



## **Crossrail's Management of Unexploded Bomb (UXB) Risk**

*Summary: Crossrail were faced with a UXB threat across certain parts of their scheme. This case study describes the problems that Crossrail faced, how they helped to establish and to document UXB best practice and how, with 6 Alpha's guidance, they employed high-resolution datasets to articulate and manage the UXB risks posed in order to deliver project safety at best value. 6 Alpha delivered an 85% reduction in potential UXB risk mitigation work, saving Crossrail potential expenditure of over £1million.*

### **Introduction**

At an early stage in the scheme, Crossrail Limited had been made aware of the potential risks posed by UXBs in certain areas of their scheme. A number of specialists had been consulted in the early stages of the project to determine their opinion not only concerning the level of UXB risk but also and what an appropriate response might be to mitigate it. Whilst it was clear to Crossrail that there may be some UXB risk, not all parts of their scheme were exposed to the same degree of risk. There were also concerns that some of the advice appeared to be over cautious either by not considering site specific factors e.g. ground conditions or being viewed as a precursor to on site survey work. The advice received did not appear either transparent or consistent between the various specialists contacted.

## **Crossrail's Action Plan**

In response to these concerns Crossrail undertook two decisive actions to address the UXB issue.

Firstly, they contacted Construction Industry Research and Information Association (CIRIA) to suggest that both clients and wider construction professionals need guidance on how they should manage both the UXB risk and the UXB specialists.

From this approach and wider consultation with the construction industry, the wheels were put in motion for the development of CIRIA Project C681 "*Unexploded Ordnance – A guide for the Construction Industry*". A wide range of construction industry stakeholders formed a Steering Group to direct the work. The resultant guide now provides construction professionals with the tools and know-how, to review UXB risk assessments and compare them against the *defacto* industry standard. The guide articulates a consistent approach to UXB risk assessment, advocating semi-quantitative processes to introduce statistical rigor in what has often been a wholly *subjective* assessment; an approach supported by the Health & Safety Executive (HSE).

Secondly, Crossrail appointed 6 Alpha Associates to the project as their specialist UXB consultant. 6 Alpha Associates are an independent risk management consultancy that does not carry out UXB site survey work and were also the technical co-authors of the CIRIA guidance.

## **Scale of the Issue**

6 Alpha were tasked to undertake a series of desk-based UXO risk assessments for the entire project; this included hundreds of site investigation exploratory positions, miles of tunnelling and numerous shaft and portal locations.

Recommendations from other UXO specialists had stated that virtually all project related intrusive engineering works within 15 metres of ground level required an intrusive magnetometer survey or specialist-watching brief. Clearly the cost associated with such an operation would have resulted in a seven-figure price tag.

Crossrail needed to balance the risk of encountering UXBs, the effectiveness of magnetometer surveys through “noisy” ground conditions i.e. made ground full of utilities and the increased risks from the intrusive survey to the Crossrail project. The ground disturbance caused by intrusive magnetometer surveys on the scale recommended would have increased the ground movements from construction and increased Crossrails risk profile.

## **6 Alpha’s Approach**

Working openly and hand-in hand with Crossrail, 6 Alpha’s strategy for dealing with UXB risk on the project consisted of three straightforward steps:

- **Step 1 - Establish the Facts:** by conducting a GAP analysis and enhancing the quality of the base data;
- **Step 2 – Establish the level of Risk;** by developing a robust, transparent and consistent semi-quantitative risk assessment (SQRA) procedure;
- **Step 3 - Manage the Risk at Best Value;** by applying apply the *As Low As Reasonably Practicable* (ALARP) principle to the over-arching risk mitigation strategy.

We have expanded upon what actions we took at each step below:

**Step 1;** Whilst some “standard” sources of information related to UXB contamination had already been gathered by Crossrail (and other UXB specialists), it was not complete and there were some gaps. 6 Alpha collated and enhanced this data by employing detailed historical mapping (provided by Landmark), as well as historical aerial photography and site-specific geotechnical information. This

proved vital on a project of this scale and incorporating the new information with the base data enabled a comprehensive UXB threat assessment to be conducted, which effectively delivered Step 1 of the process.

**Step 2;** by intelligently employing the data gathered in Step 1, a project specific SQRA procedure was developed for this project by 6 Alpha, but in conjunction with and close cooperation of our Client. The aim was for the risk assessment process to be transparent, balanced, repeatable, consistent and quantifiable. However Crossrail and 6 Alpha appreciated that a wholly quantitative analysis was not appropriate to type of UXB risks that had been exposed, and a semi- quantitative analysis would have to be adopted, for the following reasons:

- **Variations in historical data;** the statistics used within the quantitative risk assessment do not take into account that *inter alia*:
  - Significant numbers of bombing raids were not recorded during WWII;
  - WWII bombing density was not precise nor “mathematically consistent”;
  - Bomb failure rates varied dependant on factors such as aircraft and bomb preparation; the prevailing environments; hostile action/counter attack; bomb release altitude; bomb varieties employed; fuze types; and ground conditions.

which (collectively), are causes of significant inconsistency of historical information/statistics.

- **Detonation Variables;** when assessing the probability (rather than the consequence), of accidentally detonating a German WWII UXB during the construction process, there is very little empirical information/evidence that can be reliably or consistently referred to. Also, there are many variables to

consider that would have a bearing upon whether or not an item would or would not detonate. These include:

- Type and numbers of fuzes in the UXB;
- Deterioration and sensitivity of the fuzes.
- Mass of the UXB and type of high explosive contents;
- The depth and angle at which the UXB comes to rest within the ground;
- The time of delivery and depth that intrusive activities (typically delivered by mechanical plant/piling) take place and, critically, the kinetic energy that is likely to be generated if such activities encounter a UXB

**Step 3;** the ALARP principle is established in law and employed by the HSE as tool for benchmarking safety (especially when investigating accidents/fatalities). Its employment for delivering UXO risk mitigation, sits neatly within the framework CIRIA guidance, but is not part of it.

6 Alpha's view (which is founded and delivered by the UXB application of the ALARP principle) is that working towards the total elimination of risk is quite impractical, not only in terms of time, effort and cost expended, but also in relation to the benefit received (in terms of total UXB risk amelioration).

There is a point beyond which further attempts to eliminate risk will only result in diminishing returns, for disproportionately increasing effort. ALARP application then, recognises that is rarely possible to prove (economically at least) that formerly contaminated sites are *defcato* 100% free from the UXO risk (even after undertaking appropriate and well executed UXB risk mitigation measures).

### **The Final Result**

6 Alpha Associates have been successful in benchmarking the actual UXB risk across

the entire project and defining the appropriate level of risk mitigation required to deliver an ALARP sign off. The approach taken reduced the requirement for on-site mitigation by some 85%; in financial terms this would equate to a saving of over £1 million when compared with undertaking the options under initial consideration. This was achieved without compromising our client's corporate governance, risk management protocols nor, critically, safety.

A project which was potentially subject to significant *UXO blight* has had the UXO risks managed effectively, efficiently and transparently not only between the UXO Consultant the Client but also their UXO Contractors. This process began at initial site assessment stage and continues through to project sign-off. A process that provides an auditable record, exposing the rationale for decisions, and ensuring that any mitigation is both necessary and sufficient for the cost effective delivery of project safety.