CHAPTER 6

Oil Spill and Waste Due to Conflict: The Case of Lebanon

The 34-day conflict in Lebanon started on July 12, 2006, and continued until August 14, 2006, when the ceasefire went into force. It killed close to 1,200 people, left more than 4,400 injured, displaced more than a quarter of the population, and severely damaged the country's infrastructure (GoL 2006a). Beyond these tragic impacts, the conflict devastated the country's fragile environment. The bombing of a power plant in Jiyeh caused 12,000 to 15,000 tons of oil to spill into the Mediterranean Sea. The widespread fires and oil burning deteriorated air quality, especially in southern Beirut. These damages significantly affected the country's economy, environment, and public health.

Several damage assessments were carried out in the aftermath of the conflict:

- The Government of Lebanon (2006a) estimated the direct damages to infrastructure and economic sectors.[1]
- The World Bank (2006) assessed the impact on the country's major economic and social sectors.
- The Food and Agriculture Organization (2006) focused on the physical damages and income losses to agriculture, fisheries, and forestry.
- The European Commission (2006a) quantified the direct damages to public infrastructure.

None of these studies focused on estimating the damages to the environment. As of April 2007, only the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) had carried out environmental assessments of the damage (UNDP 2007; UNEP 2007). These studies illuminated several important aspects of the environmental degradation; however, none of them measured the associated costs in monetary terms.

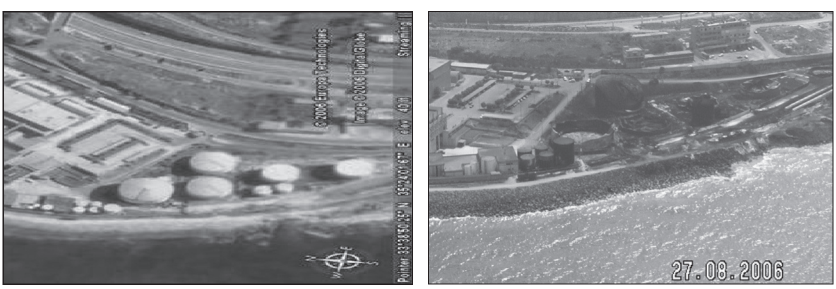
To bridge this gap, World Bank (2007) conducted an economic assessment of the environmental damage caused by the conflict. The next sections summarize the valuations of (a) the impacts of the oil spill on the coast and (b) the impacts of the conflict on the waste sector—the two most important areas of environmental damage caused by the 2006 conflict in Lebanon. It is important to note that this analysis was undertaken between October 2006 and April 2007. Several changes may have occurred since then, entailing potential changes in the estimated damage costs.

The Oil Spill

On July 13 and 15, 2006, bombs hit the storage tanks of the Jiyeh power utility, located 30 kilometers south of Beirut—storage tanks that contained approximately 44,000 tons[2] of stored intermediate fuel oil (IFO).[3] As a result, about 12,000 to 15,000 tons of oil spilled into the Mediterranean Sea, and the rest burned, according to communications with the Lebanese Ministry of Environment (MOE) in 2007. Photo 6.1 shows aerial views of the Jiyeh station's tank area before and after the bombings.

Photo 6.1 Jiyeh Electrical Power Station and Tanks

a. Before the July 2006 bombings **b. After the July 2006 bombings**



Source: Google Earth. *Source:* Lebanon MOE.

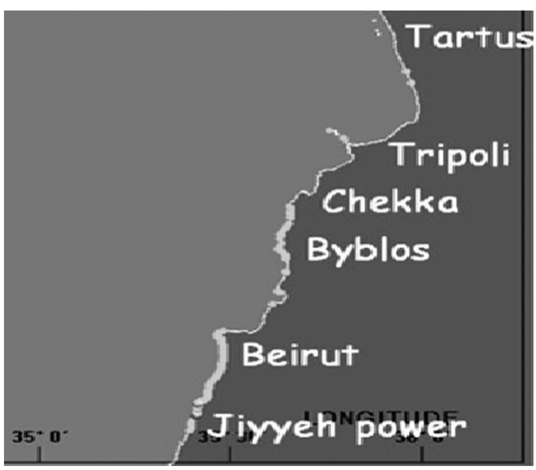
Overview of the Oil Spill

The sea currents and winds moved the spilled oil northward and onto the shoreline. The heaviest impacts occurred between the Jiyeh power station and Beirut, between Byblos and Chekka, and onto the Palm Islands off the Tripoli shore. By July 29, 2006, the oil reached Syrian Arab Republic waters and affected the shoreline there, as observed at Tartus. Most of the oil remained relatively close to the shoreline, as shown by the MEDSLIK model (in photo 6.2),[4] satellite image analysis, and aerial surveys. Some oil was observed on the bottom of the sea, particularly in areas adjacent to and offshore the Jiyeh power plant, Beirut, and Byblos.

A similar occurrence was noted in 1991, when the supertanker Haven burned off the shore of Genoa, Italy, and part of its crude oil cargo sank. The main causes of the bottom oil in Lebanon likely included (a) oil burning, creating neutrally buoyant to slightly heavier-than-water material, and (b) oil mats formed when heavy oil mixed with sediment on the bottom. On September 26, 2006, the Italian mission involved in the damage assessment reported a bottom-oil density of about 1.2 grams per cubic centimeter and a 50 percent weight content of sand.

The *Centre de Documentation, de Recherche et d'Expérimentation sur les pollutions accidentelles des eaux* (Centre of Documentation, Research and Experimentation on Accidental Water Pollution, or CEDRE) analyzed several oil samples and found that the spilled IFO 150 had a biodegradability

Photo 6.2 Oil Impact Areas, July 15 to August 2, 2006



Source: Cyprus Oceanography Center, University of Cyprus (from the MEDSLIK oil-spill model).

of about 47 percent, after which nondegradable tars and resins were expected to remain (CEDRE 2006). Although biodegradation was not active on the remaining residues, physical weathering (for example, movement by wave action) was expected to continue removing portions of the remaining residue. The Jiyeh oil had high saturate levels (above 50 percent) and low aromatics (below 28 percent). Because of the oil's low aromatic content, toxicity was relatively low, particularly compared with that of the Prestige spill in 2002 and Erika spill in 1999, as table 6.1 shows.

Environmental Impacts of the Oil Spill

The Jiyeh oil spill had likely effects on several biodiversity components. The impacts on shoreline biota included direct oiling and smothering of organisms on rock-dominated shorelines. In heavily affected areas, the impacts on sand and gravel beaches may have lasted for weeks or even months. Natural cleansing by wave action, assisted by beach washing through the mitigation effort, aided the recovery on sand and gravel shorelines, as seen in photo 6.3. However, because this oil greatly adheres

Table 6.1 Comparison of Jiyeh Fuel with Other Fuels
% content

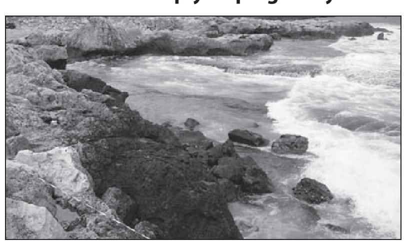
Spill incident and fuel type	*Saturates*	*Aromatics*	*Resins and asphaltenes*
Jiyeh (IFO 150)	50	28	22
Erika (heavy fuel no. 6)[a]	23	53	24
Prestige (heavy fuel no. 2 M100)[a]	22	56	22
Testing fuel	20	53	27

Source: CEDRE note by Francois Merlin to MOE.
Note: IFO 150 = intermediate fuel oil with a viscosity of 150 CentiStokes (cSt) at 50°C.
a. Spill details at www.cedre.fr.

Photo 6.3 Oil Impact on Major Shoreline Types

a. Byblos oiled gravel beach being cleansed by wave action in active intertidal zone

b. Enfe oiled steeply sloping rocky shore



Source: E. Gundlach.

to rocky shorelines, natural cleansing in these areas is slow, and mitigation efforts, such as high-pressure washing, are tedious and time-consuming.

Impacts on subtidal communities. The effects on subtidal communities are most evident where oil mats on the bottom of offshore waters smothered the resident organisms, as observed in the near-shore areas off the Jiyeh power plant and Beirut coast. No observations were made on the effects of the oil spill on bottom communities from chemical toxicity in the water column. Potential injury by smothering occurred only in localized areas where large tar mats were present on the bottom. The Italian mission observed some smothered sponges and corals (madrepores) near the power plant.

Impacts on birds. Shorebirds and marine waterfowl birds are likely to have been injured because the oil stayed fairly close to the shore, where birds typically feed. From July through October 2006, no dead or heavily oiled birds were reported. However, 92 oiled birds were observed following that period until April 2007 in the Palm Islands Nature Reserve, probably because the oil resurfaced after winter storms on the islands, affecting the winter visitors. Although direct impacts of the spill on birds were relatively minimal, indirect effects are likely to be felt for many years to come.[5] The Government Appointed Committee (GAC) for the management of the reserve observed a major reduction in the number of visiting birds, most likely due to the contamination of habitat and possible loss of access to food.[6]

Impacts on marine reptiles (turtles). The marine turtles found in Lebanese waters include the green turtle (*Chelonia mydas*), the loggerhead turtle (*Caretta caretta*), the Nile soft-shelled turtle (*Trionyx triunguis*), and the leatherback turtle (*Dermochelys coriacea*) (BTC 2003; Dimirayak and others 2001; MOA and UNEP 1992; IUCN 2006). All marine turtles are globally classified as threatened species and are protected by most Mediterranean countries. Loggerheads are an endangered species, and green turtles are critically endangered (IUCN 2006).

The oil spill affected three beaches with turtle nesting: Jbail, Palm Islands Nature Reserve, and Ramlat Al-Baida. It is not known whether other oiled sites, such as Jiyeh and Damour, had active turtle nesting. Turtle areas to the south of Beirut were affected by the direct bombing of the conservation site at Mansouri Village, south of Tyre, rather than by the spill (UNDP 2007).

Impacts on marine mammals. Mammals found in the eastern Mediterranean Sea include dolphins, sperm whales, fin whales, and the rare Mediterranean monk seal. The latter, a critically endangered species, has been occasionally observed on Palm Islands Nature Reserve in the past decade (MOE 2004). While no injuries were reported, the movement of tar balls and other hydrocarbons from the spill with the currents might have affected the already stressed population of remaining seals.

In addition to the above impacts, the media reported a small number of dead fish or fish exhibiting unnatural behavior because of the oil spill. However, indirect effects might have occurred because the food source to fishery was likely reduced as the spill spread. The oil spill also affected large areas of Palm Islands Nature Reserve (Kremer, Pasche, and Kilani 2006), damaging the invertebrate community (crabs, small crustaceans, and mollusks)[7] and plants (golden samphire, sea spurge, glasswort, sea purslane) (Ramadan-Jaradi 2007).

Groundwater contamination through seawater intrusion, which usually occurs in densely fissured zones, is another potential impact of the spill. However, results of the groundwater sample analysis collected from Mina Daliyi in Beirut and the coastal area immediately north of Jiyeh at Saadiyat conducted by UNEP were not conclusive (UNEP 2007).[8]

Methodology

The valuation of damages caused by the oil spill is based on the users' forgone benefits: the difference between the *expected* and *actual* benefits derived from activities on the coast. "Expected benefits" refer to the level of environmental benefits that would have been enjoyed had the oil spill not occurred. "Actual benefits" are those provided after the outbreak of the conflict.

Valuation challenges. Valuing the impacts of oil spills is particularly challenging. The valuation issues relate to a wide range of factors, such as the types of goods and services in question, the space and time scale, the sectors affected, the poor quality of available statistics, and the possible existence of irreversible and long-term effects (Chas-Amil and others 2004).

In this light, Grigalunas and others (1986) present the empirical and conceptual problems, including the estimation of nonmarket losses to tourists, the determination of fisheries' losses in the absence of accurate biological data, and the decision on whether or how to account for the distribution of costs. Efforts to estimate the impacts of oil spills worldwide have encountered most of these problems, and the Lebanese case is no exception.

Although the subsequent sections address most of the valuation problems, two issues deserve special attention: the time frame of oil-spill impacts and the oil spill's particular contribution to the total environmental damage brought by the conflict.

Time frame of oil spill impacts—Early oil spills have shown that the impact time frames vary widely, depending on many factors such as the type of oil, quantity spilled, type of ecosystem services and species affected by the oil spill.[9] Estimating the time frame of damage becomes even more complicated when unexpected impacts occur at some extended time after the event.[10] In Lebanon, no precise information is available about the time frame of the Jiyeh spill's effects.[11] Two field visits to the Lebanese coast in October 2006 and March 2007, however, indicated the following:

- The strongest impacts of the oil spill on coastal activities covered the period between the August 14 ceasefire and the end of 2006.
- In 2007, the visual effects of the oil pollution would significantly subside if restoration and cleanup continued.[12]
- In 2008 and after, the oil spill may still have site-level impacts, either because the environment was not appropriately cleaned or because of lingering perceptions that potentially negative health effects persist.

Based on the above, this report adopts a *three-year time frame for the analysis (2006–08), during which losses are assumed to subside gradually*.[13]

Oil spill contribution to the damage—Because the oil spill is a direct consequence of the conflict itself, it is difficult to single out its contribution to the overall damage.[14] McCay and others (2004) estimate that the potential impact of oil spills on natural resources may range from as little as 2 percent to as much as 50 percent of the total socioeconomic, environmental, and response-related costs, depending on the type of oil, volume percentile, and other characteristics.

Given the inconclusive information related to other oil spills and the timing of the analysis so shortly after the event, this estimation relies on several assumptions, as illustrated in table 6.2. Because more data were available for 2006 than for successive years (for example, expected income or forgone benefits from coastal activities), the assumptions for 2006 rely on the existing baseline information and, consequently, vary

Table 6.2 Oil-Spill Damages to Selected Coastal Activities
% of expected income

	2006		*2007*	*2008*
Affected site or activity	*July–Aug.*[a]	*Sept.–Dec.*	*Jan.–Dec.*	*Jan.–Dec.*
Commercial fishing	0	50[b]	5–10	0–5
Shoreside fishing	0	50[b]	5–10	0–5
Hotels	0	10–20	5–10	0–5
Byblos World Heritage Site	0	25–50	5–10	0–5
Beach resorts and chalets[c]	0	25–50	5–10	0–5
Palm Islands Nature Reserve	0	75–100	5–10	0–5
Restaurants	0	75–100	5–10	0–5
Marinas' sport services	0	75–100	5–10	0–5

Source: Authors' estimates and 2007 interviews with local representatives.
Note: "Expected income" is the income that would have been expected had the oil spill not occurred.
a. The significant July–August impact of the oil spill was overshadowed by that of the conflict, which completely halted coastal recreational activities. Thus, the conflict is assumed to have caused all July–August losses.
b. Percentage of forgone income instead of expected income, based on interviews with fishermen.
c. Because beach and seawater characteristics directly influence recreational services at these sites, the oil spill is assumed to equally affect the activities at beach resorts, chalets, and public beaches in each of the three years.

from one activity to another. In the absence of accurate information, the cleanup efforts are assumed to cause a gradual decline of the oil-spill impacts in future years—5–10 percent of expected income in 2007 and 0–5 percent in 2008 for all coastal activities. These assumptions are based on local interviews with representatives of each activity concerned (for example, hotels and restaurants) at the time of valuation. Because no precise information was provided, the numerical ranges take the uncertain impact level into account.

Cost of Degradation due to the Oil Spill

The valuation of the cost of degradation is based on the assumptions presented in the methodology section above. For each activity, the total damage reflects the present value of forgone benefits during 2006–08, uses a 4 percent discount rate, and refers to 2006 as a base year.

Hotels and furnished apartments. The Syndicate of Hotel Owners lists 337 licensed hotels in Lebanon, of which 54 are on the coast and include about 3,500 rooms.[15] The average daily income is about US$150 per room.[16] In addition, the coast hosts about 97 furnished apartment buildings,[17] totaling about 2,800 units, at an average price of US$220 per night.[18] Consequently, the daily income of fully booked coastal hotels and furnished apartments totals about US$1.1 million. Based on peacetime occupancy rates, the expected income is estimated US$313.2 million per year.

The oil spill reduced the occupancy rate of hotels and furnished apartments along the coast. In 2006, this reduction was significant, mainly because of the visual signs of oiled beaches and contaminated water. Based on interviews with hotel owners, the oil spill induced an income decline of 10–20 percent from September through December 2006. In April 2007, both tourism and hotel occupancy rates recovered slightly because of successful cleanup efforts. It is assumed that the hotel industry would be better off and would fully recover in the following years. Accordingly, as the figures in table 6.3 show, the total forgone income due to the oil spill is estimated at *US$23 million to US$60 million*.

Beach resorts. Beach resorts are clubs with daily access to the beach, pools, and other recreational facilities but with no sleeping accommodations.[19] The Lebanese coast hosts about 68 beach resorts.[20] According to discussions with the Syndicate of Maritime Establishments, there are about 500 daily visitors per beach resort during peak season (May–August) and about 300 daily visitors during the rest of the season (September). Considering that visitor spending averages US$20 per day,[21] the resorts' expected peacetime income is estimated at about US$55.4 million per year.

Table 6.3 Forgone Coastal Hotel and Apartment Income due to Oil Spill

	Min	Max	Assumptions
Expected income/day	1.1	1.1	(3,500 rooms x $150) + (2,800 apts. x $220)
Expected income			
Sept.–Dec. 2006	87.0	87.0	Based on expected hotel occupancy of 50% of full capacity in winter (Nov.–Feb.) 75% in spring (Mar.–Apr.) 100% in summer (June–Aug.) 75% in fall (Sept.–Oct.)
Jan.–Dec. 2007	313.2	313.2	
Jan.–Dec. 2008	313.2	313.2	
Forgone income			
2006	8.7	17.4	10–20% of the expected income
2007	15.7	31.3	5–10% of the expected income
2008	0.0	15.7	0–5% of the expected income
PV of forgone income	22.8	59.6	

Source: Authors' estimates and interviews with hotel owners in April 2007.
Note: PV = present value. "Expected income" is the income that would have been expected had the oil spill not occurred.

The conflict and the oil spill heavily affected the activities on beach resorts. The Syndicate of Maritime Establishments reported about 60 visitors per beach in September 2006—only 20 percent of the peacetime average. In other words, the conflict and the oil spill caused beach resorts' expected income to decline by 80 percent in September 2006. There is no documented information concerning the oil spill's contribution to the income forgone from beach activities. It is reasonable to assume, however, that oil pollution of beaches and water substantially affected the recreational activities of nearby beach resorts, on the order of about 25–50 percent of the expected income in September 2006. As a result, the total 2006–08 forgone income due to the oil spill is between *US$5 million and US$13 million*.

Table 6.4 displays the estimated forgone income to beach resorts, chalets, public beaches, and events that can be attributed to the effects of the oil spill.

Table 6.4 Forgone Beach Resort, Chalet, Public Beach, and Event Income due to Oil Spill
US$ millions

	Min	*Max*	*Assumptions*
Beach resorts			
Expected income			
2006 (Sept., 30 days)	11.9	11.9	68 (resorts) x 300 (visitors) x 30 days x $20/day
2007 (May 15–Sept., 108 days)	55.4	55.4	68 x [(500 x 47days) + (300 x 61days)] x $20/day
2008 (May 15–Sept., 108 days)	55.4	55.4	68 x [(500 x 47 days) + (300 x 61 days)] x $20/day
Forgone income due to spill			*% of expected income*
2006	2.9	6.0	25–50
2007	2.8	5.5	5–10
2008	0.0	2.8	0–5
PV of forgone beach resort income	**5.4**	**13.3**	
Chalets			
Expected income			
2006 (Sept.–Oct., 2 months)	10.0	10.0	$5 million x 2 months
2007 (May–Oct., 6 months)	30.0	30.0	$5 million x 6 months
2008 (May–Oct., 6 months)	30.0	30.0	$5 million x 6 months

(continued)

Table 6.4 Forgone Beach Resort, Chalet, Public Beach, and Event Income due to Oil Spill *(continued)*
US$ millions

	Min	*Max*	*Assumptions*
Forgone income due to spill			*% of expected income*
2006	2.5	5.0	25–50
2007	1.5	3.0	5–10
2008	0.0	1.5	0–5
PV of forgone chalet income	**3.8**	**8.9**	
Public beaches			
Expected income			
2006 (Sept.)	2.6	2.6	$2.6 million x 1 month
2007 (July–Sept.)	7.8	7.8	$2.6 million x 3 months
2008 (July–Sept.)	7.8	7.8	$2.6 million x 3 months
Forgone income due to spill			*% of expected income*
2006	0.6	1.3	25–50
2007	0.1	0.2	5–10
2008	0.0	0.1	0–5
PV of forgone public beach income	**0.7**	**1.5**	
Events			
Expected income			
2007 (May–Oct.)	71.4	80.3	Equivalent to 6,000–6,700 events per season
2008 (May–Oct.)	71.4	80.3	Equivalent to 6,000–6,700 events per season
Forgone income due to spill			*% of expected income*
2006	0	0	0
2007	3.6	8.0	5–10
2008	0.0	4.0	0–5
PV of forgone event income	**3.3**	**11.0**	
PV of forgone beach resort, chalet, public beach, and event income	**13.2**	**34.8**	

Source: Authors' calculations.
Note: "Expected income" is the income that would have been expected had the oil spill not occurred. PV = present value.

Chalets. Chalet complexes are clubs that include privately owned chalets that can be rented on a seasonal basis.[22] The Lebanese coast hosts 25 chalet complexes north of Jiyeh.[23] The high season for renting chalets covers six months, from May through October. On average, each chalet complex has 200 chalets, which can be rented for about US$1,000 per month.[24] Thus, the income from renting chalets averages US$5 million per month, or US$30 million per year. Assuming that the oil spill contributes to the income decline as it did in the case of beach resorts, the total forgone income to chalets is about *US$4 million to US$9 million*.

Public beaches. These beaches are owned by the state and provide free public access. Based on discussions with the Syndicate of Professional Divers and the nongovernmental organization (NGO) Cedars for Care, there are about 15 public beaches in Lebanon, extending over 10–12 kilometers. The peak season covers three months, from July to September. Most likely, the oil spill affected only the beaches north of Jiyeh–namely, Aabdeh, Tripoli, Batroun, Jbail, Tabarja, Jounieh, Ramlet el Baida, St. Simon, and Rmeileh.

Ramlet el Baida is by far the largest and the most frequented public beach in Lebanon, receiving about 4,600 daily visitors.[25] Assuming that each of the other public beaches receives only 10 percent of the visitors in Ramlet el Baida, this corresponds to about 460 daily visitors per beach. Accordingly, the average number of visitors to the public beaches affected by the spill is about 8,400 per day.

Because public beach entry is free, the individual benefit is assumed to be about half of that enjoyed by visitors to beach resorts, that is, US$10 per day.[26] Therefore, the expected benefits from using public beaches during high season amount to US$2.6 million per month,[27] or US$7.8 million per annual season. Assuming that the oil spill contributes to the decline in public beach benefits in a way similar to its effect on beach resorts, the total forgone income is about *US$0.7 million to US$1.5 million*.

Events. Beach resorts and chalets frequently organize weddings and other social events, from May through October. An interview in October 2006 at the Jannah coastal resort in Damour revealed that social events usually draw about 300 participants and cost US$40 per person. Beach resorts can organize at least four events per week during four months per year, and chalet complexes can arrange at least three events per week during six months of the year. Overall, there are about 6,000 to 6,700 events per season, providing an income of *US$71 million to US$80 million per year.*

Security concerns and damaged infrastructure—and, to a lesser extent, the signs of oil and potential impacts on health—led to a decline in event income. Therefore, it can be conservatively assumed that the 2006 event income declined due to conflict rather than the oil spill. Assuming that in 2007 and 2008 the oil spill contributes to the decline in event income in a way similar to its effect on beach resorts, the total forgone event income is about *US$3 million to US$11 million*.

Marinas' sports activities. Marinas offer recreational services such as boating, diving, waterskiing, docking, and maintenance of private boats. The conflict and the oil spill affected marinas' activities in different ways during different periods. For example, the conflict and the naval blockade halted the marinas' recreational services until September 8, 2006. Afterward, oil pollution of seawater and equipment and concerns about possible health effects led to a decline in the public use of marinas' recreational services and caused losses to private boats' owners.

Losses to marinas from boat rental and water sports—The Movenpick marina rents leisure boats (for fishing and boating) to hotels and private companies and provides jet skis and diving services to the public. An October 2006 interview indicated that the marina's income was about US$150,000 in 2004 from boat and jet ski rentals. The interview also suggested that three other marinas (Riviera, St. George, and Dbayeh) have the same level of revenue and together represent about 60 percent of all marinas' revenue in Lebanon. Thus, marinas' total revenue is estimated at about US$1 million per year, as shown in table 6.5.

The season for recreational activities covers May through October, peaking in July through August, when about 50 percent of the income occurs. Lacking accurate information, the estimate assumes that the

Table 6.5 Forgone Marina Income from Boat Rental and Water Sports due to Oil Spill
US$ millions

	Min	*Max*	*% of expected income*
Expected income			
2006 (Sept.–Oct.)	250	250	25
2007 (May–Oct.)	1,000	1,000	100
2008 (May–Oct.)	1,000	1,000	100
Forgone income due to spill			
2006 (Sept.–Oct.)	188	250	75–100
2007 (May–Oct.)	50	100	5–10
2008 (May–Oct.)	0	50	0–5
PV of forgone income	**238**	**377**	

Source: Authors' estimates and interview at Movenpick marina in October 2006.
Note: "Expected income" is the income that would have been expected had the oil spill not occurred.
PV = present value.

May–June and September–October periods each generate about 25 percent of total annual income. Because recreational activities resumed in September 2006, the expected income for the rest of the year was US$250,000. Based on the assumptions presented in table 6.5, the total forgone income from recreational activities at marinas is estimated to be between *US$238,000 and US$377,000*.

Losses to owners of private boats—The oil spill also damaged many private leisure boats docked in marinas and fishing boats docked in ports. The oil damage limited the owners' benefits from using their boats throughout 2006 and imposed additional cleaning costs. The forgone benefit to private owners from not using the boats from September through December 2006 is assumed to equal at least the value of the annual depreciation of the boats and the maintenance costs (cost of upkeep and docking in marinas).[28] The loss due to oiled fishing boats is estimated based on the annual maintenance costs.[29]

Interviews with several marina managers revealed that about 1,775 of boats were docked in marinas.[30] Because they belong to marinas north of Jiyeh, theoretically all of them were oiled. In reality, many marinas escaped the oil spill because of their orientations and sea currents. Because the available information does not distinguish between oiled boats and clean boats, only 50 percent, or 890, boats are assumed to have been oiled. In addition, observations during cleaning operations show that an additional 20 fishing boats were oiled in Daliyi port alone. Photo 6.4 illustrates fishing boats oiled in Daliyi port.

A boat of average size (6 to 12 meters) has a price of about US$30,000 and a lifetime of about 20 years,[31] hence an annual depreciation value of US$1,500. The cost of upkeep and docking in marinas is conservatively estimated at US$300 per meter per season. Assuming an average boat size of 9 meters, the annual cost of upkeep and docking is about US$2,700 per boat.[32]

The loss to owners of private leisure boats (890 boats) is based on the annual depreciation value and maintenance costs (US$4,200), totaling US$3.7 million. The loss to owners of oiled fishing boats (20 boats) is estimated based on the annual maintenance costs (US$2,700), amounting to US$54,000. Adding the two loss figures, the total damage to private owners of leisure and fishing boats is about *US$3.8 million*. When that estimate is added to the other marina-related loss estimates above, the overall losses to marinas' sports activities are *US$4 million to US$4.2 million*.

Photo 6.4 Oil Pollution in the Port of Daliyi

Source: Ministry of Environment of Lebanon.

Palm Islands Nature Reserve. Palm Islands Nature Reserve is a marine reserve and a Mediterranean Specially Protected Area under the Barcelona Convention (1995) and the Ramsar Convention of Wetlands (1971). Access to the reserve was halted from the start of conflict until the lift of the naval blockade. The conflict and oil spill considerably reduced the tourism and associated revenues to local communities (for example, transportation and other services) and affected the area's biodiversity (for example, by oiling birds and turtles).

Loss of recreation—The oil spill played a major role in reducing the number of visitors to Palm Islands Nature Reserve, especially after the end of the naval blockade. The loss in tourism in 2006 is estimated by the difference between the expected number of tourists and actual arrivals.

About 80 percent of tourists to the reserve use its facilities for boat transportation and group excursions to islands. Over the course of a tourist season, there are usually 500 visiting groups of about 15 people per group. The forgone number of individual visitors and groups who use the Palm Islands Nature Reserve facilities is estimated at 20,760 individuals, as shown in table 6.6. The estimated expected annual income from tourist activities is US$72,000, based on a tourist season of about 13 weeks (July–September) and the fees for each recreational activity. Therefore, the total loss in tourism-related income to the reserve due to the oil spill is valued at about *US$15,300 to US$25,900*.

Table 6.6 Forgone Visitors and Boat-Use Income at Palm Island Nature Reserve

Visitor type	*Number of visitors*	
Expected visitors in 2006[a]	*22,500*	
Individual visitors by own boats[b]	4,500	
Individual visitors by PINR boats	10,500	
Groups by PINR boats	500	
Actual visitors in 2006	*1,740*	
Individual visitors by PINR boats	812	
Groups by PINR boats	62	
Forgone visitors in 2006	*20,760*	
Individual visitors by PINR boats	9,688	
Groups by PINR boats	438	
Income	*Minimum (US$ 000)*	*Maximum (US$ 000)*
Expected annual income (13 weeks)[d]	72.4	72.4
Forgone income due to the oil spill		
2006[e] (3 weeks)	12.5	16.7
2007[f] (13 weeks)	3.6	7.2
2008[g] (13 weeks)	0.0	3.6
PV of forgone income	**15.3**	**25.9**

Source: Authors' estimates and as noted below.
Note: "Expected visitors" and "expected income" are the number of visitors and amount of income, respectively, that would have been expected had the oil spill not occurred. PINR = Palm Island Nature Reserve. PV = present value.
a. Number varies between 20,000 and 25,000 (MOE statistics).
b. Number represents the difference between the total number of visitors and the number of those (individuals and groups) using PINR boats.
c. Number represents same ratio of individual visitors to total visitors as used in estimating "expected visitors."
d. Expected annual income is based on an average fee of US$62.50 per group, US$4 for individual transportation, and US$6 for renting chairs and umbrellas (5 percent of visitors rent chairs and umbrellas): (62.5 x 438) + (4 x 9,688) + (0.05 x 6 x 20,760) = 72,355.
e. Range between a minimum of (0.75 x 72,400 x 3/13) and a maximum of (1.0 x 72,400 x 3/13).
f. Range between a minimum of (0.05 x 72,400) and a maximum of (0.1 x 72,400).
g. Range between a minimum of (0.00 x 72,400) and a maximum of (0.05 x 72,400).

[[AU: Why does the "visitors by own boats" category NOT appear under "Actual visitors in 2006" or "Forgone visitors in 2006"? Add any explanation for the absence of the corresponding data to note "b" above.]]

[[AU: which number?]]

[[AU: Where does this note now go (which is now note "c" because of the deletions)? Place the superscript "c" at the appropriate place(s) in the table.]]

Damage to biodiversity—Around 92 oiled birds from 19 different species were observed in the Palm Islands Nature Reserve, one of which is displayed in photo 6.5.[33]

In addition, three dead loggerhead turtles (*Caretta caretta*) were reported on Palm Islands Nature Reserve.[34] The insufficiency of the data makes it difficult to estimate the damages to loggerhead turtles.[35] We estimate only the damages to birds based on a restoration cost model developed by McCay and others (2004), which relates the cost per bird to the average abundance per unit area:[36]

$$y = 10{,}260 * e^{-0.0138*x}, \tag{6.1}$$

Photo 6.5 Oiled bird

Source: Italian Task Force.

where x = annual mean abundance (number per square kilometer),
y = cost per bird (US$),
e = 2.718.

Applying this model to the injured species[37] provides a total damage cost estimate of US$48,600. Loureiro and others (2006) indicate that the birds found and collected after an oil spill typically represent only 15–50 percent of all the oil-killed birds. Assuming the same range for the Lebanon case, the total damage cost associated with the oiled birds falls between *US$97,200 and US$324,000*. The result should be regarded with extreme caution, however, because no other studies valuing these damages were found.

Cost of impact assessment and monitoring—The MOE carried out an impact assessment study of the oil spill on Palm Islands Nature Reserve biodiversity, which cost about US$27,000.[38] In addition, a long-term monitoring program foreseen for the reserve and other ecologically significant sites affected by the spill is estimated to cost about US$1.2 million to US$1.7 million over a period of 7 to 10 years.[39] Thus, the total cost of the impact assessment and monitoring program is about US$1.2 million to US$1.7 million. Only a part of this cost is likely directly related to the oil spill damage, the rest being an expression of the willingness to pay (WTP) for future information.

Assuming that 50 percent of the total impact assessment and monitoring cost is due to the oil spill damage, this represents about US$600,000 to US$850,000. Added to the above estimates, the overall impact of the oil spill on the Palm Islands Nature Reserve and other ecologically sensitive areas amounts to *US$0.7 million to US$1.2 million*.[40]

Byblos World Heritage. Built during Phoenician times, Byblos is considered the oldest inhabited city in the world and is designated a World Heritage site. The oil spill heavily contaminated the harbor, two medieval towers at its entrance, and other ancient ruins below the archaeological Tell in Byblos (UNDP 2007). This reduced significantly the number of visitors and threatened the historical value of the ruins.

Loss of recreational-tourist value—Visits to Byblos take place throughout the year and are usually organized both by tour operators and private individuals. According to the Ministry of Tourism, there are 22 tour operators in Lebanon, of which at least 8 organize trips to Byblos.[41] There are about 300 visitors per year, and the fee is about US$30 per person if meals are excluded.[42] Accordingly, the tour operators' annual income from organizing visits to Byblos is about US$72,000.

The proximity of Byblos to Beirut (only 40 kilometers away) suggests that more visitors travel there in private cars than with tour operators. Assuming that they number twice as many as those coming with tour operators and that their average spending is US$15 per person,[43] the annual income from individual trips would be about US$72,000. Thus, the annual income from all visits to Byblos is about US$144,000. The associated damage to tourism in Byblos and other historical towns ranges between US$15,300 and US$42,800, as shown in table 6.7.

Table 6.7 Forgone Tourism Income from the Byblos World Heritage Site
US$ 000

Income	*Min*	*Max*	*Assumptions*
Expected annual income	144	144	(8 tour operators x 300 visitors x US$30) +(4,800 individual visitors x US$15)
Forgone income due to oil spill			
2006 (Sept.–Dec.)	9.0	24.0	25–50% of expected Sept.–Dec. income
2007 (Jan.–Dec.)	7.2	14.4	5–10% of annual expected income
2008 (Jan.–Dec.)	0.0	7.2	0–5% of annual expected income
PV of forgone income	**15.3**	**42.8**	

Source: Authors' estimates and interviews with tour operators.
Note: "Expected income" is the income that would have been expected had the oil spill not occurred.
PV = present value.

Loss of historical-cultural value—No studies estimating the losses of historical-cultural value of Lebanese sites were found.[44] Thus, the present valuation relies on the restoration cost method. A September 2006 mission undertaken by a team of the United Nations Educational, Scientific and Cultural Organization (UNESCO) declared that the most serious damages of historical-cultural value resulting from the conflict concern the World Heritage site in Byblos.

Accordingly, a special procedure to clean the archaeological remains covered by fuel was recommended. Assuming that the stones were cleaned manually with a specially prepared solution according to the components of the fuel, the total cleanup cost of operations would be US$100,000 (UNDP 2007). This figure is assumed as the minimum bound of the damage caused by the oil spill to archaeological sites. Overall, the estimated damages to Byblos range between *US$115,300 and US$142,800*.

Restaurants. Fish is an important food served in many Lebanese restaurants on the coast. Both the conflict and the oil spill negatively affected the activity of these restaurants. The conflict reduced the number of tourists, which decreased fish demand and consumption. The oil spill also contributed to this reduction, mainly because of people's fears that contaminated fish could harm human health.

According to the Syndicate of Restaurant Owners, about 170 restaurants specialize in fish, of which 150 are on the seashore and the rest inland.[45] Based on the same source, the annual turnover of a fish restaurant is in the range of US$200,000 to US$600,000, averaging to US$400,000 per year, or US$33,000 per month. The interviews with the restaurant owners suggested that the oil spill reduced the expected income from September to December 2006 by about 75–100 percent, as shown in table 6.8. Therefore, the total forgone benefits to restaurants due to the oil spill range between *US$19.5 million and US$31.1 million*.

Fishing. In Lebanon, fishing is usually artisanal and small-scale. It supports about 30,000 fishermen (IUCN/Green Line 2006) who catch an average of 8,000 tons of fish per year (FAO 2006). The oil spill caused *direct* losses—oiling boats and gears—and *indirect* losses by reducing the demand for fish, either because of actual fish contamination or the perceived ill effects of the fish on health. Below are the estimated impacts of the oil spill on commercial and seashore fishing.

Table 6.8 Income Forgone to Restaurants due to the Oil Spill

	Min	*Max*	*Assumptions*
Total number of fish restaurants	170	170	n.a.
Annual turnover (US$000/rest./yr.)	400	400	n.a.
Monthly turnover (US$000/rest./mo.)	33.3	33.3	n.a.
Expected income Sept.–Dec. 2006 (US$000/rest.)	133.3	133.3	n.a.
Forgone income due to oil spill			
2006 (US$ millions)	17.0	22.7	75–100% expected income, Sept.–Dec. 2006
2007 (US$ millions)	3.4	6.8	5–10% expected annual income, 2007
2008 (US$ millions)	0	3.4	0–5% expected annual income, 2008
PV of forgone income due to oil spill	**19.5**	**31.1**	

Source: Authors' estimates and interviews at the Syndicate of Restaurant Owners in October 2006 and April 2007.
Note: "Expected income" is the income that would have been expected had the oil spill not occurred.
PV = present value. n.a. = not applicable.

Commercial fishing—FAO (2006) provides information on the fish catch per season and total income from fishing in 2004. The fish catch varies widely across seasons, accounting for 30 percent of the annual catch in spring, 42 percent in summer, 22 percent in autumn, and only 8 percent in winter. The annual income from fishing is about US$31 million. Applying the seasonal catch factor in terms of percentage of total catch to total income, the expected fish income from September through December 2006 is estimated at US$7.4 million.

A University of Balamand survey of about 200 fishermen from North Lebanon found that the conflict and the oil spill caused a 45 percent drop in their income.[46] Extrapolating the estimates to all fishermen on the coast north of Jiyeh and conservatively assuming that only 50 percent of this income drop is attributable to the oil spill, the associated damage cost in 2006 is about US$1.3 million. Consequently, the total losses during the 2006–08 period are estimated at *US$3 million to US$6 million*.

Shoreside fishing—Shoreside fishing is popular in Lebanon for both recreation and consumption. No accurate information on the impacts of the oil spill on recreational fishermen is available, except that it reduced fish price and catch. Thus, this report assumes that the oil spill affected recreational fishermen similarly to commercial ones.

In the south of Lebanon, there are about 1,300 anglers,[47] who account for one-third of the total number in the country.[48] As the oil spread from Jiyeh toward the north, it is assumed that it affected the remaining two-thirds of the total number, or another 2,600 anglers. Based on an average catch of 2 kilograms per day for a minimum of 50 days and an average price of US$4 per kilogram (FAO 2006), the consumption value of the shoreside catch is US$1 million per year. In the absence of information on the recreational value of shoreside fishing in Lebanon, we assume it is similar to that of public beaches (US$10 per day), amounting to a total recreational value of US$1.3 million per year. Overall, the annual value of shoreside fishing is US$2.3 million.

Considering that the fish catch varies seasonally in the same proportion as in commercial fishing, the expected shoreside fish income from September through December 2006 is estimated at about US$0.7 million. The impact of the oil spill on shoreside fishing is valued based on the same percentages adopted for commercial fishing. Accordingly, the present value of the benefits forgone during 2006–08 is in the range of *US$260,000 to US$472,000*.

Overall, the aggregated impact of the oil spill on commercial and shoreside fishing is in the range of *US$3.2 million to US$6.5 million*.

Oil fuel spilled and burned in Jiyeh. Of the total estimated 44,000 tons of IFO 150 stored at the Jiyeh electrical power plant, about 12,000 to 15,000 tons of oil leaked into the sea and the rest burned. At an approximate cost of US$450 per ton, this loss is estimated at US$20 million. In addition, the cost of hiring three floating tankers to replace the burnt tanks is estimated at around US$4 million. The maintenance and operation of the floating tankers, transfer of fuel from different plants to Jiyeh power plant, and soil testing at the burnt tanks' site is valued at US$15 million.[49] Overall, the direct loss due to the spilling and burning of Jiyeh fuel oil is *US$39 million*.

Oil spill cleanup. The expenditures related to the oil spill cleanup include the direct cleanup cost, the cost of treating and transporting the oiled waste, and the cost of monitoring the cleanup operations.

Cleanup cost—Soon after the ceasefire, the MOE estimated the cost of oil spill cleanup in the range of US$137 million to US$205 million (MOE 2007b), based on the average per-unit marine oil spill cleanup cost of US$13,800 per ton in the region (MOE 2006b, 2006c). The cleanup priorities set by the MOE included two phases (PCM 2007):

1. Removal of free-floating mobile oil from the sea and shore and removal of contaminated debris, including sand, pebbles, used equipment, and garbage

[[AU: Please provide text citation]]

Table 6.9 Income Forgone to Commercial and Shoreside Fishing due to the Oil Spill

US$ millions

	Commercial fishing			*Shoreside fishing*		
	Min	*Max*	*Assumptions*	*Min*	*Max*	*Assumptions*
Expected annual income	31.0	31.0		2.3	2.3	
Expected income (Sept.–Dec.)	7.4	7.4	\$31 million x (0.22 + 0.08/3)	0.7	0.7	50% of total forgone loss (50% x 45% x \$0.7 million)
Forgone income due to the oil spill						
2006 (Sept.–Dec.)	1.3	1.3	50% of total forgone loss (50% x 45% x \$6 million)	0.16	0.16	50% of forgone income (Sept.–Dec.)
2007	1.6	3.1	5–10% of expected annual income	0.12	0.12	5–10% of expected annual income
2008	0.0	1.6	0–5% of expected annual income	0.0	0.12	0–5% of expected annual income
PV of income forgone due to oil spill	**3.0**	**5.9**		**0.26**	**0.47**	

Source: Authors' estimates and FAO 2006.

Note: "Expected income" is the income that would have been expected had the oil spill not occurred. PV = present value.

2. Cleanup of polluted sites to a higher level of cleanliness, depending on the nature and the environmental and economic sensitivity of the site

The cleanup expenditures as of April 2007 are estimated at US$14.9 million (UNDP 2007; SDC 2007; communication with experts).[50]

Cost of oiled waste—The first cleanup phase (illustrated in photo 6.6) generated about 1,030 cubic meters of liquid waste and 6,250 cubic meters of solid waste (PCM 2007).[51] We estimate the cost of treating and transporting the oiled waste based on the waste management options considered by the MOE (2007a). Accordingly, if the liquid waste is reprocessed at the Zahrani refinery, it would cost about *US$92,000*.

For the solid waste, options to treat low- to medium-contaminated sand are different from those to treat heavily contaminated sand and solid waste. Most of the 6,250 cubic meters is considered hazardous waste because of the toxicity of the fuel (MOE 2007b, 2007c). Lacking more accurate information, it is assumed that 25 percent of the solid waste includes low- to medium-contaminated sand, and 75 percent represents heavily contaminated sand and pebbles.

Considering that (a) the quantity of low- to medium-contaminated sand will be reused in the cement, construction, or asphalt industries; (b) the unit cost is US$10 per cubic meter;[52] and (c) the transport cost is US$80,000, the total cost of transporting and treating the low- to medium-contaminated sand is estimated at US$96,000. The heavily contaminated

Photo 6.6 Containers of Oiled Waste

Source: M. El Sarji.

sand and pebbles are likely to be shipped under the Basel convention. At a cost of US$10,000 per cubic meter,[53] the total cost to ship and treat the heavily contaminated sand and pebbles would be about US$47 million.

Adding the costs of transporting and treating all the oiled waste resulting from the first cleanup phase, the total is estimated at *US$47.1 million*.

Cost of monitoring operations—In addition to the estimated cost of oil spill cleanup already spent as of April 2007, more cleanup and monitoring are needed. Some of these costs are estimated based on discussions with MOE. They include the costs related to the second phase of the cleanup and monitoring operations in the Palm Islands Nature Reserve (US$1 million) and the costs of monitoring pilot sites along the Lebanese coast (US$0.5 million), totaling *US$1.5 million* (World Bank 2007).

Overall, the cost of oil spill cleanup, treatment of oiled waste, and monitoring the Lebanese coast is estimated at *US$63.5 million*.

Summary: Oil Spill Damages

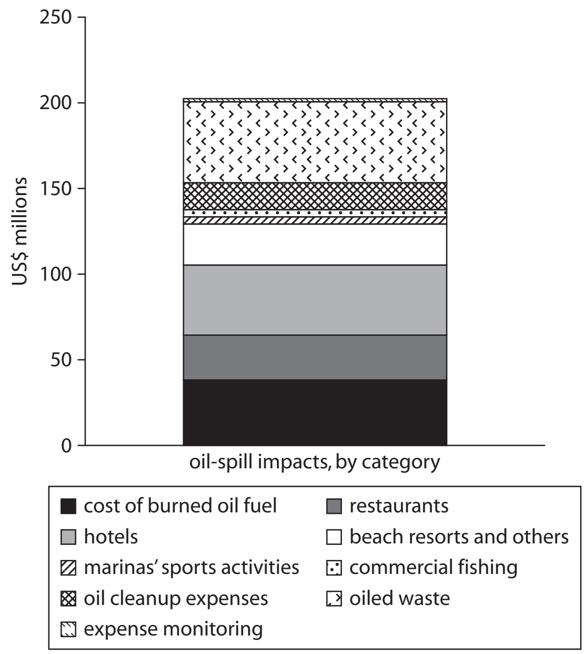
The overall damage and cleanup cost due to the oil spill is conservatively estimated at about *US$203 million*, or *1 percent of GDP* in 2006. Table 6.10 and figure 6.1 present the main components of this cost.

Table 6.10 Estimated Costs of Damage and Cleanup due to the Oil Spill

Type of cost	*Min*	*Max*	*Mean*	*% of total*
Damage costs, by impact category			39.1	19
Cost of oil fuel burnt	39.1	39.1		
Restaurants	19.5	31.1	25.3	12
Hotels	22.8	59.6	41.2	20
Beach resorts, chalets, public				12
beaches, events	13.2	34.8	24.0	
Marinas' sports activities	4.0	4.2	4.1	2
Commercial fishing	3.0	5.9	4.4	2
Seashore fishing	0.3	0.5	0.4	0
Palm Islands Nature Reserve	0.7	1.2	1.0	0
Byblos	0.1	0.1	0.1	0
Total damage costs	**102.8**	**176.4**	**139.6**	**69**
Oil-spill cleanup				
Expenditures as of April 2007	14.9	14.9	14.9	7
Oiled waste	48.2	48.2	48.2	24
Monitoring expenses	1.5	1.5	1.5	1
Total cleanup costs	**63.5**	**63.5**	**63.5**	**31**
TOTAL COSTS OF OIL SPILL	**166.3**	**239.9**	**203.1**	**100**

Source: Authors' calculations.

Figure 6.1 Annual Degradation Cost Caused by the Oil Spill



Source: Authors' calculations.
Note: NPV = net present value (t = 25 years, r = 4 percent).

The damage cost accounts for nearly 70 percent of the total oil spill cost. Such a high share is attributable mainly to the costs associated with the burnt oil and the losses to hotels, beach resorts, and restaurants. Relatively important damages also occurred to marinas, sports activities, and commercial fishing. The lowest estimates—for damage to the Palm Islands Nature Reserve and Byblos—are mainly a result of scarce data and do not suggest that they are the least important values.

The cleanup cost accounts for about 30 percent of the total oil spill cost and is dominated by the treatment and shipment of oiled waste, as a result of the expensive shipping procedures under the Basel convention.

It should be noted that the total estimate represents the lower bound of real costs because it does not capture several damage costs, such as the effects on health (for example, skin diseases), on ecosystem services (for example, loss in habitat for spawning), and on marine biodiversity. The estimate also fails to cover the cost of many cleanup operations expected to be performed after April 2007. In addition, for many impacts, the aggregate result tends to reflect the real cost of the oil spill only in part because of the conservative assumptions adopted for valuation. Moreover, the overall estimate and its breakdown by impact should be regarded with much caution because many of the assumptions are subjective for lack of accurate data.

Demolition, Military, and Medical Waste

The conflict in Lebanon destroyed the country's infrastructure in many areas, leaving enormous amounts of demolition, military, and medical waste. This section focuses on (a) the impacts of demolition waste resulting from the military aggression; (b) the impacts of unexploded ordnances (UXOs), as environmental waste, on people's lives and sources of income; and (c) the increase in medical waste associated with the humanitarian relief effort.

During the conflict, the bulk of the military operations concentrated in three areas: the southern suburbs of Beirut, the districts of the South, and the Baalbek El-Hermel region. Destruction of residential units in these areas caused significant quantities of demolition waste. The constituents of typical demolition debris can be grouped into the following categories:

- *Primary inert fractions:* asphalt, brick, cinder block, concrete with rebar or wire mesh, concrete without steel reinforcement, masonite or slate, ceramic tile, glass, dirt or earth, plastic sheet film, plastic pipe, porcelain including bathroom fixtures, ferrous and nonferrous metal, electrical wiring, fiberglass insulation, and plastic buckets or containers.
- *High organic-based fractions:* ceiling tiles; corrugated shipping containers; insulation-treated cellulose; insulation-sheathing; pallets, spools, and reels; pressboard or chipboard; roofing materials (such as roofing felt and asphalt shingles); dimensional lumber and shapes (clean); plywood and particle board; and oriented strand board.
- *A range of composite materials* (that may require special handling): carpeting, carpet padding, gypsum wallboard (mainly gypsum with paper backing), electrical fixtures (metal, light tubes or bulbs, and ballasts), electrical switches, rubber hosing and conduits, tires (some with wheels), painted wood, pressure-treated wood, and wood composites.
- *Furniture, electronic appliances, and personal belongings,* which constitute a considerable portion of the demolition waste resulting from destruction by military activities.

The demolition waste caused damages related to waste hauling, disposal in landfills, road depreciation during transport, traffic delays, and depreciation of land surrounding dump sites. In addition, the demolition waste in ponds and valleys most likely provoked ecosystem damages, such as groundwater pollution.

As of April 2007, there were 864 cluster bomb strike locations in South Lebanon, with an estimated *1 million unexploded cluster munitions* on the ground, contaminating a total of 34 million square meters.[54] Between August 14, 2006, and April 03, 2007, UXOs caused 29 deaths and 195 injuries among residents of South Lebanon (MACCSL 2007). The UXOs also prevented access and exploitation of agricultural land, rangeland, and forests.

With the rise in casualties and hospital bed occupancy numbers, generation of medical waste also increased significantly. The conflict caused 1,200 deaths and 4,400 injuries (GoL 2006a), generating an estimated 200 to 250 tons of medical waste (UNDP 2007), with impacts on the treatment, transport, and disposal costs.

Methodology

Valuation of the impacts of waste generated during the conflict refers to 2006 as a base year. It should be noted that the lack of information concerning the extent of the impact sometimes prevented valuation, as in the case of groundwater pollution by demolition waste. Safety concerns also made it difficult to arrive at accurate estimates—for example, of the impacts of UXOs on agricultural land. Thus, the estimates tend to undervalue the real damage.

Impacts of demolition waste. The additional costs or damages generated by waste loading, transport, road depreciation, traffic delays, and disposal are based on cost-based methods:[55]

- *Damages due to loading, hauling and transport* are valued based on the cost of these activities on the market.
- *Road depreciation* is valued based on the cost of refurbishing the roads damaged by demolition waste transport.
- *Traffic delays* are valued based on the cost of fuel and the opportunity cost of the time lost in traffic due to demolition waste.
- *The cost of land for waste disposal* is valued based on the market price of land near the damaged sites.

Impacts of military waste. The cost of human deaths and injuries caused by military waste is estimated in terms of disability-adjusted life years (DALYs).[56] The DALY provides a common measure of disease burden for illnesses and premature mortality.

To estimate the value of 1 DALY, we use two approaches. The human capital approach (HCA) estimates the indirect cost of productivity loss through the value of an individual's future earnings (Kirch 2008). Accordingly, 1 DALY corresponds to one person's average contribution to production, namely the GDP per capita. This method provides a lower bound for the loss of 1 DALY.

The second approach, the value of a statistical life (VSL), measures the WTP to avoid death. This estimate is reached by observing individual behavior when trading off health risks and money (Johansson 2006). The VSL is calculated by dividing the marginal WTP to reduce the risk of death by the size of the risk reduction. By this measurement, the value of 1 DALY corresponds to the VSL divided by the number of discounted average years of life lost because of an adult's death (World Bank 2005). The VSL method provides an upper bound of health damages.

The impact of military waste on access to agricultural lands is based on the value of lost income due to the scattered UXOs. Lacking more accurate information, it is assumed that the limited access would have a significant impact on farmers for at least two years. In addition to the above costs, valuation includes the costs of demining carried out by the government.

Impacts of medical waste. These impacts are estimated based on the costs of handling the medical waste generated during the conflict, which include the costs of treatment, transport, and disposal.

Damage Costs due to Demolition Waste

To assess the environmental damage associated with the demolition waste, the analysis considers the impact of the actual handling of the waste after the ceasefire. The following subsections estimate the generated quantities of demolition waste and the associated costs of hauling and transport, road depreciation, traffic delays, and the cost of land for waste disposal.

Generated quantities. Government agencies and international organizations conducted field visits to assess the extent of the physical damage in Beirut's southern suburbs, the South, and Baalbek El-Hermel. These efforts resulted in different estimates of the generated quantities of demolition waste. This subsection presents the available information as of April 2007 and adopts the most recent government estimate as an input to the analysis.

Beirut's southern suburbs—UNDP reported that about 150 residential buildings were destroyed, each building containing an average of 30 units, for a total of 4,500 units (UNDP 2006). Other buildings had been damaged or partially demolished.

A joint effort between the Municipality of Haret Hreik and the Department of Architecture and Graphic Design at the American University of Beirut assessed 102 completely demolished buildings, 28 partially blasted buildings, and 70 damaged buildings in August 2006, as the set of images in photo 6.7 depict.

A rapid preliminary damage assessment by the European Commission's Joint Research Center and the European Union Satellite Center indicated that 326 residential buildings were either damaged or destroyed in the southern suburbs, of which 269 were in Haret Hreik (EC 2006b). The Order of Engineering in Beirut assessed 200 destroyed buildings and an additional 100 inhabitable buildings (GoL 2006b).

South and Baalbek El-Hermel—The study team conducted a field survey in October and November 2006 during the preparation of this study. Interviews with heads of municipalities revealed that more than 8,790 housing units were demolished in the South. Most are concentrated in the Cazas of Marjeyoun, Nabatieh, Bent Jbeil, and Tyre, with relatively less destruction in the Cazas of Hasbaya and Saida.

In Baalbek El-Hermel, the field visit revealed that the conflict affected more than 6,000 housing units, of which 375 were destroyed, 400 badly damaged, and the rest severely to lightly damaged. Based on this information, the authors' own estimate of the quantity of demolition waste generated varies between 2 million to 3.7 million cubic meters, as shown in table 6.11.

A UNDP-sponsored initiative to assess the environmental damage of the July conflict estimated the total volume of rubble resulting from destruction in the range of 2.5 million to 3 million cubic meters (UNDP 2007).

Based on August 2007 communication with the office of the President of the Council of Ministers (PCM), the latest figures indicate 11,140 housing units destroyed, 1,249 housing units partially destroyed, and 81,000 housing units lightly damaged in the South and the Baalback

Photo 6.7 Building Damage in Beirut's Southern Suburbs

a. Destroyed buildings

b. Partially blasted buildings

c. Damaged buildings

Source: M. El Fadel and the study team.

El-Hermel areas. The volume of demolition waste transported to that date was 5.75 million cubic meters, of which 1.43 million cubic meters was in Beirut, 3.32 million cubic meters was in the South, and 1 million cubic meters was in Bekaa (PCM 2007). This indicates that previous calculations were extremely conservative and underestimated the actual volumes being removed. *Subsequently, this estimate of the damage costs due to the conflict is based on the latest numbers reported by the PCM.*

Table 6.11 Estimated Volume of Demolition Waste

Waste type and location	*Volume*	*Assumptions*
Surface area per apartment	150–200 m^2	
Total walls (inner, outer, pillars)[a]	45–90 m^3	10–15% of surface area 3m as average height
Unit slab[a]	45–60 m^3	0.3 m average thickness
Furniture and personal belongings[a]	18.75–50 m^3	25–50% occupancy of surface area 0.5 m as average height
Total per housing unit	**109–200 m^3**	
In Beirut's southern suburbs		
Number of units destroyed[b]	9,000	300 buildings, 10 stories, 3 apts./story
Number of units partially blasted[c]	840	30% of the housing unit damaged
Number of units damaged[c]	2,100	5% of the housing unit damaged
Area's total demolition waste	**1,020,000–1,871,000 m^3**	
In the South		
Number of units destroyed[d]	8,791	
Area's total demolition waste	**956,000–1,758,000 m^3**	
In Baalbek El-Hermel		
Number of units destroyed[e]	375	
Number of units badly damaged[e]	400	30% of housing units damaged
Area's total demolition waste	54,000–99,000 m^3	
TOTAL FROM ALL AREAS	**2,030,000–3,728,000 m^3**	

Source: Authors' estimates in addition to data sources noted below.
Note: Data are based on field visits conducted during the preparation of this report (October and November 2006). m^2 = square meters. m^3 = cubic meters.
a. Expert opinion, field visits.
b. GoL 2006b.
c. Dr. M. Fawaz, Department of Architecture and Graphic Design, American University of Beirut, pers. communication, November 2006.
d. Municipalities of South Lebanon.
e. M. El Jammal, head of Baalbek Municipality, pers. communication, October 18, 2006.

Waste loading, transport, and disposal. Although demolition waste is usually landfilled, the corresponding landfills are generally not subject to the same regulatory procedures as municipal solid waste (MSW) landfills because the latter contain mostly inert material.[57] While the cost of landfilling the demolition waste is relatively lower than that of MSW, some components of the demolition materials may be recycled, such as concrete, asphalt, metals, and wood.

In Lebanon, immediate removal and disposal of demolition waste was required to allow for reconstruction activities. Concerned municipalities, together with the Council for Development and Reconstruction in Beirut, the Ministry of Public Works and Transport in Baalbek, and the Council of the South in the Southern Districts, identified disposal sites for each region and contracted the excavation, hauling, transport, and disposal of the demolition waste.

In Beirut's southern suburbs, the collected demolition waste has been haphazardly dumped at four sites—two in low-lying areas near the sea, one on the other side of the road within the Choueifat cadastral area, and a temporary dump site along the Airport Road within the Bourj Al Barajneh cadastral area, as seen in photo 6.8.

The slope of the deposited waste has reached almost a 1-to-1 ratio, which could pose a safety hazard in the absence of adequate stability control measures. Sea encroachment occurred to a minimum extent on the dump sites by the sea. Wherever this encroachment occurred, the bulky nature of the demolition waste gave it a relatively good angle of stability, minimizing the likelihood of its collapse into the sea. Although this invariably damaged the coastal ecosystem, the impact is difficult to quantify monetarily.

In the South, some municipalities where little demolition waste was generated used the waste to fill depressions in the roads or to reconstruct other building sites. In towns where large volumes of demolition waste were

Photo 6.8 Rubble Disposal Site in Beirut

Source: M. Sarraf.

generated, it was disposed of on nearby lands. Such is the case of Al Khyam, where the municipality threw the rubble in a nearby valley, 300 meters off the main road, facing the Israeli border. In Bint Jbeil, the municipality disposed of part of the waste in a valley 2 kilometers off the main road. However, the neighboring municipality of Aytaroun intervened and requested that the waste be directed to its own town to fill a seemingly abandoned pond, as shown in photo 6.9. The municipality of Maroun el Ras also sent its demolition waste to Aytaroun.

The damage associated with dumping of demolition waste in valleys and ponds goes beyond the cost of land, to include ecosystem damage and visual intrusion. However, the latter costs are difficult to quantify monetarily. Impacts on hydrology and hydrogeology are equally difficult to quantify monetarily but are expected to be limited because a considerable portion of the household hazardous material was removed prior to transport to the dump sites (UNDP 2007). Similarly, the opportunity cost associated with land use at dump sites is difficult to quantify but is not expected to be high, particularly in Khyam because of its proximity to the Israeli border.

In Baalbek El-Hermel, the collected waste was dumped in an abandoned quarry and in several other locations in the suburbs of Baalbek. Some waste was also used to rehabilitate land depressions caused by the military aggression.

Field visits revealed that sorting of some material such as construction steel, asbestos mats, and concrete bricks took place at the dump sites,

Photo 6.9 Aytaroun Pond Filled with Demolition Waste

Source: M. El Fadel and the study team.

primarily to recover steel for recycling. Other waste components such as personal belongings, furniture, and white goods could not be sorted because of the intensity of the destruction.

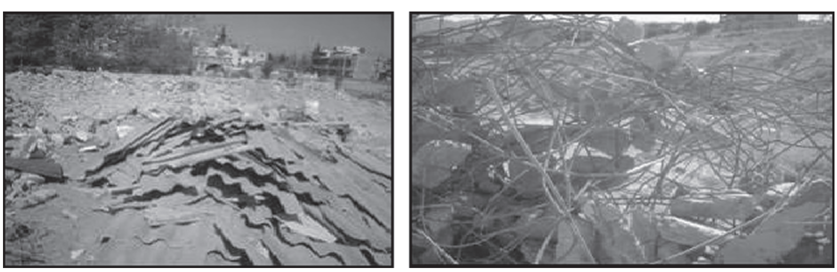
Asbestos mats were encountered mainly in Baalbek El-Hermel, as seen in photo 6.10. No asbestos was found upon preliminary site assessment as part of the UNDP initiative in the Beirut's southern suburbs and the South. No official reports on asbestos contamination of the waste have been published to date. Moreover, visual site inspections for asbestos-containing materials suggest that asbestos contamination is not a major issue of concern (UNDP 2007). As such, while friable asbestos poses a potential occupational hazard, the limited short-term exposure during the postconflict period is not likely to cause the development of severe health implications among the workers. Again, it is difficult to assign a monetary value to this impact, especially following such a short-term exposure.

Based on field visits and interviews, the equivalent unit cost of hauling and transporting the demolition waste is estimated at US$2.38 per cubic meter, as shown with the other cost estimates in table 6.12. Accordingly, the total cost of hauling and transport of the generated demolition waste is around *US$13.7 million.*[58]

Road depreciation. Two sets of roads can be identified in terms of damage from the movement of trucks transporting demolition waste: (a) roads in the South and Baalbek El-Hermel and (b) roads in the Beirut area. The transport of demolition waste did not significantly affect the roads in the South and in Baalbek El-Hermel, thus the damage to road infrastructure in these areas can be directly attributed to the military aggression.

Photo 6.10 Demolition Waste in Baalbeck El-Hermel

a. Asbestos mats **b. Steel waste**



Source: M. El Fadel and the study team.

Table 6.12 Estimated Cost of Loading and Transporting Demolition Waste

Cost type	*Estimate*
Waste hauling[a]	
Bulldozer charging rate[b] (US$/day)	400
Filling capacity of 3 bulldozers[c] (truck/day)	30
Daily volume of demolition waste loaded (m^3/day)	540
Cost of loading each truck (US$/$m^3$ of demolition waste)	**0.07**
Waste transport[a]	
Truck charging rate[b] (US$/day)	250
Daily number of round trips	6
Loading capacity per truck (m^3)	18
Daily volume of demolition waste transported per truck (m^3/day)	108
Cost of transport (US$/$m^3$ of demolition waste)	**2.31**
Total unit cost (US$/$m^3$)	**2.38**
Cost in Beirut's southern suburbs (US$ millions)	**3.4**
Cost in the South (US$ millions)	**7.9**
Cost in Baalbek El-Hermel (US$ millions)	**2.4**
TOTAL COST (US$ millions)	**13.7**

Source: Authors' calculations.
Notes: All cost estimates from the year 2006. m^3 = cubic meters.
a. Based on field surveys and expert opinion.
b. Including wage of driver.
c. Average number of bulldozers per site, based on field surveys and expert opinion.

[[AU: Specify unit indicator of truck capacity: "m3/truck/day"? If it's 30 cubic meters per truck, would the estimate be 90 instead of 30? Or is the capacity 10 cubic meters per truck?]]

In contrast, the road infrastructure in the Beirut area was negatively affected by the high number of trucks required to move the significant demolition waste volume concentrated in Beirut's southern suburbs. Based on Geographical Information Systems (GIS) analysis and field surveys, table 6.13 shows that the estimated road refurbishment cost in Beirut due to the damage of demolition waste transport ranges between *US$240,000 and US$720,000*. These estimates are associated with a high level of uncertainty because it is difficult to separate the damage related directly to the conflict from the damage related to truck travel in Beirut's southern suburbs.

Traffic delays. In Baalbek El-Hermel and in the South, traffic delays due to transportation of demolition waste were not encountered because of traffic rerouting away from the city center and because the dump site was on the city outskirts. In contrast, in Beirut's southern suburbs, the increased number of trucks on congested roads caused many people using the southern corridor of Beirut to spend an extra one to three hours in traffic.

Table 6.13 Cost of Road Depreciation in Beirut

Cost factor	*Estimate*
Average road length (km)[a]	2–3
Average road width (m)[a]	6–8
Average road area (m^2)	12,000–24,000
Cost of road refurbishment (US$/$m^2$)[a]	20–30[b]
40 cm of compacted gravel	
10 cm of asphalt	
TOTAL COST (US$)	**240,000–720,000**

Source: Authors' calculations.
Note: Data based on 2006 estimates.
a. Based on field surveys, expert opinion, and GIS analysis.
b. Range accounts for degree of intervention and thickness damaged.

[[AU: Move the road materials to this note ("40 cm of compacted gravel and 10 cm of asphalt")? Otherwise, table seems to be missing data under the "Estimate" column.]]

While it is difficult to differentiate between delays related to trucks transporting demolition waste and delays related to bombed roads in Beirut, the delays arguably would have been much shorter without truck movements. Therefore, a delay of two hours per day is attributed to the transport of demolition waste.

This delay translates to an economic loss of about *US$51 million to US$68 million*, in terms of wages and fuel, as detailed in table 6.14. A factor of 0.5 is applied to account for opportunity cost versus actual cost, assuming that half of the time lost in traffic delays is productive. The other half could be translated into an impact on quality of life, which was not estimated in monetary terms. In assessing these estimates, the following factors are also worth noting:

- The road structure (narrow and poorly maintained roads) exacerbates traffic congestion.
- Trucks carrying debris were working around the clock with practically no alternate routes or sites, particularly in Beirut's southern suburbs.
- Working off-peak was not an option, even when the hauling schedule decreased to 12 hours or less.
- A proper public bus transit system does not exist in the area, and general traffic is dominated by passenger trips or shared taxis.

Cost of land for waste disposal. We assume conservatively that all the waste in each area is disposed of in one equivalent landfill with a height of 25 meters and a buffer zone of 30 percent. By the estimates shown in table 6.15, the cost of land needed for disposing of the demolition waste is around US$78,000 in Baalbek El-Hermel, US$1.7 million in the South,

Table 6.14 Estimated Cost of Traffic Delays

Type of delay or cost	*Estimate*
Average extra time spent in traffic (hrs./day)[a]	2
Average hourly wage (US$/hr.)[b]	2.5
Number of working days/mo.[c]	22
Fraction of lost productive time[a]	0.5
Duration of waste removal (mos.)	6–8
Opportunity cost of time (US$/person/6–8 mos.) month)	330–440
Average daily number of affected commuters[d]	115,150
Opportunity cost of time (US$ millions)	**38–51**
Fuel consumption per hour in traffic (liter/hr.)[a]	1.0
Unit cost of fuel (US$/liter)[a]	0.8
Cost of fuel spent (US$/person/mo.)	35.2
Number of affected vehicles[d]	60,000
Cost of fuel spent (US$/person/6–8 mos.)	211–282
Fuel cost spent per 6–8 mos. (US$ millions)	**13–17**
Total cost of traffic delays (US$ millions)	**51–68**

Source: Authors' calculations.
Note: Costs based on 2006 estimates.
a. Based on field surveys and expert opinion.
b. Based on GDP of US$5,300 per capita.
c. Peak travel delays are assumed to occur 22 working days per month.
d. DMJM+HARRIS 2003.

Table 6.15 Estimated Cost of Land for Demolition Waste Disposal

Location	*Waste volume (000 m^3)*	*Landfill height (m)*	*Waste area (000 m^2)*	*Landfill area (000 m^2)*	*Land cost[a] (US$/$m^2$)*	*Total land cost (US$ millions)*
Beirut's so. suburbs	1,430	25	57.2	74.4	1,000	74.4
South	3,320	25	132.8	172.6	10	1.72
Baalbek El-Hermel	1,000	25	40.0	52.0	15	0.78

Source: Authors' calculations.
Note: Costs based on 2006 estimates. m^3 = cubic meters. m^2 = square meters.
a. Estimated land cost per square meter is based on real estate information and expert opinion.

and US$74 million in Beirut—totaling *US$76.9 million*. These numbers are underestimates because, in reality, there are more sites and the height of the waste is often lower than 25 meters, resulting in a need for larger areas.

Because most selected sites are not in prime locations, the unit cost of land adopted in the estimations is average to low. In the case of Beirut, for example, the unit cost of land by the sea ranges between US$2,000 and US$5,000 per square meter. Yet, the selected waste sites are by the airport and hence of lower value.

Disposing demolition waste on land valued at around US$1,000 per square meter may seem an enormous cost. However, it is important to note that in Beirut, alternative dump sites near the damaged sites were extremely difficult to locate, if not nonexistent. Hauling rubble from Beirut to cheaper sites in the Bekaa, the South, or the North of the country was not feasible at the time, given that the infrastructure and most connecting bridges had been destroyed. In addition, political pressure to keep the waste within the area of the southern suburbs of Beirut was mounting because of the potential benefit from steel recycling. Although the income from the latter should theoretically be deducted from the overall damage estimates, this was not possible for lack of well-documented information about recycling activities.

In the South, the pond and the valley are considered as prime lands, and road depressions have minimal direct cost. In Baalbek El-Hermel, lands along the roads are of considerable value, and quarries are of lower value.

Depreciation of land surrounding dump sites. Disposal of rubble and debris in various dump sites, especially in those along the coast, represents a health hazard to the surrounding neighborhoods as well as a visual intrusion that affects the quality of life. Within the context of this analysis, it was not possible to assess the effect of the dump sites on the value of surrounding land.

Overall, the estimated damage caused by the presence of large quantities of rubble and debris ranges within *US$142 million to US$159 million*, as table 6.16 summarizes.

Table 6.16 Estimated Damage Costs of Demolition Waste
US$ millions

	Damage cost, by location			
Type of demolition waste	*Beirut's southern suburbs*	*South*	*Baalbek El-Hermel*	*Total*
Waste loading, hauling, and transport	3.4	7.9	2.4	13.7
Road maintenance	0.2–0.7	0	0	0.2–0.7
Traffic delays	51–68	0	0	51–68
Land for disposal	74.4	1.7	0.8	76.9
Land depreciation	n.a.	n.a.	n.a.	n.a.
Total cost	**129–146.5**	**9.6**	**3.2**	**142–159**

Source: Authors' calculations.
Note: Costs are based on 2006 estimates. m^3 = cubic meters. m^2 = square meters. n.a. = not available.

[[AU: Please provide text citation]]

Box 6.1

Options for Treating and Disposing of Demolition Waste

A 2007 UNDP report assessed two main scenarios for treatment of demolition waste in Lebanon: (a) treatment in a fixed recycling facility and (b) on-site treatment with mobile equipment.

UNDP evaluated each of the two scenarios for three levels of material recovery:

1. Volume reduction with no material recovery
2. Typical levels of material recovery (30–40 percent), producing scrap metals and mixed aggregates for use in road-base or landscaping and paving
3. Full material recovery (85 percent), generating scrap metals, mixed aggregates, and clean aggregates for use in asphalt and other aggregate

Each treatment alternative was also assessed for four disposal options:

1. Landfilling in an inert waste landfill (Bsalim)
2. Backfilling for quarry rehabilitation
3. Donating to landfills to be used as daily cover
4. Donating to Solidere (a redevelopment company formed as a public-private partnership after the 1990 war) for sea reclamation[59]

Under the various scenarios, the estimated cost ranges for the treatment and disposal of demolition waste were (a) from US$4 million to US$33 million (US$17 million on average) for 1 million cubic meters of rubble in the Beirut southern suburbs and (b) from US$8 million to US$65.5 million (US$35 million on average) for 1.8 million cubic meters of rubble in the South and Baalbek El-Hermel.

The least-cost alternative involves crushing the waste to reduce its volume at the temporary storage sites, followed by disposal as landfill cover. The most expensive option involves the transport and treatment of the waste at a central facility where 85 percent of recyclables are recovered, followed by disposal as quarry fill.

Source: UNDP 2007.

Damage Costs due to Military Waste

The impacts of military waste are estimated in terms of human deaths and injuries, limited access to agricultural land, and demining efforts. Given the complexity of the demining process and its associated delays, the economic valuation uses a period of two years as a minimum time lag for demining completion.

Deaths and injuries. According to the Lebanese National Demining Office, from August 14, 2006, to April 03, 2007, UXOs caused 224 casualties, including 29 deaths and 195 injuries (MACCSL 2007). The number of UXO casualties by the end of the two-year study period (August 2006 to August 2008) is projected based on the casualty trends as of April 2007. The distribution of the projected numbers in terms of mortality, morbidity, and age is assumed to be similar to the current distribution. Overall, the UXOs caused an estimated 36 deaths and 239 injuries.[60]

We estimate the damage cost of premature mortality and morbidity from UXOs based on DALYs. Illnesses are weighted by severity such that a relatively mild illness or disability represents a small fraction of a DALY, while a severe illness represents a larger fraction of a DALY. One year lost to premature mortality represents 1 DALY, and future years lost are discounted. For injuries resulting from UXOs, such as leg or arm amputation, the disability weight adopted to assess damage cost is 0.3 (Murray and Lopez 1996).

Using the HCA approach, the lower value of 1 DALY is equal to the GDP per capita, or US$5,300. The upper value of 1 DALY is estimated at US$42,000, based on the VSL divided by a time horizon of 25 years and a discount rate of 4 percent.[61] Table 6.17 presents the calculation of

Table 6.17 Estimated Damage Cost of Unexploded Ordnances (UXOs)

Age group	*Current number of casualties*[a]	*Current and projected number of casualties*[b]	*DALYs per case*[c]	*Value of 1 DALY (US$)*	*Current and projected economic loss (US$ millions)*
Mortality					
0–12	2	2.5	33	5,300–42,000	0.43–3.40
13–18	4	4.9	36	5,300–42,000	0.94–7.43
19+	23	28.2	20	5,300–42,000	2.99–23.72
Subtotal	**29**	**35.6**	**n.a.**	**5.300–42.000**	**4.36–34.55**
Morbidity					
0–12	24	29.5	9.9	5,300–42,000	1.55–12.25
13–18	39	47.9	10.8	5,300–42,000	2.74–21.72
19+	132	162.1	6.0	5,300–42,000	5.15–40.84
Subtotal	**195**	**239.4**	**n.a.**	**5.300–42.000**	**9.44–74.81**
TOTAL	**224**	**275**	**n.a.**	**5.300–42.000**	**13.80–109.35**

[[AU: Under the "Value of 1 DALY" column, OK to restate all values with fewer decimal points? If the values mean "US$5.30–US$42.00," change column entries to "5.3–42.0."]]

Source: Authors' calculations and sources of data as noted below.
Note: DALY = disability-adjusted life year. The monetary value of 1 DALY is based on the GDP per capita as the lower bound and the VSL as the upper bound. n.a. = not applicable.
a. MACCSL 2007.
b. The projected number of casualties is based on the same age distribution of current casualties.
c. Murray and Lopez 1996.

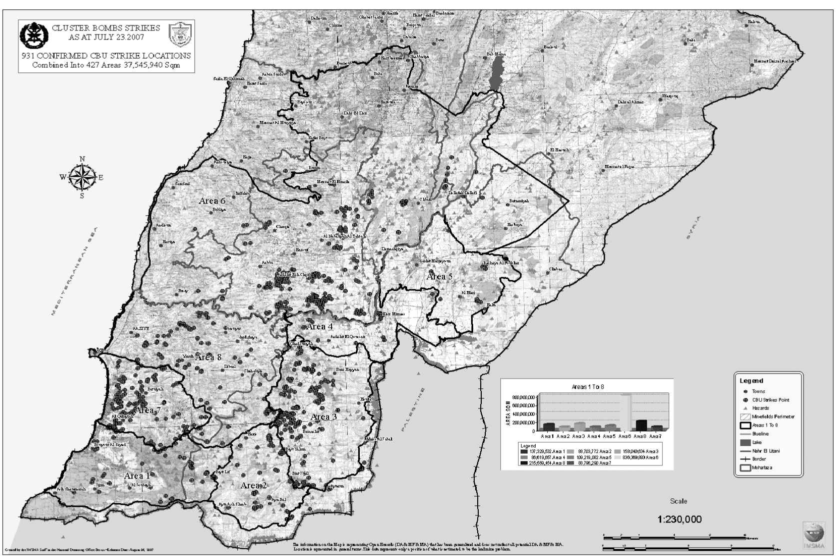
the damage cost due to mortality and morbidity by age group. Accordingly, the estimated damage cost of casualties resulting from UXOs ranges between *US$14 million and US$109 million*.

Access to agricultural land. The limited access to agricultural lands in the South imposed by UXOs was expected to have a significant impact on agricultural production and farmer livelihoods for at least two years. Farmers may respond to this crisis in various ways. They may burn their orchards to eliminate the UXOs, losing their plantations in the process; they may simply wait for their lands to be cleared of the UXOs; or they may migrate to urban areas. Again, it is difficult to assign a monetary value on these types of behaviors. As such, the impact of the UXOs on farmers is estimated by assessing only the loss in production due to lack of access to agricultural lands.

As figure 6.2 illustrates, however, cluster bombs were scattered throughout the South, making it difficult to quantify the total area of inaccessible agricultural lands.

The valuation is based on (a) estimating the total value of the annual production in the areas concerned, and (b) calculating the share of this

Figure 6.2 Map of Cluster Bomb Strikes as of July 23, 2007



Source: Lebanon Mine Action Center.

value lost to UXOs. In table 6.18, the annual production in the South and Nabatyieh is estimated at US$268 million.

Accordingly, we adopt two scenarios to estimate the damage cost to agricultural productivity. They assume that 10–25 percent of the South and Nabatiyeh agricultural land[62] would be inaccessible during the first year, and 5–10 percent would be inaccessible during the second year. Based on these assumptions, table 6.19 estimates that the total loss in agricultural production due to UXOs ranges between *US$40 million and US$94 million* over a period of two years.

Demining. As of May 2007, the Lebanese Army, the UN Mine Coordination center, and some NGOs had worked hard to clear an estimated 14 million square meters affected by UXOs (PCM 2007). Cleaning agricultural land started around February 2007, after giving priority to clearing schools, public roads, and housing areas. An annual budget of US$5.5 million has been allocated to demining.[63] Assuming two years of operations until demining would be complete, the total cost is estimated at *US$11 million*.

Overall, the damage by large quantities of rubble and debris is estimated to range within *US$142 million to US$159 million*, as table 6.20

Table 6.18 Estimated Annual Value of Agricultural Production in the South and Nabatiyeh

	Cultivated area (000 du)[a]			*Producti on rate*[b]	*Total pro-duction*	*Value*[c]	*Value (US$*
Crop type	*South*	*Nabatiyeh*	*Total*	*(ton/du)*	*(000 tons)*	*(US$/ton)*	*millions)*
Cereals	37.6	59.5	97.2	0.28	26.8	297	8.0
Legumes	2.1	5.8	8.0	0.54	4.3	565	2.4
Fruit trees	123.3	20.8	144.0	1.26	182.0	746	135.8
Olives	89.3	116.1	205.5	0.29	58.8	1,268	74.5
Oleaginous trees	5.8	3.8	9.6	0.10	0.9	2,083	1.9
Vegetables	20.8	12.1	32.9	3.19	104.9	251	26.3
Raw tobacco	14.6	40.0	54.7	0.12	6.4	2,988	19.1
TOTAL	**293.5**	**258.1**	**551.9**	**0.70**	**384.1**	**698**	**268.0**

Source: Authors' calculations and sources of data as noted below.
Note: 1 dunum (du) = 1,000 square meters.
a. Based on the 1999 agricultural census, Ministry of Agriculture (MOA). www.agriculture.gov.lb.
b. Based on the MOA 2004 production statistics and calculated by dividing the total production for each crop category by its cultivated area for the year 2004.
c. Average of the import and export values. The value per ton of import (export) is calculated by dividing the import (export) total value of each crop category by its quantity. Totals may not add up due to rounding.

Table 6.19 Estimated Range of UXO Damage Cost to Agricultural Productivity
US$ millions

	Assumptions for damage cost estimation under each scenario	*Low-bound scenario*	*High-bound scenario*
First year	Losses of 10% of annual production value under the low-bound scenario and of 25% under the high-bound scenario	26.8	67.0
Second year	Losses of 5% of annual production value under the low-bound scenario and of 10% under the high-bound scenario	13.4	26.8
TOTAL		**40.2**	**93.8**

Source: Authors' calculations.
Note: UXO = unexploded ordnance.

Table 6.20 Estimated Damage Cost due to UXOs
US$ millions

Damage type	*Minimum*	*Maximum*
Casualties	14	109
Loss in agricultural opportunities	40	94
Demining	11	11
TOTAL	**65**	**214**

Source: Authors' calculations.
Note: UXO = unexploded ordnance.

presents. It is a conservative estimate; for example, it does not consider other impacts such as that of UXOs on forests.

Damage Costs of Medical Waste

The casualties due to the conflict produced an estimated 200 to 250 tons of medical waste (UNDP 2007). Health-care waste can be grouped into two broad categories: nonrisk waste and risk waste.[64] Because of the lack of data regarding the composition of the medical waste produced during conflict, we assume that no segregation is practiced, and therefore assume that the generated waste is infectious. This requires sterilization at a cost of US$60 per ton, followed by disposal with regular solid waste at an operational landfill in the country, at a cost of US$15 to US$120 per ton.[65] Therefore, the cost of handling the medical waste generated during the conflict (including treatment, transport, and disposal) ranges between *US$15,000 and US$45,000*.

Shipping of hazardous waste in accordance with the Basel Convention on the Transfrontier Shipment of Hazardous Waste would cost US$10,000 per ton. However, this option has not been considered in this analysis, because, to the best of our knowledge, shipment of infectious medical waste has never been practiced in Lebanon.[66] Given the large quantities of medical waste generated by the conflict, if the option of shipping and treating medical is considered by Lebanon, the overall damage cost resulting from medical waste will be substantially increased.

In addition, Lebanon received about 502 tons of medicines and medical aid supplies during and after the conflict (PCM 2007).[67] Some pharmaceuticals may have arrived in Lebanon past their expiration dates, while others arrived in unwanted quantities (UNDP 2007). Safe disposal of unwanted or expired drugs often creates a major problem. However, because at the time of writing the quantity of unwanted and expired drugs was not known, it was not possible to account for their disposal cost. Due to the limitation mentioned above, the total estimated impact of *US$15,000 to US$45,000* likely underestimates the full impact of medical waste on the environment.

Summary: Damages due to Demolition, Military, and Medical Waste

The assessment of the impacts of demolition, military, and medical waste resulting from military aggression during the July–August 2006 conflict are conservatively estimated to range from US$207 million to US$373 million. Overall, the impact averages to *US$290 million, or 1.4 percent of GDP in 2006* (World Bank 2007).

More than half of the estimated impact is due to demolition waste, particularly as a result of the high cost of land for waste disposal and the traffic delays in and around Beirut's southern suburbs. The costs of waste loading, transport and disposal, and demining are considerably lower, as presented in table 6.21 and figure 6.3.

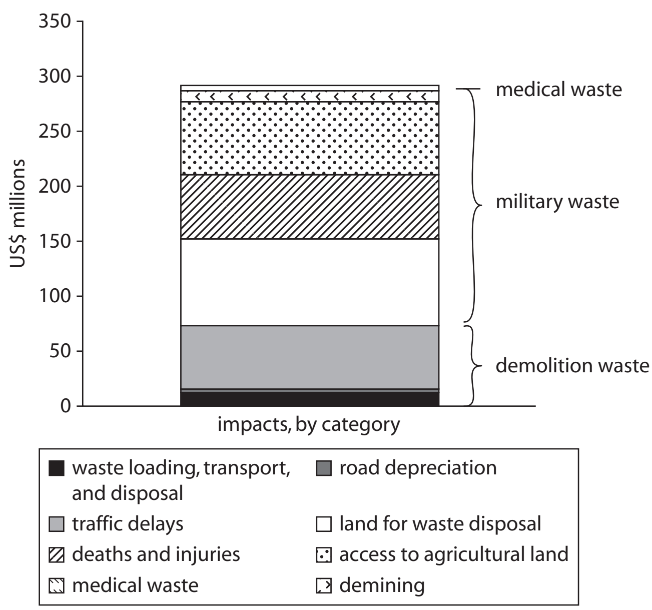
The overall estimate is likely to underestimate the overall impact caused by the conflict on the waste sector because several potential impacts have not been quantified. For example, the chapter does not account for the depreciation value of the real estate surrounding huge dump sites, the health hazard generated by the manipulation of the demolition waste, and the impact of UXOs on forests.

Table 6.21 Estimated Cost of Damage due to Military Waste
US$ millions

	Damage cost			
Damage type	*Minimum*	*Maximum*	*Mean*	*Mean (% of total)*
Demolition waste	**141.8**	**159.3**	**150.5**	**52**
Waste loading, transport, and disposal	13.7	13.7	13.7	5
Road depreciation	0.2	0.7	0.5	0
Traffic delays	51	68	59.5	21
Land for waste disposal	76.9	76.9	76.9	27
Military waste (from UXOs)	**65.0**	**214.2**	**139.6**	**48**
Deaths and injuries	14	109	61.5	0
Access to agricultural land	40	94	67	0
Demining	11	11	11	4
Medical waste	**0.02**	**0.05**	**0.04**	**0**
Total	**207**	**373**	**290**	**100**

Source: Authors' calculations.
Note: UXO = unexploded ordnance.

Figure 6.3 Impacts of Conflict on Waste



Source: Authors' calculations.

Conclusions

The previous sections estimated the damages associated with the oil spill and waste caused by the 2006 conflict in Lebanon. In addition to these damages, the conflict affected other environmental categories and economic activities, such as water, forests, air quality, and quarrying. The World Bank (2007) estimated the total COED, which includes the costs of all the conflict-related impacts of environmental degradation (except for those related to air quality, due to insufficient information). Table 6.22 indicates that the total COED caused by the 2006 conflict in Lebanon is between US$527 million and US$931 million, averaging at *US$729 million, or 3.6 percent of GDP* in 2006.

It is interesting to note that a previous study estimated the annual COED in 2000 at US$565 million, or 3.4 percent of GDP (Sarraf, Larsen, and Owaygen 2004).[68] A comparison between the two estimates shows that the environmental damage caused by the 34-day conflict was higher than that caused in a whole year in peacetime. On average, the environmental damage caused by one day of conflict costs about US$21.5 million, compared with US$1.7 million per day in peacetime.[69]

Figure 6.4 illustrates the main components of the damage cost attributable to the 2006 conflict. The largest estimated impact is on the *waste* sector, mainly due to the high costs of disposing of the waste attributable to demolition, casualties, and agricultural losses caused by UXOs in South Lebanon. The impact of the *oil spill* is the second most important, primarily because of the high costs of cleaning the oiled waste, the cost of burnt

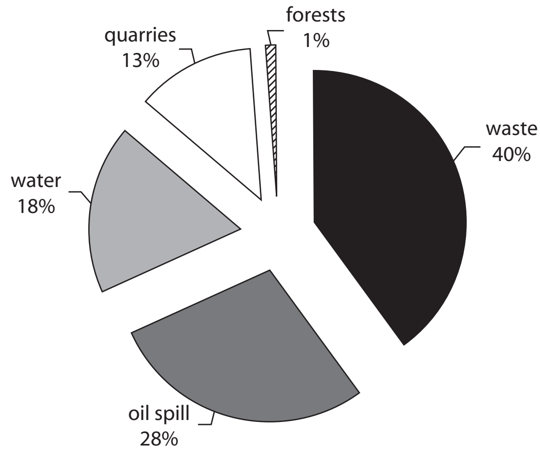
Table 6.22 Estimated COED of the 2006 Lebanon Conflict
US$ millions, except where noted

Impact category	*Min*	*Max*	*Mean*	*Mean (% of GDP)[a]*
Waste	206.8	373.5	290.2	1.4
Oil spill	166.3	239.9	203.1	1.0
Water	131.4	131.4	131.4	0.6
Quarries	15.4	175.5	95.5	0.5
Forests	7.0	10.8	8.9	0.0
Air[b]	n.a.	n.a.	n.a.	n.a.
Total COED caused by the conflict	**526.9**	**931.1**	**729.0**	**3.6**

Source: Authors' calculations; World Bank 2007.
Note: COED = cost of environmental degradation. n.a. = not available.
a. Based on an estimated GDP for 2006 of US$20.5 billion (Economic Intelligence Unit 2006).
b. Air-quality impact costs were not available because of insufficient data.

[[AU: Add reference information for the EIU citation to the reference list.]]

Figure 6.4 Annual COED in Lebanon, by Category



Source: Authors' calculations.
Note: Percentages represent the estimated share of the US$729 million COED caused by the Lebanon conflict and attributable to each damage category. COED = cost of environmental degradation.

and spilled oil, and the income losses from coastal services (for example, beach resorts). The impacts of the conflict on water, quarries, and forests are comparatively less important, although they are conservatively estimated. Once again, the limited data availability makes these estimated costs only indicative of the real value of damages.

The damages that the conflict caused to the waste sector also exacerbated long-lasting environmental issues, such as larger waste management concerns. Lebanon can take several measures to resolve this problem, including (a) agreeing to allocate land for sanitary landfills in different Mohafazats; (b) enacting the Integrated Waste Management Law and implementing the National Solid Waste Strategy in a competitive and cost-effective manner; and (c) providing incentives to municipalities to treat their waste.[70]

The damage caused by the 2006 oil spill revealed the need to develop and implement sustainable oil-spill preparedness and response systems. A national oil-spill control and contingency plan should be in place and exercised periodically with the various government agencies and all relevant stakeholders. It should also include a joint effort at capacity building by key stakeholders such as local industry, government, and NGOs to accommodate for local conditions.

Notes

1. The estimation was based on several assessments, including the one by Khatib and Alami (2006).
2. Communication with the Lebanon Ministry of Environment (MOE), August 2007.
3. According to tests done by CEDRE, the oil spilled appeared to be an intermediate fuel oil (IFO) with a viscosity of 150 CentiStokes (cSt) at 50°C. www.cedre.fr.
4. The MEDSLIK computer model can calculate the oil-spill trajectory and fate developed for the eastern Mediterranean. The European Union helped to obtain the MEDSLIK model from the Oceanography Centre at the University of Cyprus.
5. These indirect effects are much harder to determine. While an oil-covered bird is clearly affected, partial oiling gives the appearance that the bird "survived" the spill, only to die sometime later from oil ingested during preening or from other complications. In addition, because a spill also damages the birds' food sources (shoreline organisms and fish), the affected areas cannot sustain the previous level of bird population. This injury may occur over a period of several years after the spill and, therefore, is particularly difficult to assess.
6. Interview in April 2007 with Dr. Ghassan Ramadan-Jaradi, professor of ornithology and chair of the Palm Islands Nature Reserve GAC.
7. Observed during a field visit in October 2006.
8. UNEP did not discover high concentrations of soluble hydrocarbons. However, dense nonaqueous phase liquids (DNAPLs) and the high volatility of hydrocarbons may have caused the contamination to go unobserved.
9. For example, 10 years after the 1992 Aegean Sea spill that released 70,000 tons of oil into a harbor of Galicia, Spain, the area had still not fully recovered (Chas-Amil and others 2004). It has also been suggested that recovery of different species of shellfish may take anywhere from a few months to more than 12 years. In 2002, the damage provoked by the Prestige spill of 64,000 tons of oil off the Galician shore had a severe impact on local biodiversity, and recovery was predicted to take between 2 and 10 years (Loureiro and others 2006).
10. For example, the 1989 Exxon Valdez oil spill in Alaska provoked a sudden death of fish population three years after the accident (Fall and others 2001). The Aegean Sea spill caused a 33 percent fall in catch no less than six years after the event (Chas-Amil and others 2004).
11. Different sources suggest different impact time frames, such as 10 to 50 years' serious impact on marine biodiversity and 1 to 10 years' catastrophic impact

on the littoral zone (UNDP 2007), or a few months to several years' impact on tourism (director general Ministry of Tourism, pers. communication, 2007).

12. This appeared credible in April 2007, when we observed that little or no oil existed in the water column, and a good portion of sandy beaches had been cleaned.
13. This is a conservative time frame because it does not capture potential effects either not yet probed or yet to occur over an extended period of time.
14. A review of oil-spill studies of the Exxon Valdez (Cohen 1995; Carson and others 2003; Monson and others 2000); the Prestige (Loureiro and others 2006); the Erika (Bonnieux and Rainelli 2002); and the Amoco Cadiz (Grigalunas and others 1986) indicates that none of them was related to conflicts. Thus, available information does not give any example or guidance on how to separate the extent of damage according to the cause because no combined causes are involved. An exception is the 1991 Gulf war, which triggered an oil spill in Kuwait, for which the economic analysis of the environmental damages was limited to remedial approaches.
15. Interview at the Syndicate of Hotel Owners, September 2006.
16. Room rates vary from US$40 to US$300 per night, averaging US$100 per night. Meals, phone, and laundry average US$50 per day.
17. Based on internal statistics of the Ministry of Tourism.
18. According to April 2007 interviews, the daily price per apartment varies widely, depending on the quality of services, number of bedrooms, the season, and other factors. For example, during low season, a one-bedroom apartment costs between US$55 per night (in Savoy Suites, Raouche Beirut, April 2007) and US$175 per night (Lahoya Homes, Manara, Beirut, April 2007), while a two-bedroom apartment costs between US$200 and US$450 per night (Lahoya Homes, Manara, Beirut).
19. A typical example is the Bamboo Bay resort in Jiyeh.
20. Based on the Lebanese Ministry of Tourism publication, *Yellow Pages Tourism 2006*.
21. Visitor spending ranges between US$7 and US$30 per day (interview with Syndicate of Beach Resorts representative, October 2006).
22. A typical example is the Rimal complex resort in Jounieh.
23. Based on the Lebanese Ministry of Tourism publication, *Yellow Pages Tourism 2006*.
24. Based on interviews at a random sample of 10 chalet complexes outside Beirut, April 2007.
25. The average is based on the number of day-visits: 1,500 on working days, 5,000 on Saturdays, and 20,000 on Sundays (Cedars for Care, pers. communication, April 2007).

26. This value does not reflect what individuals actually pay to visit public beaches because they are usually free of charge. Rather, the benefit amount reflects the economic value in terms of willingness to pay (WTP) to enjoy the beach. Because no information on the WTP for public beaches is available, we use data on the WTP for private beaches (US$20). The services provided by private beaches are of better quality than those of public beaches; therefore, the WTP for public beaches is assumed to be around 50 percent of that of private beaches.
27. 8,400 visitors per day × 30 days × US$10.
28. The cost of boat cleanup is captured in the total cleanup costs at the end of this section.
29. The overall losses due to the oiled fishing boats are reflected through the loss in fish catch and the maintenance costs paid for one year (2006). Because the loss in fish catch is already accounted for in the "Fishing" subsection, this section considers only the maintenance costs to avoid double-counting.
30. The interviews suggested that there are about 20 to 30 boats per small marina (for example, Miramar and Las Salinas), 80 to 100 boats per medium-size marina (for example, Movenpick and Halat sur Mer), and about 300 to 400 boats per large marina (for example, Dbayeh and ATCL).
31. According to interviews at the Power Marine and Dolphin Team boat suppliers in Mount Lebanon, boat prices vary from US$10,000 to US$500,000, depending on size and model. The lifetime of a boat usually varies from 20 to 30 years. Because boats often become obsolete much before the end of their lifetimes, it is reasonable to assume a lifetime of 20 years.
32. Interviews at five marinas show that the cost per meter per season varies widely: for example, US$400–US$700 per meter per season in Marina Dbayeh, US$300–US$400 in Holiday Beach, and US$2,500–US$3,000 in Movenpick.
33. Interview with Dr. Ghassan Ramadan-Jaradi, chair of the Palm Islands Nature Reserve GAC, April 2007.
34. Interview with Dr. Ghassan Ramadan-Jaradi, chair of the Palm Islands Nature Reserve GAC, April 2007.
35. We found no studies estimating the damage cost of dead or injured turtles in Lebanon as a result of the oil spill. Whitehead (1993) found a WTP of about US$11 per year to ensure the continued existence of the loggerhead sea turtle (*Caretta caretta*) in the United States. In another study, Whitehead (1992) estimated the WTP of about US$44 per person for continued existence of turtles for the next 25 years. It is difficult, however, to apply these estimates in the Lebanon's case because (a) only a small (unknown) fraction of the total WTP can be attributed to the loss of the three loggerheads, and (b) these estimates do not reflect the country's specific biodiversity conditions.

36. Alternatively, benefits transfer could be used. Brown (1992) estimated a range of values from US$167 per gull to US$6,000 per peregrine falcon. Loureiro and others (2006) valued a cost of about US$250 per dead bird. That would correspond to about US$60 per dead bird in Lebanon, after adjustment to GDP ratio. Assuming that all oiled birds found in Lebanon would die, as in many other oil spill incidents (McCay and others 2004), the total value of the 92 injured birds would be about US$5,500. However, because of the method's inability to reflect the specific biodiversity conditions in Lebanon, this estimate will not be considered in the analysis.
37. It is known that there are 3.5 white pelicans per square kilometer and 3.8 squacco herons per square kilometer. There was one injured white pelican and four injured squacco herons. (Ramadan-Jaradi and Ramadan-Jaradi 2001; MOE 2004)
38. The study, which aims to develop indicators for future monitoring, is funded by the Italian government through the World Conservation Union (IUCN) and implemented by the American University of Beirut (communication with Ms. H. Kilani of IUCN, Lebanon, April 2007).
39. The monitoring program includes the following activities: developing measurable indicators, setting guidelines for monitoring, analyzing data on a yearly basis and developing a set of guidelines for use in future incidents (interview with Dr. Ramadan-Jaradi, April 2007, and communication with Ms. H. Kilani of IUCN, April 2007).
40. This figure does not cover either the cleanup cost already spent of US$85,600 at the time of writing in April 2007 (Dr. Jaradi communication; SDC 2007) or the estimated cost of the second phase of cleanup and monitoring operations, estimated at about US$1 million (according to MOE). Both of these costs are accounted for in the "oil spill cleanup" subsection.
41. The Byblos tour operators are Tania Travel, Kurban Tours, Nakhal, Anastasia, Ariane, Rida Travel, and Wild Discovery.
42. Visitor cost estimates are based on interviews with tour operators Tania Travel, Kurban Tours, and Nakhal.
43. This is the minimum spending on souvenirs and boat rental, based on the judgment of local experts.
44. Navrud and Ready (2002) make a comprehensive review of studies valuing the WTP to conserve sites with cultural heritage, such as monuments and archaeological sites. Accordingly, the annual WTP ranges from as little as US$0.6 to US$1 per household to preserve Bulgarian monasteries to as high as US$134 per household to conserve the recreational value of aboriginal rock paintings in Nopimi Park, Canada. These estimates represent the WTP to protect historical sites from pollution other than oil.
45. Interviews, October 2006 and April 2007.

46. Communication with Dr. M. Nader at the Marine Resources and Coastal Zone Management Program, Institute of the Environment, University of Balamand, October 2006.
47. Interview at the Syndicate of Fishermen, October 2006.
48. Interview at the University of Balamand, October 2006.
49. Estimate based on data provided by the MOE in August 2007.
50. See World Bank (2007), table 2.24, for a detailed list of organizations, activities, and estimated cleanup costs.
51. The second phase of oil spill cleanup is assumed to generate an additional 4,500 cubic meters of solid waste, based on surveys of the remaining polluted sites conducted along the Lebanese coast (MOE 2007c). Because there is no information about the management of oil waste that would be generated under the second phase, the cost of managing the 4,500 cubic meters of solid waste is not accounted for in the study.
52. UNDP (2007) indicates a cost of US$25,000 for treating 2,400 cubic meters of low- to medium-contaminated sand and pebbles.
53. UNDP (2007) estimates that shipping 100 cubic meters under the Basel Convention costs about US$1 million.
54. Information from E-MINE (Electronic Mine Information Network). "Mine Action Co-ordination Centre South Lebanon: Unexploded Ordnance Fact Sheet." http://www.mineaction.org/overview.asp?o=540.
55. The analysis does not account for the potential treatment of demolition waste because it did not enter the actual handling scenario. For information about options for treatment and disposal of the demolition waste, one can refer to the extensive analysis carried out by UNDP (2007) and summarized in box 5.1.
56. Information on the WHO Web site further defines disability-adjusted life years: http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/.
57. Demolition waste results from military activities rather than from a systematic, well-organized effort that produces mostly inert demolition material. Therefore, it can be easily associated with potential subsurface pollution due to rainwater infiltration.
58. The average hauling distance was about 2 to 3 kilometers, whether in suburbs of Beirut, the South, or the Bekaa. Therefore, contracts with hauling contractors implicitly took the distance into consideration and appeared to have been based mainly on the volume hauled, set as a function of truck capacity. This may explain the difference between the estimated volumes and the reportedly hauled volumes, taking into consideration the density variations.
59. "Solidere" stands for *Société libanaise pour le développement et la reconstruction de Beyrouth* (The Lebanese Company for the Development and Reconstruction of Beirut). http://www.solidere.com/solidere.html.

60. Projections for the two-year period are made because of the early writing of the original report (April 2007), which did not allow for information gathering on the ground for future years. As of February 2010, the United Nations Interim Force in Lebanon reports that cluster munitions and UXOs killed 27 and injured 234 civilians in South Lebanon, and accidents during demining caused another 14 deaths and 41 injuries of demining personnel. Since spring 2008, the civilian casualties dropped significantly in the range of 0 to 2 per month (http://unifil.unmissions.org/Default.aspx?tabid=1519). Accordingly, cluster munitions and UXOs had caused 41 deaths and 275 injuries until spring 2008. These numbers are in line with the projections made in April 2007 (36 deaths and 240 injuries, as reported in table 6.17). Because no information is available concerning the distribution by age of the updated data, this chapter uses the information collected in April 2007 for the estimation.
61. This value is based on the meta-analysis by Viscusi and Aldy (2003), who suggested a VSL between US$5.5 million and US$7.6 million in 2000. This value is adjusted to Lebanon, taking into account the GDP per capita differential and the inflation rate.
62. Evenly distributed among crop categories in the two Mohafazas, South, and Nabatiyeh.
63. Interview with the Director of Lebanese Army National Demining Office, April 2007.
64. "Nonrisk" waste, as defined by WHO, is estimated to constitute 75 percent or more of the total hospital waste stream—in some cases, 90 percent. Nonrisk waste, which comprises general domestic waste components generated primarily from domestic and administrative services, is considered to represent no potential risk from infectious, chemical, or other properties associated with health care. If waste separation and segregation are undertaken properly, nonrisk waste can be disposed of similarly to municipal waste. The remaining 10–25 percent of hospital waste comprises those components that are potentially contaminated with material associated with infectious, chemical, or other hazardous characteristics. WHO defines waste with such characteristics as "risk waste" that must be handled and disposed of in a way that minimizes the potential for human exposure and contamination. WHO has classified risk waste into seven distinct environmental categories: infectious, pathological, sharps, pharmaceutical, chemical, pressurized containers, and radioactive wastes.
65. Cost estimate is based on landfilling charges in 2006 at Zahlé and Nehmé landfills.
66. The American University of Beirut ships selected hazardous waste (but not infectious medical waste) on a periodic basis.
67. Medical aid included anesthetics, antibiotics, anti-convulsants, anti-depressants, anti-diarrheals, anti-fungals, anti-inflammatories, anti-retrovirals, heart medicines (anti-arrhythmic, anticoagulant, anti-cholesterol, anti-platelet & hypertension

treatments), laxatives, stomach medicines (beta-blockers and H2- antagonists), painkillers and tranquilizers.

68. The study estimated the COED due to air pollution at 1.1 percent of GDP; water degradation, at 1 percent; land and wildlife degradation, at 0.6 percent; coastal zone degradation, at 0.7 percent; and waste management, at 0.1 percent.
69. Adjusted from 2000 to 2006 using the GDP deflator.
70. Financial incentives such as carbon finance can alleviate the financial burden imposed by the waste sector.

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