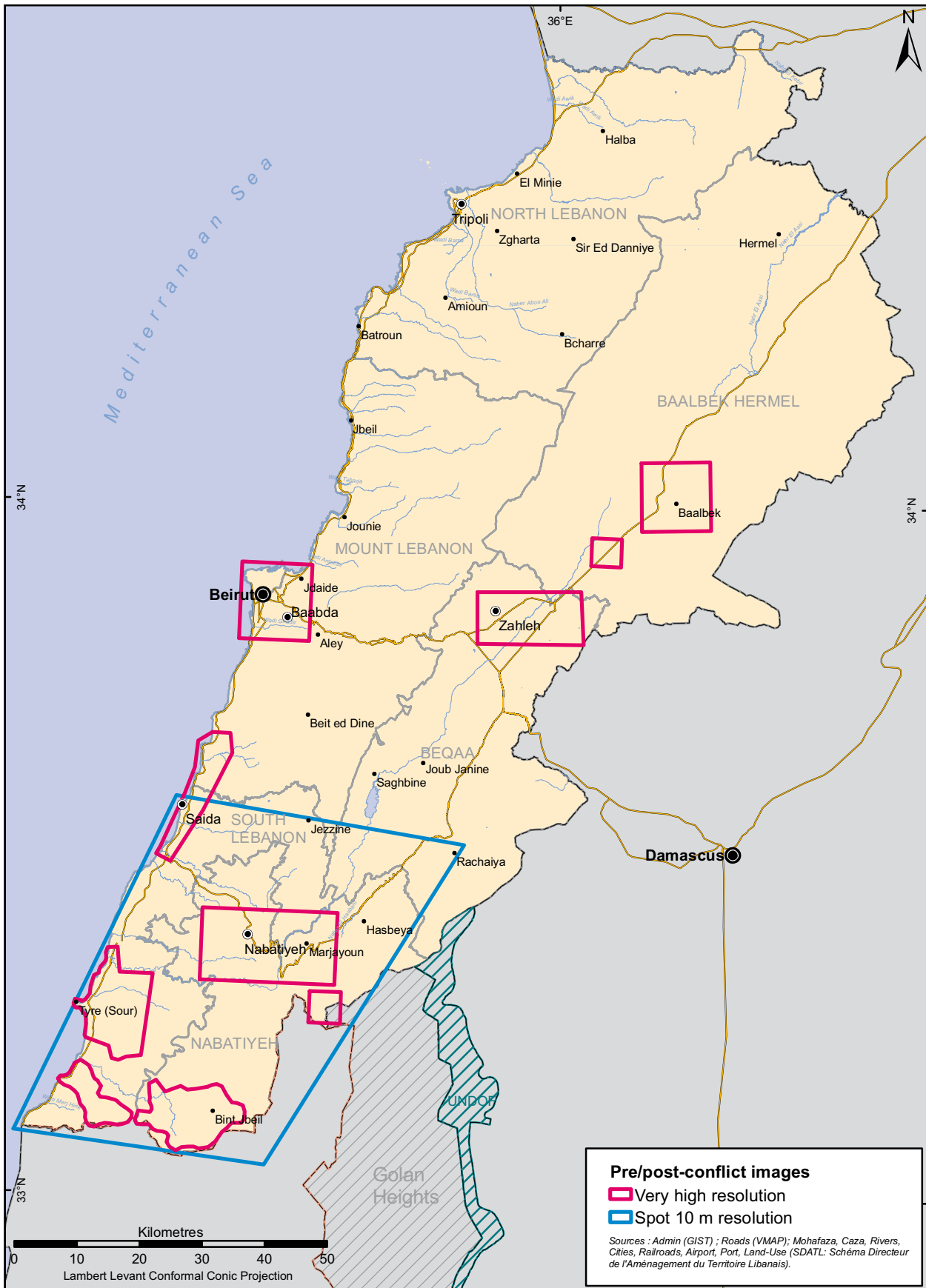
The following satellite coverage was obtained:

- 1,500 km<sup>2</sup> were covered by pre- and post-conflict very high resolution Ikonos and QuickBird images (from 1 m to 60 cm resolution); and
- 3,600 km<sup>2</sup> (the whole southern region) were covered by a 10 m SPOT 5 color image.

Table 1. Satellite imagery used in the assessment

Area name	Area (km <sup>2</sup> )	Pre-conflict image			Post-conflict image		
		Satellite	Resolution	Acquisition date	Satellite	Resolution	Acquisition date
Liban Lait	25	Ikonos	1 m	11/06/05	Ikonos	1 m	07/08/06
Nabatiyeh	125	Ikonos	1 m	17/06/05	Ikonos	1 m	10/09/06
El Biyada	130	Ikonos	1 m	20/07/05	Ikonos	1 m	13/09/06
Bint Jbeil	240	Ikonos	1 m	17/06/05	Ikonos	1 m	10/09/06
Tyre	192	Ikonos	1 m	09/07/05	Ikonos	1 m	14/08/06
Baalbek	120	Ikonos	1 m	28/07/05	Ikonos	1 m	10/09/06
Beirut	120	Ikonos	1 m	17/06/05	Ikonos	1 m	19/08/06
Riyah	136	Ikonos	1 m	09/07/05	QuickBird	60 cm	06/08/06
Marjayoun	140	Ikonos	1 m	17/06/05	Ikonos	1 m	10/09/06
Wazzani	48	Ikonos	1 m	17/06/05	Ikonos	1 m	30/08/06
Saida	105	Ikonos	1 m	17/06/05	QuickBird	60 cm	09/08/06
South Lebanon	3600	SPOT5	10 m	05/08/06	SPOT 5	10 m	30/08/06

Map 5. Coverage of satellite images used



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

**Stage 2: Damage assessment**

The very high resolution satellite images were interpreted in partnership with UNOSAT to detect the damage caused by the conflict and determine the nature of damaged sites, according to the steps detailed below:

- i) Using a 500 x 500 m grid and comparing post-conflict to pre-conflict images, photo interpreters scanned images for impacted zones (as indicated, for example, by dispersed debris);
- ii) Interpreters then zoomed in on identified impact zones and compared post-conflict images with pre-conflict ones in order to:
  - determine which buildings and building types were heavily affected by bombing;
  - determine the exact points of impact;
  - estimate the extent of damage; and
  - note corresponding attributes and coordinates;
- iii) A 100 m blast radius was drawn around all identified bombing sites. All buildings in this blast zone were assumed to be potentially damaged;
- iv) A post-conflict building count, based on pre-conflict imagery, was performed with respect to the blast zone.

The photo interpretation approach followed was conservative, avoiding over-estimation of damage. Later field surveys of bombed sites confirmed a very high correlation with image interpretation results.

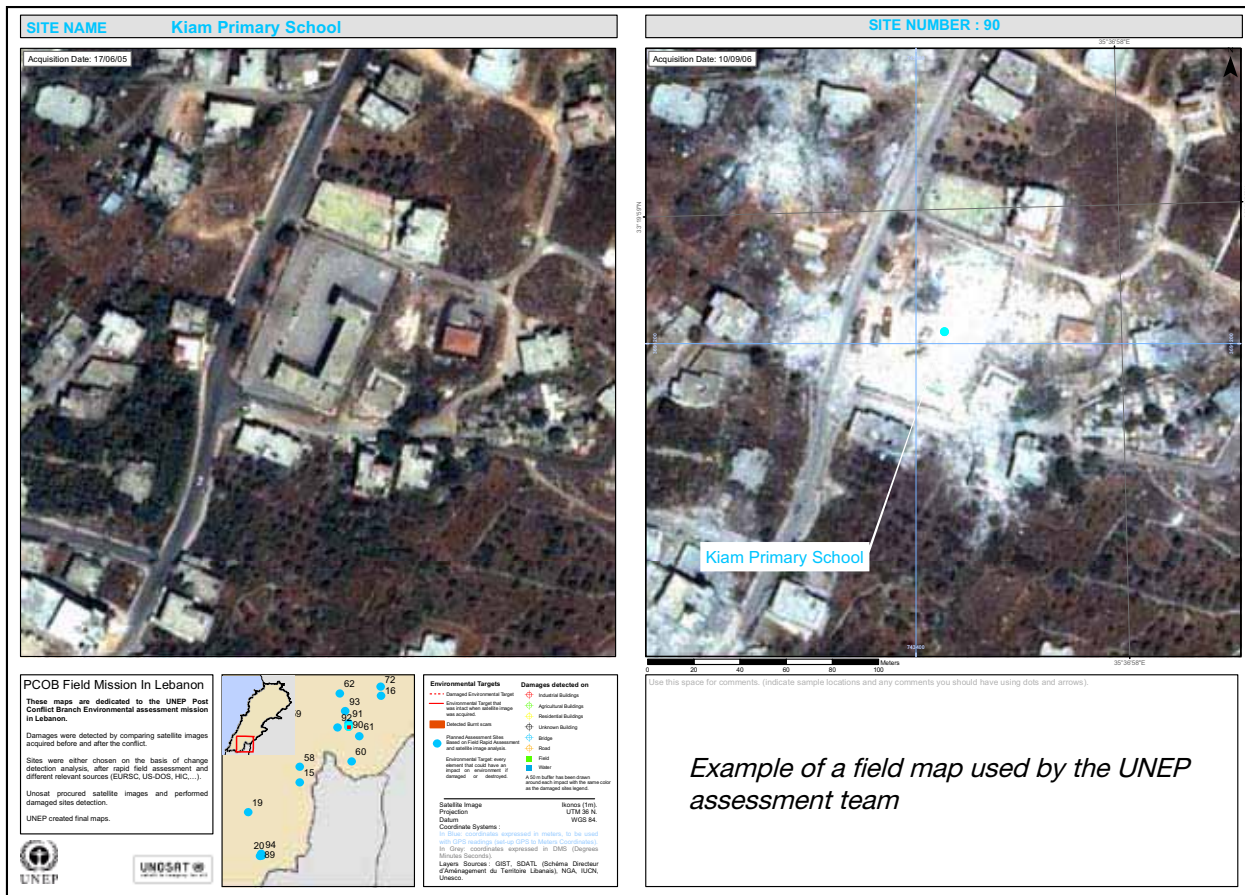
The satellite image analysis identified 2,624 damaged sites, which it was possible to divide into 11 classes:

- 1) airport runways;
- 2) agricultural buildings (e.g. greenhouses and storage facilities);
- 3) bridges;
- 4) buildings – generic (residential, business or industrial buildings that could not be classified further with the available satellite imagery);
- 5) fields – cultivated;
- 6) fields – uncultivated;
- 7) industrial buildings;
- 8) irrigation systems;
- 9) residential buildings;
- 10) roads; and
- 11) towers.

Table 2 below sets out the number of damaged sites per class and per region:

Table 2. Damage assessment based on satellite imagery

Class / Region	1	2	3	4	5	6	7	8	9	10	11	Total
Nabatiyeh			3	121	39	9	1			33		206
El Biyada			2	125	22	5						154
Bint Jbeil				802	41	37	2			81		963
Tyre		10	11	119	113	55	3	2	16	212		541
Baalbek				69	3	3				21	2	98
Beirut	16		2	247			23			6		294
Rayak	4		5	4		3						16
Marjayoun			3	190	8	6				45		252
Wazzani				64	3	1				4		72
Saida			14	4		2	8					28
<b>TOTAL</b>	<b>20</b>	<b>10</b>	<b>40</b>	<b>1,745</b>	<b>229</b>	<b>121</b>	<b>37</b>	<b>2</b>	<b>16</b>	<b>402</b>	<b>2</b>	<b>2,624</b>



### Stage 3: Mapping

Based on the above damage evaluation, a set of maps was created to assist the field team. Very precise location maps were produced for each of the planned assessment sites, showing each site before and after conflict.

While in the field, the assessment team requested additional maps, which were produced in Geneva and rapidly transmitted to Beirut. In total, more than 50 field maps were drawn and used to prepare site visits, navigate within the sites, gather information on the ground, plot sample locations, and report main field observations to UNEP in Geneva.

## Assessment parameters and activities

### Soil/land contamination

Soil contamination occurs when hazardous or toxic substances are spilt, dispersed or leaked and can cause harm to humans through direct

soil contact or digestion through plants, animals or groundwater. Potential soil contamination is evaluated according to the mass and nature of the material that has been spilled. Lists of hazardous substances and concentrations in soil are in use in many countries<sup>1</sup>. These are derived from scientific evidence regarding health risks emanating from toxic substances, and consider underground conditions, land use and the depth of the groundwater table. Although such lists can assist scientists, all factors and circumstances are systematically taken into account in the assessment of potential contamination before specific remediation actions are recommended.

Contaminated land can lead to surface and/or groundwater contamination and can have a bearing on waste management. Not only does most contamination result from waste mismanagement, but its remediation can also generate waste. The necessity, extent, most appropriate type and cost of remedial action can only be determined after the horizontal and vertical distribution of hazardous materials, the history of a site, underground



structures and groundwater movements are known. Accordingly, a combination of the following methods was used to assess potentially contaminated sites in Lebanon:

- consideration of land use history;
- visual and sensory inspection;
- sampling;
- consideration of geology and hydrology;
- consideration of soil quality and composition; and
- consideration of groundwater use.

### Surface and groundwater

Fieldwork comprised site-specific single investigations to examine whether the conflict had affected water resources, particularly in terms of water quality. The objective was to provide a snapshot of post-conflict contaminant concentrations (biological, chemical, and physical) and to compare it with national and international guidelines. As it was not possible to collect samples before the conflict, other sites were sampled for comparison (e.g. upstream of targeted sites).

The standard approach for the freshwater assessment was based on the following steps:



*UNEP expert supervises collection of water sample at Bint Jbeil in South Lebanon*

- consultations with the site manager on site history, operations and damage sustained during the conflict;
- reconnaissance ground survey, aided by satellite maps, to define the spatial boundary of the site, characteristics of the surface and groundwater system (drainage pattern, relief, groundwater level, soil, geology);
- identification and location of potential contaminant sources;
- determination of potential pathways from contaminant source areas to water receptors;
- assessment of seasonal variability (precipitation, flooding, etc.) and how it may affect contaminant mobilization and distribution; and
- collection of multiple samples, including groundwater, surface water, wastewater and piped water, as appropriate and feasible.

Photographs and field notes describing sampling locations were taken for cross-referencing.

The measurement of temperature, electric conductivity, pH, dissolved oxygen and oxygen reduction potential was carried out in the field. Laboratory analysis parameters included heavy metals, inorganic minerals, nutrients, VOCs, SVOCs, EPH, PRO and PAH. No biological sampling was carried out, but qualitative field observations of aquatic life were noted.

The WHO Guidelines for Drinking-water Quality are internationally used – including in Lebanon – as a key reference standard in measuring the safety of drinking water. In this assessment, WHO's Guidelines were applied only where the water source in question was intended for drinking and/or domestic purposes. Specifically, the standards set by WHO were used in assessing the risk to consumers from microbial and pathogenic contamination. For the chemical standards, it should be noted that WHO's guidelines are applicable for daily consumption of drinking water over a lifetime. This means that exceeding permissible levels over a short period of time may not necessarily result in adverse health effects. Finally, snapshot sampling as conducted in the present study does not necessarily signify that the water is safe to drink. Water quality needs to be monitored on a continuous basis. Lebanese standards for drinking water and wastewater were used for cross-referencing purposes in appropriate cases.

## Dutch Values

The standards according to which soil and water samples are evaluated are a matter of international debate between experts and authorities. There are several lists worldwide for Verification Values, Precaution Values, Action Values and Intervention Values.

For its environmental assessment in Lebanon, UNEP used the Dutch Intervention Values and Environmental Screening or Target Values, for the following reasons:

- 1) Dutch standards have been used around the world for more than two decades; there is hence substantial knowledge of their application within the international scientific community;
- 2) Dutch standards are comprehensive in terms of the number and range of parameters for which standards have been set; and
- 3) Whenever soil or groundwater assessments lead to a need for intervention, Dutch Values can further provide target values for clean-up activities.

In the context of water quality, Dutch Environmental Screening or Target Values indicate concentrations above which there may potentially be adverse risks to aquatic life in the long term. They also suggest values that would need to be achieved to rehabilitate water quality to the natural range; although this should be examined on a case-by-case basis, to control for natural metal background levels.

It should be noted, however, that it is not sufficient simply to compare numbers based on Dutch Values to decide on remediation measures. Rather, the need for remedial action should be considered in the local context, taking into account factors such as land use. For example, an elevated PAH soil concentration that would not cause any concern within an industrial location would most certainly require remediation if found within a children's playground or a vegetable patch.

Further, the Dutch list and others – such as the German Soil Protection Act's lists – are designed to evaluate local soil under local conditions. Given that Dutch or German soil is different from Lebanese soil, its comparison to Dutch Values must be viewed as a guideline only.

The Dutch Values used in the assessment can be accessed at:

**<http://lebanonreport.unep.ch>**

### Solid and hazardous waste

Hazardous waste, whose properties render it harmful to human health and/or the environment, may exhibit one or more of the following characteristics:

- ignitability;
- corrosiveness;
- reactivity (explosiveness); and
- toxicity.

The Basel Convention<sup>2</sup> defines hazardous waste as any waste or material that poses a threat to human health and/or the environment. This typically covers chemicals and oil by-products that have no useful purpose and that pose a threat when improperly disposed of.

The types of hazardous waste that could be expected as a result of the conflict in Lebanon included hydrocarbons and industrial chemicals (due to the targeting of industrial plants and equipment), waste from oil spill clean-up operations, asbestos fibres (from the demolition of buildings), hazardous healthcare waste (as a result of deaths and injuries from the conflict), agrochemicals and wastewater.

To evaluate the impact of the 2006 conflict with regard to waste issues, the assessment team undertook a variety of activities, including:



*UNEP expert extracting groundwater sample at Jiyeh power plant using a portable bailer*

- Visiting existing waste disposal facilities;
- Visiting targeted areas that could provide an indication of the types of waste materials to be disposed of post-conflict (e.g. housing areas, schools, hospitals, industrial and commercial locations); and
- Reviewing relevant documentation, both domestic and international, to compile background information on the solid waste management sector in Lebanon<sup>3</sup>.

The assessment of risks linked to asbestos was carried out in accordance with standard UK practice and legislation:

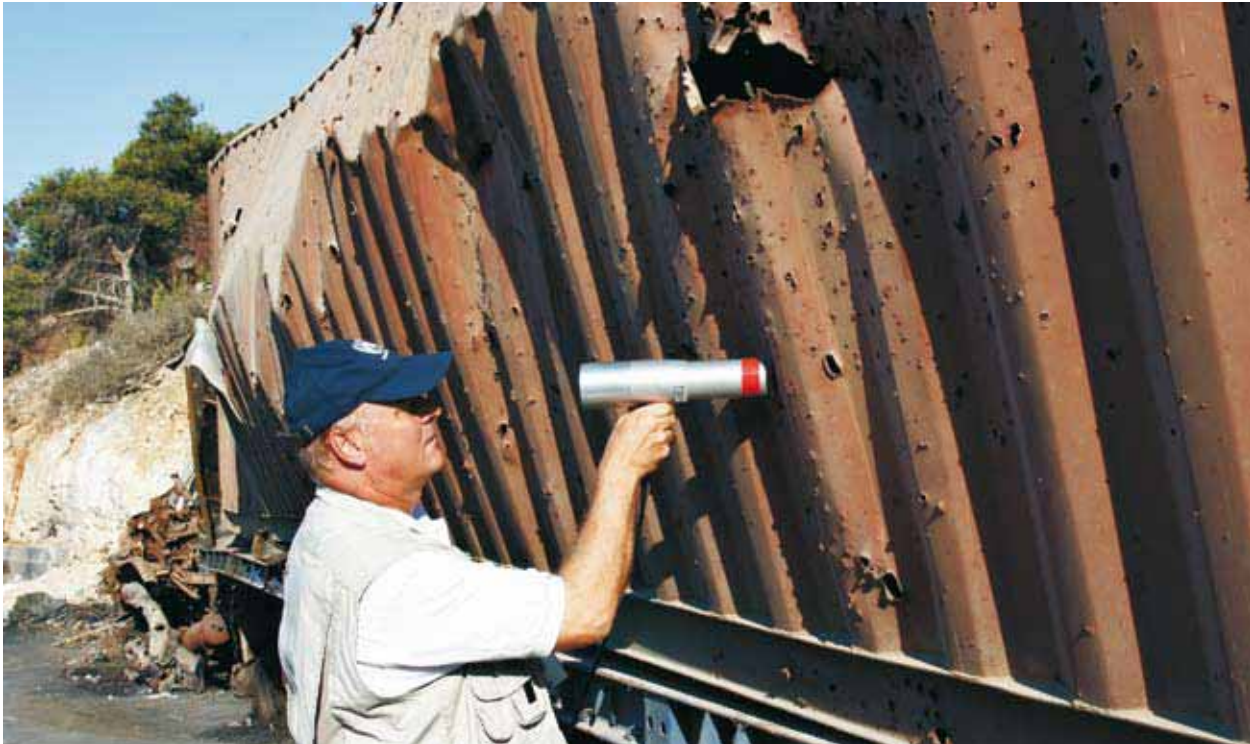
- Walk-round surveys were undertaken at each site and supplemented with local knowledge regarding potential areas of concern and suitable sampling locations;
- Samples were collected for analysis from materials suspected to contain asbestos. Where reasonable, materials visually similar to asbestos were presumed to have the same asbestos content as the sampled materials. Where the appearance of materials was consistent with known non-asbestos containing materials (e.g. man-made mineral fibres and fibreglass-based materials), these were presumed to be non-asbestos in nature; and
- Photographic records of building materials were taken at each site.

### Marine and coastal contamination

The marine and coastal assessment was carried out from small boats, using scuba-diving gear, cameras, and oceanographic sampling equipment. A general underwater survey was conducted at most sites. Where the location was too deep for diving, water samples only were taken. Land-based sources of marine and coastal degradation were also inspected.

Three types of underwater sampling were performed:

- Surface sediment (0-2 cm) was collected from the sea floor at depths ranging from 2 to 25 m, in 200 ml glass containers. Care was taken not



*On-site measurements of radioactivity at a military base on the outskirts of Beirut*

to disturb the fine surface flock while taking the samples. Approximately 100 g of sediment were taken per site. While in the field, the samples were stored on ice in an icebox. At the end of each day, the samples were frozen at a temperature of minus 20°C;

- Oysters (*Spondulis spp.*) were found and collected at 22 of the 27 visited sites. The samples were stored in an icebox during the day and frozen each evening. Each sample consisted of a pooled sample of the soft tissue of four to eight oysters; and
- Three litre water samples were collected at a depth of 10 metres, either with a Ruttner water collector or by diving. Samples were taken at 12 of the 27 visited sites. The water samples were stored cool and sent to the American University of Beirut for analysis.

In addition, free-floating oil, ash and liquid oil samples were taken where appropriate, including at the Jiyeh power plant.

The concentrations of petroleum hydrocarbons (PHC) and polycyclic aromatic hydrocarbons (PAH) in bivalves and fish were analysed using gas

chromatography. After extraction, samples were injected into a HP5890II gas chromatograph with a 30 m, 5 per cent phenyl methyl silicone column with a flame ionization detector. Temperatures were programmed between 50 and 320 °C. The quantification was calculated according to the EU-ISO 9377-2 standard. After changing the solvent to methanol, the extract was injected into a high pressure liquid chromatograph to determine PAH concentrations.

Petroleum hydrocarbons were analysed according to “Determination of EPH” from Massachusetts EP, 1998. PAH levels were determined using a modified method based on the US EPA 8100, which determines PAH concentration using gas chromatography and mass spectrometry.

Samples of oil from the site of the fire at the Jiyeh power plant were analysed using a gas chromatograph with flame ionization to determine the distribution of different hydrocarbons (fingerprinting).

Water samples were injected into a gas chromatograph with a flame ionization detector after extraction using pentane/hexane according to the SS-EN ISO 9377-2 standard.

### Weapons used

Sites were observed visually to assess the type of ammunition used. At a number of sites, weapon parts were found and identified. In addition, discussions were held with the United Nations Mine Action Coordination Centre (UNMACC) (South Lebanon) and UN Explosive Ordnance Destruction (EOD) experts, as well as, in some cases, with Lebanese Army EOD experts. To develop a comprehensive overview of the types of ammunition used during the conflict, the UNEP weapons team visited two EOD camps where the wide range of ammunition remnants found was displayed.

Smear sampling was performed according to international standards. Areas of no less than 20 x 20 cm, usually 40 x 40 cm, were dry smeared on low uranium content smear papers, marked and double-packed for transportation and to avoid cross-contamination. Smear locations were chosen on surfaces untouched by the impact of the weapon, in an appropriate range of distances to the point of impact. Soil and dust samples were also collected where appropriate.

Smear samples were leached in 50 ml 8 M HNO<sub>3</sub> for four hours at a temperature of 50°C. Indium was added as an internal standard. During the leaching process, the samples were put in an ultrasonic bath for one minute. The leachates were filtered through <0.45 µm cellulose filters (Spartan 30/0.45 RC; Schleicher & Schüll). Aliquotes of the filtrate were diluted with distilled water for ICP-MS measurements.

About 20 g of the soil and dust samples were ashed in quartz crucibles at 520°C in high-temperature furnaces for 16 hours (weight constancy). The ashed soil was milled in a 250 ml Syalon ball mill with silicon nitride balls (SiN<sub>4</sub>, 15 balls, diameter 20 mm) for two minutes at 600 rpm. Five grams of the milled soil ash were mixed with 7 g of fluxing agent (lithium metaborate/lithium tetraborate 80%/20%). The mixture was transferred in a platinum/gold crucible (Pt/Au; 95/5) and indium was added as an internal standard. After drying in a drying oven for 30 minutes at 70°C, the samples were fused in a high temperature furnace for 20 minutes at 1100°C. The melt was poured into a 250 ml beaker containing 200 g 4.5 M HNO<sub>3</sub>;

1 ml of 0.2 M polyethylene glycol (PEG-2000) was added as a flocculating agent to precipitate silica gel. This mixture was heated to 40°C with constant stirring for three hours. After cooling down, 3 ml of the upper layer solution was filtered through <0.45 µm cellulose filters (Spartan 30/0.45 RC; Schleicher & Schüll). Aliquotes of this solution were diluted with 2% HNO<sub>3</sub> for ICP-MS measurements.

In addition, the prepared samples were analysed for other ammunition-related inorganic metals. Analysis was performed by the ELAN 6000 ICP Mass Spectrometer. The Perkin-Elmer “Totalquant-®” analysis programme, which allows a rapid, semi-quantitative determination with a precision of approximately 20%, was applied.

### Equipment used

#### Soil sampling kit

Eijkelkamp Soil Augur kits were used to collect soil samples at various depths. These shallow augers are operated manually.

#### Photo-ionization Detector (PID) (model HNU 102)

This hand-held tool, which gives an instantaneous reading, measures volatile organic compound concentration in parts per million (ppm) using an ultraviolet light source. It is used to evaluate the presence of hydrocarbon contamination, particularly that of lighter end fractions. A soil sample is placed in a glass container sealed with aluminium foil. The container is then shaken to stimulate the release of volatile organic compounds and a probe is inserted through the foil to take a reading. For this assessment, the instrument was calibrated using an isobutylene gas and had a 10.6 eV lamp.

#### Landfill Gas Analyser (model Geotechnical Instruments GA 2000)

The analyser is a portable unit that measures five types of gases using chemical cells. It gives an instantaneous reading. The analyser's probe was inserted into areas of potential concern, including drains, tanks and excavations.

### **Interface Meter (Heron dipper T water level meter)**

An interface meter is used to determine the depth of the water column in a well. Some interface meters can detect the interface between a floating hydrocarbon level and the water level beneath it.

### **Multi-Parameter Field Analyser (MP TROLL 9000)**

An MP TROLL 9000 was used to measure water quality parameters. Permanent sensors available in the MP TROLL 9000 were used to measure pressure, temperature, electrical conductivity, oxygen reduction potential, pH and dissolved oxygen. Win-Situ software was installed on a laptop to take measurements.

### **Disposable bailers**

Some water samples were collected with bailers. Agitation and turbidity due to surging and the sudden impact of the sampling device was avoided by allowing the bailer to descend on its own until it filled. Water was collected in appropriate bottles, which were stored in a cool box.

### **Asbestos sampling kit**

In accordance with standard practice and to minimize possible asbestos-related health and safety concerns, tools and equipment used for the investigation were restricted to simple hand tools including torches, screw drivers, and chisels. No power tools were used. The potential for fibre release was minimized by using a dust suppressant spray where required.

### **Geographical Positioning System (Garmin-60 and E-trax, hand-held)**

In order to corroborate the information compiled from remote sensing and to obtain accurate coordinates of various sampling points, all field teams used Geographical Positioning Systems (GPS).

The weapons team used the following equipment in the field:

The *Saphymo-SRAT S.P.P.2 NF scintillometer* is designed for uranium exploration in rugged conditions. The detector is a 1 x 1.5 inch (15.2

cm<sup>3</sup>) NaI(Tl) (sodium iodide activated with thallium) scintillation crystal. The range of operation for gamma radiation is 0.02 to 30 µSv/h. The instrument has a built-in audible alarm with a time constant of 0.25 seconds. The threshold and frequency of the sound alarm can be varied according to the strength of the radiation. The unit of measurement is counts per second (cps).

The *Inspector* has very high sensitivity to beta radiation, thanks to its pancake GM-tube. Its large (50 mm diameter) window allows for measurements very close to the source to detect beta radiation from DU. The detector is a halogen-quenched Geiger-Müller tube with an effective diameter of 45 mm. The detector window can be covered with a metal lid, which only allows gamma radiation to reach the detector. When the lid is removed, gamma, beta and alpha radiation is measured. Units of measurement are counts per minute (cpm), counts per second (cps), mR/h or µSv/h. A sound alarm clicks for each radiation event detected.

The *Automess Dose Rate Meter AD 6* and its *Alpha-Beta-Gamma Probe AD-17*, allow good quality measurements of radioactivity dose rates and contamination levels. The AD 6 can be used with a wide range of probes. It is calibrated according to internationally accepted standards, allowing direct comparison of results measured. This instrument was mainly used to measure ambient dose rates.

The *Fieldspec Instrument identiFINDER-N/He-3* is a hand-held gammaspectrometry system with a dose rate meter and a neutron counter. It includes a multi-channel analyser with memory, amplifier and a NaI(Tl) scintillation crystal (Ø 1.2" x 1.5"). It can measure gamma spectrums and perform gammaspectrometric analysis, including radionuclide identification, by using radionuclide libraries.

### **Laboratory analysis**

The soil, water, dust and ash samples collected by the main team were submitted to **Alcontrol Laboratories** in the UK for analysis. Alcontrol has ISO 170253 standard accreditation and participates in the MCERTS<sup>4</sup> programme of certification, as well as the AQUACHECK and CONTEST proficiency testing programmes.

Oyster and fish samples were analysed by the **IVL Swedish Environmental Research Institute** in Stockholm (Sweden), which undertakes project assignments and research across the environmental spectrum. The analysis of petroleum hydrocarbons in marine water samples was carried out at the **American University of Beirut**.

Weapons-related samples were submitted to the **Spiez Laboratories** in Switzerland, a governmental institute of the Swiss Ministry of Defense, Civil Protection and Sports. UNEP has collaborated with the Spiez Laboratories in the field of depleted uranium and other environmental issues since 1999. All the laboratories' departments are accredited in accordance with ISO/IEC 17025.

### Limitations and constraints

- Not all sites of interest could be visited within the three-week time frame of the field component of the assessment. Accordingly, some sites were considered representative of similar locations. For instance, two petrol stations were visited as examples of fuelling stations across the country.
- Security considerations limited access to some sites. The presence of unexploded cluster bombs, in particular, prohibited access to some areas of interest. Damaged or partially demolished buildings were not entered when deemed structurally unsafe.
- Pre-conflict satellite imagery was not available for all assessed sites. In such cases, the team had to rely on post-conflict imagery alone.
- While the best possible water sampling locations were selected to cover visited sites – focusing on the contaminant source where feasible – it was not possible to collect samples at some sites, due to dry season conditions, damaged well casings and/or because there was no access to a water source. Where feasible, groundwater was purged and examined to ensure that it was representative of aquifer conditions.
- Air pollution was an important and visible impact of the recent conflict. However, by the time the UNEP team was allowed access to the field, all of the primary pollutants had disappeared, limiting the assessment of this issue.



*UNEP security expert demarcates an unexploded cluster bomblet for deactivation. Unexploded ordnance limited access to numerous sites*

# Industrial and Urban Contamination

*Smoke rises from the fuel tanks at Jiyeh  
power plant on 16 July 2006.  
Hydrocarbon-contaminated soil at the  
power plant and a number of other sites  
require appropriate disposal.  
© AP Photo – Mohammed Zaatari*





## Industrial and urban contamination

The UNEP team visited more than one hundred sites in Lebanon in the course of the assessment between 30 September and 21 October 2006. This chapter sets out the findings with respect to specific sites investigated for sources of industrial and urban contamination. Environmental issues in various sectors, such as freshwater resources, waste management and marine and coastal management, are discussed in the following chapters.

### Combustible storage and processing facilities

#### Jiyeh thermal power plant

The Jiyeh thermal power plant site, whose total area comprises some 40,000 m<sup>2</sup>, is located directly on the coast, approximately 30 km south of Beirut. The underlying ground consists of Cretaceous (Cenomanian - Turonian) limestone. Major faults are not documented in the Ministry

Due to the large number of sample analyses conducted, only selected field and laboratory results have been included in this report. However, complete results, as well as Dutch and WHO standards, can be accessed at: <http://lebanonreport.unep.ch>

of Public Works geological map (1955), but may be present nonetheless. A visual inspection of the shoreline revealed cracks and fissures in the rocks, which may have been influenced by karstic phenomena. The ground surface is approximately 3 to 10 m above ground level, depending on the distance to the sea.

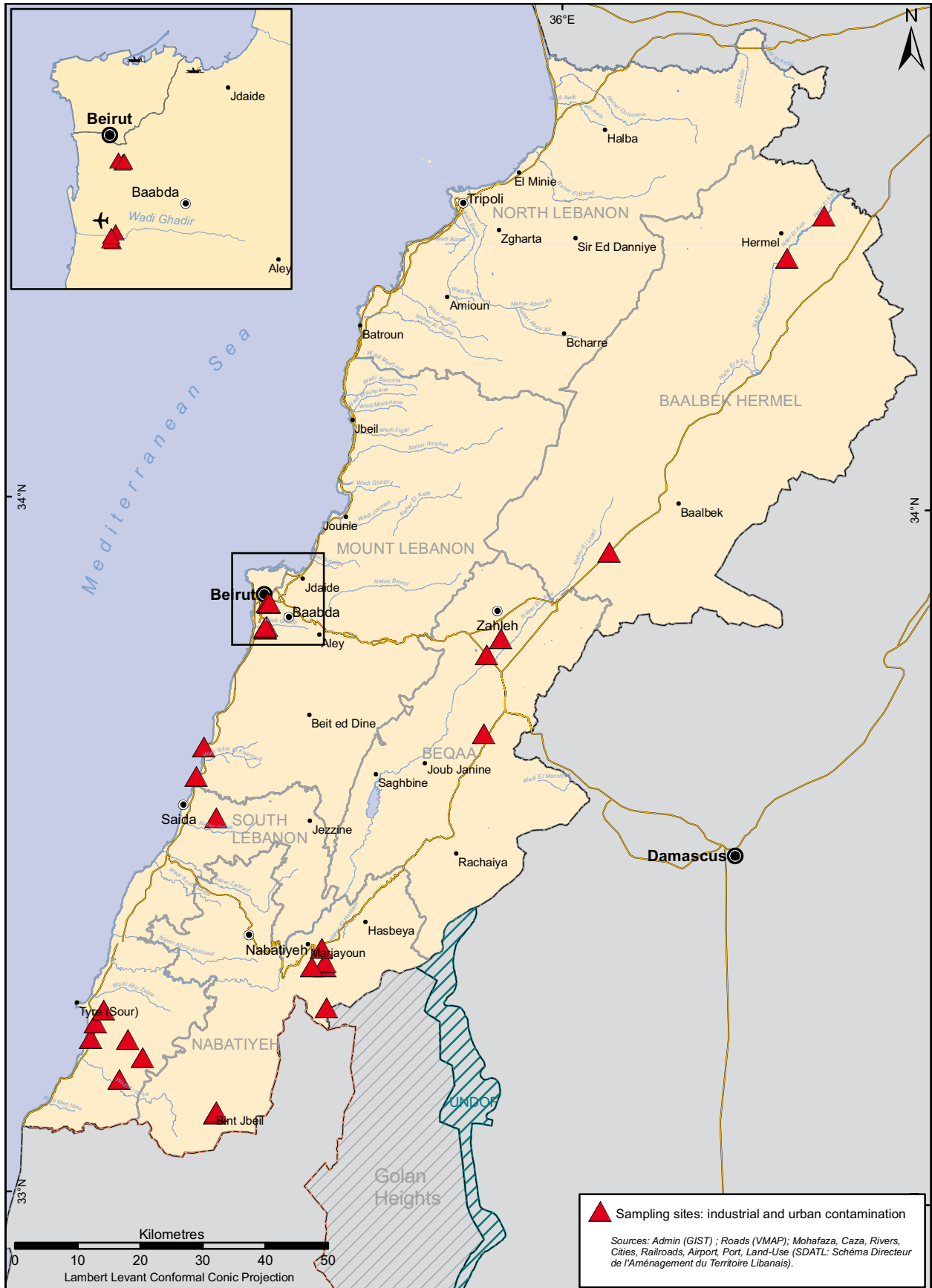
The relevant parts of the tank farm consist of six tanks of different sizes:

- one tank measuring 25,000 m<sup>3</sup>;
- two tanks measuring 15,000 m<sup>3</sup>;
- two tanks measuring 10,000 m<sup>3</sup>; and
- one underground gas oil tank measuring 500 m<sup>3</sup>.



*The remains of the fuel storage tanks at the Jiyeh power plant*

Map 6. Sampling sites – industrial and urban contamination



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

The Jiyeh fuel tanks before the conflict



The site management reported that two of the larger tanks were directly hit during the bombing of the site on 13 and 15 July, and that fire engulfed and largely destroyed the remaining tanks. Consequently, only the small underground tank was still intact at the time of inspection.

The total amount of oil burned and spilled as a result of the air raids has not been ascertained, but up to 75,000 m<sup>3</sup> of oil, which was identified as heavy IFP – number 6 fuel, could have been burned, spilled into the sea and leaked into the ground. All tanks and pipelines on the site were severely damaged by the fire, which is reported to have burned for a total of 27 days. Much of the infrastructure melted under the extreme temperatures and railway tank wagons on tracks within the compound were also reduced to molten metal.

The power plant itself, however, was not directly damaged and has remained in partial operation since the attack.

The inspection of the site revealed that the intense heat generated by the fire had not only caused

the concrete surface of the tank farm to crack extensively, but had also completely destroyed much of the concrete infrastructure, such as pipeline stands. The surface of the whole area was covered with a thick layer of ash, which in some areas measured up to 0.5 m.

On the seashore, a crust of dried oil was found on the rocks, while fresh oil could still be seen at other locations, apparently seeping from cracks in the rock. It remains unclear whether this phenomenon is due to an accumulation of oil underneath the gravel at the shore, or rather results from oil that has seeped into the rock underlying the tank farm and is slowly migrating to the shore.

### Contaminated land

Soil samples were collected within the boundaries of the tank farm to help determine the nature and extent of the ground contamination:

- Sample no. 1-WM/CL-01 was taken from the ash around the actual tanks. The greyish ash resulted either from incomplete combustion or from additives to the fire-fighting water;

The Jiyeh fuel tanks after the conflict



- Sample no. 1-WM/CL-02 was pure product found in an oil separator. It was black and viscous; and
- Sample no. 1-WM/CL-03 was taken directly by the seashore at the tank farm and consisted of limestone gravel and sand mixed with heavy oil.

Samples referred to as “JPPV” were collected some distance from the power plant and over 5-10 m away from the nearest road to avoid the side effects of automobile traffic. These were either plant samples collected from leaves, stems, weeds or trees, or soil samples taken from gardens. The soil in all samples was reddish, with clayey components, and mixed with gravel.

Though most of the oil released during the attacks on the Jiyeh plant either burned or spilled into the sea, it is likely that a significant proportion seeped into the rock underlying the site. During clean-up operations, staff should therefore wear suitable health and safety equipment, and adhere to appropriate practices and procedures.

If present, oil located within cracks and fissures of the underlying rock might affect groundwater

wells in the vicinity. Further, oil trapped beneath the site may continue leaking into the sea, thus impacting water quality and local fishing industries.

Due to the very intense temperatures generated by the fire, the stability of the concrete is likely to have suffered. Given the potential structural instability of the damaged material and the very high risk of settlement, it would be extremely unwise to construct new tanks upon it.

As is shown in table 3 on page 47, no soil sample collected within the power plant itself had concentrations of polycyclic aromatic hydrocarbons (PAH) above Dutch Intervention Values. The ash sampled from the storage tank site, however, did contain high PAH levels.

The ash cover on the ground is not a contaminated land hazard (though when it rains hazardous materials could dissolve and leach into groundwater and eventually the sea), but should be considered as hazardous waste. When removing the ash or working in affected areas, safety measures must be taken (i.e. protective clothing, appropriate breathing masks, etc.).

## Atmospheric pollution

The military strike on the fuel tanks in Jiyeh resulted in massive oil fires and generated a plume of smoke stretching for several kilometres. Anecdotal evidence indicates that the fire burned continuously for up to 27 days. The smoke itself would have contained a potentially toxic cocktail of pollutants – including soot, particulate matter, carbon monoxide, methane and a range of hydrocarbons – the combination of which could be expected to cause a significant degree of environmental pollution and respiratory problems for local residents.

However, in the absence of primary data gathered during the conflict, determining the exact extent and impact of the atmospheric pollution caused by fires such as the one at Jiyeh, is an extremely complex scientific undertaking. Approaches based on modelling require extensive information, such as that relating to prevailing atmospheric conditions. When reliable primary data is not available, the end result of such modelling is, at best, dubious.

Consequently, it was not possible for UNEP's post-conflict assessment to examine the environmental impacts associated with air pollution, even though it is recognized that it was probably one of the most serious environmental impacts of the conflict. The assessment did, however, attempt to address the issue in a limited manner:

- First, a limited survey of soil quality around the Jiyeh power plant was undertaken to study the fallout of soot from the fire;
- Second, smear samples were taken in the immediate vicinity of major bombing sites; and
- Finally, UNEP is working with the American University of Beirut to monitor the quality of rain and snow in Lebanon, to determine whether some of the air pollutants that reached the upper atmosphere may return in the form of precipitation.

Soil and plant samples were taken from a number of locations around the power plant, at a maximum distance of 4 km from the plant. The analysis of samples collected showed that, even at a distance of several kilometres from the power station, negative impacts on soil quality could be identified. The fact that all five soil samples taken from the vicinity of the power plant – covering some 5 km<sup>2</sup> – showed an average PAH concentration of 1 mg/kg, confirmed that a significant amount of PAH had been deposited in the area.

It was not possible, though, to ascertain whether these elevated levels of PAH were the result of the massive short-term impact of the fire, or whether they were the consequence of poor exhaust gas filtering during normal plant operations. Continuous soot fallout from the power station was observed throughout the site inspection. It is unclear whether this occurred as a result of the conflict, or whether it represents the normal state of operations.

Figure 1 demonstrates the similarity of the PAH spectrum in four of the soil samples. The sample JPPV-CL/WM-03SO shows the lowest PAH concentration, with some of the other substances being below the detection limit.

A longer-term investigation should be undertaken to determine the source of the elevated PAH concentrations around the plant. To achieve this goal, soil analysis should be carried out within a radius of several kilometres. The assessment should take into account both the conflict-related power plant fire and power plant emissions under normal operations.

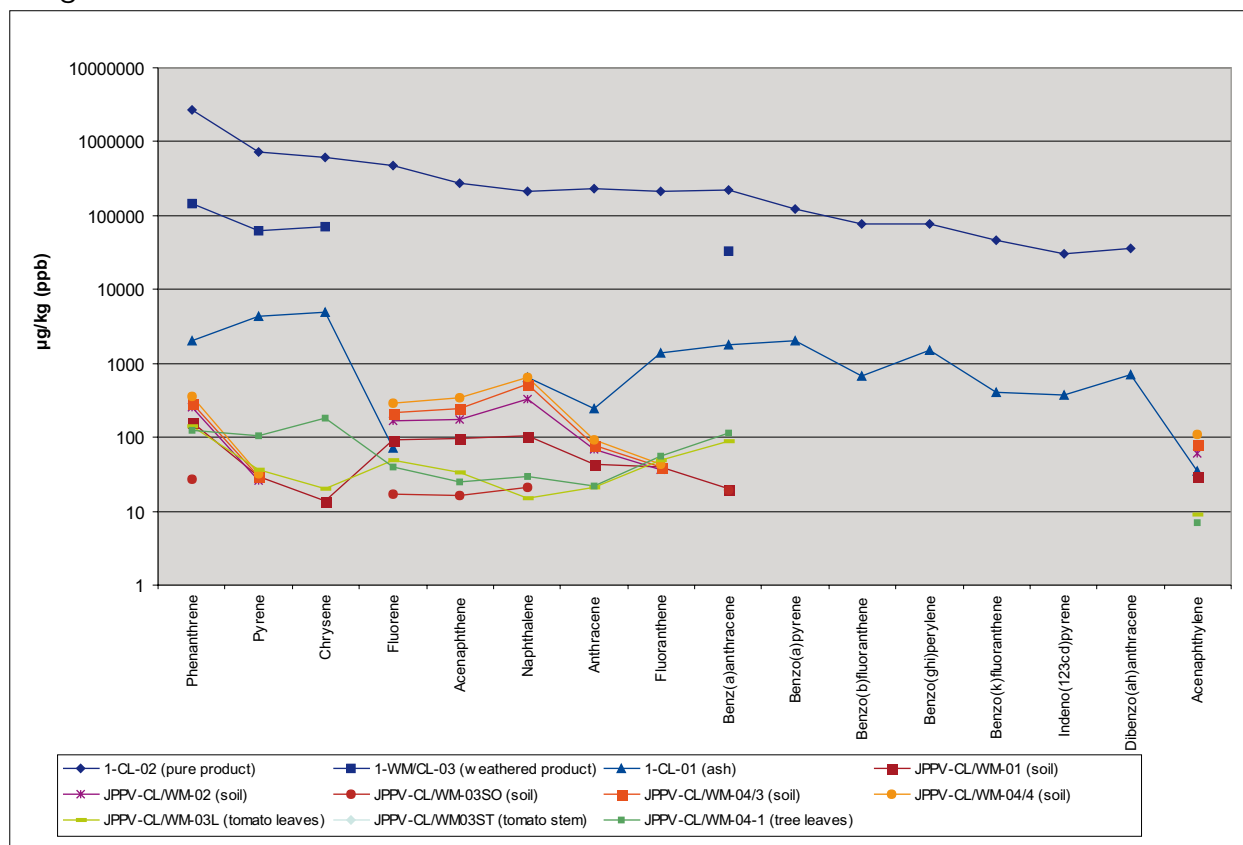
It is recommended that a national registry of people living in close proximity to the power plant be established, and that their health be tracked henceforth for long-term impacts. Such a programme would allow early identification of unusual health trends, such as respiratory and cardiac problems and cancer, and assist in the provision of adequate measures and support mechanisms.

Table 3. Selected sample results from Jiyeh power plant and its vicinity

Sample Identity		1-CL-01 <sup>1</sup>	JPPV-CL/WM-01 <sup>2</sup>	JPPV-CL/WM-02 <sup>3</sup>	JPPV-CL/WM-03SO <sup>4</sup>	JPPV-CL/WM-04/3 <sup>5</sup>	JPPV-CL/WM-04/4 <sup>6</sup>	JPPV-CL/WM-03L <sup>7</sup>	JPPV-CL/WM-03ST <sup>8</sup>	JPPV-CL/WM-04-1 <sup>9</sup>	Dutch List Intervention Value
<b>PAH by GCMS</b>											
Naphthalene	µg/kg	648	107	327	21	531	652	15	<10	29	–
Phenanthrene	µg/kg	1,987	161	252	27	295	365	139	<21	126	–
Anthracene	µg/kg	244	43	68	<9	77	91	21	<9	22	–
Fluoranthene	µg/kg	1,405	40	37	<25	40	44	48	<25	56	–
Benz(a)anthracene	µg/kg	1,753	20	<12	19	<12	<12	89	<12	115	–
Chrysene	µg/kg	4,866	14	<10	<10	<10	<10	20	<10	180	–
Benzo(k)fluoranthene	µg/kg	399	<25	<25	<25	<25	<25	<25	<25	<25	–
Benzo(a)pyrene	µg/kg	1,988	<12	<12	<12	<12	<12	<12	<12	<12	–
Indeno(123cd)pyrene	µg/kg	371	<11	<11	<11	<11	<11	<11	<11	<11	–
Benzo(ghi)perylene	µg/kg	1,539	<10	<10	<10	<10	<10	<10	<10	<10	–
<b>PAH Dutch List 10 Total</b>	<b>µg/kg</b>	<b>15,200</b>	<b>385</b>	<b>684</b>	<b>67</b>	<b>943</b>	<b>1,152</b>	<b>332</b>	<b>–</b>	<b>528</b>	<b>40,000</b>
Acenaphthylene	µg/kg	35	30	61	<5	80	108	9	<5	7	–
Acenaphthene	µg/kg	<70	95	176	16	247	343	33	<14	25	–
Fluorene	µg/kg	73	91	168	17	216	286	48	<12	39	–
Pyrene	µg/kg	4,278	29	26	<22	29	32	36	<22	103	–
Benzo(b)fluoranthene	µg/kg	668	<16	<16	<16	<16	<16	<16	<16	<16	–
Dibenzo(ah)anthracene	µg/kg	699	<8	<8	<8	<8	<8	<8	<8	<8	–
<b>PAH 16 Total</b>	<b>µg/kg</b>	<b>20,953</b>	<b>630</b>	<b>1,115</b>	<b>100</b>	<b>1,515</b>	<b>1,921</b>	<b>458</b>	<b>&lt;25</b>	<b>702</b>	<b>–</b>

- <sup>1</sup> ash sample from power plant storage tanks area
- <sup>2</sup> soil sample, ~4.3 km N<sup>1</sup> power plant
- <sup>3</sup> soil sample, ~2.5 km NE<sup>1</sup> power plant
- <sup>4</sup> soil sample, ~1.5 km SE<sup>1</sup> power plant
- <sup>5</sup> soil sample (salad bed), ~0.5 km E<sup>1</sup> power plant
- <sup>6</sup> soil sample (clay from watering furrows), ~0.5 km E<sup>1</sup> power plant
- <sup>7</sup> plant sample (leaves), ~1.5 km SE<sup>1</sup> power plant
- <sup>8</sup> plant sample (stem), ~1.5 km SE<sup>1</sup> power plant
- <sup>9</sup> plant sample (leaves), ~0.5 km E<sup>1</sup> power plant

Figure 1. Relative PAH concentrations in different media





*Dismantling of the fuel storage tanks was ongoing at the time of assessment. The complete absence of personal protective equipment for staff was a concern*

## Groundwater

Samples were collected from two wells located up-gradient from the destroyed fuel tanks to determine if hydrocarbon contamination had migrated into the aquifer underlying the site (15-20 m below ground surface). Although the sampling locations were situated uphill from the tank farm, fractures in the limestone and groundwater extraction could potentially have led to hydrocarbon contamination progressing into the aquifer as part of the seawater intrusion phenomenon.

Laboratory analysis did not detect hydrocarbons in the samples taken. Nevertheless, given hydrocarbon volatilization losses and the potential for oil compounds to reach and dissolve into groundwater following rains, follow-up sampling should be carried out over several months to monitor potential hydrocarbon contamination.

Nickel, selenium and zinc were detected above the environmental screening values, but significantly below intervention levels. Of greater concern was the faecal coliform contamination, which ranged from 260-700/100 ml. These elevated coliform levels place site workers who use the water for washing at a high risk of cross-contamination and accidental ingestion of pathogens.

## Waste management

During the site inspection, work was ongoing to dismantle the metal tanks, which were being cut into sections and transported off the site by tipper-trucks. The complete absence of health and safety equipment for the individuals participating in these activities is a matter of concern.

It was anticipated that the site would be cleared of all metal recyclables, including railway tracks, wagons and engines, all of which were extensively damaged in the fire.

Clearly, the most significant waste disposal issue on the site is that of the contaminated soil and material, the exact extent of which could only be determined through a thorough site investigation. In addition, the large quantities of ash across the surface of the site, particularly in the vicinity of the fuel tanks, should be considered as hazardous waste, and should be removed, stored and disposed of accordingly.

## Asbestos

The visual inspection of the tank farm and power station did not reveal any asbestos-containing material. Rather, significant amounts of man-made insulating material, such as mineral wool, were used as thermal insulation for the pipework



transporting the oil stored in the tanks. The tanks that were still standing did not appear to have any insulating material.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. Undertake a thorough site investigation, using drilling-rigs and equipment such as excavators and back-hoes for digging trenches, to determine the vertical and horizontal extent of the oil contamination.
2. Until the clean-up of contaminated soil is completed, conduct follow-up sampling of the two wells around the spill site to determine whether the water has been impacted by the potential oil spill migration.
3. Evaluate the stability of the concrete base of the tank farm to determine whether it is structurally sound. If it is not, it should be removed and replaced with a new concrete base, prior to the construction of new tanks on the site.
4. If the concrete platform is to be replaced, the underlying contaminated gravel and soil should be excavated and replaced with clean sand and gravel, thus creating a stable base for a new concrete surface. A worst case estimate of the volume of contaminated material is approximately 80,000 m<sup>3</sup> (40,000 m<sup>2</sup> by 2 m in depth).



*The spilled contents of damaged oil drums adds to the significant contamination of the site*

5. Collect all the ash from the surface of the site, and treat it as hazardous waste: the material should be placed inside resealable drums, appropriately labelled to warn of the potential hazard, and – in the absence of suitable disposal options – temporarily stored in a suitable and secure location until a disposal option is identified.
6. Soil with elevated concentrations of hydrocarbons should also be treated with the appropriate technology, including biological remediation.
7. All individuals engaged in site clean-up activities, such as the dismantling of the obsolete tanks, must be provided with, and use, appropriate health and safety equipment, including boots, gloves, overalls, hard hats, and disposable masks/respirators.

#### Medium-term recommendations (3 months – 1 year)

1. When building a new concrete surface, or restoring the existing one, concrete bund walls should be installed to prevent leakage of oil into the sea, should any future incidents occur.
2. The source of the elevated PAH concentrations around the plant should be verified. To this end, the analysis of soil from within a radius of several kilometres should be carried out. The assessment should take into account both the conflict-related power plant fire and power plant emissions under normal operation.
3. Monitor groundwater around the power plant to detect potential oil seepage from the destroyed tanks into the underlying aquifer.
4. Monitor seawater and run-off.

#### Long-term recommendations (1 year +)

1. To protect public health and environmental quality in the future, enhanced filter technologies for the plant's exhaust fumes should be employed.
2. Continue monitoring programmes.

## Beirut airport fuel storage tanks

The airport fuel tanks are situated on the eastern perimeter of the complex, some 2 km from the coast, at 10-12 m above ground level. The underlying soil consists of quaternary littoral sands and red soil. After approximately 200 m, the site is bordered by residential housing, industrial complexes and agricultural land.

The tank site consists of three tanks of equal size (~ 1,500 m<sup>3</sup>) set in 40 x 40 m basins with concrete perimeter bund walls. Signage on the tanks indicates that they contain kerosene as Jet Fuel A1, which is standard for international airports.

Only the northernmost tank was destroyed during the attacks on the airport, releasing a total estimated volume of up to 1,500 m<sup>3</sup> of kerosene. The relative proportions of kerosene burnt and kerosene leaked into the ground could not be determined.

At the time of UNEP's visit, the destroyed tank was already being dismantled, and the scrap metal cut into sections and removed from the site.

Inspection of the concrete base of the tank farm revealed cracks, which may have been due to excessive heat from the fire, but also to the age of the concrete.

## Contaminated land

Auguring was not possible at the site due to the high content of rocks and gravel in the underlying soil. However, two soil samples were collected by hand from the perimeter of the concrete basin, where a breach had been created to facilitate the dismantling of the damaged tank:

- One sample was taken from soil underneath the concrete wall of the impounding basin, approximately 0.3 m above ground level;
- The second soil sample was taken from below the perimeter wall, 0.5 m away from the concrete base of the impounding basin at ground surface level.

Both samples consisted of the red soil omnipresent in the coastal areas, with a high mineral and gravel content. Results from the two samples are provided in table 4.



© AP PHOTO - HUSSEIN MALLA

Fire fighters try to extinguish the burning fuel storage tank at Beirut's airport, 13 July 2006



The concrete base of the damaged fuel storage tank at Beirut's airport was being demolished

Table 4. Selected soil analysis results

Parameter / Sample Identity	Unit	5-CL-01	5-CL-02	Dutch Intervention Value
Sample depth (bgs)	m	+ 0.3 m	- 0.3 m	
<b>EPH (DRO) (C10-C40)</b>	mg/kg	3,918	<b>5,402</b>	<b>5,000</b>
<b>PAH by GCMS</b>				
Naphthalene	µg/kg	1,047	956	–
Phenanthrene	µg/kg	157	518	–
Anthracene	µg/kg	53	362	–
Fluoranthene	µg/kg	157	547	–
Benzo(a)anthracene	µg/kg	70	328	–
Chrysene	µg/kg	78	386	–
Benzo(k)fluoranthene	µg/kg	35	221	–
Benzo(a)pyrene	µg/kg	43	356	–
Indeno(123cd)pyrene	µg/kg	35	242	–
Benzo(ghi)perylene	µg/kg	52	361	–
<b>PAH Dutch List 10 Total</b>	<b>µg/kg</b>	<b>1,727</b>	<b>4,277</b>	<b>40,000</b>
Acenaphthylene	µg/kg	199	547	
Acenaphthene	µg/kg	307	138	
Fluorene	µg/kg	89	189	
Pyrene	µg/kg	217	584	
Benzo(b)fluoranthene	µg/kg	70	433	
Dibenzo(ah)anthracene	µg/kg	11	106	
<b>PAH EPA 16 Total</b>	<b>µg/kg</b>	<b>2,620</b>	<b>6,274</b>	–

The airport fuel storage tanks before the conflict



Both soil samples emitted a strong smell of kerosene, leading to the conclusion that a significant amount of the fuel had leaked into the ground following the attack on the tank. The soil samples, however, showed less contamination than expected. The sample from the wall of the impounding basin showed concentrations of extractable petroleum hydrocarbons (EPH) and polycyclic aromatic hydrocarbons (PAH) below Dutch Intervention Values, while intervention values for hydrocarbons were exceeded only slightly in the sample taken from below ground surface.

The sampling could not reveal the total extent of the spill, but given that it showed definite signs of kerosene-contamination, a larger spill (several hundred cubic metres) resulting from the attack could not be ruled out.

Kerosene contains a large amount of benzene, toluene, ethylbenzene and xylenes (BTEX), which are highly toxic and highly mobile. Hydrocarbon plumes in the groundwater can reach several hundred metres in length, depending on groundwater movement,

biological activity, etc. If water wells are found in close proximity to the site, the potential for contamination exists.

These concerns will have to be verified by further investigations and monitoring.

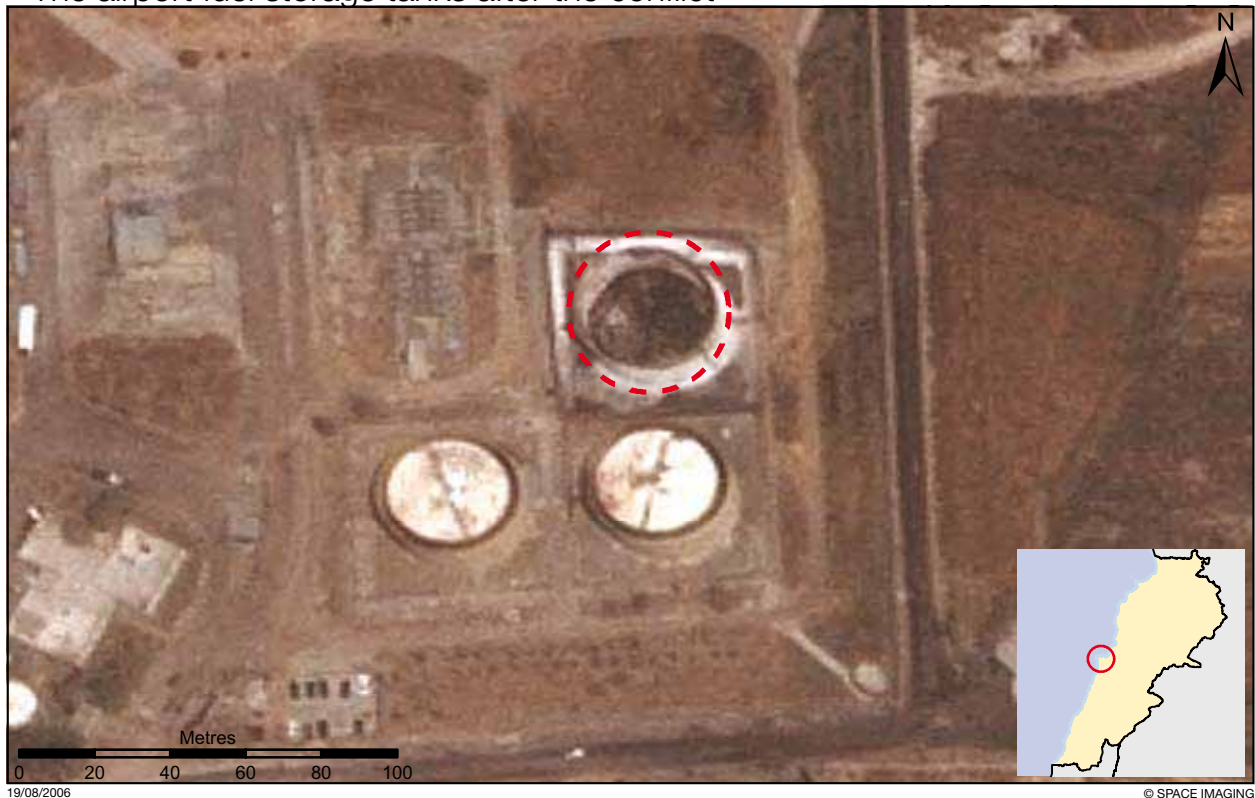
### Surface and groundwater

No borehole or surface water was identified within the site and thus no water samples were recovered. The oil spill, however, represents a pollution risk for the nearby Ghadir stream as well as for groundwater in the area, particularly following heavy rainfall. These need to be investigated further in future. In addition, hydrocarbon contamination of surface and groundwater found at the neighbouring El-Twait feedlot site is suspected to originate from the airport's damaged fuel tanks.

### Waste management

During the site inspection, work was ongoing to dismantle the damaged fuel tank, which was being cut into sections and transported off the

The airport fuel storage tanks after the conflict



site by tipper-trucks. The complete absence of health and safety equipment for the individuals participating in these activities is a matter of concern.

Clearly, the most significant waste disposal issue on site is the contaminated soil and material, the exact extent and magnitude of which could only be determined through a thorough site investigation.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. Investigate the vertical and horizontal extent of the oil contamination using drilling rigs and, where necessary, appropriate equipment for excavating trenches such as excavators or back-hoes.
2. Monitor groundwater quality from the neighbouring site, El-Twait feedlot, as well as from other wells in the vicinity (in a 500 m radius).
3. If the presence of water wells is confirmed,

investigate the water quality in the wells to determine any impact from the oil spill.

4. Remove the damaged and structurally unsound concrete base beneath the dismantled fuel tank.
5. Remove the contaminated soil and gravel and replace with clean material (a worst case estimate would be an area of 50 x 50 m of contamination, with a maximum thickness of 10 m, or 25,000 m<sup>3</sup> of contaminated soil).
6. Construct a new concrete base for the tank to avoid the risk of settlement.
7. All individuals engaged in site clean-up activities, such as the dismantling of the obsolete tank, must be provided with, and use, appropriate health and safety equipment, including boots, gloves, overalls, hard hats, and disposable masks/respirators.

#### Medium-term recommendations (3 months – 1 year)

Establish a groundwater monitoring programme.

## Petrol station on the Saida highway

Numerous petrol stations throughout Lebanon were reportedly targeted during the conflict. While some uncertainty about the exact number of petrol stations hit remains, official government reports state that 22 such sites were damaged. The petrol station on the Saida highway was inspected as a representative example.

Located mid-way between Jiyeh and Saida, the station is situated approximately 50 m from the seashore and 10-15 m above sea level. The area comprises some 1,500 m<sup>2</sup>. The neighbourhood is over 90 per cent agricultural, and less than 10 per cent residential.

The underground strata consist of red clay on Cretaceous (Turonian and Cenomanian) limestone. A 15 m deep well is located directly within the site, but was found to be dry. There were no other wells in the vicinity.

The petrol station had stored different types of fuel in a number of underground storage tanks, including 95 octane gasoline, 98 octane gasoline, and two different brands of diesel fuel in tanks of 20,000 l each.

Furthermore, a considerable number of used tyres were stored at the perimeter of the site, and a significant volume of various detergents was kept in the building itself, though much of it had been damaged by the fire.

## Contaminated land

The presence of a large crater made clear that the underground tanks in front of the building had been hit directly by a bomb, setting the building and stockpiled tyres ablaze. However, an inspection of the underground tank itself did not reveal any evidence of burning, and there was little, if any, odour of gasoline in the area. It was therefore concluded that the tank itself was empty, or near empty, at the time of the attack.

However, the very strong odour of hydrocarbons emanating from the 15 m deep water well strongly suggested fuel had been released and had migrated from the underground tanks, whether from conflict-related impacts or operational leaks.

The underlying limestone in this area is known to be interspersed with faults and fissures, and is probably influenced by karstic erosion. Hazardous substances, such as hydrocarbons, may thus potentially reach groundwater supplies.



*The severely damaged Saida fuel station with bomb crater in the foreground*



UNEP experts inspect a damaged fuel tank

Another matter of concern is the fact that agricultural areas directly adjacent to the petrol station could suffer from the impact of gasoline on their irrigation water.

A soil sample consisting of quartz sand mixed with ash from the burnt tyres was collected.

### Surface and groundwater

Due to the fact that the well was dry at the time of inspection, it was not possible to collect water samples at the petrol station. Given the evident oil spill, it is likely that gasoline and diesel fuel seeped into the groundwater. Sampling should therefore be carried out in the near future.

### Waste management

A number of waste management issues were observed at the site, though they were fairly limited in extent and potential impact.

As mentioned above, a large number of waste tyres were stockpiled towards the rear of the site and many burned to ash as a result of the bombing.

Further, the soil in the immediate vicinity of the underground tanks is likely to have elevated concentrations of hydrocarbons, due to fuel being released.

The final waste management concern relates to the numerous bottles and packages of detergent, many of which were damaged in the blaze.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. Due to the nature and scope of the UNEP assessment, not all of the 22 petrol stations could be assessed. It is, however, important that each of the impacted stations is systematically evaluated following similar protocols.
2. The heavily damaged building should be dismantled and the destroyed underground tanks excavated.
3. If it is the intention to re-establish a petrol station in this location, the remaining tanks should be checked for leaks.
4. If the site is to be abandoned, the remaining tanks should be emptied and excavated, or alternatively left *in situ* and filled with concrete.
5. After the on site infrastructure is dismantled, a comprehensive soil and groundwater investigation is recommended to estimate the amount of fuel that leaked into the underground and its potential impact. The source of drinking and irrigation water for the adjacent agricultural and residential areas should also be investigated.
6. All waste materials within the site, including tyres, ash, partially burnt detergent bottles and containers, should be collected, contained and ultimately disposed of in an engineered sanitary landfill site.
7. Having determined the extent of soil contamination through further investigations, all contaminated soil should be excavated and removed for treatment and disposal, before the remaining void is back-filled with clean sand and rubble.

### Medium-term recommendations (3 months – 1 year)

If significant contamination levels are found following the proposed groundwater and soil monitoring exercise, a groundwater monitoring programme should be initiated.

## Safieddine gas refill station

The Safieddine domestic gas refill station is situated approximately 3.5 km southeast of the Tyre city centre, 1 km from the seashore, and 20 m above sea level.

The rear of the site consists of a car sales compound containing approximately 50 cars and pickup trucks, while the front of the site comprises the domestic gas service forecourt, where the gas (propane) was stored in a 72,000 kg above-ground tank.

The geological setting for the site is within the Quaternary arable sediments of the Tyre coastal area, with underlying Tertiary or Quaternary limestone. There was no information available regarding the depth of the groundwater table at this location.

The land use in the immediate vicinity is agricultural, consisting mainly of banana plantations. The nearest residential buildings are located 600-800 m away from the site.

It was clear from initial site observations that the propane tank had suffered a direct hit, had exploded, and come to rest several metres away in one of the banana fields nearby, setting fire to the field, the adjacent car-sales compound and numerous trees.

## Contaminated land

Upon combustion, propane gas is oxidized and forms carbon dioxide and water. Consequently, except for burnt trees, there were no significant impacts on soil or groundwater from this site.

## Surface and groundwater

No borehole or surface water was identified on site and thus no water samples were recovered. No follow-up groundwater sampling is considered necessary.

## Waste management

Though they were fairly limited in extent and potential impact, a number of waste management issues were observed at the site.

As mentioned above, there were approximately 50 burnt car shells. Further, the concrete surface of the car compound and tree leaves were covered in a thin layer of dust and soot, presumably as a result of the fire.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. The possibility of recycling the metal from the derelict vehicles should be explored. If it is not a viable option, the vehicle shells should be removed from the site, and taken to a sanitary landfill for disposal.
2. The thin layer of ash should be collected, placed inside secure re-sealable drums, and transported to a sanitary landfill site for disposal, as rain may cause leachate to migrate towards the groundwater. Due to the potentially hazardous nature of the ash, personnel involved in the clean-up activities should be provided with appropriate health and safety equipment, in particular breathing masks.



*Cars damaged in the explosion of the gas refill station*



## Factories and plants

### Transmed warehouse

The site, which covers an area of approximately 2,000 m<sup>2</sup>, is located immediately east of Beirut's Rafik Hariri International Airport, within the Choueifat industrial area.

The site lies upon the Quaternary sediments of the coastal zone, with underlying Tertiary or Cretaceous limestone. The groundwater level is 35 m below ground.

The warehouse, which was almost totally destroyed, was used for the storage of various domestic items, such as cleaning products, detergents and soaps. A significant number of lead acid batteries were also stored on wooden racks in the basement. The nature of the damage indicated that the building had been hit by a deep-penetrating ('bunker buster') bomb, and by a number of smaller bombs.

At the time of the team's inspection, some limited clean-up activities had commenced, though there was still a significant amount of work ahead to clear the site.

### Contaminated land

At a number of locations, the thick concrete base of the site had cracked extensively, probably from the impact of the bomb. The potential pollution pathways thus created constitute a matter of concern, particularly during the rainy season.

In the basement, a thick layer of grey ash-like substance was found, as thick as 0.25 m in places, which was presumably due to the impact of the 'bunker buster' bomb. The immense heat and shock wave of the explosion had obviously pulverized the concrete, exposing the underlying steel structure. In addition, there were large piles of burnt batteries.

A dust sample taken for laboratory analysis to verify the composition of the powder was screened for aluminium, magnesium and phosphorus. Results are shown in table 7.

Table 5. Dust analysis results

<b>Aluminium</b>	5,481 mg/kg
<b>Magnesium</b>	2 742mg/kg
<b>Phosphorus</b>	319 mg/kg



*The Transmed facility was extensively damaged during the conflict*

Transmed warehouse before the conflict



Not only was the level of aluminium in the dust compatible with that of concrete, but the magnesium and phosphorus concentrations were not exceptionally high. These results led to the conclusion that the dust in the basement was composed of pulverized concrete.

### Surface and groundwater

Groundwater on the site, which is located at a depth of 35-40 m below ground level, is used for both warehouse sanitation and by factory workers to wash and bathe. Given the large number of damaged containers of household products found, there is a significant risk that products such as detergents and cleaning solvents could be mobilized

– particularly during periods of heavy rainfall – and impact underlying groundwater resources.

On site analysis was carried out using portable equipment, and water samples were collected for laboratory analysis both at the site itself (50aGW1) and down-gradient from the area (50aGW2). A further sample was taken from an underground desalinization plant on site (50aWW1).

The water in the desalinization tank was found to be stagnant and potentially contaminated. The tank itself was properly cemented, but may have developed small fractures as a result of the attack and may thus have been leaking its contents into the sub-surface, from where it could migrate to the underlying aquifer.

Table 6. Sample no: 50aGW1 (E731518, N3744808)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	10	Nil
COD	mg/litre	74	Nil
Sodium	mg/litre	412.50	200
EPH	µg/litre	135	Nil

Transmed warehouse after the conflict

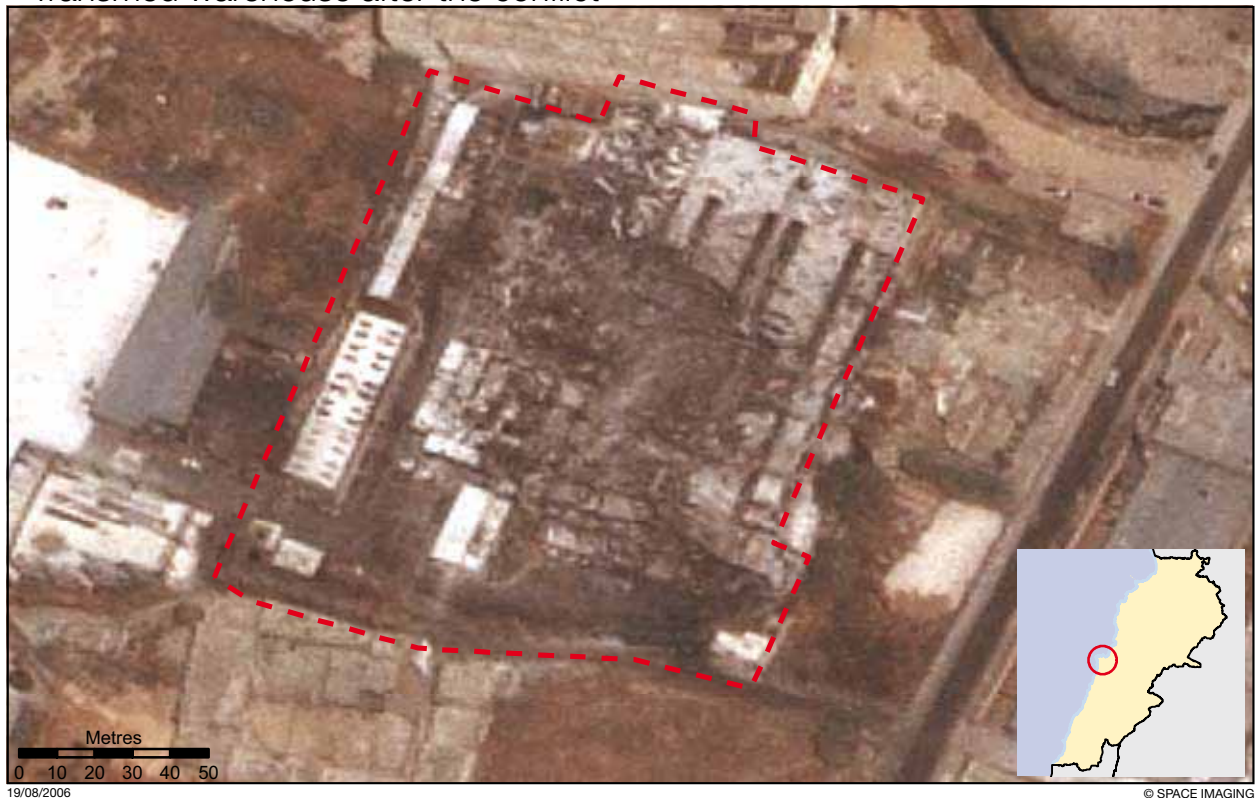


Table 7. Sample no: 50aGW2 (E731416, N3744720)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	3	Nil
COD	mg/litre	65	Nil
Sodium	mg/litre	825	200
Zinc	µg/litre	1173	Nil

Table 8. Sample no: 50aWW1 (E731544, N3744785)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	8224	500
Selenium	µg/litre	12	10
BOD	mg/litre	157	Nil
COD	mg/litre	735	Nil
Sodium	mg/litre	1050	200
EPH	µg/litre	12706	Nil

On site water analysis showed that both wells demonstrated high salinity, which may be due to salt water intrusion, given the site’s proximity to the coast.

The groundwater down-gradient from the site was more saline than the groundwater at the site itself, despite both wells being relatively close to each other,

indicating possible over-exploitation of groundwater at the down-gradient well. It was reported that 6,000 l of water are pumped each day.

Extractable petroleum hydrocarbons (EPH) were detected at levels of 135 µg/litre in one of the groundwater samples, and in very high concentrations – 12,706 µg/litre – in the

wastewater, suggesting that a surface hydrocarbon leak contaminating the wastewater had migrated to the underlying aquifer. The EPH detected were medium to heavy hydrocarbon compounds (C10-C40), most likely diesel fuel, which are known for their persistence and long-lasting environmental impacts. Nickel and selenium exceeded environmental screening values but were significantly below intervention levels. Zinc, however, was measured at an elevated concentration (1173 µg/litre) in one of the groundwater samples, significantly above the intervention threshold.

## Waste management

The extensive destruction of the Transmed site generated a significant amount of solid waste to be disposed of, much of which is hazardous in nature. Disposal should include but not necessarily be limited to the following:

- demolition waste, composed primarily of steel beams, aluminium sheeting and concrete rubble;
- crates and containers of household cleaning products such as detergents and soaps;
- large quantities of burnt lead acid batteries; and
- a few vehicle wrecks found on site.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. The clean-up of the Tansmed site should be completed with minimum delay to minimize the general risk of pollutants being flushed into the groundwater through heavy rainfall.

2. Demolition material should be removed from the site and disposed of, although it is likely that the steel beams and aluminium sheets will have sufficient value to make recycling and reuse viable within local markets.
3. The burnt and damaged batteries should be removed from the site, and disposed of. Again, it is possible that some components of the batteries, such as the lead, may be attractive for the local recycling market.
4. The thick layer of ash in the basement should be collected, preferably in re-sealable drums and disposed of in a sanitary landfill site. Care should be taken when handling this product, as the primary constituent, calcium oxide, is an irritant for skin and eyes. Appropriate health and safety equipment, including gloves, boots, overalls and breathing masks must be issued and used.
5. The potential to recycle the metal from the derelict vehicles should be explored. If this is not a viable option, the vehicle shells should be removed from the site and taken to a sanitary landfill for disposal.
6. EPH levels are elevated in both the groundwater samples and the wastewater sample, suggesting that a surface hydrocarbon leak has resulted in contamination of the wastewater and migration to the underlying aquifer. The source of the elevated hydrocarbon readings should be further investigated, the extent and magnitude of contamination determined and corrective action taken to prevent further migration from the source.



UNEP expert collects smear samples close to the point of impact of a 'bunker buster' bomb



*The interior of the damaged Transmed facility*

## Lebanon Company for Carton Mince and Industry

This site is situated immediately east of the Transmed site, within the Choueifat industrial area.

It covers an area of approximately 1,700 m<sup>2</sup> and is approximately 10-12 m above sea level. To the north, the site is bounded by the Ghadir River. It is located in the same geological and geomorphological setting of Quaternary red soils with underlying Tertiary or Cretaceous limestone as the Transmed site.

The plant's primary operation is the sorting and packaging of waste plastic and paper, prior to dispatching to local processing plants.

The main building appeared to have taken a direct hit from a missile, causing a fire throughout the plant.

A large amount of ash (some 50-100 m<sup>3</sup>) from burnt plastic and paper products, containing particles of wood and plastic, had been dumped in the vicinity of the river.

### Contaminated land

From a contaminated land perspective, the only matter of concern is the possible toxic nature of the ash that was dumped on the banks of the adjacent stream. A sample of the ash was collected for laboratory analysis; results are provided in table 9.

Table 9. Ash analysis results

Parameter / Sample Identity	Units	50B-WH-01	Dutch Intervention Value
Arsenic	mg/kg	<3	55
Cadmium	mg/kg	3,5	12
Chromium	mg/kg	14,2	380
Cobalt	mg/kg	–	240
Copper	mg/kg	121	190
Lead	mg/kg	40	530
Mercury	mg/kg	<0.6	10
Nickel	mg/kg	7.3	210
Zinc	mg/kg	782.9	720
<b>PAH by GCMS</b>			
Anthracene	µg/kg	75	
Benz(a)anthracene	µg/kg	62	
Benzo(a)pyrene	µg/kg	<12	
Benzo(ghi)perylene	µg/kg	<10	
Benzo(k)fluoranthene	µg/kg	<25	
Chrysene	µg/kg	93	
Fluoranthene	µg/kg	64	
Indeno(123cd)pyrene	µg/kg	<11	
Naphthalene	µg/kg	3,321	
Phen anthrene	µg/kg	494	
<b>PAH Dutch List 10 Total</b>		<b>4,109</b>	<b>40,000</b>
Acenaphthene	µg/kg	73	
Acenaphthylene	µg/kg	61	
Fluorene	µg/kg	237	
Pyrene	µg/kg	97	
Benzo(b)fluoranthene	µg/kg	<16	
Dibenzo(ah)anthracene	µg/kg	<8	
PAH 16 Total	µg/kg	4,577	
Pentachlorophenol	µg/kg	<1	10



A view of the factory with a stockpile of plastic goods in the foreground awaiting processing



*Work has been partially resumed at the Lebanon Company for Carton Mince and Industry*

The ash sample showed a zinc concentration slightly above Dutch Intervention Values, indicating that the ash was the result of a plastic waste fire. A second ash sample collected on the first floor of the main building showed an elevated antimony concentration (120 mg/kg).

Given that the ash has the potential to impact negatively on the water quality in the river, and ultimately on the marine environment, it should be removed from the river bank and disposed of in a sanitary landfill.

### **Surface and groundwater**

On UNEP's initial visit, substantial quantities of debris ash were stockpiled along 75 to 100 m of the banks of the Ghadir stream, which forms the northeastern boundary of the site. A follow-up

visit by UNEP after heavy rainfall in mid-October revealed that all of the ash had been swept away into the stream.

Laboratory analysis of the ash indicated elevated levels of several heavy metals and toxic organic compounds, including dioxins and PAH. This represents a significant pollution load for the Ghadir River and for the down-stream coastal environment, which constitutes the ultimate sink for the effluent. In addition, there is a possibility that the ash may settle on the riverbed, from where it may migrate and contaminate the underlying groundwater.

Two water samples were collected from the river (50bSW1 and 50bSW2) down-gradient and up-gradient from the location of the ash. The latter sample was taken for inference of baseline conditions.

Table 10. Sample no: 50bSW1 (E731687, N3744796)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	625	Nil
COD	mg/litre	1735	Nil
Sodium	mg/litre	222	200
EPH	µg/litre	1103	Nil

Table 11. Sample no: 50bSW2 (E731741, N3744707)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	769	Nil
COD	mg/litre	2680	Nil
Sodium	mg/litre	228	200
EPH	µg/litre	2580	Nil

The results showed that the surface water was highly saline, which might have been due to local pollution or to local geological formations.

Due to high biological oxygen demand (BOD) and chemical oxygen demand (COD) readings, dissolved oxygen (DO) concentrations were measured between 1-1.25 mg/litre, which is well below the level required to support fish populations and most aquatic life. This was confirmed by field observations.

In addition, the upstream river water was brown in color and the vegetation along the banks of the river was withered and dry, whereas it was green further away from the water. This phenomenon may be explained by high nitrate levels in the river, which typically result from inadequate sewage treatment in urban areas.

The results of the analysis showed a noticeable difference in BOD, COD, and EPH levels between the water samples collected up- and



Ash from the burnt plastic goods stockpiled beside the Ghadir River





*During a follow-up visit all the ash (see photo on the previous page) had been washed away following heavy rainfall*

down-gradient. At both sampling locations, however, the concentrations of BOD and COD significantly exceeded the environmental limit values for wastewater set by the Lebanese Ministry of Environment. The presence of hydrocarbon contamination is also a cause for concern.

### Waste management

The partial destruction and subsequent burning of the factory generated significant quantities of potentially hazardous ash, possibly containing dioxins, resulting from the combustion of the large volume of plastics and paper stockpiled on site. This material is leaching into and having an adverse affect upon the river water.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. Clean-up of the site should be undertaken to prevent further ash leaching into the river, if indeed there is any ash left on the site after recent heavy rainfall.
2. Given the high antimony concentrations within the rubble and ash on the first floor of the main building, this material should be

disposed of in a sanitary landfill site rather than dumped on adjacent land or buried.

3. If a sanitary landfill is not available, or refuses to accept the ash and rubble, the material should be stored in re-sealable containers and placed in a safe location, protected from the rain, until a suitable disposal option is found.
4. Care should be taken when handling the ash, as it may be an irritant to skin and eyes; appropriate health and safety equipment must be issued and used, including gloves, boots, overalls and breathing masks.
5. After use, the drums should preferably be disposed of to prevent their reuse and the risk of contamination of whatever commodity may be stored inside them.
6. Sediment in the stream should be monitored to locate the ash flushed into the stream during the rain. If located, the stream should be dredged and the waste handled as indicated in steps 2 to 3.
7. A toxicity characteristics leaching process (EPA) test should be performed on the ash to determine whether it is hazardous prior to disposal in a sanitary landfill site.

## Al Arz Lilnasiej textile factory

The Al Arz Lilnasiej textile factory, which is located in Al Khyara - Al Manara (Zahleh area), is surrounded by agricultural land, primarily olive trees and vineyards. It covers some 6,000 m<sup>2</sup> and is situated approximately 1,050 m above sea level. The groundwater level (obtained from a nearby well) is 170 m below ground surface.

The zone is at the transition of an outcrop of white marls and limestone to fertile valley clays. The geological map (Ministry of Public Works, 1955) and the hydrogeological map (United Nations, 1967) indicate Eocene to Oligocene reef complexes. The limestone contains widespread faults and is referred to as 'merokarstic' (influenced by fluvial erosion).

The factory was found to have been completely destroyed. Mixed in with the piles of rubble were machines and equipment used in the textile weaving process, including numerous spindles.

### Contaminated land

From a contaminated land perspective, the principal environmental impact of the air strike on the textile factory was the spill of machine oil and of textile industry special fluids and dyes.

The quantity of machine oil spilt at the generator could not be estimated, as the whole site was

buried under demolition waste comprising steel beams and debris. Besides, the serious health and safety risks made sampling in the vicinity of the generator impossible.

The spill covered some 100 m<sup>2</sup> of the actual site, and could be traced several metres down the site's access road. Most of the lubricant oil, however, was still inside the containers, and a comparatively small amount had leaked out.

The fluids spilled consisted of a substantial quantity of conning oil, an emulsion used mainly for the treatment of textile fibres in the production process. According to the manufacturer of this product, conning oil is a mineral oil-based chemical used in the spinning/yarning process. It is composed of 90 per cent mineral oil and 10 per cent emulsifier, mixed with ethoxylated alcohol, and can be diluted with water.

Samples were taken directly from the original substance and from the soil surface. The oil was of a straw or honey colour, while the soil was a brownish yellow. Due to the hardness and high proportion of gravel in the soil, auguring to a significant depth was not possible.

The GC-FID fingerprint of the oil product showed the characteristics of used lubricant oil. The soil analysis detected levels of aliphatic hydrocarbons over three times above the Dutch Intervention Values, as indicated in table 12.



UNEP inspects the damaged structure of the textile factory

Table 12. Hydrocarbon analysis results

Parameter / Sample Identity	Units	50B-WH-01	Dutch Intervention Value
EPH (DRO) (C10-C40)	mg/kg	18,829	5,000
<b>PAHs</b>			
Anthracene	µg/kg	<100	
Benzo(a)anthracene	µg/kg	<100	
Benzo(a)pyrene	µg/kg	<100	
Benzo(ghi)perylene	µg/kg	167	
Benzo(k)fluoranthene	µg/kg	<100	
Chrysene	µg/kg	<100	
Fluoranthene	µg/kg	<100	
Indeno(1,2,3-cd)pyrene	µg/kg	154	
Naphthalene	µg/kg	<100	
Phenanthrene	µg/kg	<100	
<b>PAH Dutch List 10 Total</b>	<b>µg/kg</b>	<b>321</b>	<b>40,000</b>
2-Chloronaphthalene	µg/kg	<100	
2-Methylnaphthalene	µg/kg	<100	
Acenaphthene	µg/kg	<100	
Acenaphthylene	µg/kg	<100	
Benzo(b)fluoranthene	µg/kg	<100	
Dibenzo(a,h)anthracene	µg/kg	161	
Fluorene	µg/kg	<100	
Pyrene	µg/kg	<100	
<b>PAH 18 Total</b>	<b>µg/kg</b>	<b>482</b>	

**Surface and groundwater**

The oil spill presents a potential contamination risk for the groundwater, as well as for neighbouring agricultural areas. Although the water table is deep, the karstic nature of the hydrogeology could lead to relatively rapid migration of on site pollution towards the underlying aquifer. One groundwater sample was taken down-gradient of the site to serve as a baseline reference for comparison with potential future contamination following rainfall.

Laboratory analysis revealed that all chemical parameters are within natural range, except for nickel, which marginally exceeds the environmental screening value, but is under the intervention value. The faecal coliform count, however, is 70/100 ml, representing an intermediate risk for users at a nearby school, especially as it is used as drinking water.

**Waste management**

The destruction of the Al Arz textile factory generated a significant amount of solid waste to be disposed of, much of which is hazardous in nature.

Disposal should include but not necessarily be limited to the following:

- demolition waste, composed primarily of steel beams, aluminium sheeting, and concrete rubble;
- heavy mechanical equipment used in the textile weaving sector;
- drums containing lubricating oil; and
- soil contaminated with chemical dyes, lubricating oil and conning oil.

**Recommendations**

**Urgent short-term measures (0 – 3 months)**

1. The debris and rubble should be removed from the site as soon as possible. It is anticipated that much of the demolition waste will have a recycling value in the local market, and will therefore not need to be disposed of.
2. Removing the rubble will reveal the actual extent of the oil spill from the generator. It is estimated that the maximum amount of contaminated soil is less than 10 m<sup>3</sup>, as there were no obvious motor oil tanks or canisters that could have led to a larger spill. Any contaminated soil should be excavated and disposed of.
3. The hazardous potential of the conning oil/dipropylene glycol dimethyl ether should be investigated in more detail. Inquiries with the producer have not yet led to a result.
4. The responsible authorities should inform the school and other neighbouring residents that the groundwater is biologically contaminated, and recommend that the water be boiled before use due to the risk of cross-contamination.

**Medium-term recommendations (3 months – 1 year)**

1. As the surface of the facility’s dirt road is saturated with lubricant oil, the upper 0.25 to 0.5 m of material should be removed and disposed of.
2. Follow-up groundwater sampling should be carried out to monitor potential contaminant migration following rainfall.

## Maliban glass factory

The Maliban glass factory is located in Taanayel, on the arable lands of the Beqaa Valley. The site, which is underlain by mainly Quaternary red soils, is surrounded by agricultural and industrial or commercial areas. The village of Bar Elias lies 1 km to the southeast.

The factory complex covers a total area of 36,000 m<sup>2</sup> and is situated approximately 860 m above sea level. The groundwater table is 11 m below ground surface.

According to the factory manager, the following chemicals were used in the production of glass:

- sodium carbonate;
- sodium sulphate;
- sodium feldspar;
- selenium salts;
- silica sand; and
- chromium salts.

The complex originally comprised several buildings including offices, production areas and three glass ovens. The factory and office buildings were completely destroyed in an air raid during the conflict, but the chimney stacks for the three ovens still stand.

## Contaminated land

Some 1,000 – 2,000 tons of sodium carbonate and approximately 10 tons of chromium salts were found in a former storage area whose roof had been destroyed, exposing the salts to weather.

Sodium carbonate is not toxic as such, but reacts with water to form a strong alkaline solution. Hence, the substantial amount of salts stored at the site constitutes a potential hazard for groundwater, particularly during heavy rainfall when much of this material could be mobilized.



*A view of the destroyed glass factory, with remaining chimney stacks in the background*



Chemicals used in glass production will leach into the groundwater unless relocated under cover

The same applies to the chromium salt ( $\text{Cr}_2\text{O}_3$ ) supplies that were found within the complex. Recommendations were given to the factory manager to collect the chromium salt immediately and store it in a dry place for later reuse. The manager was further informed that burial of the chromium salt, which he intended, was not advised due to potential impacts on groundwater.

Two samples were collected in a part of the factory in which, according to the manager, the tin-organic chemicals had been employed. One sample was taken in the immediate vicinity of the machine with which the substance was used. The other was taken from an area where another machine had obviously leaked oil. Both samples consisted of a mixture of rubble and dust from the building debris. No reliable information could be obtained about the state of the concrete floor, as the whole area was made virtually inaccessible by debris and twisted metal.

The results of the sample analysis are provided in table 13.

Table 13. Rubble/dust analysis results

Sample Identity	Units	8-CL-WM-01	8-CL/WM-02	Dutch Intervention Value
Aluminium	mg/kg	-	5931	-
Magnesium	mg/kg	-	1808	-
Phosphorus	mg/kg	-	556	-
Tin	mg/kg	-	-	-/*
		*organo-tin-compounds: 2,500 µg/kg		
EPH (DRO) (C10-C40)	mg/kg	<b>92,287</b>	<b>49,679</b>	<b>5,000</b>
<b>PAH by GCMS</b>				
Naphthalene	µg/kg	8,456	1,828	
Phenanthrene	µg/kg	2,069	413	
Anthracene	µg/kg	241	81	
Fluoranthene	µg/kg	754	208	
Benzo(a)anthracene	µg/kg	28	<12	
Chrysene	µg/kg	35	<10	
Benzo(k)fluoranthene	µg/kg	<25	<25	
Benzo(a)pyrene	µg/kg	<12	<12	
Indeno(123cd)pyrene	µg/kg	<11	<11	
Benzo(ghi)perylene	µg/kg	<10	<10	
<b>PAH Dutch List Total</b>	<b>µg/kg</b>	<b>11,583</b>	<b>2,530</b>	<b>40,000</b>
Acenaphthylene	µg/kg	539	232	
Acenaphthene	µg/kg	383	76	
Fluorene	µg/kg	789	171	
Pyrene	µg/kg	818	274	
Benzo(b)fluoranthene	µg/kg	<16	<16	
Dibenzo(ah)anthracene	µg/kg	<8	<8	
<b>PAH 16 Total</b>	<b>µg/kg</b>	<b>14,112</b>	<b>3,283</b>	

The levels of aliphatic hydrocarbons in the dust and rubble samples collected close to the destroyed machinery indicate that some machine oil was spilt. Due to the relatively small amounts of oil in the machines, the possibility of more extensive soil contamination was discounted.

### Surface and groundwater

A groundwater sample was collected down-gradient from the site to determine whether any pollutants originating on site had migrated into the underlying aquifer.

Field measurements indicate that the water is marginally brackish. This may be due to saline return drainage from surrounding agricultural land, as well as to rock water interaction.

Meanwhile, laboratory analysis detected levels of chromium ( $\text{Cr}^{+3}$ ) (1  $\mu\text{g}/\text{litre}$ ) at the environmental screening threshold, while nickel and zinc exceed the target value. The chromium is likely to have originated from the chromium salts used in the factory. The faecal coliform count was also exceptionally high (1200/100 ml), indicating significant sewage contamination and presenting a very high risk for users.

A water sample was also taken from a sub-surface storage tank at the site to determine whether it contains any pollutants that could migrate if its integrity had been compromised in the air raid.

In terms of their physical parameters, the quality of the storage and groundwater is similar. The slightly elevated levels of BOD and COD in the water from the storage tank (see table 14) are most likely due to the fact that it had remained stagnant for the previous three months. Copper, nickel, selenium and zinc were detected above environmental screening criteria. The groundwater does not appear to be affected by the polluted storage water, though seepage from the tank could potentially contaminate the shallow underlying aquifer.

Table 14. Sample no: 8WW1 (E766749, N3732018)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	2	Nil
COD	mg/litre	84	Nil

### Waste management

The extensive destruction of the Maliban glass factory generated a significant amount of solid waste to be disposed of, some of which is potentially hazardous in nature. Disposal should include but not necessarily be limited to the following:

- demolition waste, composed primarily of steel beams, aluminium sheeting, and concrete rubble;
- heavy mechanical equipment used in the glass-making process;
- chemicals used in the glass-making process, including chromium salt ( $\text{Cr}_2\text{O}_3$ ) and sodium carbonate; and
- isolated areas of soil contaminated with spilt lubricating oils.

### Asbestos

Generally, the insulation material found on the site was man-made mineral wool and modern ceramic fibres used for the insulation of the kilns. Very little material appeared to contain asbestos.

In the storage area, a single-story building had an asbestos flue pipe, as well as an asbestos cement soffit board above the door. Both, however, were in good condition and considered fit for purpose.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. To avoid the risk of heavily impacting the groundwater, both the sodium and the chromium salts should be recovered and relocated to an area protected from rain before the rainy season starts.



*UNEP team with Ministry of Environment counterparts inspect glass factory for radiation*

2. The stagnant water in the storage tank should be removed as early as possible to avoid groundwater pollution.
3. The debris and rubble should be removed from the site as soon as possible. It is anticipated that much of the demolition waste will have a recycling value in the local market, and will therefore not need to be disposed of.
4. Removing the rubble will reveal the actual extent of any oil spills that may be hidden underneath.
5. Any contaminated soil should be excavated and disposed of appropriately.
6. Due to the elevated faecal coliform levels, the site management should be advised not

to use groundwater other than for industrial processing operations.

### **Medium-term recommendations (3 months – 1 year)**

The groundwater in the vicinity of the site should be tested on a regular basis to ensure that salts and other chemicals used in the glass-making process are not leaching into the relatively shallow groundwater.

### **Long-term recommendations (1 year +)**

Measures should be implemented to ensure that potential pollutants are handled appropriately from the perspective of personal and environmental safety.

## Lamartine Food Industry

The site is located in the Beqaa Valley, approximately 2 km northeast of the Maliban glass factory, in the same geological and geomorphological setting.

Given that the factory produced chewing gum and sweets, it was not expected that hazardous substances would be found on site. The plant was completely destroyed in a bombing. The remaining structure is very unstable and is not safe to enter.

### Contaminated land

As a result of the bomb blast and ensuing fire, several cubic metres of ash were found inside the factory complex. However, laboratory analysis of this material established that it did not contain hazardous substances.

In addition, isolated areas of oil spillage were noted in proximity to equipment, and small quantities of spilled glucose were identified around the factory.

The omnipresent fine dust was analysed for traces of materials from deep-penetrating bombs, but the results, as shown in table 15, did not indicate elevated levels of aluminium, magnesium, or phosphorus:

Table 15. Dust analysis results

<b>Aluminium</b>	12,070 mg/kg
<b>Magnesium</b>	5,621 mg/kg
<b>Phosphorus</b>	729 mg/kg

Indeed, the aluminium concentration within the dust corresponds to the average aluminium concentration of concrete, which is 1.7 per cent. The magnesium and phosphorus concentrations are not high either, leading to the conclusion that the dust in the factory was generated by the enormous heat and shock wave from the bomb and its impact on the concrete structure of the building.

### Surface and groundwater

The risk of pollution from the glucose spillage is limited, due to its semi-solid state, non-toxic nature, and the depth of the local aquifer (about 80 m below ground level). Direct risks for public health are further diminished by the fact that residents in the area receive drinking water through a mains pipeline.

On site field measurements were within acceptable limits. Laboratory analysis identified nickel, selenium and zinc in concentrations marginally above their environmental screening thresholds but significantly below intervention values.



*The site of the destroyed Lamartine Food Industry*





*Demolition waste at Lamartine Food Industry requires disposal*

The main source of contamination was found to be biological, as a very high faecal coliform count of 500/100 ml was detected, indicating significant sewage contamination. Nitrate (18.3 mg/litre) was also found above natural background levels, also indicating sewage and/or agricultural run-off pollution

Despite the relatively low risk of contamination, precautionary measures should be taken to prevent impact on groundwater during heavy rainfall, in particular that of other potential contaminant sources, such as oil spills that were not visible during the visit due to wreckage. This would include removing the spilled glucose, building rubble and waste materials from the site.

### Waste management

The extensive destruction of the Lamartine food factory generated a significant amount of solid waste requiring appropriate disposal, including but not necessarily limited to the following:

- demolition waste, composed primarily of steel beams, aluminium sheeting, and concrete rubble;
- heavy mechanical equipment used in the food processing industry;
- isolated spillages of glucose powder; and
- several cubic metres of ash resulting from the fire in the factory.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. The debris and rubble should be removed from the site as soon as possible. It is anticipated that much of the demolition waste will have a recycling value in the local market, and will therefore not need to be disposed of.
2. Removing the rubble will reveal the extent of any oil spill that may be hidden underneath.
3. Any contaminated soil should be excavated and disposed of.
4. The spilled glucose should be removed as a matter of priority to prevent the material being washed into the groundwater during heavy rainfall.
5. The ash should be collected and placed inside re-sealable containers. This material should then be disposed of in a sanitary landfill site, with leachate collection and treatment.
6. Due to the fact that the ash may be irritating for skin and eyes, personal protective equipment should be made available to staff involved in the clean-up activities. At minimum, it should include: gloves, boots, overalls, and breathing masks of suitable specification.
7. Due to the elevated faecal coliform levels, the site management should be advised to use potable quality water unless the industrial processes ensure disinfection.

## Ghabris detergent factory

The site is located 3.5 km east of the Tyre city centre. The area covers 600 m<sup>2</sup> and is approximately 75 m above sea level. The geological setting is within the Quaternary arable sediments of the Tyre coastal area, with underlying Tertiary or Quaternary limestone. The groundwater table can be found 60-70 m below ground surface.

The neighbourhood consists of residential and commercial buildings. According to information provided by the local consultants, the site was previously home to a detergent factory, although the building had been totally demolished at the time of the site inspection and most of the rubble had already been removed.

Except for a small area showing signs of machine oil leakage, no obvious spills could be observed. A faint smell of chlorine detergent was present, but the source of the smell could not be located.

### Contaminated land

As virtually all of the rubble and debris had already been removed from the site, and there were no obvious signs of contamination, there was little cause for concern from a contaminated land perspective.

## Surface and groundwater

Water samples were taken from a storage tank within the factory and from a groundwater source used by local residents. The storage tank was filled with wastewater which had been contaminated by the fallout of the bombing. As most of the houses in the immediate vicinity of the factory were found to have underground freshwater storage tanks, it was considered possible that, during prolonged periods of heavy rainfall, overflow from the wastewater tank and leachate from the factory debris may pollute residential storage tanks.

Field measurements taken of water in the field using portable equipment were found to be within the natural range for all parameters.

A groundwater sample was taken 20 m from the source of pollution for laboratory analysis, which showed the groundwater to be highly contaminated. Several PAHs were found to be considerably above intervention threshold values, including the highly toxic benzo(a)pyrene, which is a known carcinogen.

Both ammonia and phosphate concentrations, almost certainly originating from the poly-phosphate detergents manufactured by the Ghabris

Ghabris detergent factory before the conflict



factory, were very high, measuring 2,073.5 mg/l and 43.7 mg/l respectively.

Zinc and nickel were also detected at concentrations slightly above environmental screening values, but substantially below the intervention requirement.

It was not possible to determine whether the contamination found within the groundwater pre-dated the conflict, or whether it was as a result of the bombing of the factory.

### Waste management

Given that the site had been largely cleared of rubble and debris, there are few, if any, remaining waste management issues.

However, illegal dumping of waste was observed on the site, which is potentially prejudicial to public health through the breeding of rats and other disease vectors.

### Asbestos

While most of the rubble had been removed from the site, a small amount (approximately 5m<sup>2</sup>) of material near the road appeared to contain asbestos.

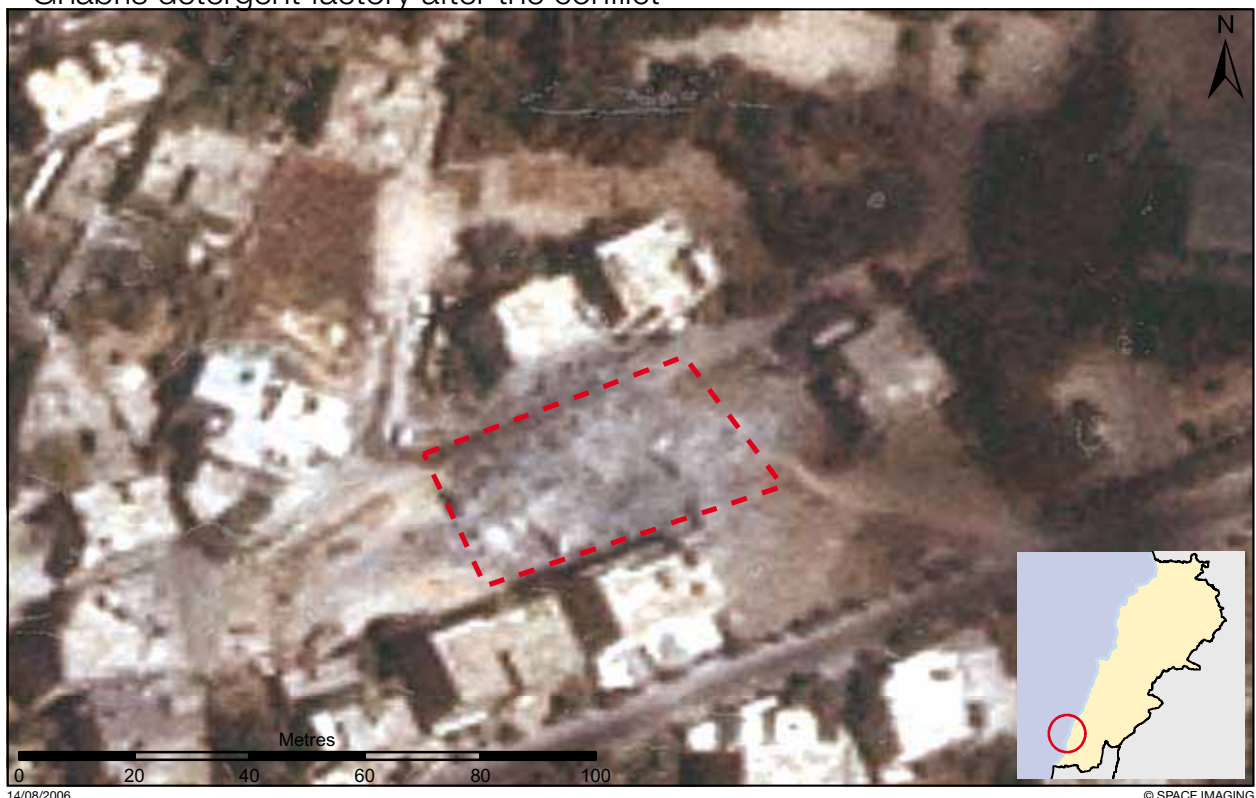
Laboratory analysis subsequently identified the material as chrysotile (white asbestos). Although it was not possible to ascertain the exact origin of the material, it was believed to be from roofing sheets.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. The water quality of water wells in the neighbourhood should be monitored to ensure that the possible spill of household detergents does not pose a health hazard for local residents.
2. A detailed survey of the area should be conducted to delineate the extent of the off-site groundwater contamination. Appropriate remedial measures should be proposed based on the findings.
3. The local municipality, with the support of the Ministry of Environment should erect notices on the site to discourage the illegal dumping of waste. Further initiatives, such as monitoring and prosecution activities should be undertaken as necessary.

Ghabris detergent factory after the conflict



## Ebl Saqi asphalt plant

The site of the Ebl Saqi asphalt plant is about 12,000 m<sup>2</sup> in size, and is situated 600 m above sea level. The surrounding land is used as follows:

- a limestone quarry is located 300 m to the southwest of the asphalt plant;
- there is an industrial plant to the northeast, some 150 m from the complex;
- a residential building, possibly housing agricultural workers, can be found some 250 m to the northwest; and
- within the valley itself, there are extensive olive and fruit tree plantations.

The site is located at the transition of an outcrop of white marls and limestone to fertile valley clays. The geological map (Ministry of Public Works, 1955) and the hydrogeological map (United Nations, 1967) indicate Eocene to Oligocene reef complexes. The limestone contains widespread faults and is referred to as 'merokarstic' (influenced by fluvial erosion).

The relevant equipment on site consisted of:

- two 15,000 l asphalt heating tanks;
- one 10,000 l diesel fuel tank;
- a burner unit to heat the asphalt; and
- a mixing unit.

A water well was located close to the above-mentioned domestic building, some 250 m from the site. The water team determined the groundwater table to be located 180 m below ground surface.

## Contaminated land

The asphalt tanks were located on a concrete surface. As it was covered by a mixture of gravel and sand, its state could not be determined.

A compacted layer of clay made auguring below a depth of 0.3 m impossible. However, four samples were taken from the immediate vicinity of the tanks, including:

- ES-CL/WM-01: oily sand from the surface;
- ES-CL/WM-02: gravel and sand from the concrete slab close to the tanks;
- ES-CL/WM-03: clay (0.1-0.3 m below ground surface) from approximately 3 m northeast of the asphalt tank; and
- ES-CL/WM-04: clay (0.1-0.3 m below ground surface), approximately 6 m northeast of the asphalt tank.

All samples showed signs of diesel contamination, and two (nos. 01 and 02) showed signs of asphalt contamination.



*A damaged diesel tank in the Ebl Saqi asphalt plant*

Table 16. Soil analysis results

Sample Identity	Units	ES-WM/ CL-01	ES-WM/ CL-02	ES-WM/ CL-03	ES-WM/ CL04	Dutch Intervention Value
EPH (DRO) (C10-C40)	mg/kg	29,481	25,768	22,833	7,563	5,000
EPH (DRO) (C10-C40)	mg/kg	–	–	–	–	
GRO (C4-C10)	µg/kg	–	–	<10	5,662	
GRO (C10-C12)	µg/kg	–	–	<10	15,994	
Benzene	µg/kg	–	–	<10	<10	1,000
Toluene	µg/kg	–	–	<10	<10	130,000
Ethyl benzene	µg/kg	–	–	<10	<10	50,000
m & p Xylene	µg/kg	–	–	<10	101	25,000
o Xylene	µg/kg	–	–	<10	110	
<b>BTEX Total</b>	<b>µg/kg</b>	–	–	–	–	
<b>PAH by GCMS</b>						
Naphthalene	µg/kg	<100	<100	<100	89	
Phenanthrene	µg/kg	978	<210	<210	1,687	
Anthracene	µg/kg	102	<90	<90	92	
Fluoranthene	µg/kg	650	<250	<250	153	
Benz(a)anthracene	µg/kg	<120	<120	<120	26	
Chrysene	µg/kg	631	138	118	91	
Benzo(k)fluoranthene	µg/kg	<250	<250	<250	<25	
Benzo(a)pyrene	µg/kg	374	528	144	<12	
Indeno(123cd)pyrene	µg/kg	<110	<110	<110	<11	
Benzo(ghi)perylene	µg/kg	<100	<100	<100	<10	
<b>PAH Dutch List 10 Total</b>		<b>2,735</b>	<b>666</b>	<b>928</b>	<b>2,138</b>	<b>40,000</b>
Acenaphthylene	µg/kg	<50	<50	<50	392	
Acenaphthene	µg/kg	353	<140	<140	985	
Fluorene	µg/kg	438	<120	<120	981	
Pyrene	µg/kg	2007	841	670	207	
Benzo(b)fluoranthene	µg/kg	473	365	173	<16	
Dibenzo(ah)anthracene	µg/kg	<80	<80	<80	<8	
<b>PAH EPA 16 Total</b>	<b>µg/kg</b>	<b>6,006</b>	<b>1,872</b>	<b>1,105</b>	<b>4,703</b>	<b>–</b>
PCBs (vs Aroclor 1254)	µg/kg	<200	<100	<40	<20	

The surface of the area immediately around the tank was partially covered with the remnants of asphalt and diesel spills. The easternmost asphalt tank was hit by a missile, causing a 2 x 1 m hole in its side.

The ground consists mainly of clay, and is most probably underlain by limestone. Due to the karstic nature of the stone, a rapid spread of the diesel cannot be ruled out if leakage occurs through the clay. If that were the case, the water well northwest of the site could be affected. However, given the relatively small amount of diesel leaked, the clay soil cover, and the large distance to the groundwater table, the risk of conflict-related damage to the groundwater may be considered low.

The routine handling of fuels and asphalt at the plant was found not to meet best practice standards and may result in long-term soil contamination.

### Surface and groundwater

Samples for laboratory analysis were collected from the Ebl Saqi borehole pumping station, located about 250 m from the source of the asphalt and diesel spill. In addition, on site measurements were taken using portable equipment.

Both field and laboratory analysis revealed that the parameters measured were within natural range. Nickel, selenium and zinc were detected at concentrations slightly above environmental screening criteria. The values, however, were well below WHO's drinking water quality standards and did not represent any health risk.

While the total coliform and faecal coliform count was low (<10/100 ml), the presence of coliforms indicated inadequate treatment and/or minor contamination. Both Lebanese and WHO standards require total absence of coliforms in drinking water.

Overall, the water analysis of dissolved constituents showed that there was no impact on groundwater from the spillage of asphalt and diesel oil within the plant. The results could therefore serve as a baseline for future monitoring of potential contaminant seepage into the underlying aquifer, which could be brought about by rainfall.

### Waste management

Solid waste was observed to be present on site in the form of hydrocarbon contaminated soil and scrap metal from the damaged tank.



*A pool of diesel and asphalt in the vicinity of the damaged tanks*

### Asbestos

Material similar to asbestos cement roof sheets was seen on a number of the site's buildings. However, the material was found to be in generally good condition and fit for purpose.

### Recommendations

#### Urgent short-term measures (0 – 3 months)

1. It is highly recommended that the extent of the soil contamination be vertically and horizontally evaluated, and that the hazard to the underlying aquifer be assessed within two to three months.
2. The contaminated soil should be excavated, disposed of and treated.
3. Biological contamination of the drinking water supplied from the Ebl Saqi borehole should be double-checked and, if confirmed, appropriate remedial measures to prevent contamination should be taken.

#### Medium-term recommendations (3 months – 1 year)

1. Safety measures for the storage tanks should be improved to avoid spills. In particular, the

tanks should be located within bunded areas, or impounding basins. These structures should be built during the reconstruction of the site and, if applicable, after the contaminated soil has been removed and replaced.

2. A groundwater monitoring programme should be introduced.
3. The company should introduce good environmental management practices in its plant operations, as this would not only prevent future spills and losses, but would also save energy, fuels, raw materials and supplies.
4. A further improvement to the site would be the provision, and use, of health and safety equipment for the staff, along with access to detergents and eye-rinsing facilities and associated equipment.

#### Long-term recommendations (1 year +)

If additional monitoring confirms biological contamination of the groundwater, measures for water purification should be considered.

### Agricultural facilities

#### Liban Lait dairy plant

The site, which covers approximately 20,000 m<sup>2</sup>, is located 19 km northeast of Zahleh in the Beqaa Valley, approximately 1,000 m above sea level. The area consists of agricultural land (> 90 per cent) and a few residential buildings.

The geological setting is within the Quaternary arable sediments of the Beqaa Valley. Groundwater was established at 700 m below ground level.

The Liban Lait dairy factory, whose operations started in the year 2000, was an ultramodern plant that produced and packaged milk products. The factory was completely destroyed during the conflict.

Three tanks were found on site, including:

- a diesel tank (50,000 l);
- a gasoline tank (35,000 l); and
- an oil sludge tank (2,500 l).

In addition to the above, site maintenance staff reported that a tank containing nitric acid had been destroyed during the bombing.

#### Contaminated land

The three tanks on site survived the conflict apparently intact. Consequently, there were no issues of concern regarding them.

However, the pipe leading from the gasoline tank to the generators appeared to have been repaired in a temporary manner (a water hose was plugged loosely into a steel pipe), leading to a (presumably) minor spill around the hose, which was not conflict-related.

A pile of electronic waste in the southernmost corner of the site, and several empty 20 l plastic containers of motor oil and hydrochloric acid a few metres away were considered cause for slight concern.

A rubbish dump was also visited some 1.5 km from the plant, where it appeared that most waste products from the process were dumped.

Two samples were collected for laboratory analysis. Sample no. 13-CL/WM-01 was taken from the small-scale spill at the diesel tank, about 10 cm below ground level. Sample no. 13-CL/WM-02 was taken from a pile of ash deposited on a strip of barren land some 800 m to the west of the factory. The ash was deposited among other residues, such as burnt yoghurt and juice packages from the dairy factory, and veterinary medical waste from the farm.



*A view of the destroyed Liban Lait dairy complex*

Liban Lait dairy plant before the conflict



Table 17. Soil and ash analysis results

Sample Identity	Units	13-CL/WM-01 Spill at gasoline tank	13-CL/WM-02 Waste dump site (ash sample)	Dutch Intervention Value
Aluminium	mg/kg	-	25,850	-
Arsenic	mg/kg	-	-	55
Cadmium	mg/kg	-	<0.3	12
Chromium	mg/kg	-	37.3	380
Cobalt	mg/kg	-	8.2	240
Copper	mg/kg	-	17	190
Lead	mg/kg	-	<2	530
Magnesium	mg/kg	-	2,418	-
Mercury	mg/kg	-	<0.6	10
Nickel	mg/kg	-	20.4	210
Phosphorus	mg/kg	-	634	-
Tin	mg/kg	-	1	-
Zinc	mg/kg	-	417.0	720
EPH (DRO) (C10-C40)	mg/kg	33,530	-	5,000
GR0 (C4-C10)	µg/kg	611	-	-
GR0 (C10-C12)	µg/kg	2471	-	-
Benzene	µg/kg	<10	-	1,000
Toluene	µg/kg	<10	-	130,000
Ethyl benzene	µg/kg	<10	-	50,000
m & p Xylene	µg/kg	<10	-	25,000
o Xylene	µg/kg	<10	-	-
<b>BTEX Total</b>	<b>µg/kg</b>	<b>-</b>	<b>-</b>	<b>-</b>
MTBE	µg/kg	<10	-	100,000
<b>PAH by GCMS</b>				
Naphthalene	µg/kg	5,835	3,935	-
Phenanthrene	µg/kg	6,991	1,691	-
Anthracene	µg/kg	950	287	-
Fluoranthene	µg/kg	535	600	-
Benzo(a)anthracene	µg/kg	121	215	-
Chrysene	µg/kg	923	764	-
Benzo(k)fluoranthene	µg/kg	<125	173	-
Benzo(a)pyrene	µg/kg	101	83	-
Indeno(1,23cd)pyrene	µg/kg	<55	130	-
Benzo(ghi)perylene	µg/kg	<50	102	-
<b>PAH Dutch List 10 Total</b>		<b>15,456</b>		<b>40,000</b>
Acenaphthylene	µg/kg	1917	312	-
Acenaphthene	µg/kg	4510	1218	-
Fluorene	µg/kg	3801	587	-
Pyrene	µg/kg	1500	503	-
Benzo(b)fluoranthene	µg/kg	<80	197	-
Dibenz(ah)anthracene	µg/kg	<40	40	-
<b>PAH EPA 16 Total</b>	<b>µg/kg</b>	<b>27,184</b>	<b>10,837</b>	
Pentachlorophenol	µg/kg	-	-	-
PCBs (vs Aroclor 1254)	µg/kg	<400	1.136	1,000

Because of the risk that PAH- and PCB-contaminated dust (from the combustion of plastics and/or from old electrical transformers) could be transported by wind, the rubbish dump is considered to pose a health hazard for neighbouring inhabitants, especially for children living near the site. In addition, due to the relatively high concentrations of PAH, wind-blown ash could contaminate fruit and vegetable crops in the vicinity, and impact negatively on ground and surface water if the ash were washed away by precipitation.

### Surface and groundwater

All the effluent from the dairy plant was reported to be piped to a treatment facility located 500 m to the northeast of the plant, although time did not allow the team to visit the facility in question.

A well close to the plant provided access to a very deep aquifer (700 m below ground level). Given its depth, the potential for aquifer contamination was considered to be minimal.

A water sample was taken from the well for baseline reference, and field measurements were



Liban Lait dairy plant after the conflict



obtained using portable equipment. According to field measurements, the quality of groundwater was potable. Laboratory analysis detected chromium ( $\text{Cr}^{+3}$ ) and zinc concentrations above environmental screening values, but substantially below intervention requirements.

Unless there are undertermined cracks and fissures, the risk to groundwater is considered quite low, due to the limited pollution sources and the deep aquifer which is overlain by relatively impermeable strata.

## Waste management

The destruction of the dairy plant generated a significant amount of waste requiring appropriate disposal, including but not necessarily limited to the following:

- demolition waste, composed primarily of steel beams, aluminium sheeting, and concrete rubble;
- a small localized leak in the vicinity of the diesel fuel tank;

- the pile of electronic waste in the southernmost corner of the site; and
- several empty plastic containers (20 l) of motor oil and hydrochloric acid.

Perhaps of greater concern was the fact that the factory appeared to be operating, or using, a dump site approximately 1.5 km from the plant, where all solid waste was apparently dumped. At the time of the inspection, hazardous healthcare waste (HHCW) relating to the cattle was found in the waste stream. This, in addition to the potentially toxic ash, poses serious risks for the health and safety of local residents, particularly children.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. Before the generator fuelled by the tanks is operated, the hose-pipeline connection should be repaired adequately.
2. The horizontal and vertical extent of the localized spill should be investigated further.



*HHCW from the dairy plant at the local dump site. Such items represent a serious risk for the health and safety of local residents*

If it is determined that only negligible amounts of fuel were spilt, and that the local neighbourhood's water is supplied from deep wells, such as the one located near the plant, no further measures will be required.

3. The operation of the dump site should be discontinued and another – official – disposal site used.
4. The HHCW in the rubbish tip should be collected immediately and disposed of in a hospital incinerator or autoclave. If this is not possible, deep burial, and the immediate application of cover material may suffice as a short-term option until more appropriate solutions are found.

#### **Medium-term recommendations (3 months – 1 year)**

1. The company should work with the local municipality to identify suitable waste disposal facilities in the vicinity.
2. It is recommended that the Ministry of Environment monitor industrial plants' waste disposal practices to ensure that they meet appropriate standards.

#### **Long-term recommendations (1 year +)**

1. It is recommended that the Ministry of Environment and local municipalities create a waste inventory to detail and track the waste management practices of commercial entities. Management plans should be prepared for each commercial waste generator to ensure that the correct procedures are applied and enforced.

### El-Twait feedlot, Beirut

The farm, which covers an area of approximately 7,000 m<sup>2</sup>, is situated immediately to the east of the Choueifat industrial area, and is thus in the same geological and geomorphological setting of Quaternary red soil, with underlying Tertiary or Cretaceous limestone. The site is 10-12 m above sea level, and the groundwater table is 12.5 m below ground surface.

Prior to the conflict, the site housed a farm that bred cattle and small livestock, but it was completely destroyed during the aerial bombardment, reportedly killing some 175 cows and 430 sheep. At the time of UNEP's visit, the site was covered in rotting animal carcasses, and there were numerous smouldering piles where carcasses were being burnt, generating both odour and smoke nuisance to the immediate environment. Animal carcasses were also seen next to and within a small river running through the site.

### Contaminated land

The obvious threat to the environment is bacteriological in nature, and could largely be addressed through appropriate waste disposal practices. No agricultural chemicals were found during the site inspection.

### Waste management

The major waste management issue on site related to the countless rotting animal carcasses that required appropriate disposal rather than incomplete burning on open fires, the temperatures of which were unlikely to destroy all pathogenic bacteria.

A secondary, relatively simple, problem related to the dismantling and disposal of the damaged structures on site, which were primarily timber animal pens.



*Piles of rotting animal carcasses across the site are contaminating surface water and present a risk for public health*

El-Twait feedlot before the conflict



**Surface and groundwater**

The worst water-related concern is the contamination of the Ghadir stream – which forms the site’s southern boundary – by the numerous dead animal carcasses. Furthermore, given that the water table at the site is very shallow (12.5 m below ground level), the possibility of groundwater pollution is a concern. Water samples were collected from surface water, river water (50cSW1) and groundwater (50cGW1).

Laboratory analysis indicated exceptionally high total coliform (2,240,000/100 ml) and faecal coliform (1,480,000/100 ml) contamination of the Ghadir stream. Elevated faecal coliform counts (13,000/100 ml) were also found in the groundwater. These counts are considerably greater than those in samples taken some 500 m upstream, suggesting that the dead animal carcasses contributed significantly to the pollution load. Groundwater from neighbouring sites had a coliform count of less than 10/100 ml.

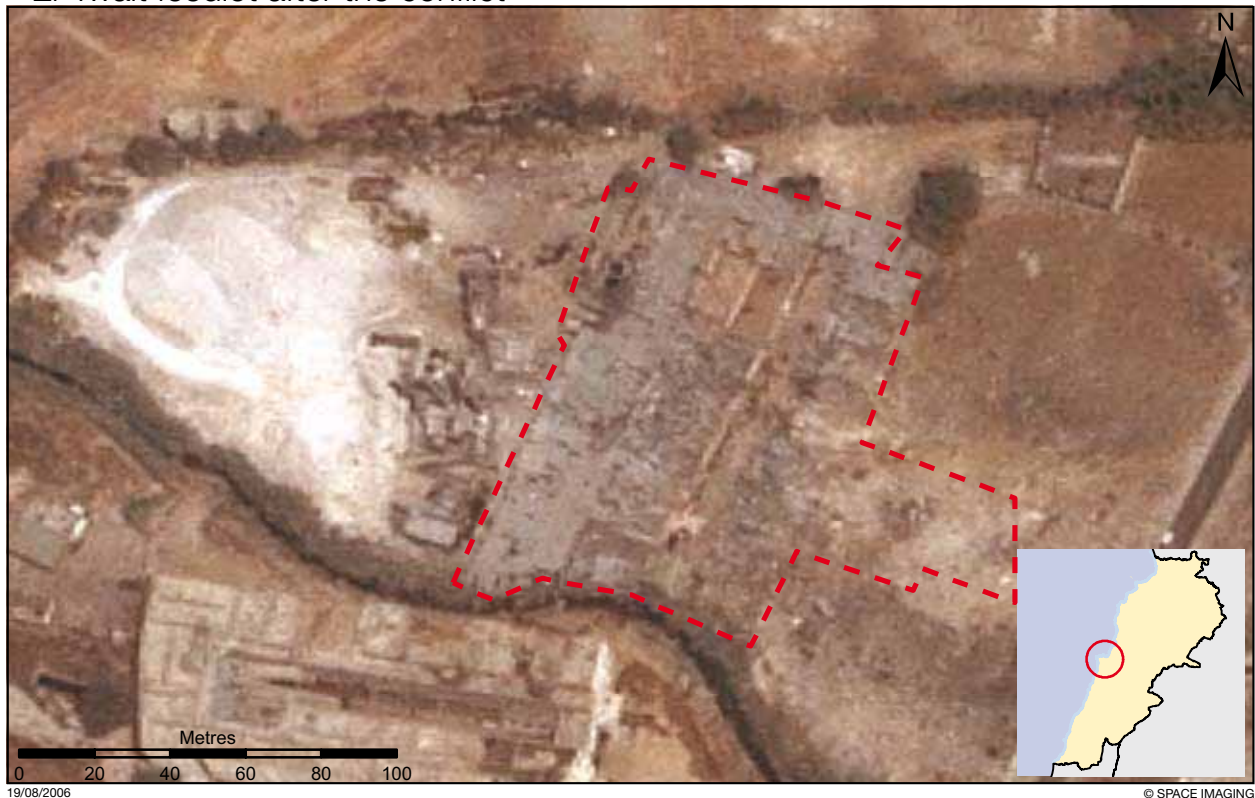
Table 18. Sample no: 50cSW1 (E731533, N3744945)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	894	500
BOD	mg/litre	625	Nil
COD	mg/litre	1710	Nil
Sodium	mg/litre	216	200
EPH	µg/litre	4149	Nil
GRO	µg/litre	8574	Nil
Toluene	µg/litre	6210	700

Table 19. Sample no: 50cGW1 (E731572, N3744982)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	878	500
BOD	mg/litre	23	Nil
COD	mg/litre	211	Nil
Sodium	mg/litre	291	200
EPH	µg/litre	56	Nil
GRO	µg/litre	75	Nil

El-Twait feedlot after the conflict



Elevated levels of extractable petroleum hydrocarbons (EPH) and gasoline range organic (GRO) were also detected in both the groundwater and surface water. As neither EPH nor GRO were found in samples taken some 500 m upstream, the most likely source for the petroleum contamination is the destroyed tanks at Beirut airport, which is immediately adjacent to the feedlot (less than 300 m). Toluene and ethylbenzene were also found in the stream in concentrations significantly above Dutch Intervention Values. The site manager reported that rainfall had washed some of the petroleum into the stream and the well.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. The carcasses on site should all be removed and disposed of either by incineration, or within specific cells of a sanitary landfill site that manages leachate.
2. Any extraction of water downstream from this site should cease immediately.
3. The whole area should be thoroughly disinfected prior to the dismantling and removal of the damaged structures, such as the animal pens. Once the animal carcasses are removed, the bacterial contamination of the soil will diminish rapidly.
4. Staff involved in the disinfection and dismantling of the site should be issued appropriate personal protective equipment, including boots, gloves, overalls, hard-hats, and breathing masks. At the completion of each day, items such as gloves and overalls should be treated as hazardous waste and disposed of accordingly.
5. Further investigation is required to ascertain whether the source of the hydrocarbon loading of both the groundwater and surface water is the destruction of the fuel tanks at the Beirut airport.
6. A detailed survey should be conducted to determine the extent and magnitude of the groundwater contamination. Based on survey results, remedial measures, including a 'pump-and-treat' system, should be proposed.

## Al Maalaka aquaculture farm

The Al Maalaka aquaculture farm is located 50 km east of Tripoli and 3 km south of Hermel, on the Al-Assi (Orontes) River, which flows north into Syria.

The aquaculture farm is 620 m above sea level and covers an area of approximately 40,000 m<sup>2</sup>. The geological setting is within Miocene and Pliocene conglomerates and limestone. The neighbouring area comprises a few buildings, probably a recreation camp.

The fish farm produced and packed trout, which were grown in six 5 x 15 m ponds fed by water from the adjacent river.

Much of the infrastructure, including drainage channels and a number of the concrete ponds, was extensively damaged in the bombing of the site. One of the ponds had a substantial impact crater, and all of the fish in it had died, presumably from the shock waves of explosions.

### Contaminated land

No relevant chemicals or hazardous substances were found during the site inspection. Accordingly, there were no significant concerns regarding contaminated land at this particular site.

## Surface and groundwater

Fresh water from the river flowed into the aquaculture complex, mixed with the water in the damaged ponds, and was then discharged back into the river. The water in the ponds contained numerous dead fish and algal blooms, and appeared to be highly contaminated.

Fish feed and other chemicals with the potential to cause contamination if flushed into the river were also seen on site.

Accordingly, river water samples were collected at the site and upstream, to determine what impact, if any, the stagnant water from the damaged fish ponds was having on river water quality.

On site analysis of water from the Al-Assi River indicated a pH below neutral range, suggesting pollution. Although the pH is not above levels that would lead to fish and macro-invertebrate mortality, it nevertheless represents a stress factor for aquatic life.

Laboratory analysis revealed chromium (Cr<sup>+3</sup>) selenium and zinc concentrations above environmental screening criteria, but below the intervention criteria. This was expected, as lower pH can induce the release of heavy metals from soil minerals. At the same time, the analysis of



*A view of the destroyed Al Maalaka fish farm*

Table 20. Sample no: 74WW1 – Wastewater on site

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
COD	mg/litre	42	Nil
Sodium	mg/litre	1110	200
Chloride	mg/litre	2284	250



Dead fish and algae in a remaining channel

the water in the fish ponds also showed zinc concentrations above intervention values, and was hence likely to be the source of the elevated zinc levels in river water.

Naphthalene, a toxic PAH hydrocarbon, was detected in both pond (ng144/l) and river water (ng89/l) at concentrations marginally above the intervention value. Potential sources included solvents and antiseptics used to disinfect the fish tanks, and/or fuel oil. In addition, high salinity was found within the damaged fish ponds.

Overall, it is considered that the shelling of the aquaculture farms caused a serious water pollution event, but that the main impact of the incident appears to be largely over. This is mainly due to contaminant dilution by the high river flow discharge rates, which typically peak in July. However, the residual contaminant in the fish ponds represents a more chronic pollution threat and should be remediated.

**Waste management**

The destruction of the aquaculture farm generated a modest amount of solid waste requiring appropriate handling and disposal, including:

- demolition waste, composed primarily of concrete rubble;
- a limited quantity of fish feed; and
- numerous rotting fish carcasses.

**Asbestos**

Most of the structures within the site were extensively damaged. Approximately 50 m<sup>2</sup> of material that appeared to contain asbestos was seen among the rubble. Laboratory analysis confirmed the material to be Chrysotile (white asbestos). In a number of locations, it was possible to identify the origin of the material as asbestos cement roof sheeting.

**Recommendations**

**Urgent short-term measures (0 – 3 months)**

1. Spoilt fish feed and dead fish should be collected and disposed of in a sanitary landfill site. If no such facility is available, burial in a deep trench would be an appropriate low-cost solution.
2. As the stagnant water in the fish ponds has PAH levels above intervention values, it should be recovered and treated using appropriate biological techniques.
3. The stagnant water in fish tanks where no PAH was detected could be drained in a staged manner, relying on natural attenuation by the fast-flowing highly oxygenated river water to rapidly dilute and disperse the pollutants. The drainage should ideally be done during periods of high river discharge.
4. The tanks should be desludged and the algae mats removed. The sludge should be placed in a compost bin to promote anaerobic organic degradation, disposed of in a sanitary landfill, or buried as in recommendation 1.

## Urban Contamination

### Haret Hreik Security Square, southern Beirut

The site is a heavily populated residential area in the southern suburbs of Beirut commonly referred to as Dahia, with high-rise buildings six to twelve storeys high.

Security Square, which falls under the Haret Hreik municipality, is approximately 20,000 m<sup>2</sup> in size, and 35-40 m above sea level. Many buildings in Security Square were destroyed or sustained serious damage. At the time of the site inspection, however, the considerable task of rubble removal was well underway.

Initial observations suggested that the major environmental problem related to the management of the debris and rubble, as well as the dust problems associated with this activity.

## Waste management

The destruction of the Haret Hreik Security Square in southern Beirut generated a significant amount of solid waste requiring appropriate disposal.

It should be recognized, however, that at the time of the site inspection, the clean-up operation was well underway, and that significant progress had been made in a relatively short period of time. The site was a hub of activity, with hundreds of heavy trucks and machines involved in the demolition of damaged structures, backfilling of bomb craters, clearing of sites and transportation of rubble for treatment and disposal.

Arguably the most significant impact of the initial destruction and the subsequent clean-up activities is the dust it produces. The level of dust nuisance recorded by UNEP varied according to proximity to the trucks, with the highest reading being 1,470 µg/m<sup>3</sup> as compared to an acceptable level



*A severely damaged building in the southern suburbs of Beirut*





Dahia residents gathering corrugated iron from building rubble

of 150 µg/m<sup>3</sup>. Therefore, appropriate mitigatory measures to control the dust problem, and the associated health impacts, should be implemented as a matter of priority.

In sum, the waste management issues included, but were not necessarily restricted to:

- huge volumes of demolition waste, composed primarily of :
  - concrete rubble;
  - steel beams; and
  - aluminium sheeting;
- numerous derelict motor vehicles; and
- localized areas of soil and rubble contaminated with fuel oil.

### Contaminated land

The presence of many small generators in the rubble is a common problem. According to residents, these generators are operated in nearly every building by one or more of the residents, and the energy generated is sold as a backup during the frequent power black-outs.

In front of one of the generator rooms, a small amount of machine oil had seeped into the ground. In addition, the whole room smelled of diesel fuel and oil. A sample was collected for laboratory analysis.

Table 21. Sample no: 44B-CL-01

Parameter / Sample Identity	Unit	44B-CL-01	Dutch Intervention Value
Sample depth bgs	m	0.0	
<b>EPH (DRO) (C10-C40)</b>	<b>mg/kg</b>	<b>17,442</b>	<b>5,000</b>
<b>PAH by GCMS</b>			
Naphthalene	µg/kg	1,655	–
Phenanthrene	µg/kg	4,946	–
Anthracene	µg/kg	602	–
Fluoranthene	µg/kg	903	–
Benzo(a)anthracene	µg/kg	217	–
Chrysene	µg/kg	565	–
Benzo(k)fluoranthene	µg/kg	130	–
Benzo(a)pyrene	µg/kg	174	–
Indeno(123cd)pyrene	µg/kg	444	–
Benzo(ghi)perylene	µg/kg	556	–
<b>PAH Dutch List 10 Total</b>	<b>µg/kg</b>	<b>10,192</b>	<b>40,000</b>
XAcenaphthylene	µg/kg	460	
XAcenaphthene	µg/kg	723	
XFluorene	µg/kg	2,213	
XBenzo(b)fluoranthene	µg/kg	261	
XDibenzo(ah)anthracene	µg/kg	278	
XPyrene	µg/kg	2,151	
<b>PAH 16 Total</b>	<b>µg/kg</b>	<b>16,278</b>	<b>–</b>

The analysis of the sample shows that the substance spilled in front of the generator was diesel. The Dutch Intervention Value is exceeded more than threefold. The size of the spill (approximately 2 m<sup>2</sup>) and the relatively good condition of the fuel drums inside the generator room led to the conclusion that:

Haret Hreik Security Square before the conflict



- The observed spill was minor;
- Soil remediation would not be necessary; and
- The polluted soil could be excavated at a later stage of the general clean-up.

It should be noted that in a residential suburb such the Haret Hreik Security Square, where over 50 per cent of the buildings were destroyed, soil contamination from small sources like the above have a comparatively low priority within the overall clean-up programme.

**Surface and groundwater**

As a result of the extensive damage to the area’s infrastructure, both sewage and water pipelines were damaged and leaking significantly. Accordingly water samples were collected from all available sources – domestic (44TW1 and 44TW2), wastewater (44WW1) and groundwater (44GW1) – to establish the water quality at the site and measure the impacts of the damage.

The on site measurements and selected laboratory results are provided in tables 22, 23 and 24.

Table 22. Sample no: 44TW2 (Water line from Beirut)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
BOD	mg/litre	1	Nil
COD	mg/litre	11	Nil

Table 23. Sample no: 44WW1 (Wastewater)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	1088	500
Chloride	mg/litre	606	250
BOD	mg/litre	144	Nil
COD	mg/litre	367	Nil
Total Coliforms	Count/100 ml	410000	3
Faecal Coliforms	Count/100 ml	360000	Nil

Haret Hreik Security Square after the conflict



Table 24. Sample no: 44GW1 (Groundwater sample)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	1594	500
Selenium	µg/litre	72	10
Sodium	mg/litre	6975	200

Tap water, supplied by the Beirut Water Establishment from Ain Al-Delbeh, is only used for domestic non-drinking purposes, as local residents buy their drinking supplies from vendors. On site sample analysis indicated that tap water was brackish and not of potable quality.

The main problem with the piped water, however, is the detection of both total and faecal coliform counts at levels that pose an intermediate risk to consumers even if the water is only used for domestic non-drinking purposes, due to the risk of accidental ingestion of pathogens.

The source of this microbial contamination could be the cross-contamination of the water supply by sewage lines that are derelict and/or were damaged during the conflict. For other tested parameters, laboratory analysis indicates that the tap water does not exceed Lebanese or WHO drinking quality standards.

Sewage lines damaged in the recent conflict resulted in substantial wastewater spillage in the vicinity of Security Square. As expected, the analysis of the spill water indicated high BOD and COD levels, as well as elevated faecal coliform counts which could potentially impact surface and groundwater receptors and act as a potential source of disease to the local community.

At the time of the sampling, some local residents had started to return to their homes and this trend rapidly increased with the start of the new school year. Exposure to pathogens from the stagnant pools is considered to represent a moderate risk for residents.

It was also observed that the reparation of the damaged pipelines was generally of sub-standard quality and could lead to a continuation of the contamination in the longer term.



*A scene from the Dahia neighbourhood*

## Asbestos

At one location in the area of inspection, the material covering some external pipes had the appearance of asbestos cement. The material, however, was in good condition, and fit for purpose.

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. During the general clean-up, areas that can be identified as having suffered small oil spillages should, as far as possible, be handled separately. The hydrocarbon-contaminated material should be disposed of separately in regular landfills, instead of being used in land reclamation projects.
2. Alternatively, if suitable land is available, soil with elevated concentrations of hydrocarbons could be biologically remediated.
3. In urgent cases, the potentially negative consequences of mixing small quantities of contaminated rubble with large volumes of clean rubble should be weighed against the urgency of clean-up and the technical options for the site.
4. During the clean-up activities and indeed throughout the rebuilding programme, workers should be provided with appropriate personal protective equipment including overalls, boots, gloves and breathing masks.
5. Due to the negative health consequences of the substantial amounts of dust generated on site, largely as a result of the movement of heavy trucks, dust control measures should be adopted, such as spraying water over the surface of dirt roads.
6. Due to the risk of ingesting pathogens from contaminated water, responsible authorities should advise all residents to routinely boil tap water even when it is only used for domestic purposes.
7. An environmental sanitary inspection of the water/wastewater system in Haret Hreik in general and in Dahia in particular should be undertaken, with a view to identifying sources of potential contamination.
8. Based on the findings of the above-mentioned assessment, damaged water and sewage pipelines and septic tanks should be repaired as a matter of urgency – preferably in advance of the residents' return.
9. Technical guidelines on best practice in water and wastewater network rehabilitation should be provided, with a specific focus on system designs that prevent potential cross-contamination.
10. Public signs should be erected to deter residents, especially children, from making contact with stagnant pools.

**Hannawiyah supermarket**

The site is located 7 km southeast of the town of Tyre, near the Hannawiyah town centre. It occupies an area of approximately 1,200 m<sup>2</sup>, and is situated 240 m above sea level. The geological setting is within Cretaceous limestone; the surrounding land use is mainly residential.

The line of goods carried by the supermarket is reported by local residents to have comprised domestic items such as detergents, packaged foods and fresh vegetables.

The building was completely destroyed during the conflict, but clean-up was undertaken rapidly

and all the rubble had been removed at the time of inspection.

**Contaminated land**

There were no major concerns regarding contaminated land on this site. Two minor (each less than 0.5 m<sup>3</sup>) oil spills were observed, but their impact on the environment could be considered negligible.

**Surface and groundwater**

Using a portable bailer, experts collected samples from a water supply pipeline originating from the Ras El-Ain springs near Tyre (HSPW1) and from a sub-surface wastewater tank (HSWW1).

Table 25. Sample no: HSPW1 (pipeline)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Total Coliforms	Count/100 ml	20	3
Faecal Coliforms	Count/100ml	<10	0
Phosphate (Ortho as P04)	mg/litre	0.22	0

Table 26. Sample no: HSWW1 (wastewater tank)

Laboratory Analysis			
Parameter	Unit	Concentration	WHO Standards
Boron	µg/litre	3246	500
Total Coliforms	Count/100 ml	20	3
Faecal Coliforms	Count/100ml	<10	0
Phosphate (Ortho as P04)	mg/litre	22.43	0



Site of the former Hannawiyah supermarket



*A young inhabitant of Zabqine tries a hard hat on for size*

Laboratory analysis found the drinking water (HSPW1) to be within natural range for the parameters measured. Slight faecal coliform contamination, however, was reported (<10/100 ml). The levels detected are low, yet represent an unacceptable risk for consumers. It is unclear whether this contamination is due to inadequate treatment or to contamination during transmission, which may have been affected by the shelling.

Laboratory analysis of the wastewater sample indicated high concentrations of ammonia, boron and phosphates, which are likely to have originated from the laundry detergents and soaps in the damaged supermarket.

The high boron concentrations are not, however, a major cause for alarm, as the levels are below WHO's drinking water guidelines. However, preventative measures should be taken to avoid further groundwater contamination including adequate treatment of wastewater and contaminant sources.

Chromium (Cr<sup>+3</sup>) and nickel were also detected above environmental screening criteria, but well below WHO's intervention guidelines.

### **Waste management**

As mentioned above, the site had been cleared of all rubble, graded and back-filled at the time

of inspection. Consequently, all major waste management issues had been addressed.

One small remaining issue is the dumping of waste on the site, as commonly occurs on vacant lots of land.

### **Recommendations**

#### **Urgent short-term measures (0 – 3 months)**

1. Debris should be cleaned up and disposed of safely to prevent potential phosphate and boron contamination of groundwater.
2. The source of the coliforms in the piped drinking water should be investigated further, and remedial measures implemented as a matter of priority, such as ensuring adequate treatment at source and repairing damaged pipelines to an acceptable standard.
3. In the meantime, residents should be advised of precautionary measures to be taken, such as boiling the water.
4. Due to the risks for public health, the local municipality, with the Ministry of Environment, should take steps to discourage the practice of dumping waste on vacant lots of land.

### Zabqine

The village of Zabqine is located 5 km southwest of Qana, and is approximately 400 m above sea level. The geological setting is within Cretaceous limestone and marls. The surrounding land is mainly used for residential and commercial purposes.

The village sustained considerable damage in the conflict, and a significant amount of debris and rubble was in the process of being cleared at the time of UNEP's visit.

### Contaminated land

The primary issue of concern at this site was an electricity transformer that had been destroyed, presumably by rubble falling from a neighbouring building. The electricity pole on which it was mounted seemed undamaged. By the time of the site inspection, however, the damaged transformer had already been replaced with a new one, and had been removed from the site.

Only a small (1 x 1 m) patch of oil-stained soil remained. A soil sample was taken directly from



*The new transformer that has replaced the one damaged in the conflict*

the patch of oil for laboratory analysis, in order to determine if the transformer oil was contaminated with polychlorinated biphenyls (PCBs). It consisted of brownish soil mixed with concrete residue and rubble from the impact on the neighbouring building.

As expected, the sample analysis confirmed the presence of PCBs in a limited area. As the quantity of oil that leaked from the old transformer was relatively small, the disposal of the contaminated soil (approximately 0.5 to 1 m<sup>3</sup>) is a matter of waste management.

Given that this spill was relatively insignificant, risks for people living in the neighbourhood or for the groundwater resources are not expected.

### Surface and groundwater

A rainwater sub-surface storage tank was identified near the site of the old transformer, and a water sample was taken to determine if any pollution from the transformer oil spillage had occurred.

Laboratory analysis indicated that none of the parameters measured, including hydrocarbons, exceeded their environmental screening values. Slight faecal coliform contamination, however, was reported (<10/100ml). Though such levels represent a low risk for consumers, users should be advised to boil the water before drinking it.

### Waste management

From a waste management perspective, the only issue of concern relates to the collection and disposal of the small quantity of contaminated soil, estimated to be approximately 0.5 to 1 m<sup>3</sup>.

### Asbestos

Approximately 1 m<sup>2</sup> of asbestos cement debris was noted in the rubble. Although the quantity was small, it was spread over a relatively large area. It was not possible to ascertain the exact source of the material, but it was most likely from roofing sheets.

Laboratory analysis confirmed the material to be chrysotile (white asbestos), but it is not considered to present a significant risk, and immediate asbestos abatement work is not deemed necessary.

Table 27. Hydrocarbon analysis results

Sample Identity	Units	Method Detection Limit	GEN1-CL/WM/01	Dutch Intervention Value
EPH (DRO) (C10-C40)	mg/kg	<1	<b>46,484</b>	<b>5,000</b>
EPH (DRO) (C10-C40)	µg/kg	<35	–	
GRO (C4-C10)	µg/kg	<10	<10	
GRO (C10-C12)	µg/kg	<10	<10	
<b>PAH by GCMS</b>				
Naphthalene	µg/kg	<10	412	
Phenanthrene	µg/kg	<21	1,794	
Anthracene	µg/kg	<9	121	
Fluoranthene	µg/kg	<25	390	
Benz(a)anthracene	µg/kg	<12	226	
Chrysene	µg/kg	<10	271	
Benzo(k)fluoranthene	µg/kg	<25	<125	
Benzo(a)pyrene	µg/kg	<12	172	
Indeno(123cd)pyrene	µg/kg	<11	146	
Benzo(ghi)perylene	µg/kg	<10	227	
<b>PAH Dutch List 10 Total</b>			<b>3,759</b>	<b>40,000</b>
Acenaphthylene	µg/kg	<5	235	
Acenaphthene	µg/kg	<14	359	
Fluorene	µg/kg	<12	512	
Pyrene	µg/kg	<22	1775	
Benzo(b)fluoranthene	µg/kg	<16	157	
Dibenzo(ah)anthracene	µg/kg	<8	91	
<b>PAH 16 Total</b>	<b>µg/kg</b>	<b>&lt;25</b>	<b>6,888</b>	
PCBs (vs Aroclor 1254)	µg/kg	<20	<200	

Table 28. Sample no: ZETW1 (sample from rainwater storage tank)

<b>On-site Analysis</b>			
Parameter	Unit	Concentration	WHO Standards
Temperature	°C	23.16	–
ORP	mV	107	–
pH		6.4	6.5-8.5
DO	µg/litre	5793	–
Conductivity	µS/cm	192	250
<b>Laboratory Analysis</b>			
BOD	mg/litre	10	Nil
Total Coliforms	Count / 100 ml	20	3
Faecal Coliforms	Count / 100 ml	<10	0

## Recommendations

### Urgent short-term measures (0 – 3 months)

1. The contaminated soil should be excavated, placed inside a re-sealable container, and disposed of in a sanitary landfill site. If no such facility is available, the material should be stored in a secure container until a suitable option is identified. Until then, children should be deterred from playing near the contaminated soil.
2. Due to the presence - albeit minor - of faecal coliforms, residents should be advised to boil the water before drinking it.



### Khiam prison

Khiam is situated approximately 4 km from the Israeli border, near Bint Jbeil. The prison, which was located on the outskirts of the village, was completely destroyed during the conflict. UNEP visited the site of the former prison during a follow-up visit to Khiam on 20 and 21 November 2006.

### Contaminated land

Approximately twenty burnt car wrecks and a scrap metal heap were found on site. Three soil samples of the omnipresent red clay were taken outside the prison, close to the car park. A sample taken 8 – 15 m from the street and 0 – 5 cm below ground level, showed a lead concentration of 6,340 ppm (mg/kg). This is significantly above the average traffic-related lead levels of up to 115 ppm (measured 3 m from the roadside), indicated in the Government of Lebanon's State of the Environment Report (2001).

The source of the elevated lead concentration is most likely to be the batteries of the burnt cars, but could also be the smoke plume generated by the burning cars or the scrap metal deposited on the site. The possible spill of lead-containing fuel gasoline was ruled out, as no gasoline smell was detected.

Given that lead is well absorbed by the red clay found at the site, the substrate would act as a natural buffer against migration, immobilizing the lead and ensuring that the contamination remains localized.

### Recommendations

Although the levels of lead found at the site are significantly above the Dutch Intervention Value of 530 mg/kg, no remediation measures are considered necessary due to the localized and static nature of the contamination.



*Burnt car batteries are likely to be the source of elevated lead concentrations at the site of the former Khiam prison*

# Solid and Hazardous Waste

*A fleet of tipper trucks queue at the Ouzaii dump site. The conflict generated a massive amount of debris and building rubble, which requires appropriate management and disposal.*

*© AP Photo – Dimitri Messinis*



## Solid and hazardous waste

### Introduction

To develop an understanding of the waste management situation in Lebanon, and to gauge the extent of the waste-related impacts of the conflict with Israel, the assessment team inspected the following waste management facilities:

- closed Normandy dump site, Beirut;
- Ouzaii rubble disposal site, Beirut;
- rubble disposal site in the Al-Aitam area municipality of (Bourj el Barajina) in Beirut;
- Tyre dump site;
- Khiam rubble disposal site;
- Zahleh sanitary landfill site;
- Naameh sanitary landfill site, Chouf;
- Bsalim inert waste disposal site, Metn;
- Karantina waste processing plant, Beirut; and
- waste composting plant, Beirut.

In addition, all the conflict-impacted sites visited by the main team, as discussed in the 'Industrial and Urban Contamination' section, were also examined from a waste management perspective.

Due to the large number of sample analyses conducted, only selected field and laboratory results have been included in this report. However, complete results can be accessed at: <http://lebanonreport.unep.ch>

### Preliminary observations

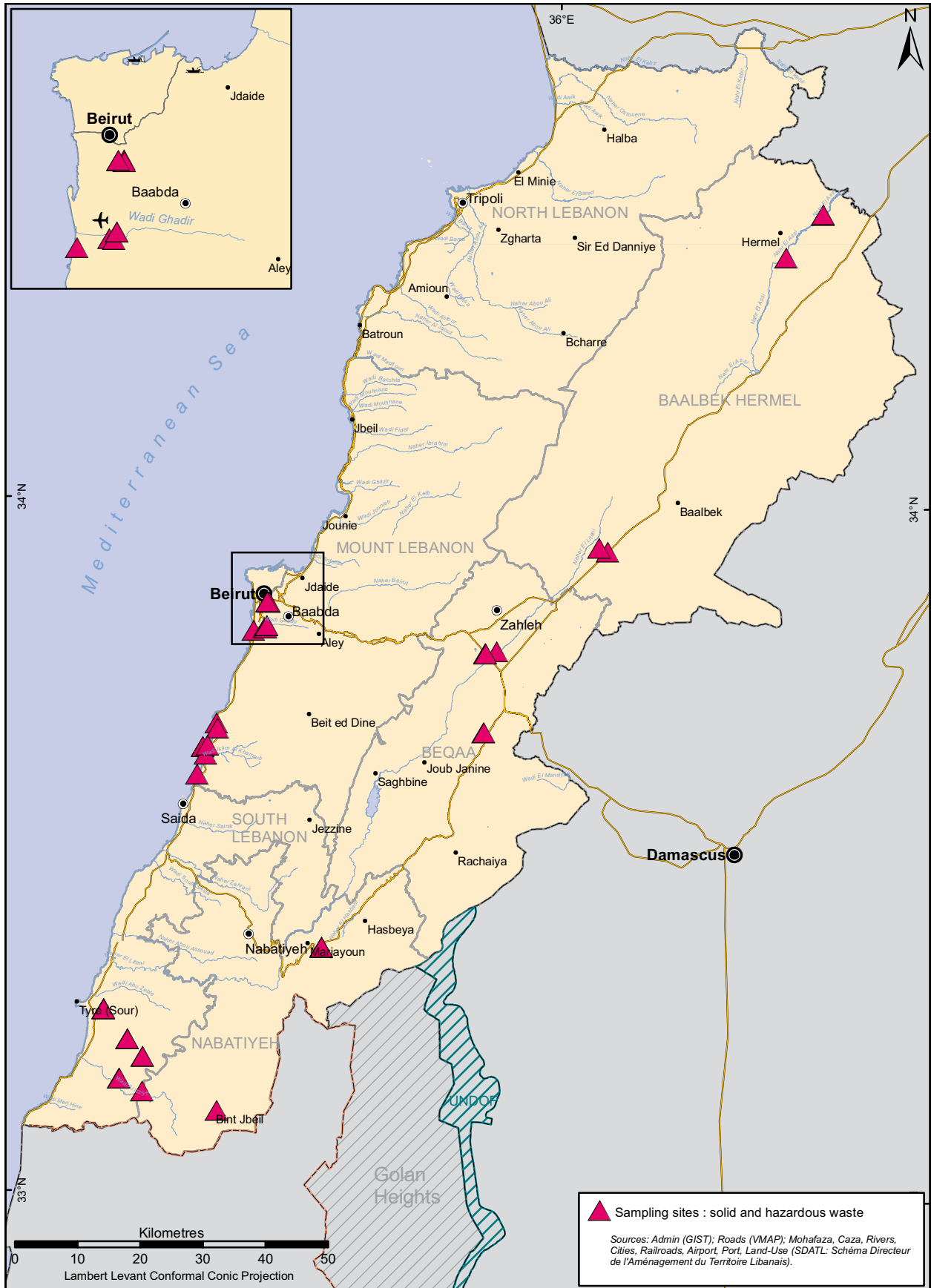
The findings of the investigation make clear that the management of solid waste remains one of the most critical environmental problems in Lebanon today. With the exception of Beirut and Mount Lebanon, which have engineered disposal sites, virtually every town and village in Lebanon operates a dump site with the result that there are over 700 dump sites throughout the country.

Given that the production of waste is reported to be growing at four per cent per annum, representing an overall growth of some 60 per cent between 2006 and 2030<sup>1</sup>, these serious waste management problems need to be addressed as a matter of national priority. In addition, the population in Lebanon almost doubles during the summer tourism season, exerting further pressure on the weak waste management system.



*A view of the Tyre dump site, which is a source of dust, smoke, odours and disease vectors*

Map 7. Sampling sites – solid and hazardous waste



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

## Asbestos Monitoring

Generally speaking, all the sites that had been bombed were derelict, though some of the locations had already been cleared, and removal of the debris was underway in others.

Asbestos-containing building materials are not expected in modern buildings, and the majority of destroyed or damaged buildings encountered during the assessment were of relatively modern construction, with most reported to be less than ten years old. In sites where the buildings were older, however, such as the Al Maalaka fish farm and the Bint Jbeil school, asbestos cement building products were observed and sampled.

Asbestos cement products were noted in several locations, but no source could be identified on site. It is possible that most of the asbestos building products had been removed from the sites, together with the general rubble, or that the asbestos cement products had been brought to the sites from elsewhere and dumped there.

Asbestos cement is generally considered to present a low risk to human health. Following suitable training and the development of an appropriate, safe method of work, it should be possible for local personnel to undertake a programme of collection of asbestos cement debris.

Collected materials would need to be suitably contained, transported and disposed of at a landfill site able to take such waste. This work would require supervision and monitoring by suitably experienced and qualified personnel.

Sites at which no asbestos materials were noted should not be considered to be free from asbestos until the security situation allows for a detailed and complete inspection of the area to be undertaken. Where sewage pipes were damaged, the presence of asbestos containing materials should be investigated, as such pipes frequently contain asbestos.

The assessment also revealed that many dump sites throughout Lebanon are situated in unsuitable locations, including old quarries, river valleys, and areas by the seashore or adjacent to major water courses.

This critical situation has clearly been compounded by the recent conflict. Many existing sites have become overrun with demolition material, and numerous new dump sites have been developed to deal with the added burden. Further, and perhaps more seriously, considerably more hazardous healthcare waste (HHCW) – due to the high number of deaths and injuries in the conflict – is reported to be mixed in with municipal waste and finding its way into the disposal sites.

With the exception of those containing only demolition waste, every site the UNEP team visited was found to be causing contamination of both ground and surface water through the uncontrolled discharge of leachate, the complex network of fissures in the underground limestone allowing pollutants to move rapidly and unpredictably to the underlying aquifers.

Another obvious threat to public health is the risk of consuming contaminated meat products, as sheep, goats and cattle were seen grazing in dump sites containing a variety of hazardous materials, such as medical, slaughterhouse and industrial waste. In addition, inspected dump sites were found to be responsible for a proliferation of several disease

vectors, including flies, mosquitoes and rodents, while the routine burning of waste materials frequently subjected residents to noxious fumes.

One example of a dump site creating serious environmental and public health issues is the site UNEP inspected in Tyre.

The recent conflict has exacerbated the Lebanese waste management situation in many respects, including:

- During the conflict, the general breakdown in the delivery of municipal services, including waste collection, resulted in a build-up of uncollected waste in close proximity to houses and surface watercourses;
- Following the conflict, existing dump sites became overwhelmed with rubble and demolition material, and numerous new dump sites were hastily created, such as the ones at Ouzaii and in Bourj el Barajina municipality;
- As a result of the oil spill from the Jiyeh power plant, several thousand cubic metres of oil-contaminated waste materials collected during clean-up operations require disposal;
- Due to the many deaths and injuries caused by the conflict, larger than usual quantities of hazardous healthcare waste (HHCW) are reported to have been disposed of in the municipal waste stream, posing a serious risk to the health of staff involved in the collection and disposal of waste, and in particular, to low-income individuals, often children, engaged in waste-picking and scavenging activities; and
- There is a risk that the rubble and debris generated by the conflict may be contaminated by asbestos. If this were the case, it would present serious long-term health risks to those involved in the site clean-up activities and those working at the waste disposal sites receiving the material.



*View of the Ouzaii rubble disposal site from the sea*

The dump site at Ouzaii, developed recently to cater for the large volumes of demolition waste created by the conflict, does not pose a significant risk to water resources, thanks mainly to the inert nature of the run-off. The site at Khiam, however, is situated in a winter water way and does pose a risk of contamination. Both sites were found to cause a number of nuisances and public health risks for those working on, and living adjacent to, the sites, including:

- dust;
- smoke;
- noise; and
- safety risks relating to the large number of heavy vehicles entering and manoeuvring around the sites, with little if any supervision, and the almost complete absence of personal protective equipment (PPE) for staff and contractors on site.

Dust readings were recorded by the mission team at a number of sites visited. The results of this exercise are summarized in the box below.

A further serious concern is the almost complete absence of basic personal protective equipment (PPE) for staff and contractors working on the various waste disposal sites. As a minimum, individuals should be provided with:

- safety boots;
- gloves;
- overalls;
- torches;
- breathing masks; and
- a helmet.

Once provided, employers should ensure that the use of appropriate personal protective equipment is a condition for working on any site.

## Dust Monitoring

Dust monitoring was carried out by the UNEP team using a hand-held Personal Data Ram. The values recorded are time weighted average values for 10 minutes per location. The values obtained were compared against the National Ambient Air Quality (NAAQ) Standards provided by the United States Environmental Protection Agency.

The NAAQ standard for dust concentration in air is  $150 \mu\text{g}/\text{m}^3$ . The readings at the Khiam dump site and the Ouzaii dump site were found to be 363 and  $1,834 \mu\text{g}/\text{m}^3$  respectively.

Clearly, both sites are generating unacceptably high levels of dust which – if unaddressed – will impact negatively on the health of site workers and that of members of the public visiting or passing in close proximity to the sites.

Further, it should be noted that high dust readings were not restricted to dump sites only. Indeed, readings as high as  $1,470 \text{ micrograms}/\text{m}^3$  were recorded in the Haret Hreik suburb of Beirut, where massive clean-up operations were ongoing.

On all sites where dust generation represents a threat to the health of workers and the general public, a number of measures should be introduced as a matter of priority:

- The areas of operation should be made inaccessible to the general public and regularly sprayed with water to suppress dust generation from vehicle movements;
- Speed limits should be implemented and enforced by site staff;
- Face masks should be issued to all staff, and their use enforced; and
- Worker rotation should be introduced to minimize individual exposure to dust.





*The Kham dump site illustrates the high levels of dust generation at most rubble disposal sites*

### Existing sanitary landfill sites

In addition to numerous dump sites, two sanitary landfill sites were visited to determine whether this relatively sophisticated technology was affordable and sustainable in the Lebanese context:

- the Naameh sanitary landfill site, Beirut; and
- the Zahleh sanitary landfill site, Beqaa Valley.

The two sites operate on very different scales: the Zahleh landfill site serves some 150,000 people, while the Naameh landfill site serves most of Beirut and Mount Lebanon (excluding caza Jbel), with a combined population of close to two million people.

Despite the different scale of operation, both sites broadly meet the criteria for sanitary landfill sites, as they have features such as:

- synthetic, low permeability base membranes;
- electronic weigh-bridge for recording incoming waste;

- leachate collection and preliminary treatment;
- landfill gas management systems, with flaring;
- waste sorting;
- waste recycling; and
- waste composting (for Beirut and most of Mount Lebanon).

In addition, both the Zahleh and the Naameh landfill sites are operated by private contractors. It is recognized by the Government of Lebanon<sup>2</sup> that where private contractors have been engaged, improvements in the quality of services provided have been realized, and there is consequently a desire on the part of the government (which is supported by UNEP) to extend the participation of the private sector in service delivery.

Despite the similarities in features, the two sites represent extremely different models of funding, contracting and operation. As a consequence, there is a wide variation in the cost of the services offered to the public, with the Zahleh landfill offering excellent value for money.



*The lack of basic health and safety equipment, as seen here at the Ouzaii dump site, is a serious concern*

It is reported that the Council for Development and Reconstruction (CDR), which answers directly to the Prime Minister, pays for the operation of both sites. However, it is understood that in addition, the municipality of Zahleh charges other municipalities for the use of the site on a tonnage basis<sup>3</sup>. These funds, which are reportedly invested, are to be used for the maintenance of the existing site and for the construction of a new landfill in the future. On the surface, this appears to be an extremely promising approach. The cost of the service is, however, problematic for some municipalities and should be passed on to the waste generator to accord fully with the 'polluter pays' principle.

It is further reported that under the World Bank SWEMP<sup>4</sup> project, a total of ten regional landfill sites were identified for development, but that only the Zahleh landfill was eventually constructed. The reasons for this are complex, but relate, at least

in part, to the very high level of objection from local residents to any landfill construction (known globally as the 'not-in my-back-yard' phenomenon). The Zahleh landfill's success is apparently due to the pro-active role of the mayor and municipality, who work in close collaboration with local NGOs, and other municipalities. There are, however, concerns regarding the location of the site.

### **Reasons for failed solid waste management initiatives**

The development of the Zahleh landfill site and the closure of the Normandy dump site in Beirut are examples of successful projects in the waste management sector of Lebanon. Unfortunately, there are numerous examples of solid waste management plans that have failed despite funding from the international community and the existence of suitable geological and environmental conditions.

The primary reason for this situation appears to be strong community opposition to the construction of new sanitary landfill sites throughout Lebanon, which is compounded by insufficient public education and consultation exercises with local residents. Local authorities are understandably reluctant to approve the construction of regional landfills within their communities, as the importation of waste from other areas is perceived as extremely negative and unpopular amongst the local electorate.

The absence of appropriate legislation to regulate waste management activities, which are the responsibility of local municipalities, is another disincentive for the development of engineered solutions. It is, however, understood that a draft law is being prepared under the ongoing METAP (Mediterranean Environmental Technical Assistance Programme), funded by the EU and managed by the World Bank.

Open dump sites – with all of their associated health and environmental consequences – are the norm in Lebanon, with Beirut and Mount Lebanon being the only exceptions. In recognition of this problem, the European Union (through its Management Support Consultant Investment Planning Programme) funded a 2005 study by Raji Maasri<sup>5</sup> on the existence and potential rehabilitation of dump sites throughout the country.

Maasri's report, which provides a significant amount of background information on waste management in Lebanon, makes a distinction between several different categories of dump sites:

- Sites contracted and managed by Central Government, such as the one in Tripoli, whose operations are controlled by a consultant; some containment measures, such as gas collection and flaring, with the daily application of cover material, are implemented there, but there is no base liner and no leachate recirculation or treatment;
- Sites contracted and managed by municipalities, such as the ones at Saida and Hbaline, where access is controlled and cover material is periodically applied;
- Sites contracted and managed by municipalities, but where no control is exercised, such as the sites at Kayyal in Baalbek;
- Sites contracted by municipalities and managed by the private sector;
- Sites owned and managed by the private sector, such as Srar, where access is controlled and cover material is periodically applied; and
- Completely unmanaged sites, such as roadside sites often located down steep slopes, where neither access nor operations are controlled.



*The Zahleh sanitary landfill, where good use of cover material minimizes problems with odours and pests*

## Institutional framework

There are several key players in Lebanon's waste management sector, at both the national and sub-national levels, including:

### At the national level:

- The Ministry of Interior and Municipalities (MoIM), which is responsible for the activities of the municipalities;
- The Ministry of Environment (MoE), which is responsible for developing solid waste management strategies and for monitoring waste management services, such as the operations of waste disposal sites;
- The Ministry of Finance, which is financing all solid waste management projects in Beirut and Zahleh through the Council for Development and Reconstruction (CDR); and
- The CDR which, under the authority of the Prime Minister, has been responsible for implementing a waste management plan in the Greater Beirut area, and has developed proposals for establishing waste management infrastructure and services elsewhere in the country.

### At the sub-national level:

- Local municipalities are responsible for collecting and transporting waste. Indeed, the 2005 National Physical Master Plan for the Lebanese Territory articulates the vision that municipalities should become more independent in managing their solid waste, and should rely less on central government and the CDR in the future.

The MoE is primarily responsible for monitoring the operations of the few existing landfills and the many dump sites. Although they constantly receive complaints from members of the public regarding smoke and odour nuisances in particular, MoE staff are unable to take direct action. Rather, they are required to communicate information relating to disposal sites to the Ministry of Interior and Municipalities (MoIM), as those are the responsibility of the respective municipalities. Information about sanitary landfill sites must be communicated to the CDR, who finances the operations.

This situation is aggravated by the fact that there is no mechanism by which either the MoIM or the CDR report back to the MoE. Little, if any, corrective measures are therefore taken, and penalties are rarely enforced.

## Legal framework

The Government of Lebanon has signed a number of national laws and regulations, as well as international treaties, including:

- the Basel Convention;
- the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter;
- the Protocol Concerning Mediterranean Specially Protected Areas and Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources; and
- the Kyoto Protocol to the UN Framework Convention on Climate Change.

The lack of a country-wide land use system which could dictate the protection of certain zones due to their natural, cultural or socio-economic resources, exacerbates the difficulties of adhering to national and international laws relating to waste management.

This situation may soon be improved, however, thanks to the production of the National Physical Plan of the Lebanese Territories (NPPLT)<sup>6</sup>, which is understood to be currently awaiting ratification by the Council of Ministers.

## The need to protect water resources

The NPPLT prioritizes the closure of dump sites, as it recognizes that the "fractures and karst networks facilitate point and non-point sources pollutants to percolate and infiltrate deep into the ground, thus making groundwater vulnerable". The document goes on to stress the need to protect the Lebanese natural and cultural heritage.

Because Lebanon receives a reasonable amount of rain and its geology is mainly karstic in nature, fairly extensive surface and groundwater resources have developed. These factors have in turn allowed the development of a thriving agricultural sector.



*The dump site in the Bourj el Barajina municipality, which has been created to deal with conflict-related debris*

Accordingly, it is essential that Lebanon's water resources be protected.

However, the prevalent open dumping of solid waste is contaminating the sea, surface water channels, groundwater aquifers and springs, and is impacting negatively on both drinking and irrigation water.

Addressing the problems associated with dump sites, and providing suitable alternatives through an integrated waste management strategy, including a network of sanitary landfill sites, waste recycling and composting, should clearly be a national priority.

An important early step in this process is the establishment of priority dump sites to be closed. From a scientific and environmental perspective, priority for closure and/or upgrading should be given to those sites impacting most negatively

on water resources and/or public health. Other important considerations should be whether an alternative waste disposal site exists, and whether the dump site in question can be upgraded to an engineered landfill.

Further, there is a need to educate waste generators, and to put mechanisms in place to ensure compliance with legal requirements, such as those addressing the illegal dumping of waste.

UNEP found that the Zahleh landfill site provides an excellent working model that could be replicated throughout Lebanon. The many positive components of the site's operations include the lead taken by the mayor and local municipality, the active participation of local NGOs, and the cooperation of other municipalities. All of the above factors have combined to provide the region with an excellent and affordable site.

# Water Resources

*Rain water reservoirs, like this one in Bint Jbeil, are one of the main sources of communal water in Lebanon*



## Water resources

### Introduction

In the arid Middle East, Lebanon is distinguished by its relatively large freshwater supplies. Given that the country benefits from one of the highest water per capita ratios in the region, freshwater is perhaps its single most important natural resource. The protection and sustainable use of its water wealth have accordingly been one of Lebanon's major development challenges, particularly as forecasts predict that the country is likely to experience a water deficit within the next ten to fifteen years<sup>1</sup>.

The heavy damage incurred by the country's civil and water infrastructure during the 2006 conflict disrupted the supply, distribution and management of water resources, and rendered them vulnerable to contamination risks. Moreover, the targeting of industrial facilities raised concerns about potential pollution of surface and groundwater.

To consider the cumulative impacts of the conflict on the water sector as a whole, it is essential to understand the pre-conflict state of water resources, including stressors and water quality conditions.

Due to the large number of sample analyses conducted, only selected field and laboratory results have been included in this report. However, complete results, as well as Dutch and WHO standards, can be accessed at: <http://lebanonreport.unep.ch>

This chapter, therefore, attempts to contextualize the results of the water quality sampling, field observations and stakeholder consultations within the overall water management situation in Lebanon. The discussion also considers, as appropriate, the significance of conflict-related water degradation within hydrologic spatial units (i.e. at the aquifer or catchment level). Finally, other issues such as land-based sources of marine pollution and transboundary water disputes are also addressed.

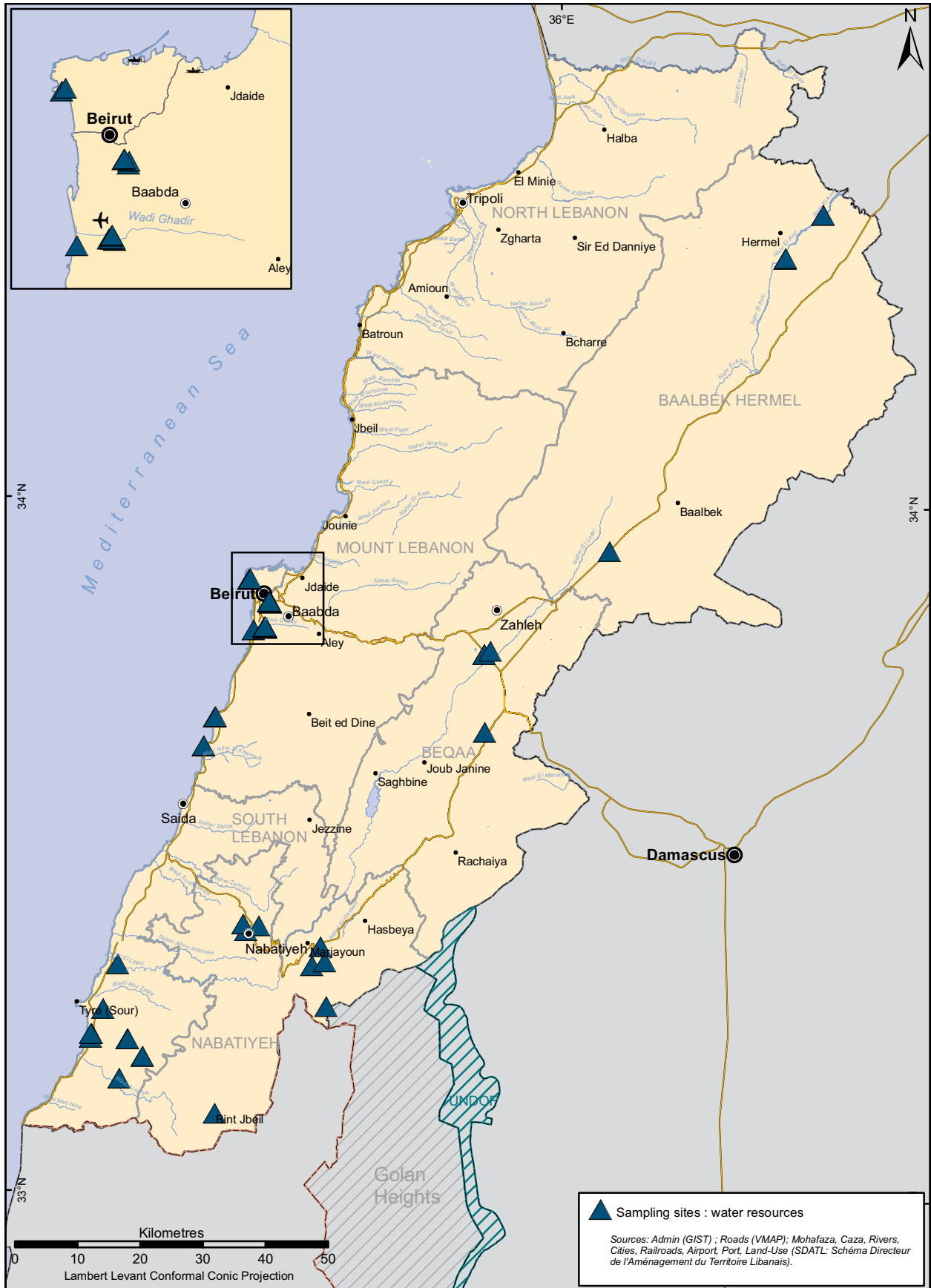
While preliminary results are indicative of the significance of potential contamination and provide a basis for recommending remedial actions and further studies, the limitations of water sampling in determining the conflict's impact on water quality should be recognized. Sample analysis



*Monitoring of surface water quality using portable analytical equipment in the Choueifat industrial area in Beirut*



Map 8. Sampling sites – water resources



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

results present a snapshot of existing conditions at a particular point in time; they are therefore temporally insufficient to make a full assessment of the magnitude and severity of conflict-related water pollution. Since the collection of samples was carried out before the onset of the rainy season (November-April), the mobilization of contaminants may have not yet occurred. Ideally, monitoring should be designed over an extended time range (i.e. hydrological calendar) to verify the trend in potential contaminant diffusion in receiving water systems. It is hence difficult to generalize or draw firm conclusions about the overall impact of conflict-related water pollution from a single field exercise.

## Overview of water resources

Some forty streams and rivers and two thousand springs originate in Lebanon, making it one of the main headwater regions of the Levant. The average annual rainfall is estimated at 823 mm<sup>2</sup>. As it is topographically more elevated than its neighbours, the direction of drainage is outward from Lebanon, with only minor external inflow. Thus, unlike most other countries in the region, Lebanon enjoys a certain “hydrological autonomy”, generating and controlling the majority of its water resources. Most of the streams and rivers discharge directly into the Mediterranean Sea, but two significant transboundary rivers arise in Lebanon: the Hasbani, a tributary of the Jordan River, and the Al-Assi (Orontes) that runs north-east into Syria.

Less than 25 per cent of Lebanon’s estimated average yearly precipitation of 8.6 billion m<sup>3</sup> is considered to be realistically recoverable as exploitable surface and groundwater. Seventeen of Lebanon’s forty major rivers are perennial – all originating from karstic springs – and the rest are seasonal. The majority of the perennial rivers flow west from the Mount Lebanon range and discharge into the Mediterranean Sea. The Litani, which originates in the Beqaa plain, is entirely within Lebanon, while the Kebir, Al-Assi and Hasbani rivers are shared with its neighbours<sup>3</sup>. The main catchments that could potentially have been affected by the conflict include the Litani, Hasbani, Al-Assi, Abou Assouad, El-Zahrani, Saitani, Awali, Damour, and the seasonal Ghadir stream.

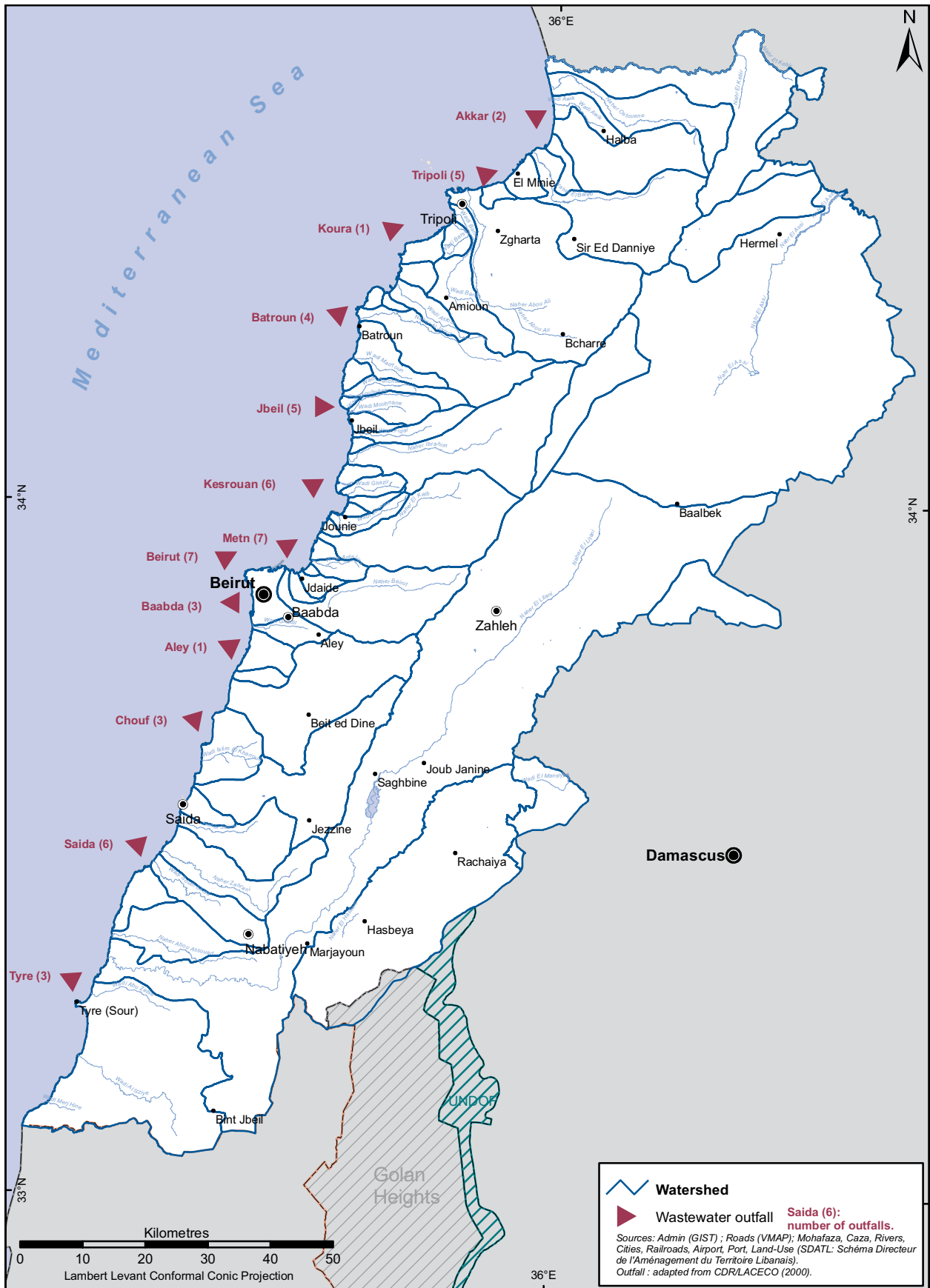
Groundwater accounts for 20 to 50 per cent of Lebanon’s two billion m<sup>3</sup> of total net exploitable water. The distinguishing characteristic of Lebanon’s hydrogeology is a highly developed karstic network in the Jurassic and Cretaceous limestone layers. As the limestone formations are heavily fissured and fractured, recharge of the aquifers by rainfall and snowmelt is relatively rapid, despite the depth of the groundwater table, which typically ranges from 50 to 300 m. At the same time, these geologic features render groundwater susceptible to leaching and pollution seepage. The lack of adequate licensing control and monitoring of well water withdrawal is the main problem undermining sustainable groundwater management.

Table 29. Approximate annual water balance

Description	Yearly average flows [million m <sup>3</sup> ]
Precipitation	8,600
Evapotranspiration	4,300
Surface water flow to neighbouring countries	670
• Flow to Syria	510
– Al-Assi (Orontes) River	415
– El-Kebir River	95
• Flow to Israel	160
Groundwater seepage	1,030
Net potential surface and groundwater available	2,600
Net exploitable surface and groundwater	2,000

Source: Adapted from Lebanon State of the Environment Report, MoE/LEDO, 2001.

Map 9. Watershed and wastewater outfalls in Lebanon



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

## Water quality

The quality of surface and groundwater has historically been impaired by untreated domestic sewage disposal, agricultural run-off, industrial effluents and leachate from open dumping. Because there is no systematic monitoring of effluent discharges and enforced ambient water quality in Lebanon, it is difficult to accurately quantify pollution loads discharged into water bodies. The most recent estimates available, however, indicate a substantial increase in pollution loads, with annual domestic wastewater releases growing by 53 per cent from 1995 to 249 million m<sup>3</sup> in 2001. A study from 1995 estimated industrial effluents at about 22.3 million m<sup>3</sup> per year. More recent extrapolations have almost doubled this volume, to 43 million m<sup>3</sup> in 2001. Most of the domestic and industrial discharge ends up in the sea<sup>4</sup>.

Water pollution from diffuse non-point sources is also an issue of concern due to the substantial growth in agrochemical application. In 2005, an estimated 7,510 tonnes of pesticides and 75,829 tons of chemical fertilisers were imported<sup>5</sup>. Uncontrolled over-pumping of groundwater in coastal agglomerations – particularly in and around Beirut – has led to water table draw-down and serious seawater intrusion into groundwater. Screening studies show elevated salinity levels in coastal groundwater compared with baseline figures from the 1960s<sup>6</sup>.

Available data on surface and groundwater quality is based on sporadic and ad-hoc studies conducted by various institutions. Moreover, information on effluent disposal routes is insufficient. The knowledge base to underpin and measure conflict-related surface and groundwater pollution requires temporally continuous water sampling and monitoring, something Lebanon presently lacks. As a result, it is difficult to identify and separate with accuracy the pre-conflict pollution legacy from that generated by the war.

## Wastewater

Untreated wastewater, mainly domestic but also increasingly industrial, is the principal threat to Lebanon's waters. It is difficult to qualify the composition of this chronic pollution load

– whose combined waste stream in 2001 was estimated at 293 million m<sup>3</sup> – and its consequent impact on water quality. As most of this polluted water finds its way into the Mediterranean Sea, it is the coastal and marine environment that is perhaps most adversely affected. Indeed, there are approximately 53 wastewater outfalls strewn along Lebanon's coastline. The severity of the impact is reflected in the fact that of the ten coastal areas monitored by the National Centre for Marine Sciences, only one station was deemed suitable for bathing, as all others exceeded WHO's faecal coliform standards for recreational waters<sup>7</sup>.

According to a housing census in 1998, less than 60 per cent of buildings in Lebanon were connected to sewage networks<sup>8</sup>. Although the spate of reconstruction that the country has undergone over the past several years has extended network coverage and building sewer connectivity, the situation remains wanting. Most of the houses in rural areas use cesspools and septic tanks which, due to poor design and maintenance, are susceptible to seepage and considered an important source of faecal contamination of groundwater. Moreover, sewage sludge is typically disposed of on land, or dumped in empty boreholes, readily polluting groundwater. While major projects to extend sewage networks are underway, their operation is dependent on their connection to treatment plants.

There is an acute deficiency in wastewater treatment capacity in Lebanon. Not only is the Ghadir treatment plant serving the southern suburbs of the Greater Beirut Area the only operational facility in the country, but it only provides basic primary wastewater treatment prior to discharging into the sea. A feasibility study has been completed to upgrade the Ghadir plant, but funding has not been secured. Thirty-nine wastewater treatment plants are at various stages of development: ten under construction, twenty-two under preparation, and seven without funding<sup>9</sup>. Despite these ambitious plans, implementation has been slow. Small-scale wastewater treatment projects have been implemented in rural areas in recent years, but their success has been mixed. Finally, there are no existing or planned facilities for industrial wastewater treatment in Lebanon.

## Conflict-related water pollution sources

While the potential for conflict-related toxic contamination of surface and groundwater could be significant locally, it is considered to be low on the national level for two principal reasons:

- (i) Military targets consisted mainly of residential and civil infrastructure, which typically contain relatively small chemical pollutant sources; and
- (ii) The lack of a heavy industrial base in Lebanon and the spatially dispersed targeting of facilities during the conflict restricted the potential for a significant hazardous waste stream.

Moreover, several firms stopped their operations and emptied storage tanks during the conflict, thereby minimizing potential pollution.

On the other hand, significant damage to the water supply and wastewater infrastructure poses a threat to drinking water supplies and sanitation services and could lead to increases in nutrient loading, as well as engender or aggravate bacteriological and pathogenic groundwater contamination.

## Damaged industrial facilities

In view of Lebanon's predominantly light manufacturing industry and fairly limited use of chemicals and hazardous substances, the overall risk of water contamination due to the conflict was considered to be low. This was generally confirmed by UNEP, as relatively few chemical spills and leakages were observed during the site visits. Nevertheless, the targeting of light manufacturing plants and storage warehouses did create a significant source of localized water pollution in specific cases.

One of the main zones impacted during the conflict was the Choueifat industrial area, located near the airport on the southern outskirts of Beirut. Reconnaissance information indicated that at least thirteen sites in Choueifat were targeted and either damaged or totally destroyed. Given that fires consumed considerable quantities of industrial materials and goods at the sites, substantial waste residue, contaminated soil and ash represent a potential pollution source for surface and groundwater. Specifically, a cluster of three enterprises located in close proximity (Transmed, Lebanon Company for Carton Mince and Industry and El-Twait feedlot) represents a contaminated hotspot requiring remedial action to remove the waste, and conduct detailed water quality surveying and regular monitoring.



*Water sampling at the El-Twait feedlot in the Choueifat industrial area*



*Stagnant water pools from damaged water mains in Haret Hreik*

The Ghadir stream that traverses the Choueifat industrial area prior to discharging into the Mediterranean Sea was found to be especially threatened by pollution. Laboratory analysis of several samples from the stream detected the presence of heavy metals and volatile organic compounds (VOCs). On site testing of dissolved oxygen showed it to be significantly below the levels required to support most aquatic organisms. Laboratory tests confirmed that the low dissolved oxygen levels were due to excessive chemical and biological demand. At the same time, however, it should be noted that the Ghadir was heavily polluted prior to the conflict by industrial and sewage effluent discharge, which continues to take place. Given the high levels of pre-existing contamination, it was difficult to assess the pollution load generated by the conflict.

Groundwater analysis detected contamination by a number of heavy metals and toxic benzene (a carcinogen), with levels generally above standard environmental screening values. Precipitation is likely to lead to the migration of contaminants to the groundwater. Indeed, a groundwater sample taken after the first rainfall in October 2006 showed considerably elevated values for several

elements including arsenic, copper, nickel and selenium, as compared to a sample taken before the rain event. A notable increase in nitrate and nitrite levels was also measured and found to be slightly in excess of WHO drinking water quality standards for the latter.

### **Damaged water and wastewater facilities**

Years of conflict and poor maintenance have left the aging water and sanitation infrastructure – whose construction pre-dates the 1970s civil war – in a derelict state. Water system losses are estimated to reach 50 per cent of the total supply, and groundwater contamination from leaky sewers has been a chronic issue of concern<sup>10</sup>. The rehabilitation and expansion of the water supply and wastewater collection infrastructure have accordingly been one of the main goals of the reconstruction drive launched by the Government of Lebanon in the mid-1990s. The 2006 conflict not only stalled rehabilitation efforts but also caused considerable damage to water supply and wastewater operations. Indeed, the Lebanese Government has reported that 45 main and 285 secondary water distribution networks, as well as 38 main and 120 secondary sewage disposal

systems, were destroyed or damaged during the conflict<sup>11</sup>. Wreckage on such a scale will invariably aggravate sewage-related pollution and water supply losses.

In terms of damage to water facilities, the areas most affected by the 2006 conflict were the southern suburbs of Beirut (Dahia) and South Lebanon. Within Dahia, Haret Hreik municipality was the main devastation zone.

### **Southern suburbs of Beirut: Haret Hreik**

The direct physical impact on the overall water supply and sewage network in Haret Hreik was relatively limited despite intensive bombing, most likely due to the fact that there were no major pumping stations or storage tanks in the area. Primary pipelines in the main streets were ruptured in the attacks, but most were already repaired when UNEP visited the southern suburbs. Problems were mainly anticipated with the secondary pipeline connections to damaged buildings that would be manifested only once they became operational. While the repair of primary pipelines is the duty of the municipality and/or water establishment, secondary connection mains are the responsibility of building owners. The rehabilitation of the secondary lines was in certain cases carried out hastily and appeared to be of poor standard. On two such occasions, secondary sewer and water pipelines were seen in close proximity, even directly overlying each other in certain sections, presenting an obvious cross-contamination risk of sewage with the drinking water supply. Moreover, clogging of the sewers by debris from the impact of the bombing could disrupt the functioning of the system and lead to overflow. It is therefore recommended that the sewers be cleansed and that new fittings be installed to improve system efficiency and prevent pollution.

Laboratory analysis revealed elevated levels of both total (12,000 - 16,000/100 ml) and faecal (60/100 ml) coliform in tap water samples taken from recently rehabilitated buildings in Haret Hreik. Although the source of these samples is reportedly not used by the inhabitants for drinking, it is evident that the water is faecally polluted by sewage and is thus not suitable for any domestic usage. The World Health Organization (WHO)

recommends that potable quality water also be used for washing and other domestic chores, due to the risk of cross-contamination and ingestion of pathogens. As such, the tested tap water is considered to present a low to intermediate risk for consumers. Although a third drinking water sample showed no faecal coliform contamination, total coliform was detected, indicating inadequate treatment or ingress of foreign material. This water, supplied by the Beirut Water Establishment from Ain Al-Delbeh, was found to be brackish with an electric conductivity ranging between 1917-2205  $\mu\text{S}/\text{cm}$ , and sodium concentration of 192-198 mg/l. These elevated values are close to the maximum acceptable threshold for drinking water; if used for domestic purposes, the water should be diluted with fresh water.

In view of these findings, it is recommended that pending the implementation of adequate disinfection measures, an alternate water source be provided to the inhabitants of Haret Hreik. The health and environmental risks created by damaged or leaky mains (particularly secondary conveyors) require that a thorough sanitary inspection of the sewers in the southern suburbs be undertaken to identify potential hazards. Overall, municipal and local water authorities, as well as NGOs, have performed well and efficiently in repairing the water supply network after the conflict. Nevertheless, technical guidance on best practice in sewer and water supply design and rehabilitation should be provided to the municipalities and civil society organizations engaged in such work to prevent cross-contamination.

The significant and widespread destruction of high-rise apartment buildings, houses, supermarkets, restaurants, cars and workshops in the southern suburbs also generated multiple potential sources of water contamination, such as household chemicals (e.g. detergents and solvents), electrical appliances, fuel, and organic matter present in the demolition waste. A sample from impounded rainwater taken to analyse washout from the conflict-generated debris showed values above environmental screening criteria for chromium, copper, nickel, selenium and toluene. Naphthalene levels were also considerable, at almost two and half times over intervention remedial values. Finally, the laboratory analysis detected high nitrite levels (6.93 mg/l), probably

originating from explosives, as the coliform count that would otherwise have pointed to sewage was insignificant. The potential for the mobilization of contaminants in demolition waste, and for their subsequent infiltration into groundwater, is therefore considerable. Although the water table is relatively deep (40 - 60 m) the high permeability of the underlying calcareous earth entails that the pollution could reach the groundwater fairly rapidly.

Following the first rains in late October, basements of damaged buildings were flooded and demolition excavations filled with water. The resulting stagnant water poses an additional significant environmental and health hazard, as it provides a habitat for pests and disease vectors. If it were to contaminate drinking water supplies, it could lead to waterborne diseases, such as hepatitis, diarrhoea, cholera, typhus, and dysentery. In this regard, it should be noted that many inhabitants had returned to their destroyed homes by October 2006, and that children had started to report to schools.

The analysis of a household groundwater sample detected values above environmental screening levels for several heavy metals including arsenic, chromium, lead and selenium. Zinc was measured at levels approaching the threshold requiring remedial intervention action. Due to the lack of groundwater baseline data for the southern suburbs of Beirut, it was not possible to conclude that the contamination was solely conflict-related rather than the legacy of pre-existing pollution. Nevertheless, the conflict undoubtedly contributed to the pollution loads and worsened the situation. Groundwater was found to be highly saline with an electric conductivity of 34,378  $\mu\text{S}/\text{cm}$  and sodium concentration of 6,975 mg/l; as such, it is deemed unsuitable for domestic usage. High salinity levels are due to intensive groundwater abstraction, which results in seawater intrusion into the freshwater aquifer.

#### South Lebanon

The towns and villages of southern Lebanon were subject to intensive shelling during the 2006 conflict. The impact on the water and



*Water trapped in the excavation site of a destroyed building in Security Square, in Haret Hreik*





*Leachate from the Tyre dump site mixes with irrigation waters before reaching the Mediterranean Sea*

sanitation infrastructure was considerable: water transmission lines, water tanks, pumping stations, artesian wells and water treatment systems were all affected. Water and sanitation services in the south were disrupted and effectively came to a halt. Immediately following the end of the hostilities, many inhabitants of the south had to rely on emergency tankering and bottled water provided by relief agencies. UNICEF alone provided an estimated three million litres. At the time of UNEP's mission, during the reconstruction phase, the Director of the South Lebanon Water Establishment reported that the main problem remains the rehabilitation of the water distribution network despite the reparation of a considerable part of the main transmission pipes. Some of the damaged pipelines, constructed from asbestos fibre more than sixty years ago – such as the one from the Nabeh El-Tasseh spring to Aanknoun – need to be replaced. Although not a serious problem, asbestos ingested in water could increase the risk of developing intestinal polyps.

Ras El-Ain, south of Tyre, is a historic spring (Solomon wells) and one of the main regional water supply stations for the districts of Tyre and Bint Jbeil. The detection of faecal coliforms and nitrate (20.1 mg/l) in water samples collected there, albeit at concentrations below WHO drinking water guidelines, is a cause for concern as it indicates sewage contamination. The spring is located within a few hundred metres of Tyre's

non-sanitary dump, which represents a potential pollution source. The analysis of leachate from the dump, which flows directly into the sea, revealed extremely high ammonia ( $\text{NH}_3$ ) levels (1,694 mg/l) and BOD load (12,960 mg/l). Biological contamination, however, should not pose a health risk to the population as water from Ras El-Ain is disinfected prior to distribution. A water sample taken at the Hannawiyah supermarket – which was bombed and totally destroyed during the conflict – from a pipe supplied by Ras El-Ain, showed the presence of faecal coliform, but at levels (<10/100 ml) indicating a relatively low risk for consumers. Although below drinking water quality requirements, nitrate (18.1 mg/l) was found above natural levels, suggesting sewage ingress. It was unclear whether this contamination is due to bomb damage to the mains, to infiltration during transportation, or to inadequate treatment. Neither was it possible to ascertain if other water supplies in Hannawiyah are also directly compromised by the conflict. It is hence recommended that further sampling be done to survey the extent of the contamination. Excess nitrate ion (>30 mg/l according to WHO<sup>12</sup>) in drinking water is a potential health hazard, as it can cause methaemoglobinaemia or so-called 'blue-baby syndrome' in newborn infants, as well as in adults with a particular enzyme deficiency. Analysis of wastewater spill within the destroyed Hannawiyah supermarket revealed elevated phosphate (22.43 mg/l) and boron (3,246 ug/l) concentrations, posing a risk of groundwater contamination. Laundry detergents were a likely source for this pollution.

Fakhr El-Din pumping station, which supplies the town of Nabatiyeh with drinking water, is an example of an artesian well targeted during the conflict. UNEP observed that two of the six Fakhr El-Din well installations had been damaged (wells number 4 and 6). It was also reported that water production in several wells had significantly diminished, dropping from 35 to 10-22 m<sup>3</sup>/s. This was either due to the damage sustained to the well casing, or to the impact of the explosion on the underlying geological structure.

Laboratory analysis of a sample from Fakhr El-Din well number 1 showed it to have elevated levels of both total (200/100 ml) and faecal (80/100 ml) coliform. These concentrations are

above both Lebanese and WHO drinking water quality guidelines, and represent an intermediate risk for consumers. These contamination problems, which reportedly pre-dated the conflict, were due to overflowing sewage pipelines following heavy rains. This situation was confirmed by the UNEP team, who observed sewage spill some 20 m from one of the well heads. The water authorities were aware of this pollution and were pumping the groundwater continuously in an attempt to draw the contamination out of the aquifer. It is more important, however, to prevent the contamination from occurring at all. This requires proper sewer system design and maintenance of control overflows. It should be noted that at the time of the assessment, no water was being distributed from the contaminated well, so that the population was not at risk. While the pollution source pre-dated the conflict, the overall situation was compounded by the war, including in terms of service and response capacity. Laboratory analysis of samples collected from other wells, including from the Nabaa El-Tasseh spring, did not detect any coliform contamination. Nitrate, however, was detected above natural levels (18.3-18.9 mg/l) and the pH (5.74) was acidic in one of the well samples from Fakhr El-Din. A possible cause for acidic pH is bacterial nitrification, from sewage and/or agricultural run-off, for example.

The inhabitants of Bayad, one of the devastated neighbourhoods of Nabatiyeh, reported widespread cases of severe diarrhoea immediately after their return, and suspected the cause to be water contamination. At the time of the UNEP visit in October, however, only a few children were reportedly still suffering from diarrhoea. Laboratory analysis did not detect any coliform in the drinking water. Of the heavy metal and chemical contaminants analysed, only copper and zinc concentrations exceeded their environmental screening values, but these were well below WHO's drinking water quality guidelines. The higher values of copper and zinc were probably due to corrosion from pipework and fittings. Acidic pH and high calcium concentrations, which were detected in the Bayad water sample, are known to increase corrosion rates.

Rainwater collection reservoirs are one of the main communal water supply sources in southern Lebanon. Thirty-one reservoirs were reported to

have been struck during the conflict, of which thirteen were completely destroyed. Although the Bint Jbeil reservoir was only lightly damaged by the shelling, Bint Jbeil town was heavily hit and most of the market centre, as well as surrounding residential areas, were reduced to rubble. The devastated zone falls within the reservoir's catchment, which lies in a downstream pathway. Hence, potential contaminants from the debris are likely to be washed out by the rains and trapped in the reservoir. Moreover, the reservoir is not lined, making it possible for potential pollution to reach the groundwater. Laboratory analysis of the reservoir water did not find any of the contaminants to exceed their environmental screening criteria. However, faecal coliform at concentrations of 100/100 ml were detected, indicating that in addition to being non-potable, the water is also unsuitable for domestic purposes due to the risk of cross-contamination. There is clearly a need to protect the reservoir from potential catchment pollution, which was worsened by the conflict. It is also recommended that follow-up water quality testing be undertaken following the onset of the rains.

Sewage infrastructure in the heavily targeted towns and villages of the south, particularly in Bint Jbeil, Khiam, Nabatiyeh, Aita El-Chaab and Siddiqine, was not adequately assessed. Septic tanks need to be inspected; damaged tanks should be replaced, and unharmed ones desludged. While inadequate disposal and treatment of sewage is a chronic problem in the south, the breakdown of sanitary services due to the 2006 conflict aggravated the situation.

## Surface water

As noted previously, UNEP's water sampling was carried out in early to mid-October, when river and stream flows were at their minimum base levels. Moreover, many seasonal watercourses were still dry, so that it was not possible to sample them during the mission. Given that 90 per cent of Lebanon's total rainfall occurs between November and April<sup>13</sup>, the potential mobilization of conflict-generated contaminants in affected catchments and their diffusion in the surface water environment could contribute to water quality changes during the next rainy season. Based on field observations of pollution sources at damaged sites, including

toxicants, UNEP's qualitative assessment of the overall risk of conflict-related pollution to surface waters is relatively low. However, pollution loads may have a potentially significant impact on water chemistry in certain locations. The examination of conflict-related pollution was further constrained by limited historical water quality data for surface waters. In view of the difficulty of estimating pollution loads from the extensive distribution of targeted sites and the high seasonal variability in water flows, a more detailed assessment would require follow-up temporal sampling which took the precipitation regime into account.

UNEP identified two point sources of surface water pollution.

### **Aquaculture farms**

The first was caused by the shelling and destruction of aquaculture farms along the Al-Assi River near Hermel, close to the Syrian border in the northern Beqaa. Sixty fisheries were reported to have been destroyed or damaged during the conflict. Based on preliminary reconnaissance information, UNEP visited two of the worst affected sites – the Bayt Tashim and Al-Maalaka fish farms – which were among the leading trout cultivating operations

in the country. At least one of the farms had a fish feed processing unit. Both sites were totally destroyed and lay abandoned at the time of the mission. Photographic documentation examined by UNEP indicated that the strike had caused a massive fish kill estimated at 300 tons. While most of the dead fish was burnt, substantial amounts of decomposing fish were still visible on one of the farms. UNEP found the principle contaminant source to be the fish feed, chemical disinfectants and antibiotics used in the operation of the fish farm. Indeed, substantial amounts of spoilt fish feed, which could be a source of ammonia, nitrite, nitrate and phosphate pollution, were seen in and around the fish tanks at Al-Maalaka.

Analysis of samples from the Al-Assi River detected pH values marginally below normal natural limits (6.5-7.5). Upstream Al-Maalaka registered pH 5.9 and downstream Bayt Tashim had pH 6.3. A sample from stagnant water in a damaged fish tank had a slightly lower pH 5.82. While these relatively low levels were indicative of the presence of a pollutant and represented a stressor to aquatic life, the pH was nevertheless above levels that would lead to fish and macroinvertebrate mortality.



*The high velocity flows of the Asi River have helped dilute pollution from the destroyed aquaculture farms*



*The Ghadir outfall at Ouzaii*

One of the river samples had cadmium, selenium and zinc values above the screening criteria. It was not possible to determine the contaminant source, but lower pH is known to increase the solubility of metals present in soil minerals. Naphthelene, a semi-volatile organic compound, was also detected marginally above the intervention value (89 ng/l) in one of the river samples. This may have been due to fuel oil, and/or antiseptics used to disinfect fish tanks. Nitrate, which was likely to have originated from the fish feed, was found at levels marginally above those expected in natural waters. In addition, nutrient loading from feed additives was observed to have stimulated the growth of algal mats in the fish ponds, which could deplete dissolved oxygen levels when they died and decomposed. However, dissolved oxygen concentrations in the river water and the fish tanks were within natural range, indicating that conditions were not anoxic. Frogs, tadpoles and aquatic insect larva were found to provide a biological indicator of reasonable water quality.

UNEP's assessment is that the destruction of the Hermel aquaculture farms created an acute pollution event in the first two to three weeks, but did not generate a continuous or long-term source of contamination. As the strike occurred when the Al-Assi was in its high stage – unlike other rivers in Lebanon, the Al-Assi's discharge peaks in July<sup>14</sup> – the spill represented a single pollution slug that was largely diluted by the sizeable volume and high velocity of the river flow. The medium- to longer-term risk to the Al-Assi river ecology is therefore considered low in severity and extent. Nonetheless, remaining contaminants present in the destroyed fish tanks represent a low-level pollution risk that should be remediated before the onset of the next rains and/or floods to prevent overflow. UNEP recommends that plans to clean up the sites be prepared, taking the possibility of decommissioning the facility into account. Plans to reactivate aquaculture farming should further include collection of baseline water data and monitoring programme to ensure that it is of a suitable quality.

### Ghadir outfall and land-based sources of marine pollution

The other main point source identified by UNEP was the Ghadir outfall, discharging directly into the Mediterranean Sea. While the routine industrial discharge of untreated effluent into the Ghadir is a chronic problem, the damage incurred by Choueifat's industrial facilities during the conflict invariably increased the pollution load and consequently contributed to the degradation of seawater quality. The Ghadir was sampled in four different locations in the industrial area and near its sea outfall. Laboratory analysis showed BOD and COD values to be two to seven times greater than the permissible "environment limit values for wastewater discharge" set by the Lebanese Ministry of Environment. In addition, faecal coliform counts revealed that it was more than 2.75 orders of magnitude of permissible levels. These exceptionally high levels may have been partially due to contamination caused by the shelling of an industrial cattle feedlot. Phosphate concentrations were also elevated, ranging from 10.62 to 14.88 mg/l, which could lead to serious eutrophication in receiving coastal waters. Finally, toxic compounds like benzene, naphthalene and toluene also considerably exceeded intervention levels.

Given its impact on both surface water and the marine environment, UNEP recommends that industrial and domestic effluent from the

headwater to the outfall of the Ghadir catchment be addressed as a matter of priority. This is all the more significant as Lebanon is a Contracting Party to the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, and that it very recently endorsed its latest amendments. Lebanon has not yet ratified the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities.

### Structural damage and hydrological flows

The United Nations damage assessment has reported that 101 bridges and overpasses were damaged or destroyed during the conflict<sup>15</sup>. Many of these bridges were located over rivers and streams. All the crossings on the Litani River, for example, were destroyed. Bridge debris has clogged rivers and, in some cases, seriously reduced their flow capacity, threatening to disrupt fish migrations. Moreover, rubble from the war was dumped into seasonal water courses in some places, such as Araya. Although there has been a major drive to rebuild the bridges, UNEP observed that in several cases the rubble remained in the river. If this wreckage is not promptly removed, it could cause flooding, particularly with the onset of the winter rains. During the summer season, the rubble obstructed river flow and created stagnant pools, affecting water quality.



*Debris from destroyed bridges, such as this one on the Litani River, could lead to flooding in the rainy season*

Map 10. Bridges damaged in the conflict



The analysis of a water sample taken near the Qasmieh causeway show that only copper marginally exceeds the environmental screening criteria. However, the UNEP team observed that the main Qasmieh temporary bypass bridge (on the lower Litani) was constructed directly on the riverbed. Although culverts have been installed, the deck of the bridge should be raised above the riverbed so as not to impede water flow. Poor and hasty construction could also lead to localized erosion problems. Guidelines on best practice in bridge reconstruction and dismantling of temporary structures should be provided to mitigate impacts on river ecology.

Other structural damage includes the destruction of irrigation and off-take canals, which has reportedly led to water losses and undermined the operation of irrigation systems, particularly in Taibe in South Lebanon, where a major project was underway to irrigate 15,000 ha of land.

## Groundwater

The aforementioned caveat regarding the precipitation regime and the fact that the sampling was conducted during the dry season is equally valid when considering the potential impact of the 2006 conflict on groundwater quality. Although intermittent rainfall did occur in late September and October, the risk of surface contaminant percolation to the water table within this short time frame, particularly given its depth (50 - 300 m), is low. In total, UNEP collected 20 groundwater samples in the Greater Beirut area, in South Lebanon, and the Beqaa. The groundwater quality analysis that was performed can provide the necessary baseline for future monitoring work.

As noted earlier, Lebanon's hydrogeology is dominated by karst, whose unique qualities make it particularly vulnerable to pollution. Its high sensitivity results from limited pollutant filtration due to large fractures and high flow rates in the preferential flow paths of karst conduits. In consequence, self-purification and biodegradation can be significantly reduced. Besides the Beqaa and Al-Assi River valley, and the narrow coastal zone including Beirut, where relatively shallow unconfined aquifers predominate, the country can generally be classified as karstic. In areas of through-flow karst, flushing is quite rapid

and flows ultimately discharge into the sea, including via submarine springs. In other areas of diffuse flow and isolated karst, the flushing of contaminants is a slower process, which may result in a longer-term problem.

The first rains occurred in mid-October 2006, causing the first flush of both conflict fallout and unrelated contaminants into the groundwater. Given Lebanon's karstic hydrogeology characterized by relatively short residence times, it is expected that the contaminants could reach the groundwater within the next few months. Follow-up sampling to gauge evolving groundwater quality conditions over time should therefore ideally start in January or February 2007. The aquifers most vulnerable to conflict-related pollution are considered to be the Lower Cretaceous and Middle Coastal Cretaceous of Mount Lebanon, and the Middle Cretaceous Western basin in South Lebanon. The latter is one of the largest aquifers in the country.

The water quality analysis found significant chronic biological and pathogenic contamination of Lebanon's groundwater. All tested samples but one indicate the presence of faecal coliform. Three samples had faecal coliform greater than 1,000/100 ml, representing a very high level of contamination and risk. Three other samples from groundwater sources used for domestic non-drinking purposes had a faecal coliform count of 260 - 700, representing an unacceptably high risk. A quarter of the samples had intermediate faecal coliform counts of 10 - 100, and nearly half were considered to present a low risk. The high levels of faecal coliform are almost certainly due to improper sewage and wastewater disposal. In addition, nitrate concentrations were above the natural range in nearly half of the samples examined. Likely sources for elevated levels of nitrate are agricultural run-off and sewage. Finally, approximately half the samples also show a pH below the range for natural waters (< 6.5), which could also be an indication of organic contamination.

The main chemical pollutants detected in groundwater are heavy metals. The most widely distributed are zinc and nickel, which exceed their environmental screening criteria in close to three-quarters of the analysed samples. However, only the two samples taken at the Jiyeh power plant (1,173 ug/l) and Transmed (921 ug/l) in Beirut registered

zinc concentrations higher than the intervention value. In the case of Jiyeh, the high concentration could be the result of acidic pH (3.88) conditions, which are known to trigger the release of metals. Further studies are required to determine if these elevated zinc concentrations are naturally caused or due to anthropogenic sources. Chromium, copper, lead, selenium and arsenic were also found to be marginally above screening values. The analysis of groundwater collected from a residential area located down-gradient of the destroyed Ghabris detergent factory in Tyre show concentrations for PAH and several SVOC/VOCs above intervention values. Benzo(a)pyrene – which is the most dangerous of the PAHs – was also found to be above intervention value. Given the ability of PAHs to bioaccumulate in fatty tissues and their carcinogenicity in test animals, this represents a serious water pollution case which should be examined in greater detail with a view to proposing remedial action. Ammonia (NH<sub>3</sub>, 2,073.5 mg/l) and phosphate concentrations (43.70 mg/l) are also extremely high, most certainly due to the polyphosphates in the detergents of the Ghabris factory.

Lebanon's calcareous coast is characterized by heavily fractured limestone. This raised concern that the oil spill caused by the destruction of the Jiyeh power plant could contaminate coastal groundwater by way of seawater intrusion, which is particularly expressed in densely fissured zones. While this phenomenon occurs naturally, it has been accentuated by the over-extraction of coastal groundwater. UNEP accordingly collected groundwater samples from Mina Daliya in Beirut and from the coastal area immediately north of Jiyeh at Saadiyat, both of which were known fracture zones that were impacted by the oil spill. Laboratory analysis did not discover soluble hydrocarbon concentrations above the detection limit. Despite these negative results, UNEP recommends that more detailed follow-up studies be undertaken, as dense non-aqueous phase liquids (DNAPLs) or the high volatility of hydrocarbons may cause the contamination to go unobserved.

### Wazzani transboundary question

The Wazzani is one of the main springs feeding the Hasbani River, one of the principle tributaries of the Jordan River, which in turn flows into Lake Tiberias – Israel's main freshwater reservoir.

Tensions between Lebanon and Israel over the Wazzani springs have flared up regularly for decades. The dispute regards water sharing and quotas. The last episode between the two countries dates from mid-September 2002, when Lebanon constructed the Wazzani pumping station to supply water to the villages of the south, to which Israel objected. The row was eventually defused following a joint intervention by the United Nations and the European Union.

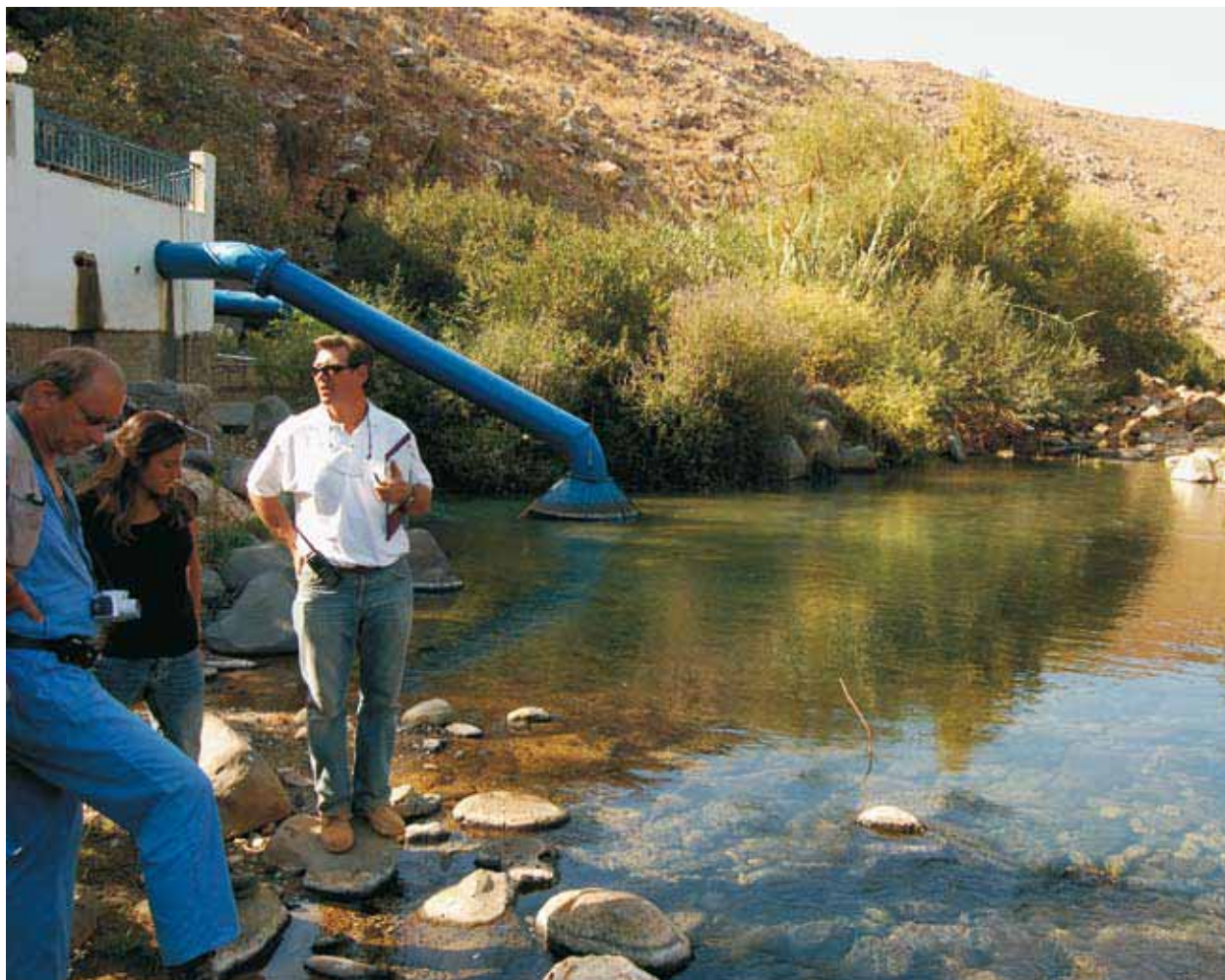
The issue re-emerged following the end of the 2006 conflict, when various statements made by Lebanese officials and media accused Israel of installing a pipeline inside Lebanon to pump water directly from the Wazzani to Israel. The pipeline was meant to supply the village of Ghajar, from which Israel did not fully withdraw at the end of the hostilities. On 3 December 2006, Israel announced that it would hand over control of Ghajar to UNIFIL, but a transfer date has not yet been set. Prior to the 2006 conflict, control of Ghajar was divided between Israel and Lebanon. When UNEP visited the Wazzani pumping station, it observed that water pipelines running towards the village of Ghajar had been laid within Lebanon. The pumps, however, were not in operation at the time. The situation remains uncertain and requires further clarification. The analysis of Wazzani water showed it to be within natural range.

This transboundary water dispute remains a sensitive flashpoint. In the longer term, an integrated water resources management plan needs to be developed to ensure that the water resources of the upper Jordan River are used in a sustainable manner.

### Conclusions

The principle conflict-related impact on the water sector is the considerable damage inflicted on an already dilapidated water supply and wastewater network that was in the process of undergoing a major rehabilitation upgrade. The cost of damaged water facilities has been estimated by the Lebanese government at USD 80 million. Given that wastewater is one of the major chronic stressors for Lebanon's freshwater and marine environment, the conflict represents a





*UNEP team at the Wazzani pumping station*

significant setback for environmental rehabilitation prospects. Broken and leaky sewer mains not only contaminate groundwater but also pose significant human health hazards. Water losses and cross-contamination will also be worsened as a result of damaged pipework, increasing the pressure on diminishing water resources. Hard-hit areas include Haret Hreik municipality in the southern suburbs of Beirut, Bint Jbeil, El-Khiam, Nabatiyeh and the many other destroyed villages of southern Lebanon. In addition, the impairment of the water and sanitation system will compromise Lebanon's efforts to meet Millennium Development Goal Seven (MDG7) on "environmental sustainability" which, inter alia, aims to reduce by one half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015.

In view of the relatively limited anticipated pollution load from targeted industrial sites, the

risk of toxic contamination is considered to be low on a national level. Nevertheless, several localized hotspots, including the Choueifat industrial area and the Ghabris detergent factory in Tyre, represent a threat to water quality and require urgent remedial action. Moreover, it should be emphasized that given the potential of pollutant mobilization during the rainy season, this assessment snapshot does not necessarily signify that the water will be safe in the coming months.

One of the main constraints in carrying out this assessment was the lack of historical baseline data on water quality to contextualize the sample analysis results. Conflict-associated pollution risks highlight the need to institutionalize a systematic water quality monitoring programme for both surface and groundwater, which Lebanon presently lacks and which is a prerequisite for sustainable water management.

# Coastal and Marine Environment

*Volunteers from local NGO Bahr Loubnan  
remove oil from the rocky coastline north of  
the Jiyeh power plant.*



## Coastal and marine environment

### Focus and method of assessment

The main goal of the environmental survey of the Lebanese coast, which was carried out from 8 to 18 October 2006, was to assess the medium- and long-term impacts of the oil spill that resulted from the bombing of fuel tanks at the Jiyeh power plant, south of Beirut, on 13 and 15 July 2006.

As UNEP's focus was on the medium- and longer-term impacts of the oil pollution, samples were taken to determine the residual levels of hydrocarbon compounds in sediment, water and marine animals, such as molluscs and fish. Areas where clean-up operations were still ongoing, such as various beaches and wharfs and the area adjacent to the Jiyeh power plant, where the spill originated, were not investigated in detail. Rather, UNEP's assessment focused on areas beyond the obviously visible impact, to determine the extent

Due to the large number of sample analyses conducted, only selected field and laboratory results have been included in this report. However, complete results can be accessed at: <http://lebanonreport.unep.ch>

and magnitude of environmental damage with possible long-term effects.

Samples were taken 100-200 m from the coastline, using scuba-diving gear and oceanographic sampling equipment.

This assessment did not investigate the economic impact of the oil spill on the fishing and tourism industries. The Food and Agriculture Organization of the United Nations (FAO) conducted a study of the conflict-related impact on fisheries, the results of which can be found in FAO's November 2006 report: *Lebanon - Damage and Early Recovery Needs Assessment of Agriculture, Fisheries and Forestry*, FAO (November 2006).



UNEP conducted an assessment of the marine and coastal environment, focused on the oil spill, from 10 to 21 October 2006

Map 11. Sampling sites – coastal and marine assessment



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

## Coastal geology and background

The continental shelf ends close to the Lebanese coast. As a result, the coastline is open, save for the area outside Tripoli, where a small group of islands – known as the Palm Islands – is situated.

A large-scale counter-clockwise current in the eastern Mediterranean transports water towards the north, up the Lebanese coast. Given that evaporation greatly exceeds precipitation and river run-off in the area, salinity is higher along the coast of Lebanon and its neighbouring countries than it is further to the west.

The seabed substrate is a mixture of bare rock, boulders, gravel and sand. A soft sediment bed is found only in a few areas protected from currents. Several types of marine biotopes – including rocky, sandy, sludgy, coastal, neritic and oceanic – can be found along the Lebanese coastline and in neritic and oceanic waters, where biocenoses develop according to the prevalent geological, physical and chemical conditions.

The Lebanese coastline, which is 225 km long, is mostly urbanized. In the Beirut area and to the north, numerous cities and towns dot the narrow coastal strip and reach up the mountainside. South of Beirut, the coastline is flatter and densely populated. Given that cities in Lebanon do not have wastewater treatment systems, untreated wastewater is released into the Mediterranean along the length of the coast, leading to high levels of organic pollutants and human pathogens in many locations<sup>1</sup>.

Several industrial plants are located on the coast, such as the Jiyeh power plant south of Beirut and the Zouk power plant to the north, as well as the Dora oil terminal and a number of industrial facilities within the capital itself. Others include the Lebanon Chemical Company in Salaata, north of Batroun, which manufactures chemical fertilizers, two cement factories in Chekka, the Deir Imar power plant north of Tripoli, and the refinery owned by the Baddawi International Petroleum Company (IPC).

There are two Marine Protected Areas (MPAs) in Lebanon. The Tyre MPA is located south of Tyre, on a patch of sandy shore. Palm Islands MPA comprises the group of three islands outside Tripoli, and an area of 500 m around them.

## The oil spill

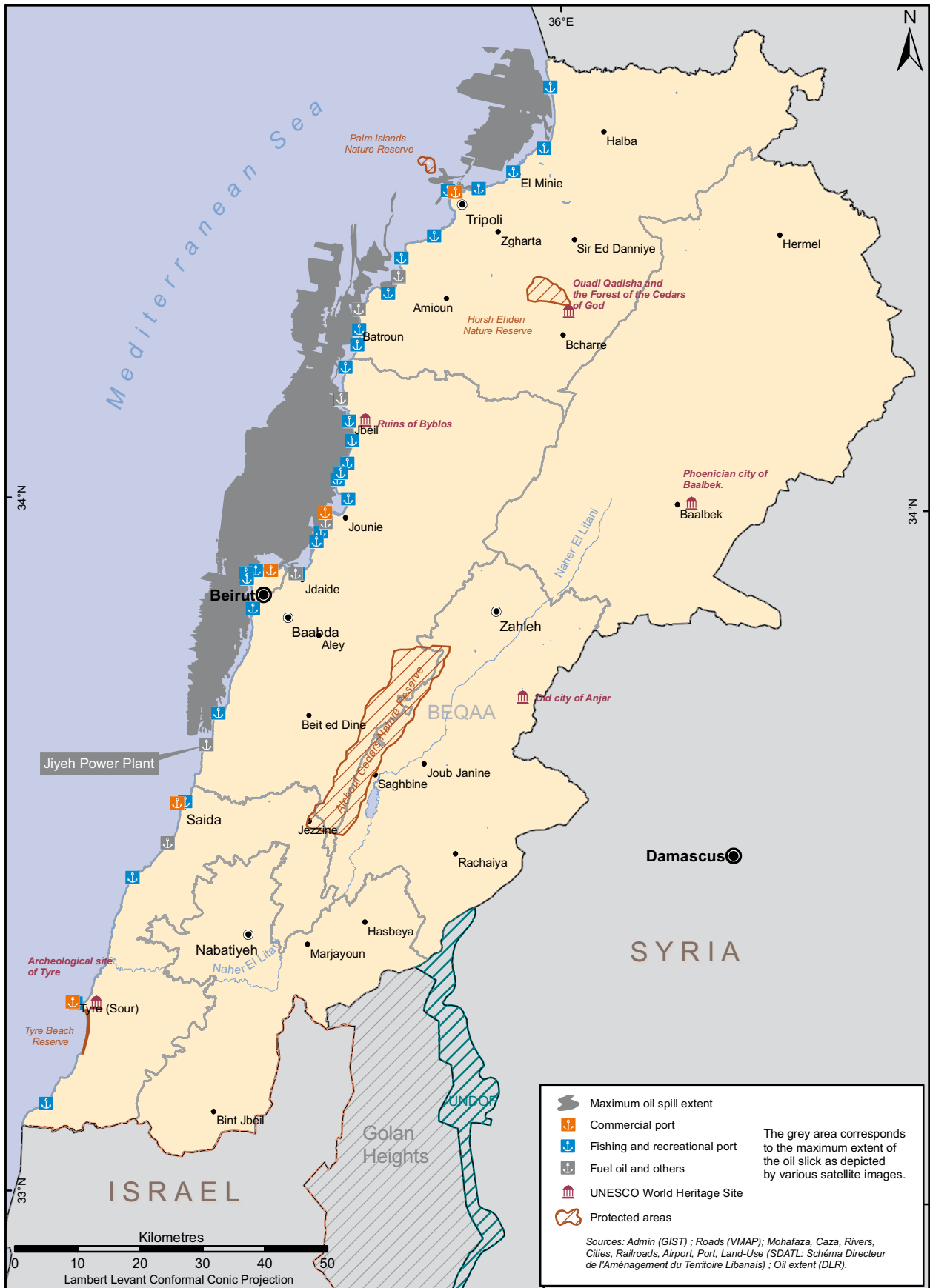
The Israeli bombing of storage tanks at the Jiyeh power plant on 13 and 15 July 2006 resulted in the release of large quantities of fuel oil into the eastern Mediterranean Sea<sup>2</sup>. As it is not possible to determine with certainty the quantity of oil consumed in the fire that engulfed the tanks, the exact amount of oil spilled into the sea remains unknown, but it is estimated to be approximately 10,000 – 15,000 tons. The oil contained in the tanks was heavy IFP-number 6 fuel, which has the following key properties:

- high viscosity, or resistance to flow, resulting in low mobility of the oil;
- high specific gravity (0.95-1.03);
- tendency to break up into tar balls and sink to the bottom when released into water; and
- low volatility, leading to low fuel evaporation.

The oil has a density very close to that of seawater. As some of the oil burned, lighter fractions were removed and increased its density further. The oil may also have picked up sand particles as it flowed over land. Consequently, a substantial proportion of the oil spilled at Jiyeh sank when it came into contact with the water, covering the seabed over an area of a few hundred metres out to sea and an equal distance along the coast.

The oil that did not sink was caught in the northbound current and transported up the Lebanese coast toward Syria. The drift of the oil slick was also influenced by the wind, which blew prevalently to the northeast. Both factors prevented the oil from spreading out to sea, pushing it instead against the coastline and northwards. The worst affected coastal areas were the ones facing west and southwest; areas facing northwest were less affected. Thus, all the peninsulas north of Jiyeh were particularly impacted along their southern coasts, but their northern coasts were protected from contamination. Harbours, coves, caves and small natural bays were particularly affected, as the oil tended to get trapped there. Impacted locations included the biologically important site of Palm Islands Nature Reserve, archeologically significant areas in Byblos and various touristically important beaches.

Map 12. Maximum extent of oil slick



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.



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*Due to the high viscosity of the oil spilled, a proportion of it sank to the seabed, particularly in the vicinity of the Jiyeh power plant*

## Oil spill response

The bombing of the Jiyeh power plant occurred close to the beginning of the conflict. Hostilities were therefore ongoing during the critical early days of the oil spill response, and security conditions severely hampered access to the coastline.

One of the first measures taken by the Lebanese Ministry of Environment was to prevent further spillage of oil into the sea by constructing sand barriers at the plant. Following a call for international assistance, a number of governments sent equipment, personnel and financial aid within weeks of the spill. Local clean-up work started on 12 August in Byblos, with international efforts commencing a few days later. Additional support was provided by the UN and other international organizations, international and local NGOs, and regional organizations. The assistance was coordinated at the global, regional and national levels.

The Joint UNEP/OCHA Environment Unit, together with the Ministry of Environment, the European Union, and with technical support from

IUCN, developed and implemented a proposal for the establishment of an Oil Spill Operations and Coordination Centre (OSOCC), to ensure effective clean-up of the oil spill at the national level under the leadership of the Ministry of Environment. On 17 August, a high-level meeting aimed at coordinating and increasing the efforts of the international community in response to the spill was hosted by UNEP and the International Maritime Organization (IMO) in Athens. The meeting agreed to an international assistance action plan prepared by the Experts Working Group for Lebanon, under the supervision of UNEP-MAP's Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the Ministry of Environment. The recovery of mobile oil in ports, confined areas, economic or socially strategic amenities and heavily polluted sites was designated as a priority. Seven sites were classified as high priority by the Ministry of Environment, with Byblos port and Raouche Fisherman's Wharf categorized as the primary priorities. Thirteen confined sites were categorized as a secondary priority.



The clean-up effort has involved experts and equipment from a number of countries under the overall coordination of the OSOCC. The Ministry of Environment has received equipment from Kuwait, Norway, Cyprus, Finland, France, Sweden, Canada, the USA, Italy, Monaco and Spain. Danish experts from the EU Monitoring and Information Centre formed the EC Marine Pollution Assessment and Coordination team, which provided training and information on the preparation of sites for clean-up operations. The Government of France seconded various experts to REMPEC from its CEDRE centre in Brest. Financial support for the clean-up of the oil spill has been received from UNDP, the Governments of Canada, Switzerland, Monaco and Japan, and from OPEC. Specialist contractors have been entrusted with the recovery of oil from the sea and heavily contaminated wharfs, and local NGOs and volunteers have played an important role in the cleansing of contaminated beaches.

By mid-October, it was estimated that approximately 600 m<sup>3</sup> of liquid oil had been recovered, the majority of which was removed from the Byblos and Beirut areas. One thousand cubic metres of oil-contaminated sand, pebbles and debris were also recovered from beaches, mainly from the Byblos area and Ramlet el Bayda. With the help of the Lebanese and French navies, the Ministry of Environment was

able to extract floating oil from seven sites, including Dalieh Fisherman's Wharf, Raouche Bay, Byblos port and the Mövenpick marina. The removal of approximately 65 m<sup>3</sup> of heavily oil-contaminated debris concentrated in this area was completed by the beginning of November<sup>3</sup>.

The cleaning of rocks, beaches and man-made structures is still underway in various sites, including Byblos, Ramlet al Bayda shore and Dalieh Fisherman's Wharf, with the help of various private sector companies. In addition, a team of Italian divers is working in cooperation with experts from Greenpeace and Bahr Loubnan to recover sunken oil at Jiyeh, while a company has been contracted to complete the clean-up of the coast between Byblos (Jbeil) and Anfeh. Finally, the clean-up of the coast between Anfeh and Tripoli, including Palm Islands, is being carried out with funding from the Swiss Agency for Development and Cooperation.

The ongoing clean-up of the oil spill has resulted in the accumulation of substantial quantities of oily solids and oil-contaminated debris and soil. The sustainable disposal of this waste remains a challenge, as no environmentally acceptable disposal option, such as biological remediation or mobile incinerators, currently exists in Lebanon.



*Temporary storage of oily waste from clean-up operations*

## Findings

The obvious direct impact of the oil spill was the environmental damage in the immediate vicinity of the Jiyeh power plant (due to sunken oil) and on the shoreline. However, given that the focus of UNEP's investigation was to determine the medium- to long-term impact of the oil spill and to understand how much of the pollution had spread

beyond those directly affected areas, observations were made at a number of locations, concentrating on the residual contamination in areas at least 200-400 m away from the immediate vicinity of the spill and impacted shoreline.

Site descriptions and observations are provided in the table below; site numbers reflect the order in which sites were visited.

Table 30. Description of the marine and coastal team's sample locations

Site n°	Date (October)	Depth (m)	Site descriptions/Samples taken	Type of sample taken
1	10	8-10	Off the church of Damour. A thick black line of oil visible on the beach front. Visibility moderate. The bottom mostly rocky with small patches of sand. Few fish; maximum size of fish less than 15 cm.	Oysters and sediment
2	10	12-14	Slightly north of Damour. A thick black line of oil clearly visible on the beach front. Visibility moderate. The bottom mostly rocky with small patches of sand. Few fish; maximum size of fish less than 15 cm.	Oysters and sediment
3	10	20-24	South of Beirut, off a resort and the "Khald Garage Mechanic" workshop. A thick black line of oil clearly visible on the beach front. Visibility moderate. The bottom a mix of rocks and sand. Few fish and oysters seen; maximum size of fish less than 15 cm.	Sediment
4	10	2-3	Off Lebanon Beach. A thick black line of oil clearly visible on the sandy/stony beach front. Visibility moderate. The bottom a mix of rocks and sand. Few fish and oysters seen; maximum size of fish less than 15 cm.	Oysters and sediment
5	10	3-5	Off the airport and Ouzaii debris site, located on the sea front; material from the site was seen being dumped into the water. Visibility close to zero in the shallowest part, but increasing to low further out. The bottom consisted only of sand. No fish seen.	Sediment
6	10	6-8	Off Mövenpick beach. A very thick black line of oil clearly visible on beach front and surrounding cliffs. Visibility moderate. The bottom a mix of rocks and sand. A few droplets of oil seen on the bottom. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
7	11	(>45)	Off the Ibrahim River outlet, in deep waters. Film of oil visible on the surface.	Water
8	11	3-8	Off Indevco. A black line of oil clearly visible on the beach front. Visibility moderate. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
9	11	10	Off Bwar. A black line of oil clearly visible on the beach front. Visibility moderate. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Sediment and water
10	11	10-25	Off Rabyeh Marine Hotel. Oil film seen on the surface and a black line of oil clearly visible on the beach front. Visibility moderate. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
11	11	(12)	North of Marina Dbayeh. Oil film seen on the surface.	Water
12	11	(23)	Facing the Marina Dbayeh in Jounieh bay. A black line of oil clearly visible on the northern beach front, but not further into the bay or on the southern beaches. The marina itself clearly impacted: oil visible on the walls and on many of the ship hulls. Patches of free floating oil also seen in the marina.	Water

Table 30. Description of the marine and coastal team's sample locations (continued)

13	11	(30)	Two miles south of Marina Dbayeh. Oil film with thick patches floating on the surface.	Surface water
14	12	10-12	Kfaraabida, Fadaaous. A thick black line of oil clearly visible on the beach front. Moderate visibility. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
15	12	18	Off a tower and church, between Jbeil and Batroun. A thick black line of oil clearly visible on the beach front. Moderate visibility. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
16	12	12	Immediately north of Tarouel and Ras Amchit. A thick black line of oil clearly visible on the beach front. Moderate visibility. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
17	12	10	200 m south of Byblos/Jbeil harbour. Patches of oil film visible on the surface. Closer to the harbour, oil coverage nearly total. A thick black line of oil also clearly visible on the beach front. Moderate visibility. The bottom a mix of rocks and sand. Low to moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
18	13	8	Ras el Chaqaa (north). No oil visible on the beach front. Visibility good. The bottom a mix of rocks and sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
19	13	5-15	Ras el Chaqaa (south). No oil visible on the beach front. Visibility good. The bottom a mix of rocks and sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
20	13	15	Off Salaata harbour. In places, a very thin line of oil visible on the beach front. Visibility good. The bottom a mix of rocks and sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
21	13	10	Off Batroun harbour. In places, a very thin line of oil visible on the beach front. Visibility good. The bottom a mix of rocks and sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
22	15	3-6	East of Palm Island. A thick line of oil visible on the beach front. Visibility good. The bottom predominantly rocks, with small patches of sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters, sediment and water
23	15	3-6	East of Sanani Island. A line of oil visible on the beach front. Visibility good. The bottom predominantly rocks, with small patches of sand. Moderate presence of fish; maximum size of fish less than 15 cm.	Oysters and sediment
24	17	2-3	Off the sandy beach line of Tyre Marine Park, 2.5 km south of Tyre. Sandy bottom, strewn with occasional rocks, ancient pillars and ceramics. High turbidity and few fish. No visible contamination.	Oysters and sediment
25	17	12	In the northernmost part of Tyre Marine Park. The bottom substrate a combination of sand and rocks. Few fish. No visible contamination.	Oysters, sediment and water
26	17	5	A shipwreck outside the harbour of Tyre. Hardly any visibility due to very high turbidity.	Oysters and sediment
27	14	3-8	Immediately off the coast at the Jiyeh power plant. A thin layer of oil floating in patches on the surface. The rocky beach covered in a thick layer of black tarry oil. Water turbid. Small droplets of oil in the water and on the sandy sea bed. Closer to the power plant, where the bottom was rocky, sunken oil found in thick layers (10 cm) in depressions between rocks and boulders. Fine sediment and detritus covering much of the oil. Gastropods seen feeding on the surface of the oil. Schools of small fish abundant. Fishermen seen fishing from land at several locations around the power plant.	Oysters

## Sunken oil

The impact of oil on the environment is determined by its chemical and physical properties. Short-chain aromatic hydrocarbons, such as benzene and toluene, are relatively toxic to most marine life. Spills of light fuel oils are therefore of greater concern from a toxicity point of view than spills of heavy fuel, with low concentrations of aromatic hydrocarbons.

The analysis of oil samples from the Jiyeh tank farm, taken on 14 October 2006, shows a degraded (weathered) heavy fuel oil with a significant unresolved complex mixture of isomers. It has a relatively low content of toxic hydrocarbons; environmental problems linked to it are mainly caused by its physical properties – such as its tendency to stick to objects.

Due to its heavy nature, a substantial part of the released oil sank to the seabed immediately off the coast at Jiyeh. The presence of oil would have smothered marine organisms, inhibiting their movements and causing suffocation. At the time of UNEP's mission, the effort to recover sunken oil was ongoing.

## Petroleum hydrocarbons (PHC) in sediment

The concentrations of petroleum hydrocarbons in sediment samples range from approximately 50 to

500 mg/kg (dry weight). The highest concentrations (over 400 mg/kg) are found in samples collected from sites 1 and 24. Complete results for the analysis of petroleum hydrocarbon concentrations are shown in the table 31.

Concentrations of petroleum hydrocarbons in sediment typically range from 20 to 50 mg/kg in non-urbanized coastal areas. Where anthropogenic activities are intensive, however, sediment concentrations of PHC are often in the range of 50 to several hundred mg/kg<sup>4</sup>. Hence densely trafficked ship channels and marinas, for example, frequently show concentrations of several hundred mg/kg, while concentrations near water-cooled refineries and oil terminals may reach several thousand mg/kg<sup>5</sup>. From a toxicological point of view, it is generally considered that the biological effects of oil in sediment start to impact more sensitive organisms at levels in the 50 to 100 mg/kg range<sup>6</sup>. More resistant organisms can tolerate concentrations in the range of 1,000 to a few thousand mg/kg.

The concentrations of petroleum hydrocarbons in the samples collected during UNEP's assessment are generally at levels expected for shallow water sediment in coastal areas with heavy boating and run-off from relatively intensive human activities on land. The higher concentrations (above 300 mg/kg) may be an indication of a local source of contamination. The contamination at site 1 may

Table 31. Hydrocarbon concentration in sediment and oysters

Site N°	Petroleum hydrocarbons in oysters (mg/kg [ww])	Oyster lipids (%)	Petroleum hydrocarbons in oyster lipids (mg/kg lip)	Petroleum-hydrocarbons in sediment (mg/kg [dw])	PAH (16 types) in sediment (mg/kg)	PAH (15 types) in oysters (µg/kg)	PAH (15 types) in oyster lipids (mg/kg)
1	45	0.47	9500	443	45.994	20	4.3
2	67	2.2	3100	105	7.960	36	1.7
3	-	-	-	128	9.259	-	-
4	45	1.0	4200	-	-	41	3.9
5	-	-	-	93	2.317	-	-
6	61	0.79	7800	191	3.278	480	61
8	22	0.83	2600	60	0.624	47	5.7
9	-	-	-	107	0.487	-	-
10	20	1.2	1700	101	0.184	9.1	0.79
14	18	0.43	4200	90	1.194	5.4	1.3
15	18	0.81	2300	89	1.086	4.5	0.56
16	29	1.6	1800	75	0.226	21	1.3
17	51	-	-	52	0.654	180	-
18	14	0.63	2200	89	0.325	2.3	0.37
19	24	1.3	1800	126	0.648	4	0.3
20	46	0.89	5200	252	0.668	15	1.69
21	41	1.4	3000	58	0.266	12	0.84
22	35	1.3	2700	-	-	5.1	0.39
23	24	0.90	2700	-	-	2.6	0.29
24	27	1.4	1900	499	174.209	4.2	0.301
25	14	0.70	2000	161	11.832	3.6	0.51
26	32	2.1	1500	88	10.238	12	0.56
27	67	1.7	4100	-	-	380	20



*Marine sediment samples were collected to test hydrocarbon concentration*

result from the July 2006 oil spill, though the site with the highest concentration, site 24, is located outside the oil spill area.

### **Petroleum hydrocarbons (PHC) in oysters**

Oysters and mussels are particularly good indicators of petroleum hydrocarbon contamination for several reasons. First, molluscs have no enzyme system to metabolize petroleum hydrocarbons (unlike crustaceans, echinoderms and most other marine organisms); they consequently bioconcentrate fat soluble substances<sup>7</sup>. Second, because they are filtering organisms, they are exposed to any dissolved or particulate substance present in the water. The analysis of filtering molluscs such as mussels and oysters thus provides an insight into previous exposure to substances such as oil.

The analysis of oyster tissue samples show levels ranging from 14 to 67 milligrams of petroleum hydrocarbons per kilogram of oyster tissue (wet weight). Full results are presented in table 31. An alternative way to investigate contamination, is to measure petroleum hydrocarbons in relation to the oysters' fat (lipid) content, as the lipids act as a solvent for the petroleum hydrocarbons. This method found concentrations in the range of 1,500 to 9,500 mg/kg. Results of the analysis of petroleum hydrocarbon concentrations in relation to lipid content are also shown in table 31.

Elevated concentrations of PHC in the tissue of filtering organisms – in the range of 10 to 100 mg/kg (wet weight) or 50 to 500 mg/kg (dry weight) – are usually found in areas exposed to chronic low-level pollution from intensive human activities such as boating and run-off from urban areas<sup>8</sup>. In extreme cases involving oils that emulsify and disperse into the water easily, concentrations may be significantly higher. While the concentrations found in the assessment – ranging from 10 to 70 mg/kg (wet weight) – may partly result from the July 2006 oil spill, they may also constitute background levels for the area. The oyster samples collected closest to the origin of the spill (site 27), only a few metres away from solid oil deposited on the seabed, show the highest concentrations (67 mg/kg), indicating that the oil is not dispersing significantly – i.e. not spreading freely – and that the tendency to produce dissolved hydrocarbons is low.

### **Polycyclic aromatic hydrocarbons (PAH) in sediment**

The levels of the 16 types of PAH measured range between 0.2 and 174 mg/kg of dry sediment (see table 31 for complete results). Most sites show concentrations below 3 mg/kg. The only site with a concentration above 50 mg/kg is site 24, with a level of 174 mg/kg. Two adjacent sites – sites 25 and 26 – also show comparatively elevated concentrations. These sites are located at a significant distance to the south of the area impacted by the July 2006 oil spill.

Elevated levels of PAH are usually found in seabed sediment from coastal areas influenced by human activities. Principal sources of PAH include fossil-fueled power plants, smelters, incinerators, heavy traffic, forest fires and oil spills. For example, the coastal sediment in shallow waters near urban areas around the San Diego Bay (USA) has shown levels ranging between 1 and 20 mg/kg<sup>9</sup>, while levels of up to 9 mg/kg have been reported in Newark Bay (USA)<sup>10</sup>. In the Mediterranean, concentrations of up to 0.6 mg/kg have been found for offshore areas in the Adriatic<sup>11</sup>, and up to 3 mg/kg for the western Mediterranean<sup>12</sup>.

## Polycyclic aromatic hydrocarbons (PAH) in oysters

The concentrations of PAH in oysters collected from all but three sites range between 3 and 50 µg/kg (wet weight). Mövenpick Beach (site 6), Jbeil (site 17) and Jiyeh power plant (site 27) show much higher levels at 480 µg/kg, 180 µg/kg and 380 µg/kg respectively. These sites were all heavily affected by the oil spill.

PAH concentrations in food items such as smoked fish and meat are often in the range of 5 to 25 µg/kg or more. Marine food items frequently show higher concentrations than food items from terrestrial environments. Several countries, including those in the EU, impose limits on the concentrations of individual PAH types in food. For example, the EU limits the concentration of Benzo(a)pyrene, a type of PAH, in mollusc products on the market to 10 µg/kg (wet weight)<sup>13</sup>. UNEP found Benzo(a)pyrene concentrations of only 1 to 4.3 µg/kg in all samples, except in samples collected at Mövenpick Beach and the Jiyeh power plant, which show concentrations approximately twice higher than the limit.

## Petroleum hydrocarbons (PHC) and polycyclic aromatic hydrocarbons (PAH) in fish

Fish were collected from fishermen's catches in the areas of Aabde, Tripoli, Qualamoun, Jbeil and Dora. Species from three different trophic levels were sampled:

- red mullet (*Mugil barbatus*), a demersal species that feeds on sediment;

- marbled spinefoot (*Siganus rivulatus*), which is herbivorous and lives near rocky shores; and
- yellowstripe barracuda (*Sphryrena chrysotaenia*), a pelagic predator.

The results of the analyses are shown in table 32. PHC concentrations are below or slightly above the detection limit of 10 mg/kg (wet weight) and are identical for fish from different areas and in species from different trophic levels. These concentrations are low and probably indicate the background levels of hydrocarbons in fish in the eastern Mediterranean.

The total values of 15 PAH types in fish samples range between 0.2 and 6 µg/kg. Such levels are in the same order as concentrations found in fish in other coastal areas of the Atlantic. In the North Sea and the Baltic, PAH concentrations in marine fish are typically in the range of 1 to 4 µg/kg. The levels found in Lebanon are therefore probably normal for marine fish in this part of the Mediterranean.

## Petroleum hydrocarbons (PHC) in water

The results of the analyses show that petroleum hydrocarbon levels are below detection limits in all water samples taken, despite the fact that oil was visible on the shoreline near the sites where the samples were collected. This indicates that the oil is not dispersing significantly and that its tendency to produce dissolved hydrocarbons is minimal. It should be borne in mind that the sampling was undertaken more than two months after the spill, by which time the oil sheen that was initially visible in the open sea had diluted and dispersed.

Table 32. Hydrocarbon concentration in fish

Sample #	Sample ID	Petroleum hydrocarbons (mg/kg [ww])	Lipids (%)	Petroleum hydrocarbons (mg/kg lip [ww])
MR 5184	Yellowstripe barracuda, Aabde	<10	0.51	<2000
MR 5185	Marbled spinefoot, Aabde	<10	1.1	<930
MR 5186	Yellowstripe barracuda, Tripoli	15	1.1	1400
MR 5187	Marbled spinefoot, Tripoli	<10	0.95	<1100
MR 5188	Yellowstripe barracuda, Qualamoun	16	0.57	2900
MR 5189	Marbled spinefoot, Qualamoun	22	0.62	3500
MR 5190	Yellowstripe barracuda, Jbeil	17	1.8	970
MR 5191	Red mullet, Jbeil	12	1.1	1100
MR 5192	Marbled spinefoot, Jbeil	10	2.1	490
MR 5193	Yellowstripe barracuda, Dora	15	1.2	1300
MR 5194	Red mullet, Dora	15	0.86	1700



*UNEP experts consult a local naval map to assist with the selection of dive sites*

### Conclusions

The main findings of UNEP's assessment are set out below, while recommendations are provided in the final chapter, 'Main Findings and Recommendations':

- Due to the high viscosity and specific gravity of the fuel oil used in Jiyeh, a substantial part of the oil released from the tanks sank to the bottom of the sea in the immediate vicinity of the power plant, most likely smothering the biota in the sediment and significantly affecting the seabed at Jiyeh. Unless the sunken oil is fully removed, the risk that it may be remobilized remains.
- The environmental effects observed along the coast, especially on beaches, are mainly related to the physical properties of the oil. Littoral invertebrates such as gastropods, crustaceans and algae were coated with oil. Significant mortality most probably occurred among these organisms during July and August, particularly on beaches with heavy contamination. Due to the relatively rapid reproduction cycle of these organisms, they are likely to recover within one to a few years. No significant mortality among sea birds was reported.
- The oil spill resulted in significant contamination of the shoreline, which exceeded the local institutional capacity to handle such an event. International assistance, consisting of equipment and expertise, had to be mobilized to carry out specialized clean-up activities. The oil spill impacted a number of tourist locations such as beaches and the archeological sites at Byblos and Anfeh. Clean-up is currently ongoing all along the Lebanese coastline, under the leadership of the Ministry of Environment. The disposal of the contaminated oil and oily waste collected is the major remaining issue related to the clean-up.
- Due to the nature of the spill and the prevailing currents, the oil that did not sink in the immediate vicinity of the power plant was transported northwards up the coast and reached the shore, thus only adding marginally to the background concentrations in the seabed sediment at a depth of 4 to 25 metres off the coast. The levels of petroleum hydrocarbons in sediment are equivalent to those generally found in coastal sediment influenced by activities like boating, and by run-off from urban areas.
- The analysis of oil samples from the Jiyeh tank farm show a degraded (weathered) fuel oil with a significant unresolved complex mixture of isomers. This kind of oil has a relatively low content of (acute) toxic hydrocarbons and environmental problems linked to it are mainly caused by its physical properties – such as its tendency to stick to objects and surfaces.
- The concentrations of polycyclic aromatic hydrocarbons (PAH) in seabed sediment and in molluscs (oysters) are similar to what is expected for coastal areas under the influence of urban zones, industry and transport. The levels of petroleum hydrocarbons (PHC) in oyster tissue are in an expected range of concentration for areas under anthropogenic influence.
- The petroleum hydrocarbon levels found in fish are below or slightly above the detection limit. The concentrations are identical for fish from different areas and in species from different trophic levels. These concentrations are low and probably indicate the background levels of PHC in fish in the eastern Mediterranean. PAH levels are likewise found to be normal for fish in this area.
- The analysis of water samples from the area did not detect any trace of oil in the water column beyond the immediate areas of impact.
- The results of the analyses, together with observations made during the mission, show that the coastal area of Lebanon is exposed to a number of chronic anthropogenic stress factors (e.g. the release of untreated sewage and industrial effluent).

# Weapons

*UN Mine Action Group expert inspects  
a cluster bomb in the village of Ouazaiyeh  
in southern Lebanon. It is estimated that  
up to one million unexploded cluster  
bomblets remain in Lebanon.  
© AP Photo – Mohammed Zaatari*





## Weapons

### Introduction

A range of ammunition was launched from aircrafts, tanks and stationary positions by the Israeli Defense Forces (IDF) during the July-August 2006 conflict. Many strikes resulted in severe damage to property and infrastructure, leading indirectly to environmental damage. Other weapons could have had a direct environmental impact by virtue of their composition, design and strike capabilities. UNEP accordingly carried out an investigation of the types of munitions used during the conflict, focusing specifically on the possible use of weapons that could cause environmental harm, including munitions containing depleted uranium (DU). Detailed inspections were undertaken at sites where the use of uranium-containing weapons had been reported. In addition, UNEP investigated the occurrence of possible bombing-related vegetation fires. The environmental implications of the extensive damage to infrastructure are discussed in

Due to the large number of sample analyses conducted, only selected field and laboratory results have been included in this report. However, complete results can be accessed at: <http://lebanonreport.unep.ch>

the 'Industrial and Urban Contamination', 'Water Resources' and 'Coastal and Marine Environment' chapters.

### Weapons of environmental concern

#### Depleted uranium

Depleted uranium (DU) is a highly dense heavy metal generated as a by-product of the uranium enrichment process. Like all uranium compounds, it is both chemically and radiologically toxic. With approximately 60 per cent of the activity of natural (i.e. unprocessed) uranium, DU is mildly radioactive.



*Unexploded ordnance ready for destruction at a Lebanese Army EOD site*

Map 13. Sampling sites – assessment of weapons used



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

## Weapons and ammunition used in the 2006 conflict

On 18 August 2006, the UN Mine Action Coordination Centre (UNMACC) of South Lebanon issued the following report on weapons and ammunition used during the conflict<sup>1</sup>:

### a. Aerial bombs

Since hostilities began there has been an average of 200 - 300 aerial-delivered bombs dropped daily (recorded by UNIFIL) on areas adjacent to the Blue Line with at least a similar and additional amount dropped on the remainder of South Lebanon. This, coupled with the extensive bombing of areas in the southern suburbs of Beirut and Mount Lebanon, North Lebanon, [and] Bekaa Valley, amount to [a] potential and extensive threat from un-exploded high-explosive bombs ranging from 500 lb to 1,000 lb. In southern Beirut, where the principal targets were supposed underground bunkers this threat may increase to bombs of 2,000 lb and upwards. An average of 10 per cent of such ordnance fails to function as designed and remains in the ground as a significant explosive hazard.

### b. Aerial-delivered missiles

Again, there have been an average of 200 - 300 aerial-delivered missiles fired daily (recorded by UNIFIL) on areas adjacent to the Blue Line with at least a similar and additional amount fired on the remainder of Lebanon in Beirut, Mount Lebanon, North Lebanon and the Bekaa Valley.

### c. Ground-launched artillery

For the initial weeks of the conflict the Israeli Forces maintained a constant delivery of approximately 2,000 rounds per day fired (recorded by UNIFIL) on areas adjacent to the Blue Line with at least a similar and additional amount fired on the remainder of South Lebanon. In the last weeks immediately preceding the ceasefire this frequency increased to approximately 6,000 rounds per day. This ordnance constitutes the biggest threat to post-ceasefire/cessation of hostilities humanitarian operations and, in general, consists of:

- 1) 155 mm High Explosive rounds SP artillery (M109 Dohar and Rochev)
- 2) 105 mm High Explosive and HEAT rounds (Merkava Mk 1 & 2)
- 3) 120 mm High Explosive and HEAT rounds (Merkava Mk 3)
- 4) 120 mm heavy mortar
- 5) 160 mm heavy mortar
- 6) 81 mm medium mortar
- 7) 60 mm light mortar
- 8) 160 mm Light Artillery Rocket System (LAR-60): High Explosive or Cluster Munitions warhead. Each launch pod contains 13 or 18 rocket pods; each rocket contains 184 bomblets (Mk2) or 105 bomblets (Mk3) and is designed to give area coverage of 31,400 m<sup>2</sup> per cluster warhead
- 9) 227 mm M270 MLRS: M77 sub-munition system (similar to M62 or KB1)

### d. Naval-launched artillery

Israeli Forces have maintained a constant delivery of approximately 100 - 200 rounds per day fired (recorded by UNIFIL) on areas throughout South Lebanon. Naval artillery was also fired into the southern suburbs of Beirut. This ordnance also constitutes a threat to post-ceasefire/cessation of hostilities humanitarian operations and, in general, consists of: 76 mm High Explosive rounds and Harpoon-type missiles.

### e. Ground-to-ground combat systems

IDF and Hezbollah have engaged in substantial ground combat operations. To date these have mainly been centred on the villages of Marwhin, Bint Jbeil/Marun al Ras and Kafa Kila/AI Taibe, Marjayoun, Al Qantara, Al Bayyada, Aadaise, and Bayt Yahun. Both sides have used conventional small arms (up to 50 cal/14.5 mm) and light missile systems. Hezbollah is confirmed as using Milan and other similar anti-armour TOW systems.

Although it has a wide range of peaceful civilian applications – such as medical radiation shielding or counterweights in airplanes – DU is mainly used for military purposes, such as armouring tanks. Due to its high density, high melting point and ability to sharpen as it penetrates armour plating, it is also used in anti-tank munitions.

DU forms a dust cloud on impact. Given that the metal is pyrophoric (i.e. the reaction of the metal to the oxygen in air causes it to ignite spontaneously), the dust cloud burns and forms an aerosol of fine DU oxide particles. The amount of depleted uranium transformed into dust depends on the type of munition, the nature of the impact and the type of target. When a target such as an armoured vehicle is struck by a DU penetrator, most of the DU remains inside as penetrator fragments or reacted dust. Some of it may, however, be dispersed into the air and be deposited in the surrounding environment. DU hits on “soft” surfaces (e.g. non-armoured vehicles, soft ground, etc.) do not produce significant amounts of dust compared to “hard” surfaces (e.g. battle tanks, concrete surfaces, etc.).

Human exposure to radiation from depleted uranium can be external, through contact with the skin, or internal, through inhalation or ingestion of depleted uranium particles. Radiation may result in an increased risk of cancer, with the degree of risk depending on the part of the body exposed and the radiation dose. Like naturally occurring uranium and other heavy metals, however, DU is also chemically toxic. The level of toxicity depends on the amount ingested and the chemical composition of the uranium, but exposure to DU – to which the liver is the most sensitive organ – can lead to severe poisoning within hours or days of exposure. DU’s chemical toxicity is usually considered the dominant risk factor, relative to its radioactivity.

The extent to which DU can filter through soil and contaminate groundwater, as well as the possibility of re-suspension of DU dust in the air by wind or human activity, are under investigation in the scientific community.

### **Deep-penetrating munitions (‘bunker busters’)**

Deep-penetrating munitions are extremely effective in demolishing hard or deeply buried targets, such

as command bunkers or ammunition stores. The technology for these types of munitions was first developed in the 1980s and evolved in the 1990s with the creation of sophisticated ‘bunker buster’ bombs, which are filled with explosives and have built-in laser guidance systems. A series of custom-made bombs that was recently developed to destroy hardened or deeply buried structures can penetrate reinforced concrete to a depth ranging from 1.8 m to over 6 m. These weapons require very heavy warheads to increase their penetrating ability. As concerns were raised about the possible use of DU-containing ‘bunker buster’ munitions by the Israeli Defense Forces (IDF) during the conflict, the UNEP team investigated this issue.

### **White phosphorus (WP)**

White phosphorus is a common form of the chemical element phosphorus. It has extensive military application as an incendiary agent, smoke-screen to conceal troop movements and as an antipersonnel flame compound capable of causing serious burns. White phosphorus is a colourless, white or yellow waxy substance with a garlic-like odour. It reacts rapidly with oxygen and catches fire easily. It is used in bombs, artillery and mortar shells, which burst into burning flakes of phosphorus upon impact, and has a long history of military use for offensive and target-marking purposes.

Burning WP produces a hot, dense, white smoke, which is usually not hazardous in the concentrations produced by a battlefield smoke shell, although breathing WP for short periods may cause coughing and irritation of the throat and lungs. Breathing WP for long periods causes a condition known as “phossy jaw”, which results in poor wound healing of the mouth and breakdown of the jawbone. However, exposure to heavy smoke concentrations of any kind for an extended period (particularly near the source of emission), does have the potential to cause illness or even death.

In air and surface soil, WP reacts with oxygen to form relatively harmless chemicals within minutes, while in water it reacts with oxygen within hours or days and can accumulate slightly in the bodies of fish living in contaminated water. In deep soil or sediment with very low oxygen concentration, however, WP may remain unchanged for many years.

## Cluster bombs

Cluster bombs consist of a canister containing a large number of sub-munitions or bomblets. The bombs are dropped from the air or launched from the ground as artillery delivery systems with an anti-personnel, anti-tank or dual purpose, or as an incendiary agent. Once released, the canister breaks apart, resulting in the further release of large quantities of sub-munitions. A CBU58 canister, for example, releases 670 BLU63 sub-munitions, while the CBU87 canister releases 202 BLU97 bomblets. Both these types of cluster bombs were used in the recent conflict in Lebanon, contaminating a wide area with sub-munitions. During release, the bomblets are activated by an internal fuse that can detonate above ground, on impact, or in a delayed mode. The failure rate of these sub-munitions ('dud rate') is known to be high and many unexploded bomblets remain on the ground, where they explode under pressure, like landmines. As such, they represent a severe hazard to the civilian population. They are similar in size to a soft drink can and are often covered by dirt or dust from surrounding rubble, making them very hard to see or recognize. The on-set of rains is likely to exacerbate the problem.

The dispersion of sub-munitions over wide areas of land as a result of unexploded ordnance

does not pose a direct measurable threat to the environment. However, the presence of bomblets severely restricts or prohibits access to agricultural land for long periods of time, as mine clearance teams prioritize urban areas.

## Findings

### No use of weapons containing depleted uranium (DU)

UNEP investigated a number of sites with underground facilities with the highest probability of having been attacked with deep-penetrating ammunition. The typical signs pointing to the use of 'bunker buster' munitions include collapsed buildings with minimal lateral damage and, usually, little or no evidence of burning.

Smear sampling of undisturbed surfaces is one of the most precise methods for detecting depleted uranium. In UNEP's experience, this method can detect the impact of as little as two 30 mm DU penetrators of 300 g each and clearly confirm the presence of DU within 300 m from the target. Given the high sensitivity of the method, the impact on a hard surface of a 'bunker buster' containing a DU penetrator weighing



*The Transmed Industry in Beirut shows typical damage from the impact of a 'bunker buster' bomb*



© AP PHOTO - LOTFALLAH DAHER

### Investigation at Khiam

Many reports and rumours circulated in the international press during and directly after the 2006 conflict regarding the use of depleted uranium and/or uranium weapons at a site in Khiam<sup>2</sup>. UNEP therefore specifically investigated this site for uranium and/or depleted uranium contamination.

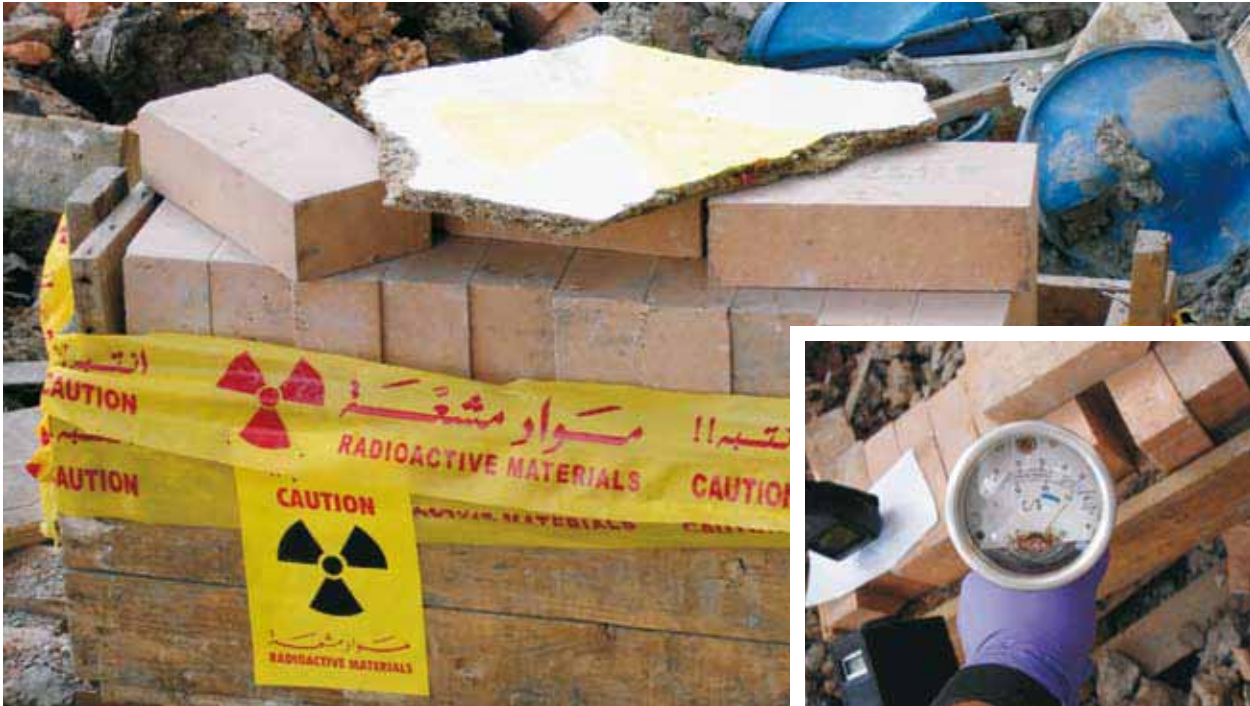
UNEP found that two buildings in the Khiam residential area had been destroyed in an air-to-ground attack. Each building was hit by one bomb, resulting in a crater with a defined diameter. The craters were already filled with rubble when the team visited the site. Lateral damage to the surrounding houses was limited.

The on-site dose rate measurements were higher than other assessed sites (where readings were usually 20 nSv/h), but were not alarming or outside the natural Lebanese range-laying readings of up to 80 nSv/h. No residue showing a higher radioactive reading was found during an in-depth investigation of the site. Three smear samples and one soil sample were taken at the site for detailed analysis.

The laboratory analysis confirmed the higher natural uranium levels present at the site. The analysis of the soil sample showed  $26.2 \pm 0.7$  [mg<sup>238</sup>U/kg] with an isotope ratio <sup>235</sup>U/<sup>238</sup>U of  $0.00722 \pm 0.00001$ , signifying that uranium with a natural isotope composition was found and that the natural uranium content in the area (a localized zone of about 100 x 100 m), was higher than average by a factor of about 10. This value could not *a priori* be linked to the missile/bomb used to destroy the building and further detailed examination of the impact site was considered necessary to identify the source. The smear samples taken from the area showed neither DU, nor enriched uranium, nor a higher than natural uranium content. In addition to the nuclear mass-spectrometric investigation, samples were screened for other metals, including heavy metals. No exceptional results were obtained.

Based on a meeting held between the Minister of Environment of Lebanon and UNEP on 7 November 2006, an additional investigation of the site was undertaken to determine the source of the elevated readings. The follow-up visit took place on 20 and 21 November. Further detailed investigations were conducted at the site and additional samples were collected for laboratory analysis, including from remnants of the bomb used in the attack. The results confirmed the original findings that no DU, enriched uranium or higher than natural uranium levels are present at the site, and that the readings are due to natural causes.

The concentration of uranium found in the ambient soil does not pose a health risk.



*High-temperature oven bricks showing elevated radioactivity readings*

approximately 200 kg, which would generate 5 - 25 per cent of its mass in DU dust, would be detected at a distance even greater than 300 m with the highest probability.

The analysis results show no evidence of the use of DU-containing penetrators or metal products. In addition, no DU shrapnel or other radioactive residue was found at the sites investigated. The analysis of all smear samples taken did not detect DU, enriched uranium, or higher than natural uranium content. After an extensive investigation, including of sites rumoured to have been hit by DU weapons, it can be stated that the 'bunker buster' ammunition used by the IDF in the conflict did not contain DU, natural uranium or any other uranium isotope.

## Radioactivity from other sources

### Military vehicle and helicopter impact sites

UNEP investigated two sites where IDF Merkava tanks had been destroyed (Wadi-El-Hujar and Maroun) and one site where an IDF military helicopter had crashed (Yatar). On site measurements showed no evidence of the presence of DU: no DU penetrators, DU shrapnel or any other DU-related material could be found. However, a melted instrument containing

radium was found at the helicopter crash site, causing a high radioactivity reading. Smear samples taken at the sites confirmed the absence of DU, leading to the conclusion that the two tanks and the military helicopter were neither armoured with DU, nor carrying DU ammunition.

The analysis of other heavy metals indicated that the helicopter crash site and surrounding area had increased levels of cadmium. This was not surprising, as helicopter navigation systems are well known to contain nickel-cadmium batteries and cadmium is used in other aeronautic applications.

### Maliban glass factory

Higher radioactivity readings were registered in a corner of the Maliban glass factory (Zahleh) during the assessment of the facility. The zone was accordingly investigated in detail. The surface dose rate measured was 1 mSv/h. The on site measurements to identify the radioisotope(s) indicated, with a probability of over 95 per cent, the presence of thorium-isotopes, but allowed a low probability of the presence of isotope Cs-137.

The material causing the high readings was found to be a box of approximately 30 high-temperature oven bricks containing large amounts of thorium. These bricks were intended to replace



part of a high-temperature glass-producing oven. Thorium is known to be occasionally used in high temperature-related applications.

The box was separated and marked by experts from the Lebanese Atomic Energy Commission (LAEC). The site manager was instructed on further steps to be taken, under the guidance of the LAEC. In addition, two bricks were taken to the LAEC laboratories for detailed analysis.

The smear sample collected was screened for other metals and showed an arsenic concentration typical for glass production industries.

Further investigations should be carried out at the helicopter crash site and the Maliban glass factory to identify and remove all materials showing high radioactivity.

### White phosphorus (WP)

UNEP investigated the use of white phosphorus (WP) during site visits south of the Litani River. Indications were found that WP-containing artillery shells were used as smoke screens or to mark targets. Some shells with WP signatures were seen in very limited numbers on the open ground

close to villages or towns in the region of Bint Jbeil and Marjayoun. Shells containing active white phosphorus were also seen during a visit to the Lebanese Explosive Ordnance Destruction (EOD) site in the south, at the Marjayoun Army Base.

UNEP, together with Lebanese Army experts, recovered one unexploded 8.1 cm light green mortar shell in Deir Mimas, where local residents had reported seeing white smoke plumes in various attacks, as well as the 'strange' burning of houses and olive trees. UNEP destroyed the shell with the assistance of Lebanese EOD experts and confirmed that it contained WP. WP-containing 8.1 cm mortar shells were used mainly in UN area number 6 (between the Litani and Awali Rivers). The IDF officially confirmed the use of WP on 21 October 2006<sup>3</sup>.

The environmental impact of the use of WP in Lebanon was limited to the burning of olive trees and houses. However, given that the efficiency of the mortar shells was relatively low, the use of WP has created an EOD problem. Residents of areas where this type of ammunition was used should be made aware of its presence and EOD teams should take the necessary safety precautions when conducting their work.



*A white phosphorus mortar shell was found by UNEP at Deir Mimas*

### **Long-term impacts of weapons-related contamination**

The smear samples taken from a number of locations show elevated levels of heavy metals. In some cases, these originated from the source of the explosion (i.e. the bombs themselves), and in other cases from the targets. In addition to the residents who suffered physical harm in the bombings, a wider section of the population may therefore have been exposed to heavy metal pollution resulting from the pollutant cloud generated by the bombing. Many of these heavy metals have short- and long-term health impacts, including carcinogenicity, and their potential effects should be tracked and treated.

It is recommended that a national registry of people living in close proximity to major bomb targets be established, and that their health be tracked in the long term to allow early identification of unusual health trends, such as cancer, and adequate support measures to be implemented.

### **Other weapons**

UNEP was able to observe unexploded ammunition or parts of most of the weapon systems that UNMACC and Mine Action Group (MAG) experts reported as having been used during the conflict. These munitions were seen either during site visits, or at the UNMACC and MAG centres, as well as at the two Lebanese Army Explosive Ordnance Disposal (EOD) centres in Nabatiyeh and Marjayoun. The team studied hundreds of objects and pictures and remained in close contact with MAG EOD experts.

All the remnants of weapons found during the period of the assessment – including those at the two Lebanese Army EOD centres – were identified as weapons of well-known design.

### **Site-specific health and environmental concerns**

In a number of villages and towns – including Bint Jbeil, Arnoun, Nabatiyeh and Kaffrah – the local population informed the UNEP team that inhabitants had suffered from headaches and skin irritations for a period of time after the attacks and

that a bad odour had prevailed. Residents were therefore concerned that weapons with a potential long-term environmental impact had been used.

In some places, such as Arnoun and Nabatiyeh, residents were able to show the team the exact impact site that caused these effects. UNEP investigated the craters in question and identified the weapons used as Mark 80-type bombs, particularly the Mark 84 (known as a 'free-fall' bomb). Indeed, a variety of Mark 84 bomb residue was collected at the sites. This type of bomb is not fully efficient in explosion, and causes surface contamination by unexploded material or impact dust. Dust contamination can result in a bad, 'chemical' smell, usually provoking headaches and skin irritations. However, these effects are not permanent, as the unexploded material degrades naturally within a few days.

UNEP did not find any cause for environmental concern relating to weapons used at the sites investigated in the above-mentioned locations.

### **Cluster bombs**

UNEP encountered cluster bombs throughout its survey of southern Lebanon. Although exact statistics regarding the number of cluster bombs used in Lebanon are not available, there could be up to one million unexploded cluster bomblets in South Lebanon according to UNMACC reports<sup>4</sup>. Most cluster bombs were delivered by rockets or artillery, with a limited number (BLU-63-type bombs) apparently dropped by aircraft.

By 13 November 2006<sup>5</sup>, with approximately 85 per cent of southern Lebanon assessed, 813 cluster bomb strike locations had been identified, covering an area of 3,271 ha or 32.7 km<sup>2</sup>. However, uncertainty remains about the exact location of bombs. For each cluster bomb strike, clearance personnel must check an area totaling 196,000 m<sup>2</sup> to locate (and eventually destroy) all unexploded bomblets. By the end of November 2006, more than 58,000 bomblets had been cleared and destroyed jointly by UNMACC (and contractors), UNIFIL engineers and the Lebanese Armed Forces, but it is estimated that 12 to 15 months will be necessary to clear all cluster bomblets from the region.

Between the end of the conflict and 11 November, 136 people were injured and 23 killed by cluster



*Cluster bomb sub-munitions recovered from South Lebanon*

bombs<sup>6</sup>. UNEP agrees with the findings and conclusions of the UN Human Rights Council's Special Rapporteurs (published 2 October 2006), which recognizes the vast number of cluster bombs with a low detonation rate dropped by the IDF as a major factor impeding the return to normal life in affected areas.

The large number of strikes resulted in a fragmentation of the territory, rendering it inaccessible to the local population and affecting substantial swathes of land south of the Litani River. Some locations on the northern banks of the Litani, including the villages of Yahmour, Zawtar and Jaouhariye, as well as areas further afield like Nabatiyeh and the southern part of the Jezzine district, were also impacted. While cluster bombs in themselves do not cause direct environmental degradation, their principle impact is to deprive local communities of access to land and natural resources. The hills of southern Lebanon constitute one of the four core agricultural areas of Lebanon, accounting for an estimated 30 per cent of the country's agricultural output. The principle crops cultivated are olive, tobacco, grape and citrus fruit. Moreover, agriculture makes up 70 per cent of

southern Lebanon's economy and an estimated 90 per cent of the local population depends on agriculture for its livelihood<sup>7</sup>.

UNEP's analysis of cluster bomb strike locations shows that agricultural land was hardest hit, accounting for 62 per cent of the total cluster bomb-contaminated area (table 33). Of the agricultural areas affected, nearly one quarter is monoculture olive groves and an additional 15 per cent are fields of olive trees mixed with other crops. Urban/artificial areas were the second main impacted land use category (13.4 per cent), followed closely by woodlands (12.6 per cent) and grasslands (11 per cent). The calculation of the impacted area was derived using an automated GIS application model defining a 100 m radius buffer around each strike location.

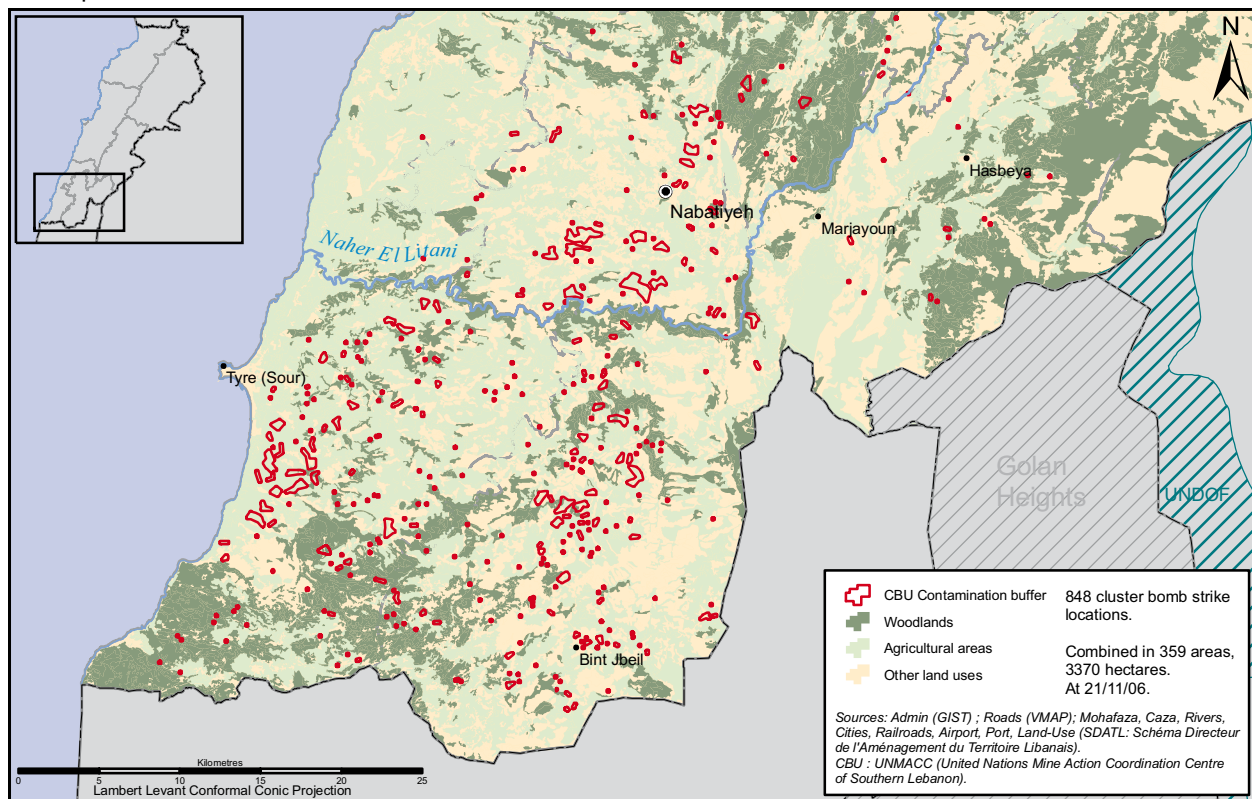
The most immediate effect on the agricultural sector was the loss of a major part of the 2006 harvest. The olive harvest season, which normally takes place in October and November, was particularly affected, as many farmers were unable to pick their crop due to the evident risks posed by cluster bombs. Valuable pasture lands have also been rendered out of bounds, most likely leading to overgrazing in accessible areas and consequent habitat degradation. Indeed, the land scarcity resulting from cluster bomb contamination has the potential to generate a new socio-economic dynamic and set in train a cycle of poverty and environmental degradation. Faced with growing livelihood pressures, the local population is more likely to resort to unsustainable practices and intensify exploitation of a diminished land base to meet short-term needs. One such reported practice is farmers setting shrubs and bushes afire with the hope that this would set off the cluster bombs. Incineration and removal of the vegetation cover, however, could also lead to obvious problems of soil and gully erosion.

Table 33. Cluster bomb-affected areas in relation to land use

Land use class	Hectares affected	Percentage of total cluster bombs affected areas
Woodlands	405	12.6
Grasslands	364	11.3
Unproductive land (bare rock)	6.5	0.2
Agricultural land	2,007	62.4
Artificial land (mainly urban)	431	13.4
Water bodies	1.2	0.04
Total	3,215	100

Source: UNMACC – October 2006

Map 14. Land use in cluster bomb strike locations in southern Lebanon



Given that the land's intrinsic environmental integrity is not compromised by the cluster bombs, the situation is reversible. Once the area is cleared of bomblets, there is good potential for economic recovery and a more balanced use of resources. The greatest challenge is the present clearance phase and the urgent need – which UNMACC has recognized – to prioritize the clearing of agricultural lands, particularly prime areas such as olive groves and fruit orchards that comprise the mainstay of the local economy. In the meantime, it is important to provide alternative livelihood support options for the population of southern Lebanon, so that they are able to cope in this critical interim period without undermining the natural resource base.

### Conflict-related vegetation fires

The fire season in Lebanon typically starts around mid-August and tapers off when the rains begin in mid-October. As the 2006 conflict occurred in summer, when the vegetation was drying out, the potential for fire outbreaks was relatively high. At the same time, given that most of the conflict took place before the start of the normal fire season, it is likely that most of the outbreaks were caused by bombing incineration.

This is corroborated by a review of archive satellite data from NASA's MODIS Rapid Response System (MRRS), which detected only two fire events in southern Lebanon between 12 July and 13 August in 2004 and 2005 respectively, but registered 48 fire events during the same period in 2006.

In total, UNEP visited nine sites – six forest stands and three reforestation sites – affected by fires in the Nabatiyeh and Jezzine regions, as well as several fire-damaged olive farms. A more detailed survey was hampered by cluster bomb contamination. This rapid qualitative survey is therefore only indicative of the vegetation fires' character and does not provide a basis for determining the size of the impacted area.

The only alternative source of information on fire incidents was satellite remote sensing imagery. NASA's MRRS developed a standard fire detection algorithm<sup>8</sup> to identify active fire locations, based on middle and thermal infrared spectral signatures of burning vegetation. While it was not possible to make a quantitative assessment of the burnt area based on satellite data, the number and frequency of fire events during the conflict period could be identified. Satellite images processed by NASA/

MRRS were screened and only individual fire events were selected. These fire locations were then overlaid on Lebanon's land cover map to determine the type of vegetation impacted. Fires captured several times on different satellite overpasses or that continued to burn for several days were all classified as a single fire event.

As mentioned above, 48 separate fire incidents were identified in southern Lebanon during the conflict period. It should be noted, however, that small fires of less than 100 m<sup>2</sup> – a probable occurrence given Lebanon's typically small and fragmented forest patches – were likely to go undetected. The majority of fires broke out in agricultural areas, mainly olive groves (37.5 per cent), and maquis formations (35 per cent), followed by woodlands (17 per cent) and finally scrub vegetation along roads (8 per cent). Fire outbreaks mostly occurred in a front line along Lebanon's southern border from Naqoura to Bint Jbeil and to the east and northeast of Nabatiyeh, in close proximity to the Litani River.

In the Nabatiyeh and Jezzine regions, UNEP observed relatively small fire scars ranging from one to ten hectares, found on average every ten to fifteen kilometres. The damage can be classified by vegetation type into four groups:

(i) **Pine trees:** Pine trees were potentially the most seriously impacted, particularly the Stone pine (*Pinus pinea*), which lacks the capacity to regenerate naturally (i.e. sprout new shoots) after fires. The damage also represents a significant financial loss, as the Stone pine's nuts (*snobar*) are of high economic value. Moreover, as pines typically

flourish on sandy soil, the degradation of the vegetation cover increases erosion vulnerability.

(ii) **Broad leaf species:** The impact of fires on broad leaf species was less severe and is largely reversible. Oaks and Carob (*Ceratonia siliqua*) were seen to sprout less than two months after the fire. The capacity to regenerate depends on whether the crown level has been affected, and on the temperature of the fires. Nevertheless, the damage could represent a substantial loss, as it could take decades for the tree canopy to recover fully.

(iii) **Maquis scrub vegetation:** Although wide areas were affected and the vegetation may be totally charred, this type of plant formation is known for its fire adaptation. Indeed, grasses, bushes and shrubs grow back either from the roots or from the ground level, rather than the apex. Hence, the vegetation is expected to recover fairly rapidly, though erosion hazards are likely to increase where soil was left bare.

(iv) **Olive trees:** The damage to olive trees represents a significant economic loss to farmers with resultant implications for local livelihoods. Yet, unless the fires are of the hot crown type, olive trees have a good potential to regenerate.

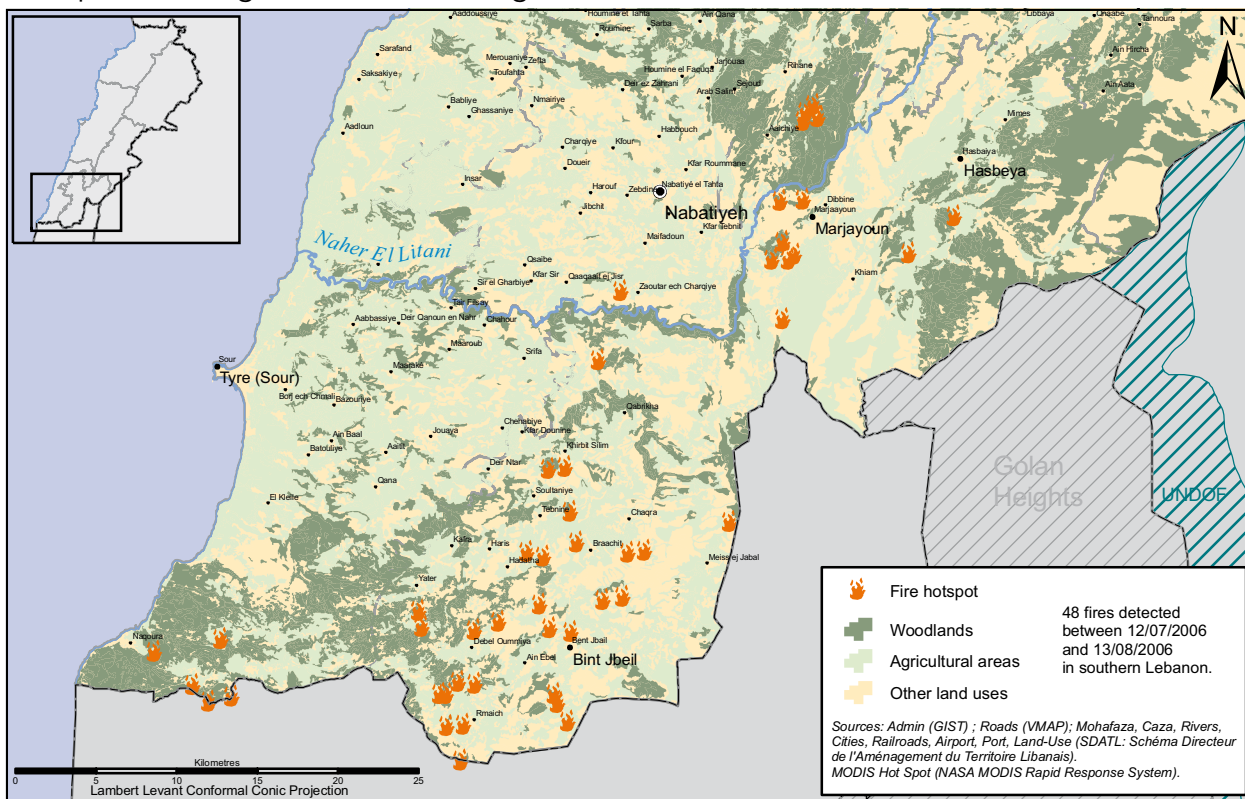
## Conclusions

UNEP investigated the possible use of weapons with a long-term environmental impact at 32 sites south and north of the Litani River. Twenty-five sites were examined in detail, and the following conclusions were reached:



Scorched maquis scrub and Calabrian pine trees in the Al-Masailah forest reserve

Map 15. Vegetation fires during the conflict in relation to land use



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

### Impact on reforestation programmes

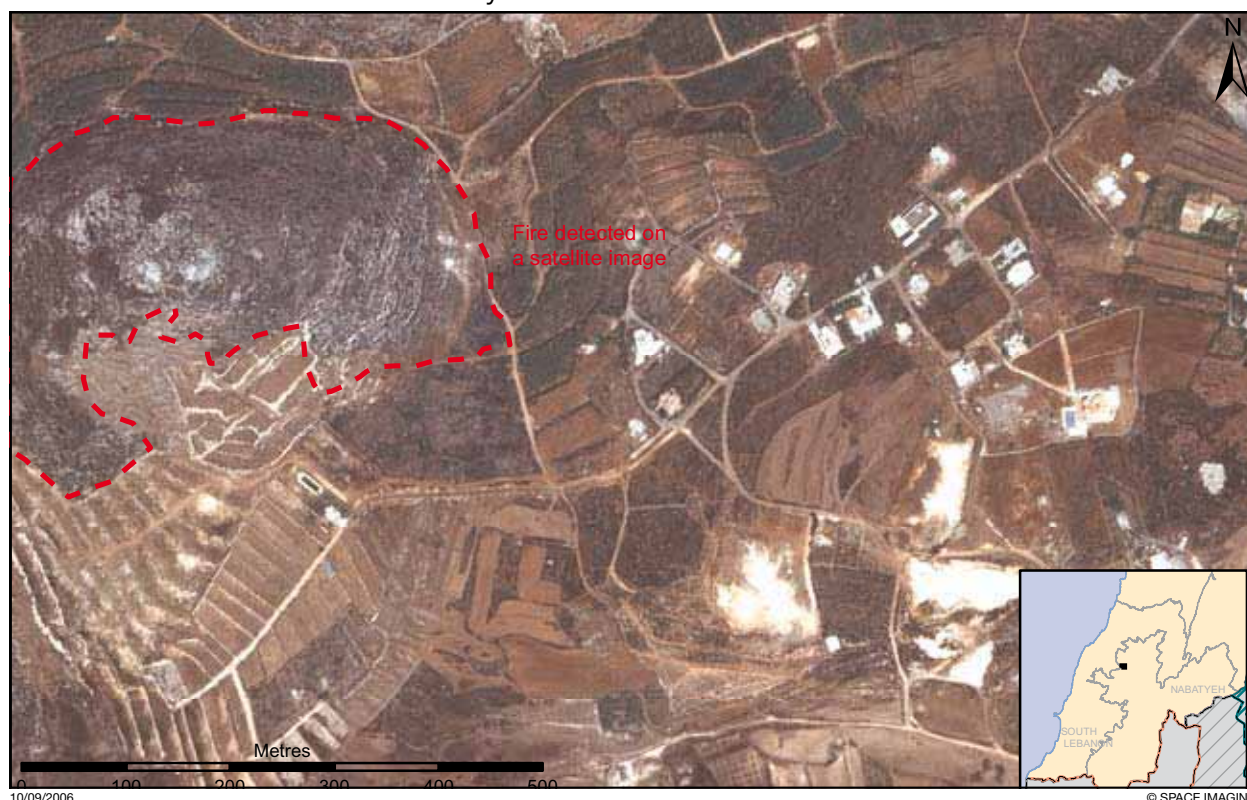
The Ministry of Environment's reforestation programme, financed by the Lebanese Government with an allocation of USD 5 million, comprised a short- and long-term reforestation plan that aimed to increase Lebanon's forested area from the present 13.3 per cent to 20 per cent by 2030. This programme was effectively halted by the conflict. In southern Lebanon, nine sites of 110 ha were reforested under Phase 1 of the project and an additional five sites of 75 ha were implemented as part of Phase II in 2005<sup>9</sup>. In the sites visited by UNEP, the seedling survival rate from both Phases I and II was generally good, despite the lack of watering and maintenance services during the dry summer season due to conflict-related security constraints. In Zawtar El-Sharqiyah, however, the whole site, covering approximately 15 ha, was destroyed by fires and an estimated 12,000 seedlings were lost.

It was also reported that the contractor had withdrawn from the Ministry's reforestation project citing an inability to fulfil the terms and conditions of the agreement, due to the conflict. Thus, the losses from the project's abrupt termination, in financial terms as well as spoilt reforestation sites, are quite substantial. A significantly larger surface of natural woodlands were burned, however, than reforested sites, underlining the potentially high cost of rehabilitating impacted areas. Finally, the consequences of habitat degradation on biodiversity should not be underestimated.

UNEP recommends that a comprehensive field-based forestry assessment of southern Lebanon be carried out to inventory the damage sustained by natural woodlands and reforested areas. Such a survey should include reforestation sites of both the Ministry of Environment and civil society organizations (the Association for Forest Development and Conservation, for example, reports that its reforestation projects in the south were also impaired by conflict-related fires). The damage assessment should serve as a basis for developing a forestry rehabilitation action plan to be carried out in collaboration with the Ministry of Agriculture, concerned municipalities and the Food and Agriculture Organization (FAO) of the United Nations.

- UNEP visited sites showing the highest probability of having been attacked with deep penetrating (potentially DU containing) munitions. The team also visited sites rumoured to have been attacked with DU-containing weapons, including a site at Khiam. Following strict field procedures, a range of smear, dust and soil samples were collected and analysed at the Swiss Spiez Laboratory. Analyses detected neither DU, nor enriched uranium, nor higher than natural uranium content. No evidence of DU penetrators, DU-containing metal products, or any other radioactive material that could be linked to a weapon used was found.
- Two radioactive sources, which were not related to weapons used in the conflict, were found. At Yatar, a damaged navigation instrument at the crash site of a military helicopter showed elevated radiation levels, and thorium-containing high-temperature oven bricks were found at a glass factory in Zahleh. The Lebanese Atomic Energy Commission (LAEC) has been fully informed and is the appropriate authority to decide on follow-up actions with respect to these sources.
- The weapons and remnants of weapons found during the assessment were all identified as weapons of well-known design. On the basis of the sites visited, UNEP cannot confirm the use of unconventional weapons by the IDF during the 2006 conflict.
- UNEP encountered unexploded cluster bomblets throughout its site visits in southern Lebanon. Not only do the unexploded sub-munitions pose a grave physical danger to populations in the affected areas, but given that 62 per cent of those areas are agricultural land, their presence also seriously impacts livelihoods and sustainable land use.
- The use of white phosphorus-containing artillery and mortar ammunition was officially recognized by the Israeli Defense Forces (IDF) on 21 October 2006 and was confirmed by UNEP's field investigations.
- A significant increase in vegetation fires in southern Lebanon between July and August 2006, as compared to other years, could be ascribed to bombing in the region. A rapid qualitative survey of forest stands and reforestation sites revealed that pine trees were potentially the most seriously affected. Damage was also suffered by olive trees, broad leaf species and maquis scrub vegetation. In addition, the government's reforestation programme was effectively halted by the conflict.

### Fire scar detected near Nabatiyeh



# Main Findings and Recommendations

*Badly damaged buildings in Haret Hreik Security Square, southern Beirut. The conflict generated a massive amount of building rubble, overloading existing waste disposal sites.*





## Main findings and recommendations

The July-August 2006 conflict had a significant impact on Lebanon, and many environmental issues remain to be addressed. The reconstruction period provides an opportunity to develop appropriate environmental plans and to enhance the country's capacity towards sustainable use of its natural resources, in terms of both the environmental impacts of the conflict and pre-existing concerns. The Ministry of Environment should play a central role in the implementation of the recommendations below, but will need the support and cooperation of other ministries and government departments. In addition, sustained technical and financial assistance from the international community is required.

UNEP's recommendations are divided into: i) institutional recommendations focused on strengthening environmental management generally, and ii) sectoral recommendations, which seek to address the problems identified in specific areas of concern. Detailed site-specific recommendations are provided in the 'Industrial and Urban Contamination' chapter.

### Institutional recommendations

- 1. Coordination mechanism for environmental emergency response:** In the recent conflict, the absence of an effective coordination mechanism led to a fragmented response and an inability to coordinate the internal response and external assistance. It is therefore recommended that the Ministry of Environment take the lead in establishing a National Emergency Preparedness and Response Infrastructure and Coordination Mechanism for environmental emergency response, with the assistance of the international community, to ensure an effective response to environmental emergencies, whether related to conflicts, man-made or natural disasters.
- 2. Institutional strengthening:** The Ministry of Environment should be strengthened as an institution, especially in terms of its enforcement capacity. Key areas that need to be reinforced are water quality guidelines, waste management, environmental monitoring and environmental inspections.

- 3. Environmental information:** It is recommended that Lebanon establish national monitoring plans in key environmental sectors such as air, water, forestry and marine resources to inform policy-making. The information gathered could be made available to interested parties, including non-governmental organizations and the general public, at an environmental resource centre accessible to the public and through appropriate websites.

### Sectoral recommendations

#### I. Solid and hazardous waste

Due to the fact that infrastructure was damaged during the conflict, management of solid waste is one of the key environmental issues associated with the conflict.

- Demolition rubble:** The conflict generated vast amounts of demolition rubble. The safe handling of the debris is one of the major challenges of the recovery process. Existing dump sites have become overloaded with conflict-related demolition rubble, exacerbating existing problems with solid waste management, and numerous additional dump sites have been created hastily and in sometimes inappropriate locations to cope with the excess debris.
- Hazardous healthcare waste:** A sharp increase in hazardous healthcare waste has been experienced as a result of conflict-related deaths and injuries. This waste has been mixed into the normal waste stream and is ending up in routine dump sites, where it constitutes a serious risk to the health and safety of site workers and the general public.
- Oil clean-up waste:** Several hundred cubic metres of oil-contaminated waste materials that have been collected during the clean-up operations of the oil spill from the Jiyeh power plant require appropriate disposal.
- Contaminated soil:** Thousands of cubic metres of hydrocarbon-contaminated soil at a number of sites, such as petrol stations and industrial facilities, potentially require treatment and/or appropriate disposal.

### Recommendations:

It is recommended that the Ministry of Environment, in cooperation with the Ministry of Public Works and Transport, take the lead in developing and implementing guidelines on the safe handling and environmentally sustainable disposal and reuse of demolition debris. This should be supplemented with the identification of central areas for processing. In addition, international technical assistance and donor support should be mobilized to provide suitable processing equipment (e.g. mobile crushers) to clusters of municipalities.

- There are currently no environmentally acceptable options within Lebanon for the disposal of oily solid waste. It is recommended that the Ministry of Environment lead the mobilization of international technical assistance and donor support to establish environmentally acceptable disposal solutions (e.g. biological remediation, incineration at cement furnaces with control measures, or use of mobile incinerators).
- Measures should be implemented at the national level to enhance the coping ability of waste management systems. UNEP recommends that the Ministry of Environment be assigned the responsibility of developing priorities, guidelines and legislation to phase out open dump sites and construct sanitary landfill sites based on transparent contracting procedures. The involvement of municipalities should be encouraged, using the Zahleh landfill site as a model, and private sector services should be used where appropriate. Inter-municipal agreements could help solve waste management problems through cost-sharing and economies of scale.
- National procedures should be developed to ensure that hazardous healthcare waste is separately stored and disposed of with appropriate technology. This would involve investment in facilities such as autoclaves or a central incinerator and the training of healthcare staff. The Ministry of Environment would be the appropriate body to develop such procedures, in coordination with the Ministry of Public Health.
- Staff working with debris at disposal sites should be provided with adequate training

and equipment to ensure that their health, safety and security are protected according to best international practice. The most significant concern is exposure to excessive levels of dust at various sites.

- With appropriate training and working methods, local personnel could undertake the collection of asbestos cement debris, which would need to be suitably contained, transported and disposed of at a landfill site able to deal with such waste. Asbestos cement roof sheets in good condition should be left in place until the end of the building's life, when they can be removed and appropriately disposed of.

### II. Industrial contamination, soil and fresh water resources

A total of 36 potentially contaminated sites were visited, which were representative of a range of land uses, including: agricultural, commercial, industrial, infrastructure and power generation. Given that the collection of samples was carried out before the onset of the rainy season (November – April), the mobilization of contaminants was fairly localized. The condition of Lebanon's fresh water resources should therefore be monitored for longer-term conflict-related consequences. UNEP found the following:

- **Soil contamination:** The Jiyeh power plant, Beirut airport fuel storage tanks, and the two petrol stations visited showed varying degrees of hydrocarbon contamination. Other industrial sites – such as the Al Arz textile factory (Zahleh), Lamartine Food Industry (Zahleh) and the Ghabris detergent factory (Tyre) – demonstrated relatively minor or localized levels of contamination. In addition, a number of sites, including the Transmed industrial facility (Beirut), the Lamartine Food Industry and the Lebanese Company for Carton Mince & Industry (Beirut) were found to have the potential to cause future contamination due to residual pollutants remaining on site.
- **Water pollution:** Localized contamination of surface and groundwater has occurred in certain industrial pollution 'hotspots', such as the Choueifat industrial area and

the Ghabris detergent factory in Tyre, where the bombing caused chemicals to be released into soil and water sources. In general, the risk of contamination of water sources is considered to be low, though this may change once rain, run-off, flushing and percolation commence.

- **Supply and wastewater networks:** Prior to the conflict, the water supply and wastewater networks were undergoing rehabilitation throughout Lebanon. These networks were extensively damaged in the conflict and hence present a risk of groundwater contamination and a potential public health hazard. Poor wastewater management constitutes a major chronic environmental stress factor, which needs to be addressed in a comprehensive manner.

#### Recommendations:

- Hydrocarbon-contaminated sites – including the Jiyeh power plant, Beirut airport fuel storage tanks, Ebl Saqi asphalt plant and the Saida petrol station – should be investigated further to determine the exact extent and magnitude of the contamination. Contaminated soil should be removed for treatment.
- It is recommended that the Ministries of Environment and Industry remove sources of toxic pollutants that could impair surface and groundwater quality and protect wells in heavily contaminated zones such as the Choueifat industrial area and the Ghabris detergent factory. Ash in the Transmed site (Choueifat) and stockpiled chemicals at the Maliban glass factory (Zahleh) should also be removed as a matter of priority. In addition, the possibility of an industrial wastewater treatment plant for the Choueifat area should be investigated.
- The level of contamination from damaged wastewater networks should be assessed in detail. In this regard, it is suggested that the Ministry of Environment and other relevant ministries such as Public Health and Energy and Water, as well as municipalities, identify and address actual and potential contamination sources representing a risk for public health and the environment. The reconstruction period could, with the support of the international

community, be used to assess the feasibility and cost of implementing wastewater treatment technologies (municipal and industrial) in Lebanon's cities and towns.

- A catchment-wide plan to control the release of pollutants into the Ghadir stream should be developed, as the stream is severely contaminated and constitutes a major source of land-based marine pollution.
- It is suggested that the Ministry of Energy and Water, Ministry of Environment and Ministry of Public Health collaborate to establish a national programme to monitor the physical, chemical and biological aspects of ambient quality of surface and groundwater on a continuous basis, as well as a discharge inspection programme. This could be combined with the World Health Organization's (WHO) plan to help establish a national drinking water quality surveillance system.
- The Ghadir is one of the most polluted watercourses in Lebanon and a principle source of land-based marine pollution. There is an urgent need to introduce an integrated water resources management (IWRM) approach, as a pilot project, to remediate the pollution problem in a comprehensive manner at basin scale.
- In the long term, an integrated water resources management plan needs to be developed to ensure that the water resources of the upper Jordan River are used in a sustainable manner.

### III. Weapons used

The UNEP assessment focused on the use of weapons with potential environmental impacts, including the possible use of weapons containing depleted uranium (DU). The weapons assessment team visited 32 sites, concentrating particularly on southern Lebanon, and reached the following conclusions:

- **Depleted uranium:** Using highly sensitive equipment, the UNEP weapons team visited sites showing the highest probability of having

been attacked with deep-penetrating (potentially DU-containing) munitions. The team also visited sites rumoured to have been attacked with DU-containing weapons, including a site at Khiam. Samples were analysed by a leading Swiss governmental laboratory in the field of radiation. The results show no evidence of the use of weapons containing DU, natural uranium or any other uranium isotope composition.

- **Cluster bombs:** At 13 November 2006, UNMACC (South Lebanon) had identified 813 cluster bomb strike locations and estimates that up to one million unexploded cluster bombs may be on the ground in Lebanon. Between the end of the conflict and 11 November, 136 people were injured and 23 killed by cluster bombs. UNEP encountered unexploded cluster bombs throughout its site visits in southern Lebanon. These munitions are considered to pose a grave risk to the Lebanese population and are a serious impediment to post-conflict recovery and reconstruction efforts. In addition, agricultural fields are heavily contaminated by cluster bombs, affecting the livelihoods of populations in those areas.
- **Fires:** The conflict led to the outbreak of fires and the loss of economically valuable tree species in southern Lebanon, and impaired the Government's fledgling reforestation programme.
- **White phosphorus:** UNEP found evidence of the use of white phosphorus-containing munitions. Their use has been confirmed by the Israeli Defense Forces.

### Recommendations:

- UNEP endorses the recommendation of the UN Human Rights Council's Special Rapporteurs that the clearance of cluster bombs from agricultural fields should be accelerated with the assistance of bilateral and multilateral donors, and that the Government of Israel should provide full details of its use of cluster munitions to facilitate the destruction of unexploded ordnance and the clearing of affected areas.
- The environmental impact of white phosphorus is limited to fires at the time of

impact. However, residents and unexploded ordnance destruction teams should be alerted to its presence and take the necessary safety precautions.

- The reactivation of the Lebanese government's reforestation programme should be supported and burnt areas should be rehabilitated.

### IV. Air pollution

Although air quality was not monitored during the conflict, UNEP compiled information from smear samples in areas that had been heavily bombed, as well as soil samples from the vicinity of the Jiyeh power plant, where bombing-related air pollutants may have been deposited. The main findings are:

- **Sample results:** Smear samples in almost all locations show the presence of heavy metals, which could result in long-term health problems if inhaled. Soil samples around the Jiyeh power plant indicate the presence of polycyclic aromatic hydrocarbons (PAHs), a carcinogenic product generated by the incomplete burning of hydrocarbons.
- **Potential long-term health impacts:** The implication of the above findings is that the population around heavily bombed sites has been exposed to air pollutants, possibly resulting in long-term health consequences.

### Recommendations:

- It is recommended that a national health registry of people who may have been exposed to air pollution during the conflict be established. Their health status should be monitored to identify any adverse, long-term health effects.
- Rain and snow should be monitored during the coming seasons to determine whether some pollutants return to the ground during precipitation.
- Air quality regulations and monitoring systems should be established in Lebanon.



UNEP investigates the site of the oil spill at the Jiyeh power plant

## V. Marine and Coastal Environment

The oil spill caused by the bombing of the Jiyeh power plant contaminated the coastline and had a severe impact on coastal communities. The ongoing conflict impaired local and international capacities to respond to the spill. Nevertheless, a massive containment and clean-up operation was launched in the weeks following the conflict. Lebanese civil society and governmental, regional, and international organizations provided technical and financial assistance, equipment and manpower. By the autumn of 2006 an estimated 600 m<sup>3</sup> of liquid oil and 1,000 m<sup>3</sup> of oil-contaminated sand, pebbles and debris had been collected. The clean-up is still ongoing. The UNEP team, at the time of assessment, found the following:

- **Sunken oil:** Due the high viscosity and specific gravity of the fuel oil used at Jiyeh, a substantial part of the oil that was released into the sea sank to the sea bottom in the immediate vicinity of the power plant, most likely smothering the biota in the sediment. The risk of its remobilization will remain unless the oil is fully extracted.
- **Coastline contamination:** As a result of prevailing wind conditions and sea currents, most of the oil that did not sink was pushed against the coast and northwards, impacting marinas, wharfs, beaches, property and archeologically important sites (including Byblos).
- **PAH in seabed sediment:** The concentrations of PAH in seabed sediment and in molluscs beyond the immediate vicinity of the power plant were similar to what is expected in coastal areas under the influence of urban zones, industry and transport, with the spill adding marginally to these background concentrations.
- **Hydrocarbons in oysters:** The levels of petroleum hydrocarbons in the tissue of oysters beyond the immediate vicinity of the power plant were in an expected range of concentration for areas under anthropogenic influence.
- **Hydrocarbons in fish:** The concentrations of petroleum hydrocarbons in the samples of fish tissue were found to be below or slightly above the detection limit. No difference was detected between the petroleum hydrocarbon concentrations in fish from different areas or in

## MAIN FINDINGS AND RECOMMENDATIONS

species from different trophic levels. The levels are low and probably indicate the background concentrations of hydrocarbons for fish in the eastern Mediterranean. Likewise, the PAH levels of fish were found to be normal for that area.

- **Water column:** At the time of investigation, oil was no longer detected in the water column. However, the potential for re-suspension remains as long as the oil is present on the seabed.

### Recommendations:

- The sunken oil from the immediate vicinity of Jiyeh should be extracted.
- During clean-up operations, the remobilization of oil in sediment, on beaches and stuck to surfaces should be avoided. The use of steam and high pressure water should therefore be limited to boats, docks, jetties and other infrastructure.
- Appropriate health and safety practices should be followed during clean-up operations.

Workers should wear appropriate protective clothing and use equipment.

- The National Oil Spill Contingency Plan should be reviewed based on the experience of the Jiyeh oil spill and lessons learned should be incorporated.
- It is recommended that the Ministry of Environment, with the support of international donors, monitor concentrations of pollutants and biological parameters on a routine basis to track the recovery of impacted sites and the general health of the environment. The data provided in this report could, together with existing data, form a baseline for future monitoring of coastal and marine sediment and biota.
- In view of the low biodiversity levels and general eutrophication of extensive areas, the discharge of untreated sewage, leachate and industrial effluent into the marine environment and over-fishing should be addressed urgently at the national and regional levels.



*Site of a damaged school in Bint Jbeil, southern Lebanon*





# Appendices

## Appendix I

### List of acronyms, abbreviations and units

BOD/COD	Biological/Chemical oxygen demand
CDR	Council for Development and Reconstruction
CNRS	National Council for Scientific Research
cps	Counts per second
°C	Degrees Celsius
°F	Degrees Fahrenheit
DO	Dissolved oxygen
DRO	Diesel range organics
DU	Depleted uranium
dw/ww	Dry/wet weight
EOD	Explosive ordnance destruction/disposal
EPH	Extractable petroleum hydrocarbons
EU	European Union
eV/uV	Ultraviolet (lamp strength for the PID)
FAO	Food and Agriculture Organization of the United Nations
GC-FID	Gas chromatograph-Flame ionization detector
GDP	Gross domestic product
GIS	Geographic information system
GPS	Geographic positioning system
GCMS	Gas chromatography to mass spectrometry
GRO	Gasoline range organics
HHCW	Hazardous healthcare waste
IDF	Israeli Defense Forces
IMO	International Maritime Organization
IPC	International Petroleum Company
ISO	International Organization for Standardization
IWRM	Integrated water resources management
LAEC	Lebanese Atomic Energy Commission
m	metres (measurement)
m <sup>2</sup>	metres squared (area)
m <sup>3</sup>	metres cubed (volume)
MAG	Mines Advisory Group
METAP	Mediterranean Environmental Technical Assistance Programme
mg/kg	Milligrams per kilograms

mg/l	Milligrams per litre
MODIS	Moderate Resolution Imaging Spectroradiometre
MoE	Ministry of Environment
MoIM	Ministry of the Interior and Municipalities
MPA	Marine protected area
μSv/h	Microsieverts per hour
NPMPLT	National Physical Master Plan for the Lebanese Territory
OCHA	UN Office for the Coordination of Humanitarian Affairs
OPEC	Organization of the Petroleum Exporting Countries
ORP	Oxidation reduction potential
OSOCC	Oil Spill Operations and Coordination Centre
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PHC	Petroleum hydrocarbons
PID	Photo-ionization detector
PPE	Personal protective equipment
ppm	Parts per million
PRO	Petroleum range organics
psi	Pounds per square inch
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
SDC	Swiss Agency for Development and Cooperation
SoER	State of the Environment Report
SVOC	Semi-volatile organic compounds
SWM	Solid waste management
μg/l	Micro-grams per litre
μs/cm	Micro-siemens per cm
UK	United Kingdom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-MAP	UNEP Mediterranean Action Plan
UNIFIL	United Nations Interim Force in Lebanon
UNMACC	United Nations Mines Action Coordination Centre
UNOSAT	United Nations Organization for Satellite Imagery
USAID	United States Agency for International Development
VOC	Volatile organic compounds
WHO	World Health Organization
WP	White phosphorus

## Appendix II

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#### Introduction

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In addition to the significant impact on the civilian population, the July-August 2006 conflict in Lebanon and in Israel caused severe damage to infrastructure in Lebanon and raised concerns about the possible contamination of land, air and water by toxic chemicals released from damaged industrial sites and the types of weapons used. In addition, the bombing of the Jiyeh power plant, south of Beirut, led to the spillage of a considerable amount of heavy fuel oil into the Mediterranean Sea, which polluted approximately 150 kilometres of Lebanese coastline, as well as part of Syria's coast.

In view of these concerns, UNEP sent a team of twelve international environmental experts to conduct fieldwork in Lebanon from 30 September to 21 October 2006. The scientific areas investigated included solid and hazardous waste (including asbestos), land and freshwater contamination, the environmental impacts of weapons used and marine and coastal pollution. UNEP visited more than one hundred sites throughout Lebanon and took close to two hundred water, soil, ash, dust, sediment and marine samples. These samples were sent to three independent laboratories in Europe for analysis.

This report presents UNEP's findings of the post-conflict environmental assessment of Lebanon and recommendations for follow-up actions.

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