



**REVIEW OF MODELLING OF THE DEMOLITIONS AT
KHAMISIYAH IN MARCH 1991 AND IMPLICATIONS
FOR UK PERSONNEL**

EXECUTIVE SUMMARY

1. The purpose of this paper is to provide the MOD's assessment of the 2002 US Department of Defense (DoD) modelling of the events at Khamisiyah. It discusses changes to the modelling of the plume, since the initial US model in 1997, and the possible level of exposure, before examining the potential implications for the health effects of UK veterans. While the DoD 2002 paper contains no new evidence specific to UK troops, it does provide a greater understanding of the events at Khamisiyah.
2. On 10 March 1991, US Forces demolished an ammunition storage facility at Khamisiyah in Iraq. Not until 1996 did it become apparent to the US authorities that weapons containing nerve agents had been destroyed in the demolitions, potentially releasing sarin and cyclosarin into the atmosphere. The DoD developed mathematical computer models in order to estimate the exposure area resulting from the possible release of chemical warfare agents. The results of these models, including an estimate of the numbers of US personnel potentially exposed as a consequence of the demolitions, were published in 1997. In December 1999, the MOD published its assessment of the potential effects on UK personnel in a paper entitled "Review of Events Concerning 32 Field Hospital and the Release of Nerve Agent Arising from the US Demolition of Iraqi Munitions at the Khamisiyah Depot in March 1991" which discussed the US Department of Defense's theoretical computer model of the events at Khamisiyah.
3. Since 1999, the DoD has refined its model and the latest results were published in 2002. Shortly afterwards, the US Government Accountability (formerly General Accounting) Office (GAO) undertook a review of the DoD work. The findings of this review were published in June 2004 and were highly critical of the DoD model, stating that the DoD's conclusions were not valid since the limitations of the model and its data meant it could not accurately estimate the area of possible exposure.
4. The MOD has assessed the 2002 DoD model carefully and welcomes the improvements incorporated. The model better estimates the size and nature of the possible area of exposure. However, MOD notes that it utilises wide parameters in order to include the maximum number of personnel who could potentially have been exposed to any level of nerve agent. While it is appropriate to include a margin of this kind, MOD believes that the limits used in the model somewhat overstate the potential risk to UK troops. Nonetheless, MOD has used the model for its own analysis and concludes that:
 - The model results in a generally smaller geographic exposure area than that described in earlier models.
 - As estimated previously, approximately 9,000 UK Service personnel may have been within the area of possible exposure, with the closest some 130km from Khamisiyah.
 - The level of nerve agent would have been too low to have any biologically detectable effect on UK troops and would have a minimal impact on health; again this is consistent with previous findings.

INTRODUCTION

5. On 10 March 1991, US troops carried out demolitions of 122 millimetre rockets in a pit adjacent to the Khamisiyah ammunition storage facility in Southern Iraq. It was subsequently discovered that these rockets contained the nerve agents sarin and cyclosarin, and that some nerve agents would have been released by the demolitions.
6. The US Department of Defense (DoD) used mathematically derived computer models to generate a theoretical picture of what might have occurred during and after the Khamisiyah demolitions. The model was used to estimate any possible exposure area and as a basis to identify those personnel who were potentially at risk of exposure to nerve agent (i.e. situated within the possible exposure area) and those who were not. The results of this initial modelling work were published in 1997 (1; all referenced documents are listed at Annex A).
7. MOD's assessment of this paper and the implications for UK personnel were detailed in a paper entitled "Review of Events Concerning 32 Field Hospital and the Release of Nerve Agent Arising from the US Demolition of Iraqi Munitions at the Khamisiyah Depot in March 1991" published in December 1999 (2). In brief, this paper concluded that, of the 53,500 UK personnel deployed to the Gulf during Op GRANBY, approximately 9,000 may have been exposed to nerve agent as a consequence of the demolitions at Khamisiyah. However, the levels of nerve agent released would have been very low and, at that time, no evidence existed to implicate low-level exposure with ill-health.
8. The initial US model proved to be controversial, with other US agencies criticising the methodologies and assumptions employed in the exercise. The US DoD responded to these criticisms by inviting a panel of experts to review its model. These experts concluded that the DoD model was credible. The DoD undertook to re-examine the events at Khamisiyah using more accurate source data and taking full advantage of improvements in modelling technologies. The results of this work were published in 2002 (3, 4).
9. MOD had committed to update its 1999 paper upon publication of the 2002 DoD report: while the report does not contain any evidence or information which relates directly to UK units stationed in the Gulf at the time of the Khamisiyah demolitions, it does contain information which is relevant to understanding the events at Khamisiyah. Therefore it is the focus of the MOD review.
10. Shortly after publication of the DoD report, the General Accounting (now Government Accountability) Office (GAO) announced that it was undertaking a review of the DoD work. The GAO review was published on 2 June 2004 (5) and was highly critical of the DoD conclusions. Modelling is highly dependent on the accuracy of source data, as well as on the quality of the models themselves and the GAO considered that DoD had neither accurate source data nor high quality models. The logical conclusion from the GAO's position is that it is impossible to

estimate who may have been exposed to low levels of nerve agent.

11. As a consequence of the GAO's decision to undertake this review, MOD officials decided to delay publication of its analysis of the 2002 US model until the results of the GAO report had been published. However, the delay has afforded the opportunity to consider not only the DoD and GAO reports but also to take into account other research findings which have a bearing on the MOD's conclusions and which may themselves be of interest to those UK veterans concerned that their health may have been affected by this incident.

AIM

12. The aim of this paper is to assess the recent DoD model and to determine how its findings impact upon UK troops stationed in the Gulf in March 1991. Specifically, the paper attempts to identify the number of personnel who may have been exposed to nerve agents as a result of the demolitions at Khamisiyah. In addition, an assessment is made of the likely impact of exposure.

BACKGROUND

13. The Khamisiyah Ammunition Storage Facility was a site of approximately 25 square kilometres located approximately 350km south east of Baghdad, 200km north-west of Kuwait City and 270km north of Al Qaysumah. It consisted of two sections: one of 88 warehouses; the other of 100 hardened concrete bunkers. An earth berm and security fencing surrounded the latter.
14. At the end of the 1991 Gulf conflict, in late February/early March, action was taken to ensure that Iraqi military equipment and facilities were not re-used once coalition forces had withdrawn. A reconnaissance of the Khamisiyah facility was conducted by US forces and a large number of complexes containing weapons, ammunition and other materials were identified. In March 1991, controlled demolition of these complexes was undertaken, the detail of which is described in the 1999 MOD paper (2) and will not be repeated here.
15. In 1996, the US Government first announced that it had been established that weapons containing sarin and cyclosarin had been present when the facility was destroyed (6). As a consequence, the demolition activities have been the subject of extensive investigations, the findings of which have been published in a number of reports.
16. No UK units¹ were involved in the Khamisiyah demolitions, nor were there any operating nearby at the time. Indeed, the nearest UK unit was some 130 km from Khamisiyah and was therefore not exposed to the highest possible levels of agent, which would have been present in the immediate vicinity of Khamisiyah. The discussion below draws heavily upon the US reports and it is intended only as a summary of the available information. Readers seeking additional detail should consult the US source reports (detailed at Annex A).

¹ One UK Serviceman has been identified as serving on exchange with a US unit that was involved in escorting the US engineers involved in the Khamisiyah demolitions. He believes he was between 1km and 10km away from the demolitions when they took place. When contacted by the Gulf Veterans' Illnesses Unit (GVIU) in May 1997, he believed himself to be fit and well, and was not seeking healthcare.

MODELLING THE PLUME FOOTPRINT

17. It is important to appreciate that the accuracy of the output of mathematical plume models depends on accurate representation of the component processes and the input data (such as detail about the meteorological conditions, the number and type of weapons destroyed and the chemical properties of the nerve agent released). Many of the criticisms of the original 1997 model have been addressed in the 2002 DoD model by improvements to the input data, thereby providing greater confidence in the results of the exercise.

Modelling Technology

18. As well as changes to the input data options, a general improvement in information technology and computing power has increased the accuracy of this latest modelling effort. Both the 1997 and 2002 exposure areas were based upon a composite of 4 different models. This ensemble approach has the benefit of including all possible exposure areas and accounting for uncertainties. However, this approach may also have over-estimated the area of the exposure footprint, a risk which the DoD accepts.
19. The GAO's major criticism of the 2002 model was the DoD's decision to exclude the Lawrence Livermore National Laboratory (LLNL) model - which identified a much larger plume than the other models generated - from the final composite. However, DoD strongly defended its decision to exclude the LLNL model on the basis that it was much less robust than the other models, being based on hypothetical and uncorroborated data. Indeed, the DoD has stated that it is misleading to overlay the DoD composite results with the LLNL model because there are numerous differences in how hazard areas were calculated.
20. The DoD maintains that the modelling was not, as the GAO described it, flawed². Uncertain model outcomes may result from uncertainties in the inputs, unvalidated models or both. However, modelling experts reviewed both the methodology and the results of the modelling and have concluded that the DoD work was sound. It has also been noted that, of the contributors to the GAO report, there was only one modelling expert and no meteorologist, suggesting that there may have been an over-reliance on anecdotal evidence to reach conclusions.

Source Data

21. The 2002 DoD model was able to incorporate observational data which had previously been classified. This new intelligence information was released by the CIA in 1999 and included revised estimates of rocket numbers, quantity and purity of nerve agents and better information regarding the dispersal of nerve agent in the environment. However, GAO considers the modelling assumptions about source term data were inaccurate since they were incomplete, uncertain and non-validated.

² The DoD responded to the GAO criticisms in a detailed letter to the GAO which was published as an appendix to the GAO final report (5).

Nerve Agent Deposition and Decay

22. The process by which suspended material (in this case, nerve agent) is removed from the atmosphere and is transferred to the surface of an object (for example, a grain of sand) is known as deposition. In the 2002 modelling, the effect of this process on the exposure footprint was more accurately accounted for, thereby reducing the possibility of over-estimating the footprint size.
23. The 2002 model made better use of topographical data. The 1997 model had estimated the ground cover to have a roughness length of about 10cm (the same as in deserts where scrub is present). However, the 2002 model used a roughness length of 1cm for vegetated areas of desert and 0.5cm for non-vegetated areas of desert in order to reflect more accurately the barren conditions of the terrain in southern Iraq.
24. By the time the plume was remodelled in 2002, there was a greater understanding of the way in which nerve agents are subject to degradation by environmental stimuli. This was not factored into the original modelling work. Taking into account all these clarifications, the revised model is considered to be more accurate than previous versions and has resulted in a reduced plume area.

Epidemiological Studies

25. A number of US studies have been published which investigate the health of veterans who were potentially exposed to sarin during the 1990-1991 Gulf conflict. These studies use the 2002 DoD plume model to categorise their study populations. Epidemiologists recognise that studies such as these have limitations, since it is difficult to acquire reliable exposure estimates relating to individuals. However, large study populations, sometimes including up to 100,000 personnel, permit robust risk estimates and provide significant statistical power. Smith *et al* (7, 8) have examined the post-war hospitalisation experiences of Gulf veterans and have observed that possible exposure to low level nerve agent, as a consequence of the demolitions at Khamisiyah, does not increase the likelihood of hospitalisation compared with veterans who were not exposed. Similarly, a study conducted by the US Department of Veterans Affairs (VA) (9), examined the rate of mortality among those veterans who could have been exposed to nerve agents resulting from the Khamisiyah demolitions. The report concluded that there was no difference in mortality rates between those veterans under the modelled plume and those who were not.
26. The GAO believes that use of the DoD modelled exposure area as a basis for epidemiological studies is inappropriate since it considers that the model is flawed and that consequently, all troops in the Gulf may potentially have been exposed. However, it has been demonstrated that mortality rates for UK Gulf veterans are similar to those troops who deployed to other theatres over the same period (10) suggesting that Gulf service, with any associated exposures, is not associated with increased

mortality. In addition, it has also been demonstrated that mortality rates among UK (10) and US (9) Gulf veterans are significantly lower than the general population (after adjustment for age, sex, race and year of death).

MODELLING THE LEVEL OF EXPOSURE

27. Determining the area of the plume created by the demolitions at Khamisiyah is an important step towards identifying those units which could have been subject to nerve agent exposure. However, it is also important to consider the amount of nerve agent which would have been released in order to determine the possible dose received by troops and its impact on health. The source data used by the DoD in the 2002 study was based on better intelligence about the quantity and quality of nerve agent which could have been released. The 2002 work also takes into consideration advances in the understanding of the chemical properties of nerve agents.

Nerve Agent Release

28. In the 1997 model, it was estimated that the demolitions at Khamisiyah had released sarin and cyclosarin from 500 Iraqi 122mm rockets. However, a CIA memo of October 1999 advised that it was likely that only 225 rockets would have released nerve agent, thereby reducing the potential level of nerve agent in the atmosphere by 55%. The GAO considers that the assumptions relating to the quantity and purity of nerve agent are inaccurate since they were based on uncertain, incomplete and unvalidated information.
29. The original model assumed that nerve agent was released in the form of aerosolised liquid droplets and vapour as should normally occur when 122mm rockets' burster-tubes, which are designed to ensure that nerve agent is released in the form of aerosolised liquid droplets to ensure maximum lethality, detonate. However, US field trials suggested that most of the rockets' burster-tubes would have failed to detonate and that the vast majority of nerve agent was released in vapour form. This is important since the exposure route influences the adverse effects.

Sarin and Cyclosarin exposure levels

30. In 1997, the DoD model only took account of the toxicity of sarin, since information about the properties of cyclosarin were not available. By 2002, more information regarding cyclosarin was known and, in addition, the rockets at Khamisiyah were estimated to contain both sarin and cyclosarin (at a ratio of 3:1). In principle, cyclosarin is three times more toxic than sarin and this difference was factored into the 2002 study, thereby providing a more accurate estimate of the exposure.
31. However, the 2002 DoD study does not account for the observation that the 3 fold difference in cyclosarin toxicity is only relevant if the agent is absorbed through the skin (percutaneous exposure) which, in turn, requires the skin to be in contact with the liquid form of the agent (most usually as droplets). As noted earlier, the vast majority of agent is likely to have been released in the form of vapour, which is absorbed predominantly by inhalation. Since the toxicity of sarin and cyclosarin are the same when absorbed via inhalation, the toxicity of cyclosarin should be regarded as being equal to that of sarin.

Human Toxicity of Sarin and Cyclosarin

32. The 1999 MOD assessment discussed in detail the effects of nerve agent on humans and the levels at which these effects occur (2). In that paper, the MOD concluded that the theoretical dosage which could have been received by any UK unit would have been 3.6 times lower than the level at which any noticeable symptoms would occur. The latest US model suggests that less nerve agent was released by the demolitions, thereby diminishing the area of possible exposure and reducing the overall degree of potential exposure. Evidence suggests that humans who have been experimentally exposed to much higher levels of nerve agent have shown no increased incidence of ill-health many years later (11).
33. As described above, the majority of nerve agent released by the Khamisiyah demolitions would have been in the form of vapour. After being inhaled by exposed personnel, the agent would be absorbed into the bloodstream via the respiratory mucosa. Since such low levels of agent were released, any agent in the blood would be quickly degraded by natural enzymes long before it reached any target organs. Consequently, no toxicological sequelae would be expected. The levels of sarin and cyclosarin postulated to have been released are too low to elicit any measurable effect at the time of exposure and no evidence exists to suggest that these levels have any long-term health effects. Indeed, no mechanism has yet been identified to describe how an absence of acute toxic effects at the time of exposure can result in chronic ill-health.
34. A recent report from the US Institute of Medicine (12), which reviewed the literature on the health effects of exposure to nerve agents, concluded that there was insufficient or inadequate evidence to determine whether an association exists between exposure to sarin at low doses and subsequent long term adverse neurological health effects. Further support for that position is provided by a study (13) which investigated hospitalisations and medical diagnoses in the nine years following the war amongst troops within 50 km of the Khamisiyah site compared with other deployed troops. This study demonstrated that there was no difference in diagnosis which could be linked with location or proximity to a potential toxin source.
35. In contrast, a recently published report by the US Research Advisory Committee on Gulf War Illnesses (14) concluded that, contrary to previous assumptions, overall evidence from varied sources, including human and animal studies, supported "a probable link" between exposure to neurotoxins, most importantly acetyl cholinesterase inhibitors (including sarin and cyclosarin) during the Gulf conflict and the development of Gulf veterans' illnesses. However, this reviewed only some of the available literature, particularly animal studies. There are issues about quality and size of the studies focussed on, as well as consistency of outcomes, and they covered a range of neurotoxin types. The report cannot be seen, therefore, to provide conclusive evidence of an association between possible low level exposure to organophosphate nerve agents and Gulf

Veterans' illnesses. It is also important to note that similar illnesses occur in personnel who did not deploy to the Gulf, and therefore were not exposed to acetyl cholinesterase inhibitors, as well as participants from many nations, despite their very different experiences and exposures.

NUMBER OF UK PERSONNEL LOCATED WITHIN THE POTENTIAL HAZARD AREA

36. In the 1999 MOD paper (2) it was calculated that, of the 53,500 UK service personnel deployed to the Gulf during Operation Granby, approximately 9,000 were situated within the calculated exposure footprint and could have been potentially exposed to nerve agent released by the demolitions. However, since no UK units were based at or close to Khamisiyah, the possible level of nerve agent to which personnel may have been exposed would have been very low.
37. Revised calculations, based on the 2002 US model, do not demonstrate any change in overall numbers. A list of units stationed in the Gulf is given at Annex B and those who were located within the potential exposure area are marked with an asterisk. It should be noted that unit C1 (elements of Chinook (ME) Squadron, RAF) is now located under the plume (having been outside the 1997 plume) but is on the boundary of the potential exposure area. In addition, 113f (5 Troop of 174 Company, Royal Military Police) is no longer within the modelled exposure area, having previously been assessed as under the plume.
38. It is important to remember that the location of an individual or unit within the boundary of the modelled potential hazard area does not equate to actual exposure to nerve agent - it represents a mathematically generated theoretical possibility that this may have happened.

CONCLUSIONS

39. The modelling of the demolitions at Khamisiyah has proved to be a complex task and, due to an absence of definitive source data, it is unlikely that any unequivocal conclusions can be drawn. MOD scientists have examined the 2002 DoD model carefully and welcome the modelling improvements implemented by the DoD. However, the MOD believes that the DoD has based its model on source data assumptions which are too broad. While it is sometimes reasonable to use assumptions which confer the benefit of any doubt, in this case these assumptions go too far and result in a model which overstates the size of the plume footprint. In particular:
- a) A General Population Limit represents the limit at or below which any member of the general population could be exposed to continuously for a lifetime without experiencing any adverse health effects. The US 2002 modelling has used a figure for a 24-hour exposure, which has been derived by multiplying the GPL by 10, to calculate the potential hazard level. However, the MOD considers that calculating exposure using a GPL is inappropriate since it takes into account all individuals present in a general population, such as the young, old and infirm, and is not representative of the Armed Forces (although the issue of civilian exposures is important, it falls outside the scope of this paper). Furthermore, if a more realistic figure were used, which reflected the absence of the young, old and infirm among the assessed population, the possible exposure area is likely to shrink dramatically resulting in the exclusion of UK forces from the area of possible exposure.
 - b) The latest DoD model takes into account the differences in toxicity of sarin and cyclosarin. However, since the major route of exposure would be through the respiratory tract, rather than percutaneously, this property should not impact upon the modelled exposure. By accounting for it, the DoD have overstated the possible risk to personnel.
 - c) The DoD model is a composite of 4 different models which have been overlaid in order to maximise the possible size of the service population potentially at risk of exposure. This was purposefully done in order to ensure that the risk was not underestimated. However, the MOD believes that this approach serves to present a disproportionate assessment of any potential exposure.
40. Without major improvements in the quality of the source data, which are unlikely to emerge, the size and nature of the hazard potentially experienced by troops in the Gulf will remain a matter of debate. Despite disagreement over the size and nature of the plume, both the DoD and GAO agree that no further modelling of the events at Khamisiyah should be undertaken.
41. The 2002 DoD utilises wide parameters in order to include the maximum number of personnel who could potentially have been exposed to any

level of nerve agent. While it is appropriate to include a margin of this kind, MOD believes that the limits used in the model somewhat overstate the potential risk to UK troops. Nonetheless, the MOD has used the latest DoD model to determine how many UK personnel may have been at risk of exposure to nerve agents. MOD's assessment concludes that approximately 9,000 service personnel were located within the possible area of exposure and considers that it is possible (though not probable) that an extremely low level exposure could have occurred within this area.

42. However, US epidemiological studies have found no association between service within the Khamisiyah exposure area and the development of ill health (7, 8) and there is no clinical evidence to support a link between low level sarin exposure and chronic illness (11, 12). The MOD therefore considers that there is insufficient evidence to link such a low level of potential exposure to nerve agent, released as a consequence of the demolitions at Khamisiyah, and the range of symptoms of ill health being experienced by some Gulf veterans.

FURTHER INFORMATION

43. Further information can be obtained from the Veterans Policy Unit's website at www.gulfwar.mod.uk. Information is also available from the Veterans Policy Unit via Freephone 0800 169 4495, by fax on 0207 218 1482 and by e-mail to SPPoIVPU-GVIDD@mod.uk. The postal address is: SP Pol Veterans Policy Unit – Gulf Veterans' Illnesses, Ministry of Defence, 7th Floor, Zone H, Main Building, Whitehall, London, SW1A 2HB.

27 January 2005

Annexes

Annex A - Bibliography

Annex B - Revised US modelled plumes with UK unit location data (incl. key to unit numbering)

Annex A

1. Modelling the Chemical Warfare Agent Release at the Khamisiyah Pit, CIA and DoD, September 1997.
2. Review of Events Concerning 32 Field Hospital and the Release of Nerve Agent Arising from the US Demolition of Iraqi Munitions at the Khamisiyah Depot in March 1991, MOD, December 1999.
3. Case Narrative, US demolition Operations at Khamisiyah, Final Report, DoD April, 2002.
4. Modelling and Risk Characterization of US Demolition Operations at the Khamisiyah Pit, DoD, W Winkenwerder et al, April 2002.
5. DOD's Conclusions about US troops' Exposure Cannot be Adequately Supported, GAO, June 2004.
6. CIA Report on Intelligence Related to Gulf War Illnesses, CIA, August 1996.
7. Gulf War Veterans and Iraqi Nerve Agents at Khamisiyah: Postwar Hospitalization Data Revisited, American Journal of Epidemiology, TC Smith *et al*, May 2003.
8. The Postwar Hospitalization Experience of Gulf War Veterans Participating in US Health Registries, Journal of Occupational Environmental Medicine, TC Smith *et al*, 2004
9. Mortality Among US Gulf War Veterans Who Were Potentially Exposed to Nerve Gas at Khamisiyah, Iraq, Environmental Epidemiology Service of the Veterans Health Administration, HK Kang *et al*, May 2002.
10. 1990/1991 Gulf Conflict – UK Gulf Veterans Mortality Data: Causes of Death, Defence Analytical Services Agency, January 2005
11. Long-term Health Effects of Exposure to Sarin and Other Anticholinesterase Chemical Warfare Agents, Military Medicine, WF Page, March 2003.
12. Gulf War and Health, Updated Literature Review of Sarin, Institute of Medicine, JM Colwill *et al*, August 2004.
13. The Postwar Hospitalisation Experience of Gulf War Veterans Possibly Exposed to Chemical Munitions Destruction at Khamisiyah, Iraq, American Journal of Epidemiology, GC Gray *et al*, September 1999.
14. Scientific Progress in Understanding Gulf War Veterans' Illnesses: Report and Recommendations, US Research Advisory Committee on Gulf War Veterans' Illnesses, JH Binns *et al*, September 2004.

Key to Unit Numbering**Army Units³**

1a	1 (UK) Armoured Division (Main)
1b	1 (UK) Armoured Division (Rear)
1c	HQ Divisional Admin Area (HQ DAA)
1d	Divisional Rear Vehicle (Div RV)
2	1 Armoured Division HQ & Signal Regiment
3	A COY, 1 Queen's Own Highlanders
4	22 Armoured Brigade HQ & Signal Squadron (201)
5a	16/5 L (Main)
5b*	16/5 L (Medium Reconnaissance)
6	QDG (Armoured Reconnaissance Squadron)
7	2 Field Regiment, Royal Artillery (RA)
8	12 Air Defence Regiment, RA
9	26 Field Regiment, RA
10	32 Heavy Regiment, RA
11	39 Heavy Regiment, RA
12	46 Air Defence Battery, RA
13	49 Field Battery, RA
14	73 (Observation Party) Battery, RA
15	4 Armoured Division Transport Regiment, Royal Corps of Transport (RCT) (Split into a: Fwd and b: Main from 11 March 1991)
16	1 Squadron, RCT
17	19 Squadron, RCT
18	38 Squadron, RCT

³ Note: Units marked with * were located within the potential exposure area

- 19a 32 Armoured Engineer Regiment, Royal Engineers (RE)
- 19b 31 Field Squadron (32 Armd Engr Regt) RE
- 19c 77 Field Squadron (32 Armd Engr Regt) RE
- 20 37 Field Squadron, RE
- 21* 15 Field Support Squadron, RE
- 22 45 Field Support Squadron, RE
- 23 49 Explosives Ordnance Disposal Squadron, RE
- 24 14 Topographic Squadron, RE
(elements attached to 1 (UK) Armoured Division)
- 25 4 Regiment, Army Air Corps (AAC)
- 26 661 Squadron, AAC (Attached to 4 Regt AAC)
- 27* Joint Helicopter Support Unit (JHSU)
- 28 7th Armoured Brigade (Main)
- 29 HQ & 207 Signal Squadron
- 30 Royal Scots Dragoon Guards (RSDG)
- 31 Queen's Royal Irish Hussars (QRIH)
- 32 1st Battalion, The Staffordshire Regiment (1 Staffs)
- 33 21 Engineer Regiment, RE
- 34 40 Field Regiment, RA
- 35 10 Air Defence Battery, RA
- 36 FRG, 7 Armoured Workshop, Royal Electrical & Mechanical Engineers (REME)
- 37 11 Ordnance Company, Royal Army Ordnance Corps (RAOC)
- 38 1 Armoured Field Ambulance, Royal Army Medical Corps (RAMC)
- 39 203 Company, Royal Military Police (RMP)
(1 Platoon with 7 Armoured Brigade)
- 40 4th Armoured Brigade (Main)

- 41 HQ & 204 Signal Squadron
- 42a 14/20 King's Hussars (14/20H)
- 42b O Battery, RA (attached to 14/20H)
- 43a 1st Battalion, Royal Scots (1 RS)
- 43b 23 Battery, RA (attached to 1 RS)
- 44a 3rd Battalion, Royal Regiment of Fusiliers (3 RRF)
- 44b 127 Battery, RA (attached to 3 RRF)
- 45* 1st Battalion, The Coldstream Guards (TACON)
- 46 A Squadron, The Life Guards (A Sqn, LG)
- 47a Q Company and 2 Company of 1st Battalion
The Grenadier Guards
- 47b Detachment of 1st Battalion, The Grenadier Guards
(attached to 1 Staffs)
- 48a 23 Engineer Regiment, RE
- 48b* 39 Field Squadron, RE
- 48c 73 Field Squadron, RE
- 49 31 Ordnance Company, RAOC
- 50 FRG 6 (11 Armd Workshop), REME
- 51 5 Armoured Field Ambulance (DS 5A), RAMC
- 52 203 Company RMP
(1 Platoon with 4 Armoured Brigade)
- 53* 1st Battalion, The Coldstream Guards
(part of Prisoner of War Guard Force (PWGF))
- 54 1st Battalion, The Royal Highland Fusiliers (1 RHF)
(part of PWGF)
- 55a* 1st Battalion, The King's Own Scottish Borderers
(1 KOSB) (Part of PWGF)
- 55b B Company, 1st Battalion, The King's Own Scottish
Borderers (1 KOSB)
- 56a HQ, 1st Battalion, The Queen's Own Highlanders (QOHldrs)

56b	B Company, 1st Battalion, QOHldrs.
57a	Royal Armoured Corps Armoured Delivery Squadron/Group (ADG(Fwd))
57b*	Royal Armoured Corps Armoured Delivery Squadron/Group (ADG(Main))
58a	1st Armoured Division Transport Regiment (Main) (1 ADTR) RCT
58b	2 Squadron, RCT (1 ADTR)
58c	33 Squadron, RCT (1 ADTR)
59	7 Tank Transporter Regiment, RCT
60	5 Armoured Field Ambulance (DS 5B), RAMC
61	60 Field Psychiatry Team (FPT), RAMC
62	61 Field Psychiatry Team (FPT), RAMC
63a	HQ, 203 Company, RMP
63b	Traffic Point 1 (TP 1), 203 Company, RMP
63c	TP2, 203 Company, RMP
63d	TP3, 203 Company, RMP
63e	TP4, 203 Company, RMP
63F	TP5, 203 Company, RMP
64a	MRG 7A, 7 Armoured Workshop, REME
64b	MRG 7B/RHQ, 7 Armoured Workshop, REME
65	11 Armoured Workshop, REME
66	3 Ordnance Battalion (Group), RAOC
67*	43 Ordnance Company (Rear), RAOC
68	9 Field Cash Office
69	HQ Force Maintenance Area (FMA)
70*	HQ Forward Force Maintenance Area (FFMA)
71	53 Field Squadron (Construction), RE

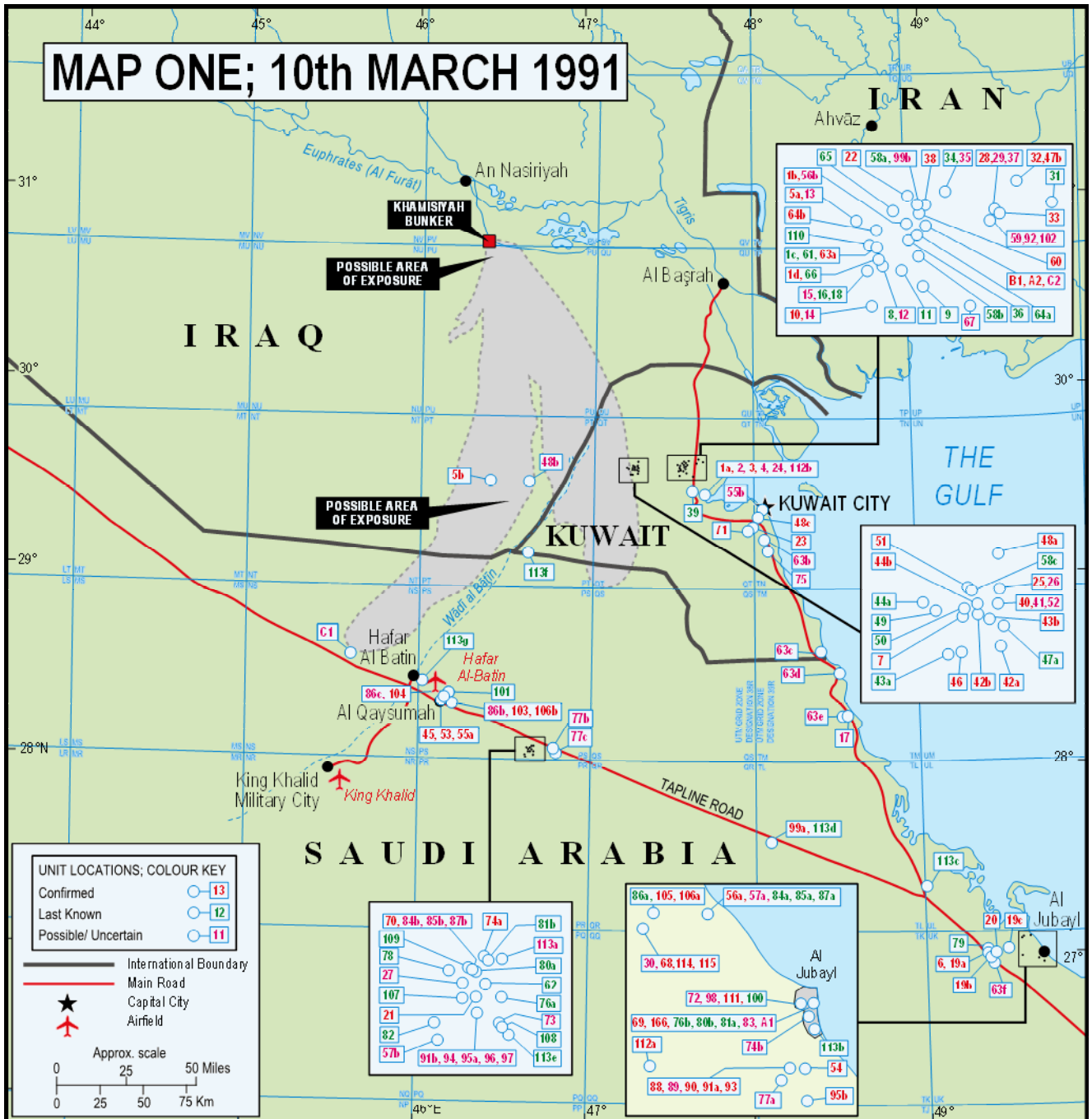
72	60 Field Support Squadron, RE
73*	3 Field Squadron, RE
74a	14 Topographic Squadron, RE - FFMA detachment
74b	14 Topographic Squadron, RE – FMA detachment
75	1 Platoon, Specialist Team Royal Engineers (STRE)
76a*	6 Ordnance Battalion (Group), RAOC – FFMA detachment
76b	6 Ordnance Battalion (Group), RAOC – FMA/Rear
77a	51 Ordnance Company (Petrol), RAOC: HQ and 512 Platoon.
77b*	51 Ordnance Company (Petrol), RAOC: 513 Platoon.
77c*	51 Ordnance Company (Petrol), RAOC: 514 Platoon.
78*	52 Ordnance Company (Ammunition), RAOC
79	53 Ordnance Company (Ammunition), RAOC
80a*	62 Ordnance Company (Materials/Stores), RAOC – FFMA detachment
80b	62 Ordnance Company – FMA detachment
81a	91 Ordnance Company (Rations), RAOC – FMA detachment
81b*	91 Ordnance Company, RAOC – FFMA detachment
82*	63 Vehicle Platoon, RAOC
83	623/624 Stores Platoons, RAOC
84a	Local Resources Section (91 Ordnance Company) RAOC
84b*	Local Resources Section (91 Ord Coy) RAOC at FFMA
85a	Bakery (of 91 Ordnance Company) RAOC
85b*	Bakery (of 91 Ordnance Company), Field Bakery RAOC at FFMA
86a	Laundry [711 Laundry Platoon with 33 General Hosp]
86b*	Laundry detachment at 22 Field Hospital
86c*	Laundry detachment at 32 Field Hospital

87a	NAAFI Expeditionary Forces Institute (EFI), FMA
87b*	EFI, Shop at FFMA
88	10 Regiment, RCT
89	HQ Squadron of 10 Regiment, RCT
90	9 Squadron (Petrol), RCT
91a	12 Squadron (DROPS), RCT
91b*	12 Squadron (DROPS), RCT (FFMA element)
92	16 Tank Transporter Squadron, RCT
93	17 Squadron, RCT
94*	27 Regiment, RCT
95a*	77 Squadron (HQ Sqn 27 Regiment), RCT
95b	77 Squadron, RCT (Rear)
96*	7 Squadron, RCT
97*	42 Squadron, RCT
98	59 MC Squadron, RCT
99a	66 Squadron, RCT
99b	66 Squadron, RCT (detachment at Petrol Point Kuwait)
100	51 Port Squadron, RCT
101*	28 Ambulance Squadron, Gurkha Transport Regiment RCT
102	414 Tank Transporter Unit, RCT
103*	22 Field Hospital, RAMC
104*	32 Field Hospital, RAMC
105	33 General Hospital, RAMC
106a	84 Field Medical Equipment Depot, FMA
106b*	84 Field Medical Equipment Depot, Al Qaysumah
107*	71 Aircraft Workshop, REME

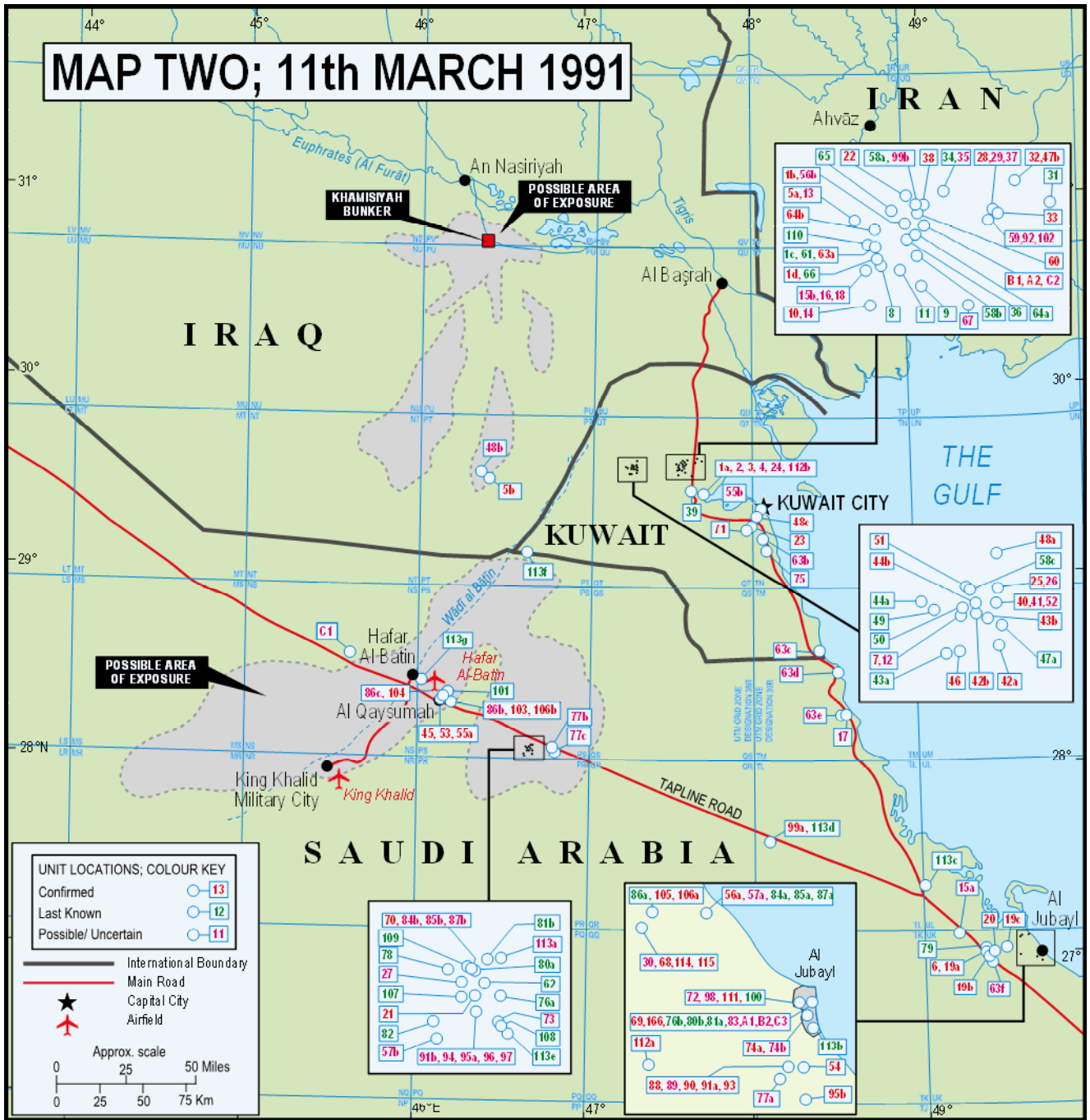
108*	MRG/Main, 6 Armoured Workshop, REME
109*	187 (Tancred) Company, RPC
110	518 Company, RPC
111	908 Pioneer Labour Support Unit, RPC
112a	Army War Graves Service (AWGS): Al Jubayl (based on 23 Group, RPC)
112b	AWGS team in Kuwait.
113a*	174 Company, RMP, FFMA
113b	174 Company, RMP, FMA
113c	174 Company, RMP, TP1
113d	174 company, RMP, TP2
113e*	174 Company, RMP, TP3
113f	174 Company, RMP, TP4
113g*	174 Company, RMP, TP5
114	1 Postal and Courier Regiment, RE
115	6 Field Record Office
116	30 Signal Regiment

RN/RAF Units

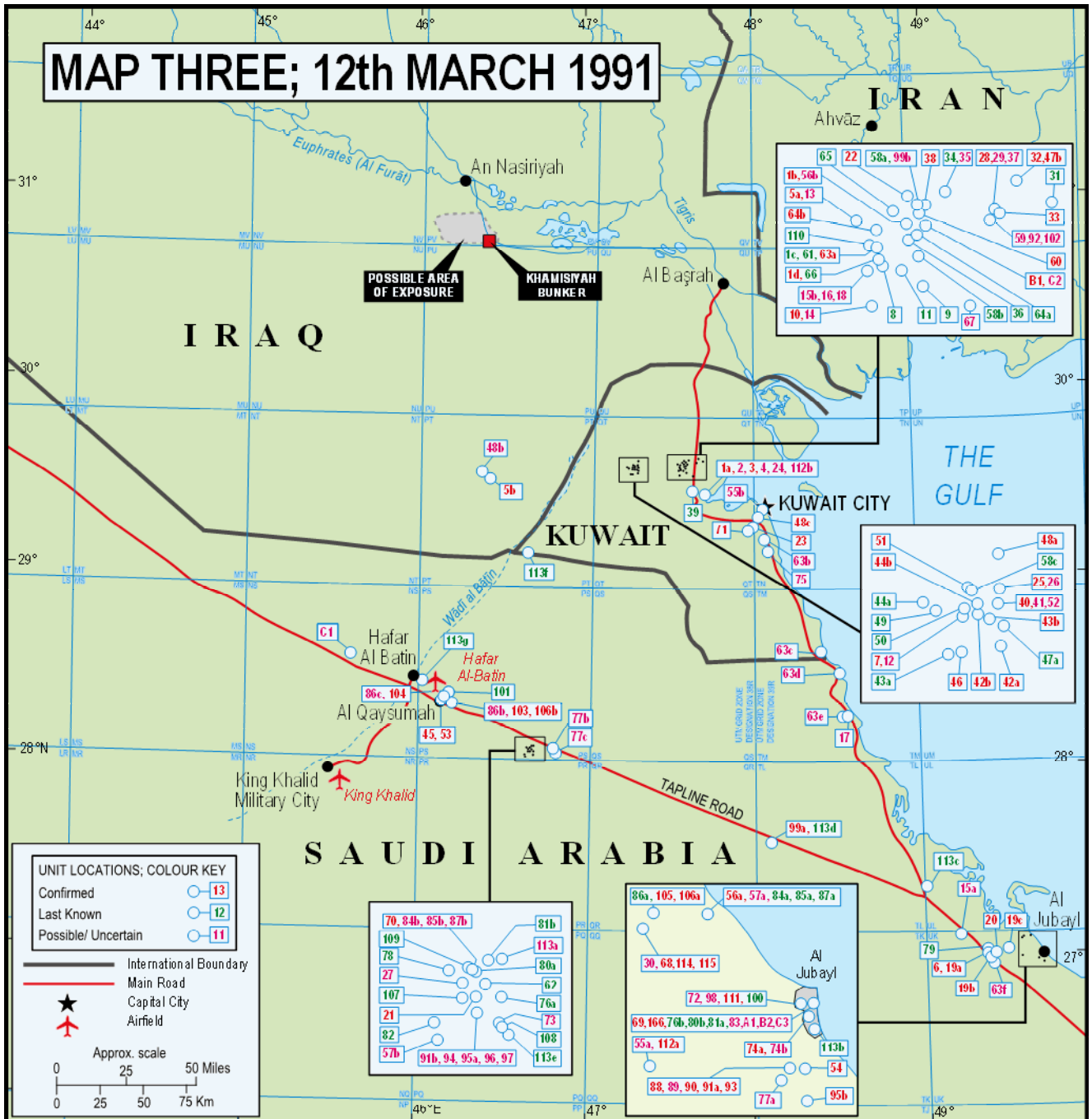
A1	Puma (Middle East (ME)) Sqn RAF, elements in Al Jubayl
A2	Puma (ME) Sqn RAF, elements in Kuwait (up to and inc. 11 March 1991 when it moved to join A1 above)
B1	Sea King (ME) Sqn RNAS, elements in Kuwait
B2	Sea King (ME) Sqn RNAS, elements in Al Jubayl (from 11 March 1991)
C1*	Chinook (ME) Sqn RAF, elements in Hafar Al Batin (up to and inc. 12 March 1991 when it moved to join C3 below)
C2	Chinook (ME) Sqn RAF, elements in Kuwait.
C3	Chinook (ME) Sqn, elements in Al Jubayl (from 12 March 1991)



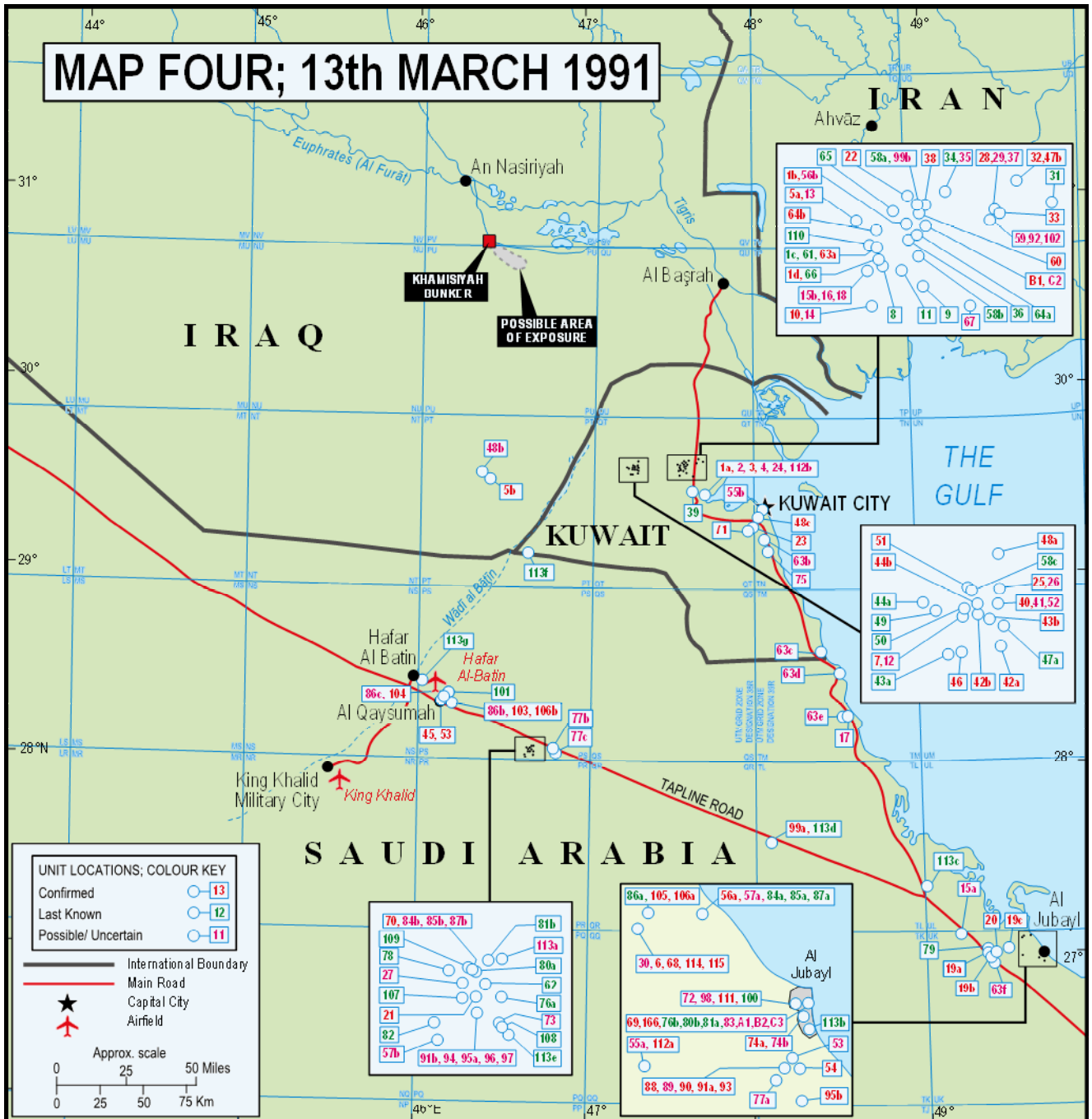
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