

How Much Oil Was Spilled in the 1991 Gulf War Oil Spill?

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Although it's no longer in the headlines, the 1991 Gulf War oil spill resurfaces each time a new spill occurs. In each new case, the estimated amount of oil spilled for the 1991 event varies significantly. In the following presentation, best available information has been assembled regarding sources and amounts spilled to provide a range of estimates that is much higher than generally reported.

The magnitude of the Gulf War oil spill has been the subject of considerable speculation since it began on January 19 of 1991. Reported estimates range between 2 and 11 million barrels². Much of this range can be attributed to the fact that the spill occurred during a major war and access to spill sources was not possible. Following the end of hostilities, access continued to be restricted due to operational limitations such as unexploded ordinance and oil well fires. As a result, "best available information" estimates are used to estimate spill magnitude.

Information regarding details of spill sources was significantly improved in the course of preparation of claims to the United Nations Claim Commission (UNCC)³ for compensation of environmental damage. Preparations of claims by Kuwait and Saudi Arabia led to spill estimates of 9.3 million barrels by Kuwait (PAAC, 1998) and 10.8 million barrels by the Saudis (Tawfiq and Olsen, 1993). Review of these calculations (Table 2) reveals that the main difference in these two estimates is that the Kuwait estimate assumes that 80% of the oil contained in the tankers was spilled while the Saudi estimate, assumes that 90% was spilled⁴. The Saudi estimate also includes an estimate of spillage from the Min al Bakr terminal in Iraq, provision for post war leakage from battle damaged tankers and terminals and includes spillage from 3 small tankers which were not included in the Kuwait estimate.

Review of the Kuwait claims, however, identified an additional 9 significant sources of oil which have not been included in any prior estimate. In addition, a survey carried out by the International Maritime Organization (IMO) identified more than 200 vessels that had been sunk in the course of the war. At least two of these are tankers loaded with oil products and which posed a potential continuing threat to the environment. This discussion paper discusses potential contribution of oil from these sources and provides an upper limit estimate to the spill that is 50% greater than presented previously.

Spill Sources

The 1991 oil spill began (Table -1) on 19 January when the Iraqi military deliberately released most of the contents of five tankers into the Northern Arabian Gulf. The next day, the amount spilled increased when the contents of the Al Ahmadi north tank field were released through the Sea Island Tanker Terminal (UN, 1991). Subsequent

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² http://en.wikipedia.org/wiki/Gulf_War_oil_spill#cite_note-8

³ http://en.wikipedia.org/wiki/United_Nations_Compensation_Commission

⁴ Immediately following cessation of hostilities, representatives of the Dutch salvage firm Smit Tak who had been working from the Saudi oil spill offices inspected many of the damaged tankers and provided Saudi authorities with their assessment of the remaining oil contained. Spillage was calculated from the difference between the Lloyd's registry and the Smit Tak values.

deliberate spills from Iraq's Mina Al Bakr offshore terminal and from battle damaged tankers and refineries continued to add to the problem until late summer when most of the sources were reported to be under control.

Unlike prior spills⁵, whose sources and amounts can be estimated with precision (Koons and Jahns, 1992), it is unlikely that the actual amount of oil spilled during the 1991 incident will ever be known precisely. Despite these limitations, considerable detail has been assembled which enable a fairly close approximation. Amounts released by these sources are presented in Table 2.

Of the above sources, greatest precision can probably be attached to the estimates from tankers because their capacity was precisely known from maritime shipping records and the proportion of their cargoes released was estimated by experts in maritime transport. The Sea Island terminal contribution to the spill was estimated from Kuwait Oil Company records which were examined by United Nations experts immediately following cessation of hostilities (UN, 1991). Together, these sources account for an estimated 10.2 million barrels or over 93% of the total estimate.

Input of oil and oil combustion products from the Kuwait oil fires provided a significant (but unknown) additional contribution to the spill. According to Readman et al. (1992) "...from the best available data it can be estimated that over (about) 250 days during which the wells were burning, some 500 million barrels (67 million tons) of oil were emitted or ignited, releasing oil aerosols, soot, toxic combustion products and gases for atmospheric transport and subsequent deposition. Even if only a few percent of those emissions fell out in the coastal marine environment, they would by far surpass the amounts of crude oil that were spilled."

Field observations of "soot" deposits were made during subsequent follow-up studies. At Khafji (Hardy, et. al., 1993) "A heavy dark slick about 100 meters offshore extended north to south for a hundred meters or more. On close examination the visible slick, as well as the surface outside the slick (where samples were collected) was coated with greasy soot-like particles, most likely deposited combustion products from the large number of oil well still burning in Kuwait at that time."

Thus, although the actual amount of oil spilled is not precisely known, it was certainly the largest spill in history, at least 3 times the Ixtoc blowout in the Gulf of Mexico (3.7 million barrels) and twice the size of the 2010 Deepwater Horizon spill in the Gulf of Mexico (4.1-4.9 million barrels⁶) It was over 40 times larger than the highly publicized Exxon Valdez spill in Alaska (Koons and Jahn, 1992).

Spill Trajectory

The 1991 spill since it came from multiple sources, created a complex problem for trajectory analysis (Figure 1). Trajectory models at King Fahd University of Petroleum and Minerals (KFUPM, Al-Rabeh, et al., 1992) and the US National Oceanic and Atmospheric Administration (NOAA) provided reasonably accurate predictions for the Ahmadi spill but specific tracking of the individual tanker and Mina al Bakr spills was not undertaken. The KFUPM model was particularly useful because of its availability for answering strategic questions regarding areas where oil

⁵ Other large spills include the Ixtoc-1 well blowout during 1978 in the Gulf of Mexico (about 4 million barrels), the *Amoco Cadiz* off Brittany in 1978 (1.6 million barrels), the *Torrey Canyon* off England in 1967 (900,000 barrels), and the *Metula* in the Strait of Magellan in 1973 (380,000 barrels). The much publicized *Exxon Valdez* 1989 spill in Prince William Sound in Alaska was only 260,000 barrels.

⁶ http://en.wikipedia.org/wiki/Oil_spills#Largest_oil_spills

might come ashore. These predictions were be used by planners to anticipate near-term movements and position response activities appropriately.

Table-1. Chronology of the Known Sources of the 1991 Arabian Gulf Oil Spill.

19 January	5 Tankers at Al-Ahmadi released cargoes.
20 January	Oil Release at Sea Island terminal.
23 January	Amuriyah near Mina Al-Bakr Terminal releases cargo.
24 January	Al-Ahmadi Sea Island Terminal spill announced during military briefing. US war planes attack and sink Iraqi tanker Sea Island terminal closed by bombing
26 January	Mina Al Bakr Terminal oil release Ras al Zour refinery at Khafji damaged, results in spill
27 January	Gen. Swartzkopf announces Mina al-Bakr spill during Military briefing. "Closed" by bombing over the following days.
30 January	Ain Salah and Rumailah release remaining cargoes.
4 March	USCG SLAR flight reports small leakages from all of the above sources. Central Command reports 3 inch pipe leaking at Mina Al-Ahmadi. Total of 6 current low level sources operating. NOAA estimates that total input is 3-6000 barrels/day ⁷ . These sources continued until early June (90 days).

Seasonal weather patterns explained much of the spill trajectory. Although oceanic circulation in the Arabian Gulf is primarily counter clockwise, a series of European weather fronts passed through the Gulf area during much of February, reversing the prevailing north west winds to south east and holding the spill front from moving south.

One effect of this phenomenon is that, coupled with the effect of multiple sources at the head of the Gulf, the spill eventually covered much of the waters of the Arabian Gulf (Figure 2-1).

Estimate of Spill Quantity

Prior estimates of spill volume were provided by both Saudi Arabia (10.8 million barrels) and Kuwait (9.3 million barrels) in their respective claims submitted to the UNCC. Differences between Saudi and Kuwaiti estimates of spill volume are accounted for in Table 2-2. The main difference in these two estimates is that the

⁷ Leakages from a destroyed pipe rack at Mina Al-Ahmadi, a destroyed loading platform, a single-point mooring at the Sea Island terminal, the Amuriyah, the Al Bakr terminal, a storm drain north of Shu'aybah Port, the Al Fao and Tariq ibn Ziyad were estimated to be releasing a total of 3-6000 bbls/day. These releases gradually diminished over a 90 day period. An average figure of 600 bbls/day is used in spill calculations.

Kuwait estimate assumes that 80% of the oil contained in the five main tankers was spilled while the Saudi estimate, assumes that 90% was spilled. The Saudi estimate also includes an estimate of spillage from the Min al Bakr terminal in Iraq, provision for post war leakage from battle damaged tankers and terminals and includes spillage from 3 smaller tankers which were not included in the Kuwait estimate.

In the course of preparing its claims for compensation to the UNCC, the government of Kuwait identified 13 additional significant sources which contributed to the amount of oil spilled during the war. While the Kuwaiti's did not quantify spillage from these sources, reasonable amounts can be estimated (shown in Table 2) which would indicate that the amount spilled may be as much as 50% greater than previously estimated.

Fate of Spilled Oil in the Environment

Once the oil was released, it followed a variety of pathways into the environment of the Gulf. These are summarized in Table 2-3 which has been reconstructed from data on the volatility and solubility of the oil under these conditions (Gundlach, et. al., 1985), MEPA oil spill recovery results (MEPA, 1991b), MEPA coastal survey results (MEPA, 1991a), and UNEP/IOC reports (UNEP/IOC, 1991).

Approximately 70% of the estimated spill can be accounted for by the various shoreline surveys Saudi recovery operations (12% of the total floating oil), volatilization and dissolution into the water. Approximately 58% of the original spill (8.6 million barrels) has found its way into the marine and coastal environments (Table 3).

Investigations of oil weathering in the area impacted by the spill (Hayes, et al., 1993) showed that the oil penetrated 15-20 cm from the surface, filling many of the infaunal burrows. As a result, normal weathering forces may be relatively ineffective and result in substantial persistence of the spilled oil over time. A field survey of the Saudi Coast during April 2000, which included UNCC Commissioners and members of the UNCC Secretariate confirmed Hayes, et al.'s prediction. This same field survey also noted persistent contamination on rocky shore, sandy shore, and all areas, which had not been cleaned by the Saudi government.

The fate of the unaccounted oil is currently unknown. Michel et al. (1993) did not find evidence for large scale sinking of oil in the near shore subtidal in the Abu Ali area. Their conclusion was that, because their study area was in the area of heavy contamination by oil, if oil were to sink anywhere it would have sunk in their study area. Some sublittoral oil was located during 197 dives completed during the Mt. Mitchell cruise. Widely scattered tar balls were located in the area offshore from Tanajib. It is apparent that further study will be required to account for the more than 2.5 million barrels shown in Table 3 as unaccounted for.

Table 2. Comparison of Saudi and Kuwait estimates of amount of oil spilled during the Gulf War. Estimated spillage from other sources identified following the war are included to provide a “maximum” upper estimate for the spill.

Spill Source	Rated Volume (dwt) ^{8,9}	% Spilled	Saudi Estimate (bbls)	Kuwait Estimate (bbls) ¹⁰	Maximum Estimate (bbls)	Position	
						North	East
Tankers¹¹ and other Vessels							
Al Qadasiyah		90%	977,829	869,182	977,829	29.1167 ¹²	48.1500
Hiteen	155,211	90%	977,829	869,182	977,829	29.1167 ⁴	48.1500
Tariq ibn Ziyad	118,139	90%	744,276	661,158	744,276	29.0833 ⁴	48.1500
Al-Mutanabbi	130,266	90%	820,676	769,490	820,676	29.0500 ⁴	48.1667
Al-Fao ¹³	89,180	20%	124,852	124,852	124,852	29.0500 ⁴	48.1667
Amuriyah ¹⁴	155,211	20%	217,295		217,295	29.6500 ¹⁵	48.8367
Ain Zalah ¹⁶	155,211	20%	49,543		49,543	29.9783 ⁵	48.2283
Rumailah	36,000	20%	50,400		50,400	29.9750 ⁵	48.2200
Other Vessels ¹⁷							
Total			3,962,701	3,293,864	3,962,701		
Terminals							
Min al Ahmadi Sea Island ¹⁸ Terminal			6,000,000	6,000,000	6,000,000	29.1000 ⁴	48.3000
Min al Bakr ¹⁹			700,000		700,000	29.6833 ⁴	48.8000

⁸ Lloyds Registry of shipping

⁹ 7 Barrels/ton

¹⁰ Kuwait estimate is based on Ala Rabagh, 1991 which assumes 80% release instead of 90% for the vessels he included in his analysis. Additionally, the Kuwaitis did not include spillage from three vessels which were included in the Saudi estimate.

¹¹ Tawfiq and Olsen (1993). Spill volumes were derived from Lloyds registered vessel tonnages. Per cent spilled was reported by through Smit Tak Towing (Amsterdam) personnel who inspected vessels prior to relocating them following the war and provided their estimates to the Saudi Oil Spill Response Center.

¹² Sadiq and McCain, 1993

¹³ Figure 2A

¹⁴ Figure 2F.

¹⁵ IMO, 1994

¹⁶ Figure 2E.

¹⁷ More than 50 vessels were sunk in Az Zubayr, Umm Qasr ports and Khawr Az Zubayr, Khawr Shityanah and Khawr Abd Allah waterways. Tanker Tadmur and two oil barges have obvious oil (port of Az Zubayr) IMO, 1990 report of survey.

¹⁸ UN Report tot the Secretary General, 1991. Report on the Scope and Nature of Damage Inflicted on the Kuwaiti Infrastructure During the Iraqi Occupation. KOC records cited in this report show 10.7 million barrels in storage prior to 22 Jan. 1991. 1.5 million barrels remained following war war, it was estimated that 3.2 million barrels were used to fill defensive trenches leaving a remainder of 6 million barrels which were pumped into the waters of the Arabian Gulf. Sea Island terminal and pipe racks at Mina al Ahmadi are shown in Figures 3-B and 3-C.

Spill Source	Rated Volume (dwt) ^{8,9}	% Spilled	Saudi Estimate (bbls)	Kuwait Estimate (bbls) ¹⁰	Maximum Estimate (bbls)	Position	
						North	East
Total			6,700,00	6,000,000	6,700,00		
Other Sources							
Tank field at al Khafji					100,000		
Tank field at Mina Su'ud Refinery			100,000		100,000		
Getty Oil Refinery at Mina Az Zor and Ras Al- Qulay					100,000		
Min al-Ahmadi Refinery					100,000		
Min Abdulla (north and south piers)							
Shuaibah Refinery					100,000		
Fuel tanks at Doha power station					100,000		
Oil lakes at Bahra oil ²⁰ fields from damaged wells.					2,642,760		
Coastal trenches (w. side of Kuwait Bay) ²¹					100,000		
Pipes at Ras as Subiyah ²²					587,280		
Bubyan oil tubs. ²³					20,000		
Subsequent leakage from battle damaged tankers & terminals ^{24,25}			54,000		54,000		
Min Abdullah ²⁶							

¹⁹ Figure 2.3A.

²⁰ Spillage from Bahra wells. Wells burned and gushed oil for a total of 9 months (al Hassan (Kuwait Marine and Coastal Claim to the UNCC, witness statement)) Well flow line is 8 inches and pressure is 250 psi. .One well gushed at full pressure (9,788 barrels/day) for nine months. Garwin and Kendall, (1991.Quenching the oil fires in Kuwait. Nature 354:11-14) said that the wells flowed 1-2000 cu. M./day.(1000 cu.M=6000 barrels). EPC, 1991 said that 613 wells during well fires were emitting 6 million barrels/day (=9788 barrel/well/day).

²¹ Estimated by USCG (EPC, 1991) reports that oil from trenches could be 4-6 million barrels. Actual USCG testimony gives this as estimate of total spill (US Congress, 1992). Examples of leakage from oil trenches is shown in Figure 2-3 A,B,C.

²² Pipes at Ras as Subiyah.Two 17 in pipelines from Sabriyah oil field to Ras Al-Subbiyah (36 km) then T junction. Eastern arm of T divides into four 7 inch pipelines which empty directly into sea. Western end divides into 20 3.5 inch pipelines that empty crude into a long trench that ran along upper line of intertidal zone. Quantity unknown (Al Hassan, 1992). One well gushed at full pressure (9,788 barrels/day) for four months. Figure 3-D shows pipeline emptying into the sea.

²³ Bubyan oil tubs.Tubs placed in trench, parallel to seashore. High spring tides spilled much of this oil. See Figure 2.3E.

²⁴ US Congress.March 1992.The environmental aftermath of the Gulf War. U.S. Gvt. Printing Office. ISBN 0-16-037720-X. "Persistent leaking until at least May 1991 from several sources including the Sea Island terminal, a damaged refinery, another offshore terminal and several tankers added anywhere from 50,000 to perhaps one-half million barrels to the initial spill." page 10. "Uncontrolled oil flow from a well could range up to 90,000 barrels/day with a typical well flowing 10,000 to 15,000 barrels/day."page 31. "Leakage following war was estimated by ARAMCO to be 3-6000/day." Page 35.

²⁵ US Congress, October 17, 1991.Oversight hearing on the ecoterrorism inflicted as a result of the Gulf War. U.S. Get. Printing Office. ISBN 0-16-037257-7. Capt. William Holt, USCG (page 82).Sources-Crude oil from several tankers in gulf near Mina al-Ahmadi; crude oil from sea island terminal at Mina al Ahmadi; tanker near Mina al Bakr; refinery at Mina Bad Allah (Kuwait); tankers north of Bobbin Island. page 83.

Spill Source	Rated Volume (dwt)^{8,9}	% Spilled	Saudi Estimate (bbls)	Kuwait Estimate (bbls)¹⁰	Maximum Estimate (bbls)	Position	
						North	East
Getty pipeline at Min Az Zour ²⁷ -							
Oil Fires ²⁸							
Total from Other Sources			154,00	0	4,004,040		
Total Spill Volume			10,816,701	9,293,864	14,666,741		

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²⁶ North and south piers are major source of oil (Capt. Ali-Hailer, (Kuwait Marine and Coastal Claim to the UNCC, witness statement), Kuwait Monitoring and Assessment Claims for Marine and Coastal Resources)

²⁷ Photograph in Hailer (Kuwait Marine and Coastal Claim to the UNCC, witness statement) of Kuwait Monitoring and Assessment Claims.

²⁸ One billion barrels were released during the oil fires (Sadie & Micatin, 1997). Kuwait Terrestrial Monitoring and Assessment Claim, p. 3-16 says 500 million were released.

Figure 1. Areas impacted by 1991 Gulf War Oil Spill.

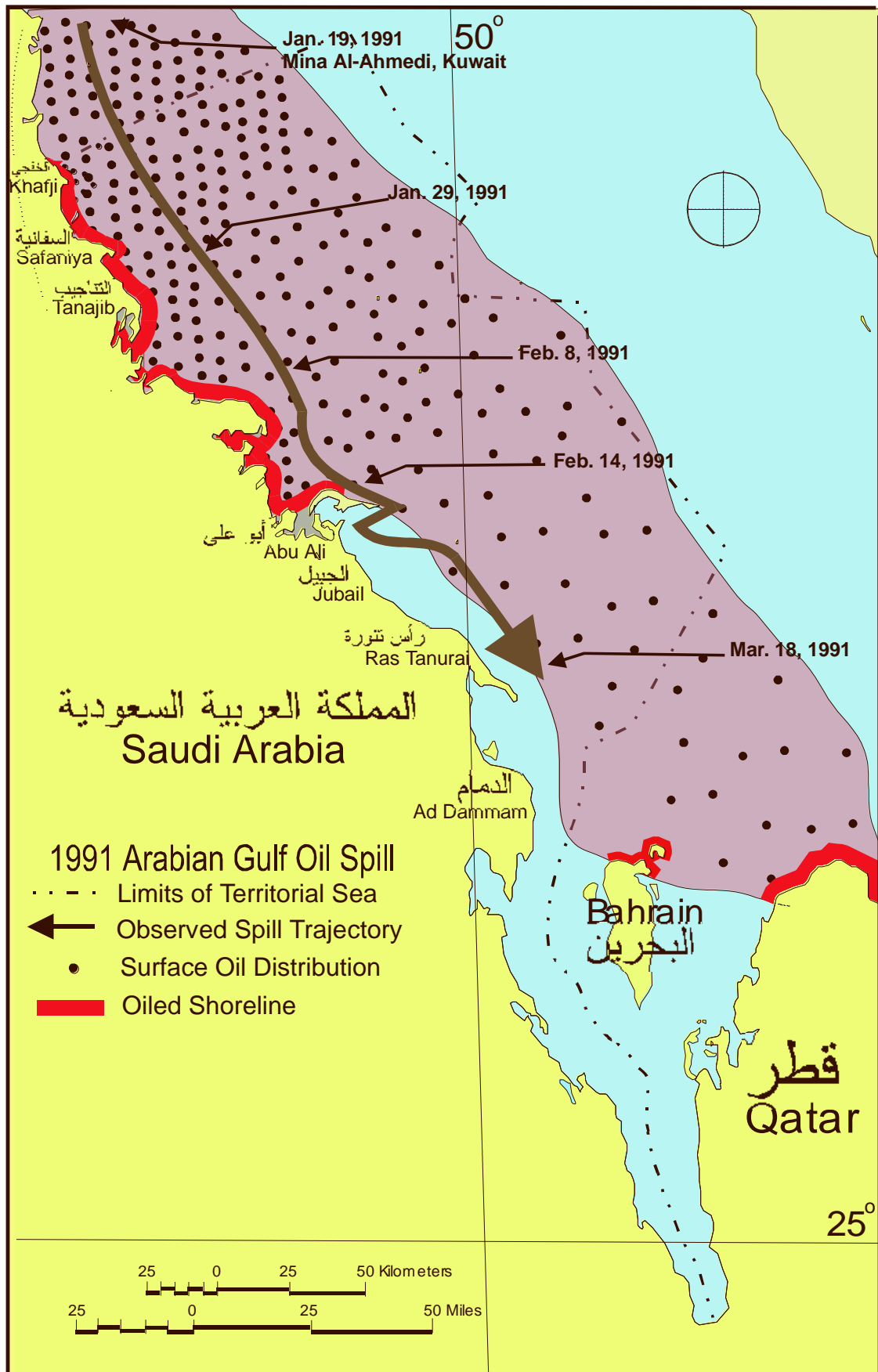


Figure 2. Tankers which contributed to the Gulf War Oil Spill: (A) *Al Fao*, (B) Unknown tanker, (C) Unknown war damaged tanker near Mina al Bakr terminal, (D) Tanker sunk near Mina al Ash, (E) *Ain Zalah*, (F) *Amurayah* near al Bakr terminal.

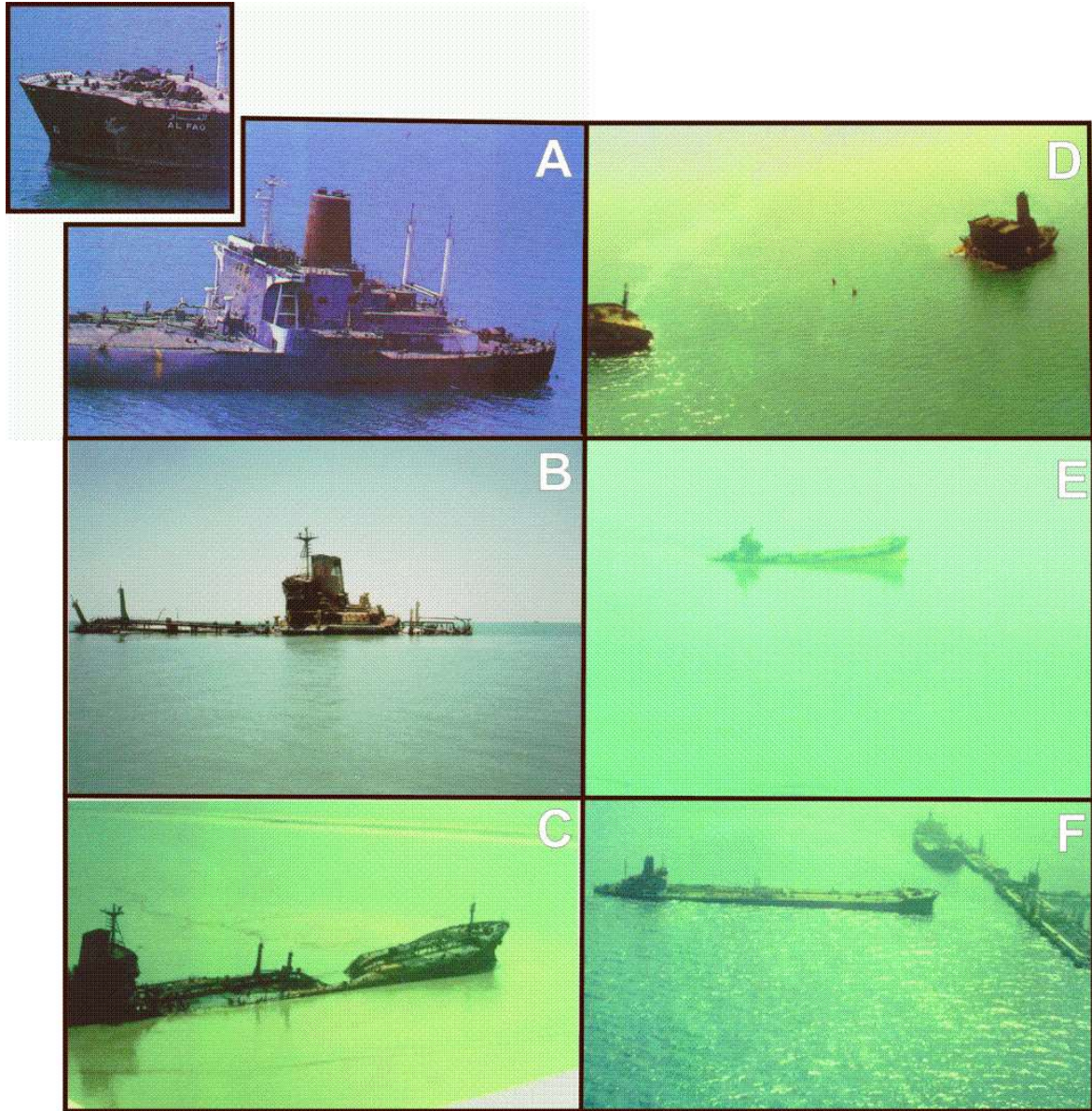


Figure 3. Oil terminals which contributed to the Gulf War oil spill: (A) Sea Island terminal, closed by bombing, (B) Min al Bakr closed by bombing, (C) Pipe racks at Mina al Ahmadi.

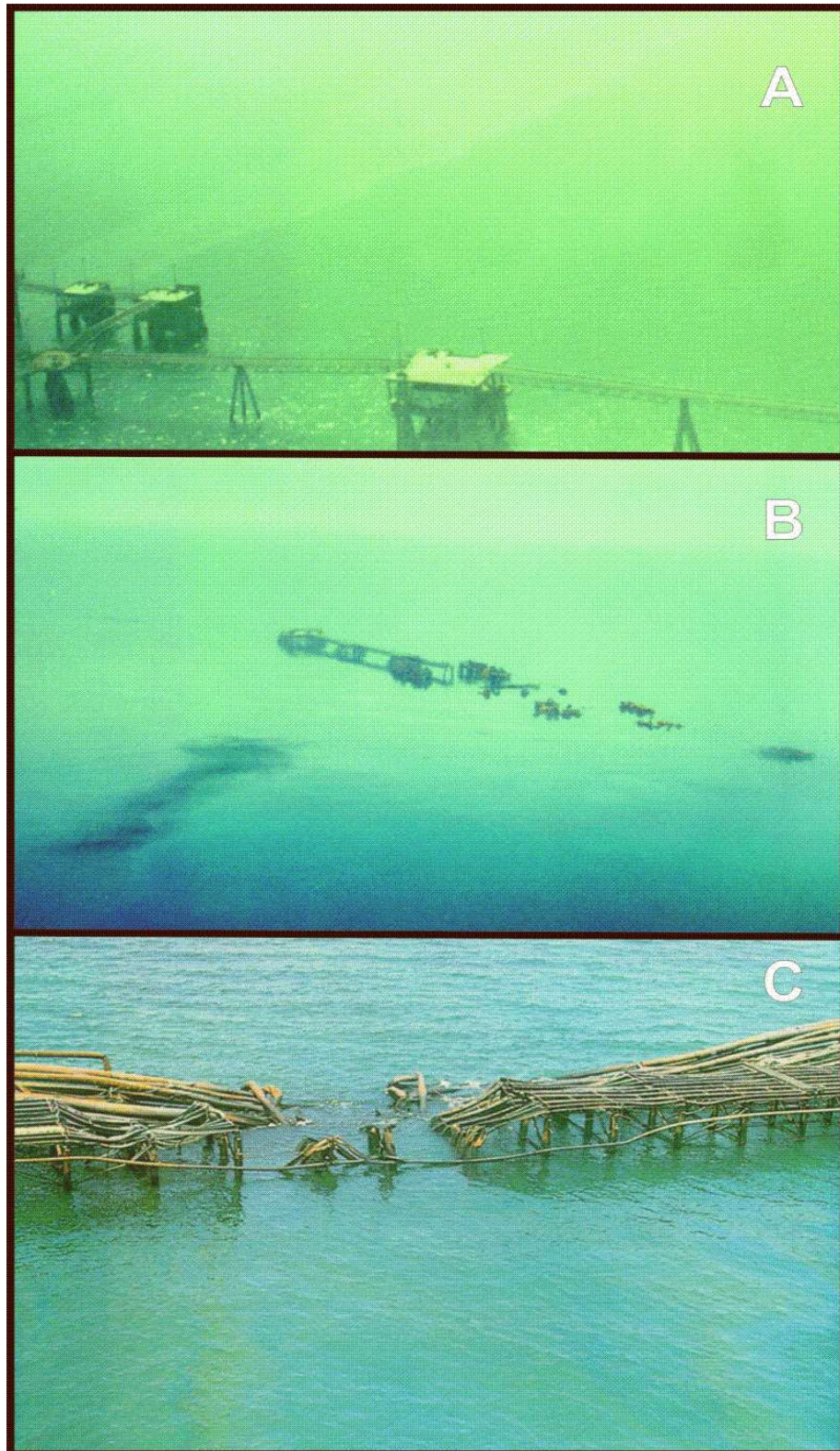
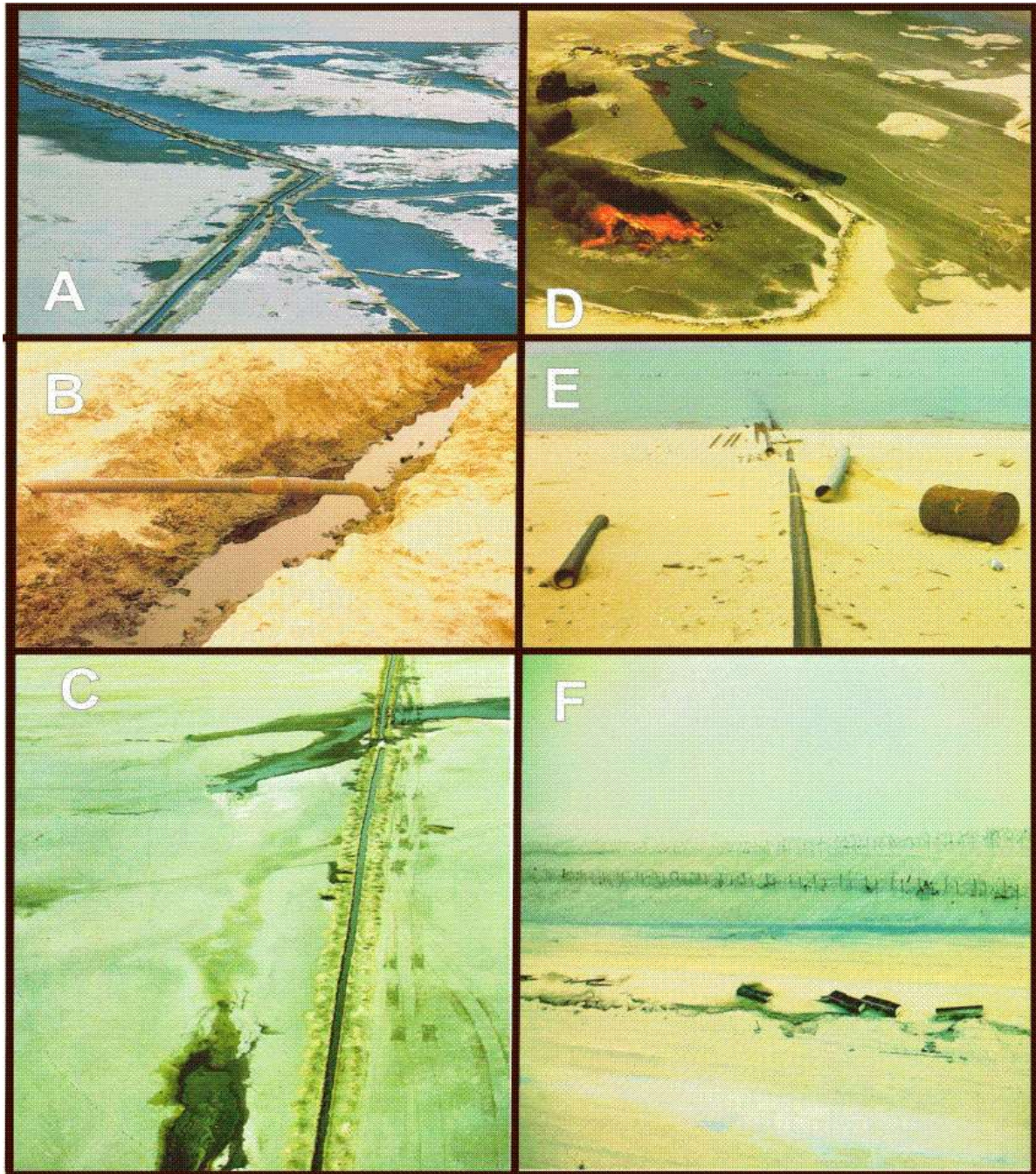


Figure 4. Land based sources of oil which contributed to the Gulf War oil spill: (A) Oil trench leaking into coastal area, (B) Pipe used to fill oil trenches leaking into coastal area, (C) Oil trench leaking into coastal area, (D) Damaged oil well leaking into coastal area, (E) Pipe run from oil wells into sea, (F) Oil filled tubs on Bubyan island which spilled into coastal area.



Summary

When available information regarding the 1991 Gulf War oil spill are summarized, the pervasive and directed nature of the Iraqi actions is seen to have resulted in a spill magnitude that is significantly greater than previously reported. While exact estimation of the spill can never be provided with certitude, the probable total spillage must have exceeded 10 million barrels and more likely lies between 15 and 20 million barrels.

Table 3. Fate of oil from 1991 Arabian Gulf Oil spill.

	Tawfiq & Olsen ²⁹ (Bbls)	Al-Rabah ³⁰ (Bbls)	Revised Estimate (Bbls)
1. Original Spill Volume	10,816,701	9,293,864	14,666,741
2. Evaporation of Volatile Components ³¹	40%	32%	32%
3. Dissolved Component ³¹	10%	1%	1%
4. Floating Oil in Spill	5,408,350	6,226,889	9,826,716
5. Recovered in Saudi Arabia ³²	1,163,457	1,163,457	1,163,457
6. Beaches (after 80 days)	45%	45%	45%
Estimated Amount	2,433,758	2,802,100	4,422,022
Saudi Arabia Beaches ^{33,34}	1,951,300	1,951,300	1,951,300
Iran, Qatar Beaches ^{35,36,37}	600,000	600,000	600,000
Kuwait Beaches ³⁸ (Difference)	(117,542)	250,800	1,870,722
Unaccounted for (Sunken)	1,811,136	2,261,332	4,241,237
Kuwait (13% of total spill area)	235,448	293,973	551,361
Saudi Arabia (87% of total spill area)	1,575,688	1,967,359	3,689,876

²⁹ Tawfiq, N.I. and DA Olsen. 1993. Saudi Arabia's Response to the 1991 Gulf Oil Spill. Mar. Poll. Bull.(27:333-348).

³⁰ Kuwait Monitoring and Assessment Claim No. 68A to the UNCC for damage to Marine and Coastal Resources.

³¹ Gundlach et al., 1985.

³² MEPA, 1991b

³³ MEPA. 1991c. 1991 Gulf Oil Spill Shoreline Cleanup Plan. The reported value has been increased to account for a 50% increase in shoreline length that is likely to result from redigitizing the Saudi shoreline from a 1/200,000 scale to a 1/50,000 scale.

³⁴ MEPA, 1991a.

³⁵ Thorhaug, A. 1991. The Environmental Future of Kuwait. The Environmental and Health Impact of the Kuwaiti Oil Fires. Univ. Birmingham Symposium (17 Oct. 1991)

³⁶ IOC/UNESCO, 1991.

³⁷ Although the IOC/UNESCO team reported approximately 500,000 barrels of oil along the Iranian coastline, the mechanism of transport from the 1991 spill is unclear. Recent oceanographic evidence from the Mt. Mitchell cruise (Reynolds, 1993) has shown a strong countercurrent flowing towards the south along the Iranian Coast as well as wind driven drifts which vary between ENE and WSW at the head of the Gulf. However, lower salinity water from the Shatt al Arab is transported across the head of the Gulf towards Kuwait where it remains as a lens in front of the Kuwaiti coast (Reynolds, 1993). Thus, it would appear that oil deposited from Min al Bakr and several battle damaged tankers in the Northern Gulf would tend to have been carried by the generally anti-clockwise circulation patterns and could not have arrived on the Iranian coast.

³⁸ Calculated from the estimated total oil on the beaches with the reported oil for Saudi Arabia, Iran and Qatar subtracted.

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