



# Ground Contamination Assessment Report

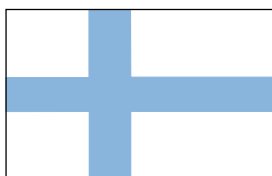
**Military Waste Storage Site, Astana, Afghanistan**

**United Nations Environment Programme**

**Post-Conflict Branch (PCoB)**



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# **1. Introduction**

## **1.1 Overview and scope of the project**

In November 2005, the United Nations Environment Programme (UNEP) was approached by the Afghanistan New Beginnings Programme (ANBP) to undertake a preliminary assessment of a military storage site located near Astana, a small village in the Panjshir Valley. This initial site visit led to a request from the Ministry of Defence (MoD) of the Government of the Islamic Republic of Afghanistan to further assess the potential environmental and health risks associated with the storage of hazardous substances at Astana. The MoD also sought assistance from UNEP in dealing with any unacceptable risks to the environment and human health. This report documents the assessment of those risks.

This project, which was managed by UNEP representatives based in Kabul and overseen by the UNEP Post-Conflict Branch in Geneva, comprised:

- the investigation and characterization of hazardous substances stored on the subject site;
- the assessment of potential environmental and health risks associated with the storage of hazardous wastes, and the communication of these risks to the relevant stakeholders; and
- the development of pragmatic recommendations for remedial action.

The project also included capacity-building for representatives from the Afghan National Environmental Protection Agency (NEPA) on the assessment of potentially contaminated land and standard procedures used to sample soil and water.

## **1.2 Structure and purpose of this document**

This technical report outlines the findings of an initial site inspection by UNEP in November 2005, and the results of an intrusive ground investigation performed in April 2006 to characterize the potential environmental and health risks associated with the storage of military materials and hazardous substances at the Astana site.

It provides a description of the site conditions, a summary and rationale for the fieldwork that was carried out, factual records, and an interpretation of the laboratory analyses. This document also sets out a series of recommendations to mitigate the identified environmental and health risks linked to the ongoing use of the site for grazing livestock.

## 2. Site Description and Status

### 2.1 Site location

The subject site is an open and undeveloped parcel of land in Astana, a small village situated in the Panjshir Valley, in the Parwan Province of Afghanistan. Covering a total area of approximately six hectares, the site extends north from the base of the Hindu Kush mountain range towards the Panjshir River. The location's coordinates, as shown in Figures 1 and 2, are: N35°20'55", E069°34'46".

#### 2.1.1 Site 1: Missile and warhead storage area

Site 1 was an excavated trench measuring approximately eight metres wide by five metres deep, cut into the base of the mountain to the south. It was used to store the bodies of three

missiles, and approximately 32 warhead casings. Several casings were partially buried by the gradual movement of sediment down the slope of the mountain, suggesting there may be additional warheads buried in this area<sup>1</sup>.

While most were sealed, many casings were not, exposing an estimated 150 kg warhead placed inside a protective wood cradle. It was not possible to confirm whether each sealed casing actually contained a warhead. A small number of warheads were also left exposed without any protective packaging at all.

Markings on the exposed warheads made it clear they were originally manufactured by a Russian source. However, it was not possible to determine whether any were live/active or calibrated for immediate use.

No visual or olfactory evidence of contamination was observed during the collection of soil samples in site 1.



SCUD missile fuel containers stored at ground level.



SCUD missile warhead casings



SCUD missile fuel containers stored below ground level in a shallow trench.

### 2.1.2 Site 2: Rocket fuel storage area

Site 2 was located immediately east of site 1. It served as a storage area for cylindrical containers presumably filled with the rocket propellant dimethylhydrazine (UDMH)<sup>ii</sup>. These containers were kept in two separate stockpiles: 22 were stored at ground level approximately 90 metres east of the warhead stockpile (site 1), while an additional 85 lay in a shallow trench approximately 30 metres further to the east. All containers were found relatively upright on exposed earth.

No secondary containment safeguards such as impermeable groundcover or bunds were provided.

The canisters – with an estimated capacity of 500 litres each – appeared to be made of stainless steel and aluminium, which is consistent with research on the storage and transportation of UDMH (Watje, 1978).

Due to the volatile nature of UDMH, each container – once filled – is sealed with a lid that is bolted in place. During the initial site inspection in November 2005, eleven lids were found to be missing from these containers. During the return visit in April 2006, twenty lids were missing. Anecdotal evidence suggests that local people were removing lids to sell as scrap metal.

Closer inspection of the open containers revealed the presence of a white residue at the bottom. Although none of the containers were found to be leaking, a faint, acrid, ammonia-like odour was clearly perceptible in their immediate vicinity.

These olfactory indications are consistent with the degradation process of hydrazine compounds, which form ammonia, hydrogen, and nitrogen when exposed to ultraviolet radiation (WHO, 1987).

No obvious visual signs of contamination were noted in the superficial soil surrounding these containers, and the analysis of air samples recovered from the area surrounding the UDMH containers found chemical concentrations for hydrazine to be below detectable limits. It should be noted, however, that the low levels of hydrazine recorded may be due to the mild temperature conditions and may hence not be indicative of summer periods.

### 2.1.3 Site 3: Warhead cover storage area

Site 3 was an excavated trench extending into the base of the mountains, which was located immediately west of the warhead storage site (site 1). Inspection of this area revealed the presence of two conical warhead covers.

It is understood that these covers fit over the warhead and contain the missile fuse, but no fuse was found in either.

The base of these covers measured approximately 0.4 metres and the length from base to tip was approximately 0.5 metres. Each warhead cover weighed approximately 10 kg.

No other materials were stored in this area of the site.



Warhead Covers found on site



Partially buried nitric acid storage containers

#### 2.1.4 Site 4: Missile casing and nitric acid storage area

Site 4 was situated approximately 200 metres west of the fuel storage site (site 1). It comprised a stockpile of 46 steel containers, which were understood to be filled with fuming nitric acid, an oxidizing agent commonly mixed with UDMH fuel (site 2) in the launching process of SCUD missiles. Each nitric acid container had a capacity of approximately 200 litres.

Several of these containers were partially buried by the gradual accretion of soil from the steep mountain slopes to the south, so it is possible that others were completely buried beneath the current surface.

Although most of the nitric acid containers were in reasonable condition, a number of them appeared to be leaking. On-site analysis of soil samples taken in this area indicated a pH of less than 3.0, suggesting that leaching or spills had occurred there in the past.

In addition, twenty missile casings lay immediately east of the nitric acid stockpile. SCUD missile casings consist of a cylindrical steel shell which houses the missile body. Because all casings were sealed, it was not possible to confirm whether they actually contained a missile.

The site's former use as a helicopter base was also apparent from various engine parts and armoury components scattered across the ground. Large containers located next to the

stockpile of nitric acid contained significant numbers of miscellaneous instrument panels from helicopters and/or other mechanical equipment. While limited radioactivity was measured across the site, levels of up to 400  $\mu\text{Sv/hr}$  were recorded for some damaged instrument panels. The source of radiation was expected to be radium or tritium within the instruments themselves.

Finally, a derelict missile launcher was found in this area of the site. Research indicates that this vehicle was used to launch Russian-manufactured SCUD missiles R-300 9K72 Elbrus/SS-1C SCUD-B/C, which used a mixture of UDMH and nitric acid for fuel (UNEP, Nov 2005).

## 2.2 Site history

According to local occupants and provincial government representatives, the site was used by the Russian army as a helicopter base during the 1980's. Traces of this activity – including helicopter engines, armoury components, and instrument panels – are still visible on site.

During the period of Taliban governance in the 1990's, it is understood that the Afghan Northern Alliance – the Taliban's main opponents – stockpiled military hardware throughout the Panjshir Valley. Anecdotal evidence shows that the rocket components found on site were transported from various areas in the country to form an arsenal that could be used against the Taliban, though it is unclear whether any rockets were actually fuelled and launched from the site during that period.

The site has also been used occasionally for grazing and agricultural purposes since the evacuation of the Russian army in the late 1980's.

## 2.3 Site description

The topography of the site is characterized by a relatively level plateau at the base of the mountain range to the south. Further to the north, towards the river, site levels fall by approximately three metres to a narrow level riverbank.

The ground cover consists of a mixture of silt and clay topsoil with occasional rock fragments. No trees or shrubs were noted at the time of inspection, but the ground was sparsely covered with grass. Large granite boulders were also seen scattered across the site, several of which were over two metres long. These boulders appeared to have broken away from the mountains to the south.

There are no above-ground structures on the site, except for a small single-storey building located in the north-western part that provides shelter and accommodation for local guards. A new radio tower is planned to extend radio transmission capability into the valley.

The site is used on a regular basis as grazing land for herds of goats and cattle. Although it does



Derelict SCUD missile launcher

not currently serve other agricultural purposes, it is apparent that crops have been cultivated in some areas in the past. Indeed, local guardsmen indicated that part of the site had been used to grow vegetables, but that this practice had been stopped approximately four years ago, due to odours emanating from the materials stored nearby.

Military equipment, can be found in several stockpiles on the site. For this assessment, these stockpiles were divided into four main sites warranting particular concern. The specificities of these individual areas are discussed in detail below, and shown graphically in Figure 3.



Goats grazing near rocket fuel containers



### **3. Natural Site Characteristics**

#### **3.1 Geology**

Limited information has been published on the geology of Afghanistan, but research shows that the region is characterized by neocene granites and the Hari-Rud Slip Fault (USGS, 1997). On-site observation confirms that the solid geology of the immediate area is dominated by the granite slopes of the Hindu Kush mountain range, which form a river valley with an alluvial basin along the flow path of the Panjshir River.

Organic silt and clay topsoil covers the main area of the site beyond 0.4 metres deep. Based on observations made along the bank of the Panjshir River, this topsoil layer is thought to be underlain by a conglomerate of cobbles, sand and silt, which forms a cemented, though permeable, matrix. It is probable that granite formation lies below these granular soils, but this could not be proven due to the limitations of the investigation equipment available on site.

The shallow soil in the riverbank area is characterized by typical alluvial deposits, consisting of uniformly-graded sand with little or no silt content.

An inferred geological cross section of the site is provided in Figure 4.

#### **3.2 Hydrogeology**

Although little information is available regarding the groundwater resources of the Panjshir Valley, the area's groundwater is thought to be divided into two distinct categories: the water within the shallow topsoil and underlying alluvial soil, and the water in the deeper granite bedrock.

The water within the surface or shallow geological deposits is linked to that flowing in the river, as the deposits themselves are the product of natural deposition processes operating within the fluvial environment. Generally speaking, the Panjshir River's base flow is provided by more mountainous areas upstream, through snowmelt or rainfall.

#### **3.3 Hydrology**

The Panjshir River is located between 50 and 200 metres north of the areas of concern on site. The river provides a water source of regional importance, supplying Astana and other villages in the Panjshir Valley with water for drinking and irrigation. Several local inhabitants were also seen fishing from the river, an indication that it also serves as a supplementary food source for the region.

## 4. Chemicals, Toxicology and Radioactivity

### 4.1 Overview

The list of chemicals present was drawn on the basis of site reconnaissance, laboratory analysis, and research on the different types of propellants used to launch Russian SCUD missiles. The primary chemicals and materials of concern were:

- hydrazine,
- nitric acid,
- unexploded ordnance, and
- radioactive aircraft instrument panels (tritium and/or radium).

Moreover, given the lack of detailed historical records on the use of the Astana site, it is possible that additional chemicals subsist in the area, such as: amines (a common degradation product of hydrazine compounds), heavy metals/metalloid constituents or fuels and lubricants from the helicopter maintenance activities previously carried out at Astana. Indeed, the range of potentially hazardous contaminants on a site such as this can be wide and varied.

The physical and toxicological characteristics of the primary chemicals of concern are discussed in more detail in the following paragraphs.

### 4.2 Hydrazine compounds

#### 4.2.1 Physical properties

UDMH is a colourless, fuming and hygroscopic liquid at ordinary pressure and temperature. It is reported to have a pungent, acrid odour, and it turns yellow upon exposure to air (ICSC, 1994). UDMH rapidly decomposes when heated or exposed to ultraviolet radiation, a reaction which may be explosive, especially when catalysed

by certain metals or metal oxides. Spontaneous ignition may also occur in contact with porous materials.

#### 4.2.2 Exposure pathways and human health risks

Hydrazine compounds are easily absorbed through the skin, lungs, and gastrointestinal tract and rapidly distributed throughout the body. Limited information is available on the effects of chronic exposure to UDMH, but acute effects of exposure range from headaches and nausea to irritation of the skin, eyes and respiratory tract, the development of pulmonary oedemas (fluid in the lungs), and adverse central nervous system depression; liver and kidney damage have also been reported (WHO, 1987). Based on sufficient evidence of carcinogenicity in experimental animals, hydrazine is '*reasonably anticipated to be a human carcinogen*', though there is inadequate direct evidence to confirm carcinogenicity in humans (IARC, 1999).

#### 4.2.3 Environmental effects, fate and transport

Hydrazine in both air and water is toxic for plants. It is also toxic for aquatic fauna, even at very low concentrations. Indeed, research indicates that certain fish species have shown LC50<sup>iii</sup> values of between 0.54 mg/L and 5.98 mg/L (WHO, 1987), while bacteria in wastewater treatment plants are inhibited by hydrazine levels higher than 1 mg/L.

Hydrazine is quickly degraded in air through reactions with ozone, hydroxyl radicals, and nitrogen dioxide. It also degrades rapidly in water, especially under aerobic conditions, though it appears more persistent in softer water. It is readily absorbed in soil and decomposes on clay surfaces. Howard et al. (1991) provides the following range of half-life values:

Compound	Range of degradation half-life values	
	Soil (hours)	Groundwater (hours)
Hydrazine	24 to 168	48 to 336
Methylhydrazine	312 to 576	624 to 1152
1,2 Dimethylhydrazine	168 to 672	336 to 8640

Given their ability to degrade rapidly in the environment, the WHO (1987) indicates that hydrazine compounds are unlikely to bioaccumulate<sup>iv</sup>.

## 4.3 Nitric acid

### 4.3.1 Physical properties

Nitric acid is a colourless, highly corrosive, poisonous liquid that gives off red or yellow fumes in moist air. It is miscible with water in all proportions. The nitric acid in commercial use is typically a solution of 52 per cent - 68 per cent nitric acid in water. Solutions containing over 86 per cent nitric acid are commonly called fuming nitric acid. Red Fuming Nitric Acid (RFNA) has a reddish brown colour that is due to dissolved nitrogen oxides. Given that the nitric acid on site is stored in metal containers, it is likely that it has been treated with an inhibitor, such as hydrogen fluoride, thus forming inhibited fuming nitric acid, which has increased corrosion resistance in metallic storage tanks (e.g. rocket fuel tanks).

### 4.3.2 Exposure pathways and human health risks

Nitric acid can cause severe burns to all parts of the body. Its vapours are corrosive for the respiratory tract and may cause a fatal pulmonary oedema. The effects of repeated or prolonged exposure are so severe that it is considered unlikely. Low-level exposure reportedly has adverse consequences for the lungs and teeth.

### 4.3.3 Environmental effects, fate and transport

Strong nitric acid dissolves some soil material, particularly carbonate-based materials. Although this neutralizes the acid to some degree, a high proportion of it is expected to subsist for either vertical or lateral transport toward groundwater and surface water receptors.

Nitric acid is soluble in water and harmful to aquatic organisms; large discharges may contribute to the acidification of water and be fatal to fish and other aquatic life. Furthermore, it is not expected to biodegrade or bioconcentrate.

## 4.4 Unexploded ordnance

Explosives and propellants behave differently from most organic contaminants. In large quantities or within unexploded ordnance (UXO) – they pose an immediate safety hazard. The mobility of these chemicals in the environment is dependent on several factors, including the melting point, solubility and crystal energy of the compound.

Explosives are solid at ambient temperature, and they are often dispersed as variously sized and shaped particles that slowly dissolve in precipitation because they are sparingly soluble. They also possess low vapour pressures and hence do not volatilize. Their distribution is typically very heterogeneous, and they are only transported through soil after they are dissolved in water. Hence, the highest concentrations of explosives are most likely to occur on or near the soil surface, unless the soil has been moved or filled.

The stability of these compounds, once in the dissolved phase, ranges from several days for nitroaromatics such as TNT, to several hundreds of days for nitramines such as RDX (Grant et al., 1993).

## 4.5 Radioactive materials

Depending on the radioisotope, radioactive contamination can be extremely persistent in the environment and poses significant risks for current and future site occupants.

Tritium, which has a half-life of 12.3 years, emits a very weak beta particle and transforms to stable, non-radioactive helium. As is the case with all ionizing radiation, exposure to tritium increases the risk of developing cancer, but as it emits weak radiation and leaves the body quite rapidly, it is one of the least dangerous radionuclides.

The most common isotope is radium-226, which emits both alpha and gamma radiation, and has a half-life of about 1600 years. Radium-228,

whose half-life is 5.76 years, is principally a beta emitter. Radium-224 only has a half-life of 3.66 days. Radium decays to form isotopes of the radioactive gas radon, which is not chemically reactive, and stable lead is the final product of this lengthy radioactive decay.

Long-term exposure to radium increases the risk of contracting several diseases: inhaled or ingested

radium may cause lymphoma, bone cancer, and diseases that affect the formation of blood, such as leukaemia and aplastic anaemia, while external exposure to radium's gamma radiation increases the risk of cancer to varying degrees in all tissues and organs.

## 5. Site Assessment Activities

### 5.1 Desk-based assessment

UNEP made an initial visit to Astana in November 2005 to inspect the hazardous waste stored at the site. Research undertaken as part of this desk-based assessment and consultations with various stakeholders identified the type and model of the SCUD missile rocket launcher found on site, and thus the types of missile fuels and oxidants likely to be stored in the vicinity.

In addition, this initial desk-based assessment identified potential pollutant linkages between the hazardous wastes on site and, (i) the Panjshir River, (ii) the site occupants, and offered recommendations for further evaluation of these risks to determine appropriate remedial strategies.

### 5.2 Investigation methodology and environmental sampling

Remote sensing data was used to compensate for the lack of detailed site plans and to develop an initial investigation strategy. The UNEP team revisited the site on 4 and 5 April 2006 to recover representative soil samples from the various areas of concern. A summary of sampling techniques, investigation methods, and the rationale for analysis is provided in the following paragraphs.



Sampling shallow soil at site 2

#### 5.2.1 Soil sampling

Composite sampling techniques were employed to obtain representative soil samples from the areas of concern.

Experts used a small hand auger to recover superficial soil samples from ten to twenty individual locations within each area.

Where olfactory or visual signs of contamination were noted, a shovel was used to acquire samples from deeper within the soil profile.



Obtaining a soil sample from deeper within the soil profile

Experts then thoroughly mixed each soil sample in a clean plastic bag before extracting a representative quantity and placing it in one of the following storage vessels:

- a 100 ml phial for the analysis of volatile compounds;
- 250 ml or 1 000 ml amber glass jars for the analysis of organic compounds; or
- a 500 ml plastic tub for the analysis of inorganic substances.

In total, 19 soil samples were recovered during the investigation (a site investigation location plan is provided in Figure 5). Each sample was then analysed for a suite of determinants consistent with the waste stored in the immediate vicinity.

#### 5.2.2 Water sampling

Due to the limitations of the soil probing equipment on site, no groundwater was tested during the

investigation. However, an intense rainfall created a shallow body of standing water large enough to recover a 500 ml sample. This body of water was located immediately down hydraulic gradient from site 4, as shown in Figure 4.

A water sample was also taken from a relatively calm section of the Panjshir River, down hydraulic gradient from the rocket fuel storage site (site 2).

A trip blank consisting of a 100 ml phial of deionized water was also included with the sampling equipment from Alcontrol Laboratory (UK), and was analysed for the full suite of determinants for quality assurance purposes.

### 5.2.3 On-site sampling and analysis

Portable testing equipment was employed to support the investigation of hazardous substances on site. The following monitoring techniques were used during the assessment:

- a Dräger active air monitoring device to detect the presence of airborne hydrazine compounds;
- Dräger tubes to check for airborne hydrazine compounds;
- Merck test kits to check for the presence of amines and ammonia in soil and water;
- a calibrated “Automess AD6” dose rate meter to screen materials for the presence of radioactivity; and
- different pH papers to gauge the pH of soil, particularly in areas adjacent to the nitric acid storage area.

### 5.3 Laboratory analysis

Samples were exported via airfreight and analysed at three laboratories in the United Kingdom and Switzerland.

Alcontrol Laboratory, based in Chester, United Kingdom, carried out the standard analyses and coordinated the specialist analyses. Alcontrol is accredited to the ISO 17025 standard for

the testing and calibration laboratories and participates in the UKAS and MCERTS programme of certification.

Alcontrol subcontracted the analysis of some determinants to specialist laboratories, including BAE Systems and MountainHeath Services Laboratory. For safety reasons, BAE Systems screened all soil samples for the presence of explosive compounds, and then carried out the analysis of hydrazine compounds. MountainHeath Services Laboratory analysed selected samples for the presence of amines, a breakdown product of hydrazine fuel.

Spiez Laboratory, based in Bern, Switzerland, analysed soil and water samples for the presence of a range of heavy metals, anions and pH. The laboratory, which is a governmental institute of the Swiss Ministry of Defence and Civil Protection, is also accredited to the ISO/IEC 17025 standard. The analyses were performed in its testing laboratory for environmental analysis – Swiss accreditation number STS 101.

Table 5.1 outlines the schedule of laboratory testing undertaken for the assessment of ground contamination issues at the Astana site.

As the range of potentially hazardous contaminants on any given site is wide and varied, the suite was selected to reflect both commonly found contaminants and those which – according to the research – were likely to be present. It is possible however, that other chemical constituents were also present, for which analyses were not carried out.

### 5.4 Ground contamination screening assessment

The objective of the screening assessment presented herein was to identify the chemical constituents that posed risks for environmental and human receptors. To evaluate the significance of the ground contamination, soil and water laboratory results were compared against Generic Assessment Criteria (GAC). In the absence of standards from the National Environmental Protection Authority of Afghanistan, the GAC used in this assessment were contaminant threshold

values published by regulatory organizations from the United Kingdom, the Netherlands, the United States, and the World Health Organization. Although these criteria were not necessarily derived through the same approach, they provide, when combined, a reasonable indication of the significance of the contamination according to international standards. A list of the GAC used in this assessment is provided in Appendix A.

It should be noted that the exceedance of the GAC does not indicate that a particular risk exists,

or that remediation or mitigation measures are required, but that further assessment is needed.

The results of the ground contamination screening assessment are discussed in the following paragraphs and shown in Figure 5.

## 5.5 Soil quality

The concentration of the various determinants in the soil samples recovered from the site was generally below the GAC, but elevated concentrations of

Determinant	Soil No.	Water No.
Explosives suite <sup>(1)</sup> : NC, HMX, RDX, EGDN, tetryl, NG, TNT, PETN, HNS, picrite, picric acid, 2,6-DNT, 2,4-DNT	19	-
Hydrazine suite: hydrazine, methylhydrazine, 1,2-dimethylhydrazine	12	3
Methylamines suite:	TBA	TBA
Extractable petroleum hydrocarbons (C <sub>10</sub> -C <sub>40</sub> )	12	-
PH	15	2
Nitrate	12	2
Nitrite	12	2
Fluoride	-	3
Chloride	-	3
Bromide	-	3
Sulphate	-	3
Phosphate	-	3
Ammoniacal nitrogen	12	2
Vanadium	15	3
Chromium	15	3
Cobalt	15	3
Nickel	15	3
Copper	15	3
Zinc	15	3
Arsenic	15	3
Molybdenum	15	-
Cadmium	15	3
Antimony	15	3
Thallium	15	3
Lead	15	3
Uranium	15	3
Mercury	-	3
Aluminium	-	3

Table 5.1: Schedule of Laboratory Contamination Testing

**Notes:** (1) The full chemical name of each explosive compound is provided in Appendix B.

several determinants were recorded above the GAC in specific locations.

For example, significant concentrations of the explosive compounds RDX and TNT were recorded for the composite sample obtained from superficial soil between the warheads stored on site 1 (site 1, sample 1). The analysis of samples taken from immediately north of this area did not, however, reveal the presence of explosive compounds above laboratory detectable limits.

Methylhydrazine was found in elevated concentrations in two composite samples, including that recovered from the superficial soil surrounding the rocket fuel containers stored at ground level (site 2, sample 1). A pH of 3.9 was also recorded from this particular sample, suggesting that the soil in this area was reasonably acidic. Given that hydrazines are basic compounds, the low pH reading could be attributable to a spill or leak of nitric acid in the past. This hypothesis is further supported by the relatively strong presence of nitrates in samples taken from this area, suggesting that UDMH and nitric acid were mixed there during rocket fuelling.

Slightly elevated concentrations of methylhydrazine were also detected in superficial soil surrounding the warheads at site 1, but hydrazine or alkylamine (a degradation by-product of hydrazine) compounds were not recorded above laboratory detectable limits in any other samples obtained from the site.

A slightly elevated concentration of diesel-range hydrocarbons was also recorded in a sample taken from an area adjacent to the redundant helicopter parts (site 4, sample 4), but the concentration of diesel-range hydrocarbon compounds was not significant in any other sample obtained from that site.

Furthermore, the four composite soil samples obtained from the nitric acid storage area in site 4 returned relatively neutral pH values, suggesting that the superficial soil in this area had not been adversely affected by the storage of acid.

Finally, heavy metals and general inorganic constituents were not recorded at concentrations exceeding the GAC in any of the composite soil samples recovered from the site.

## 5.6 Water quality

Elevated concentrations of methylhydrazine, nitrates, ammoniacal nitrogen and arsenic were found in a sample obtained from standing rainwater in site 4. Although pH values were recorded as relatively neutral, the presence of nitrates and ammonia suggested that leaks or spills of nitric acid had occurred in this particular area in the past.

In addition, the analysis of a sample recovered from the Panjshir River not only indicated slightly elevated concentrations of nitrates, but also concentrations of dimethylamine that were above laboratory detectable limits. However, it is likely that the presence of this compound in the river was primarily due to the use of nitrogen-based pesticides in agricultural plots upstream. The concentration of all other determinants was below the corresponding GAC.

Due to the limitation of the equipment available at the time of investigation, the condition of the groundwater underlying the site is largely unknown.



## 6. Qualitative Risk Assessment

### 6.1 General

This section of the report provides a *qualitative* assessment of the environmental risks associated with the Astana site. The use of risk-based methods to evaluate the significance of land contamination is standard practice worldwide. In adopting the principles of risk assessment and risk management, the intention is to ensure that contaminated land is managed effectively, in accordance with its current use and environmental setting.

The key principle of risk-based management of contaminated land is the identification of significant 'pollutant linkages'. That is, evidence of the presence of: i) a contaminant (the source), ii) a pathway (or pathways) through which contaminants may travel, and iii) a receptor that may be harmed by the contaminant.

### 6.2 Potential risk sources

Based on the review of readily available information, consultations with local inhabitants, site reconnaissance and findings from intrusive ground investigation, the following potential risk sources were identified:

- locally impacted soil,
- groundwater underlying the site,
- hazardous chemicals stored on site (e.g. rocket fuels, nitric acid etc.),
- explosives,
- radioactive helicopter instruments, and
- miscellaneous helicopter parts and military hardware.

### 6.3 Potential risk pathways

The main environmental pathways and exposure routes by which potentially contaminating substances could reach environmental and human health receptors were deemed to comprise:

#### Indirect pathways

- vertical and lateral transport of contaminants through the unsaturated soil,
- lateral contaminated transport through the groundwater underlying the site,
- atmospheric transport, and
- overland flow.

#### Direct pathways

- inhalation of airborne dust and vapours,
- dermal contact with the soil, and
- direct or indirect ingestion of soil particles.

### 6.4 Environmental and human receptors

The primary environmental and human health receptors that were identified as a result of the ground conditions recorded on site were:

- the groundwater underlying the site,
- the Panjshir River, and
- existing site users.

### 6.5 Risk rating

The degree of risk that a receptor may actually be exposed to land contamination depends on the original contaminant source (i.e. the toxicology and concentration of chemicals present), the vulnerability/sensitivity of the receptor (i.e. lifestyle and physiology), and the exposure pathway between the source and receptor. The following risk ratings were used in this assessment:

### 6.6 Discussion of potential risks

Based on the potential sources on site, a number of environmental risks were identified. As the future use of the site is yet unknown, the following discussion relates to its current functions. A reassessment of these risks may be required if a more sensitive end-use is proposed (e.g. agriculture, residential use etc).

Low risk:	Concentrations of constituents of concern are below the Generic Assessment Criteria (GAC). Pollutant linkages are complete but indirect exposure pathways predominate, indicating a measurable but generally low risk of significant environmental and/or health impacts. No further assessment or remedial action warranted.
Moderate risk:	Concentrations of constituents of concern are above the Generic Assessment Criteria (GAC), but only in specific locations. Pollutant linkages are complete with direct and indirect exposure pathways, indicating a moderate risk of significant environmental and/or health impacts. Further assessment and/or remedial action warranted.
High risk:	Concentrations of constituents of concern are significantly above the Generic Assessment Criteria (GAC). Direct exposure pathways predominate, indicating a reasonable likelihood of significant environmental and/or health impacts. Further assessment and/or remedial action warranted.

Table 6.1: Risk ratings used in this assessment

### 6.6.1 Groundwater quality

The superficial soil in the area comprises a high proportion of silt and clay, which are considered to limit the infiltration potential of rainwater. The risk that contaminated leachates adversely affect the quality of the underlying aquifer is therefore overall limited.

However, some pollutant linkages were found between locally impacted soil and the underlying aquifer via rainfall infiltration, contaminated leachate generation and vertical contaminant migration. For example, the uncontrolled storage of hazardous chemicals such as UDMH and nitric acid was considered to pose significant risks for the area's groundwater, as the storage containers could deteriorate through corrosion, weathering, or human intervention (e.g. the looting of UDMH container lids to sell as scrap metal or accidental damage).

Because RDX and TNT are not readily soluble, the storage of explosives on site was considered to pose only **low** risks to the underlying groundwater, even though high concentrations of explosive compounds were recorded in the superficial soil surrounding the warhead storage area.

Although it is not currently used for drinking or irrigation, the groundwater on site is regarded as a sensitive source of base flows to the Panjshir River. Given the limited permeability of the topsoil and the localized extent of impacted soil recorded on site, the risk posed to the groundwater is

generally assessed to be **low to moderate**, but it is considered to increase to **moderate to high** in areas where locally impacted soil was detected and where UDMH and nitric acid is currently stored.

### 6.6.2 The Panjshir River

The Panjshir River is situated 50 to 200 metres north of the site. Although no assessment of groundwater flow was carried out during this investigation, it is considered likely that it flows in a northerly direction towards the river. Furthermore, given the topography of the region and the relatively low infiltration capacity of the topsoil on site, overland flows resulting from rapid snowmelt or intense rainfall have the potential to wash site soil into the river.

The analysis of samples taken from the river and riverbank sediment indicated that the storage of hazardous chemicals on site had not impacted significantly on the quality of the Panjshir River, though elevated concentrations of nitrates were recorded in the river water sample. It was noted, however, that the river had a significant dilution potential, and may thus not have been wholly representative of the risks of storing chemicals on the site.

The Panjshir River is an important resource for many small towns downstream from Astana, providing water for drinking and agricultural purposes. A leak or spillage of nitric acid or UDMH may result

in significant adverse impact to aquatic receptors in the river and to users downstream. Given the nature of the chemicals stored on site and their proximity to the river, these substances and the locally impacted soil represent **moderate** risks for the quality of the water in the Panjshir River.

### 6.6.3 Existing site users

The site is occupied on an intermittent basis by local guards and herdsman who graze goats and cattle. In the past, a small area immediately north of the UDMH site (site 2) was used to cultivate crops, but this practice was stopped approximately four years ago. Anecdotal evidence indicates that locals have suffered from headaches and nausea after spending prolonged periods on the site during the summer months.

As hydrazine compounds were recorded in superficial soil in specific locations, the most significant exposure pathway was considered to be dermal contact and the ingestion/inhalation of soil particles. Although agricultural activities have ceased on site, it should be noted that growing crops for human consumption in areas adjacent to the UDMH storage area would significantly increase the potential of exposure to hydrazine-contaminated soil.

Besides, while the site is used to graze livestock, the risk of exposure to hydrazine through the

consumption of animals is considered to be **low**, for hydrazine is not thought to bioaccumulate.

The theft of fuel container lids for scrap metal also exposes looters to significant concentrations of hydrazine vapours. Given that hydrazine compounds are a 'probable carcinogen', the storage of these materials on site represents a **high** health risk for the local population.

In addition, exposure to nitric acid can cause severe burns. Furthermore, its vapours are so corrosive for the respiratory tract that significant exposure could prove fatal. Although observations and laboratory analysis of site soil did not identify significant nitric acid leaks, the storage of this material on site is considered to pose **moderate** risks to the local population.

Explosive compounds and propellants such as hydrazine pose an immediate safety hazard to the local population. Indeed, some 45 m<sup>3</sup> of hydrazine propellant are stored within 100 m of three missiles and approximately 4 800 kg of warheads<sup>v</sup>, representing an unacceptably **high** risk in the event of an explosion.

Finally, prolonged exposure to the radioactive substances identified on site also poses health risks to the users, but given that these materials were generally well contained on site, these risks were assessed to be **moderate**.

## 6.7 Summary of risks

A summary of the potential pollutant linkages associated with the site is outlined in Table 6.2.

Source	Identified pathways	Receptors	Risk rating	Proposed risk reduction strategy
Hazardous chemical storage	Leakage and soil leaching	Groundwater	Moderate to high	<ul style="list-style-type: none"> <li>• Removal of hazardous chemicals from the site to a secure compound</li> <li>• Assessment of disposal/re-use options for chemicals and storage containers</li> </ul>
	Leakage, soil leaching & lateral/vertical groundwater migration	Panjshir river	Moderate	
Soil conditions	Soil leaching	Groundwater	Low Moderate to high (locally)	<ul style="list-style-type: none"> <li>• Localized investigation and analysis of deeper soil and groundwater in areas where impact has been recorded</li> <li>• Localized remedial work (if necessary) combined with the removal of hazardous chemicals from the site</li> </ul>
	Soil leaching & lateral/vertical groundwater migration	Panjshir river	Moderate	
Residual shallow groundwater conditions	Lateral/vertical groundwater migration	Panjshir river	Moderate	<ul style="list-style-type: none"> <li>• Localized investigation and analysis of deeper soil and groundwater in areas where impact has been recorded</li> <li>• Localized remedial work (if necessary) combined with the removal of hazardous chemicals from the site</li> </ul>
Explosive compounds	Soil leaching	Groundwater	Low	<ul style="list-style-type: none"> <li>• None proposed</li> </ul>

Table 6.2: Summary of risks

	Source	Identified pathways	Receptors	Risk rating	Proposed risk reduction strategy	
Human health risks	Hazardous chemical storage	Dermal contact Inhalation of vapours	Site users Trespassers/looters	Moderate (nitric acid) High (UDMH)	<ul style="list-style-type: none"> <li>Removal of hazardous chemicals from the site to a secure compound</li> <li>Assessment of disposal/re-use options for chemicals and storage containers</li> </ul>	
	Radioactive substances	Direct exposure	Site users	Moderate	<ul style="list-style-type: none"> <li>Removal of radioactive substances from the site to a secure compound</li> <li>Assessment of storage and disposal options</li> </ul>	
	Explosives	Ignition/explosion	Site users	High	<ul style="list-style-type: none"> <li>Removal of explosives from the site to a secure compound</li> <li>Appraisal of other risk-reduction options should removal prove to be an unacceptable option</li> </ul>	
	Locally impacted soil conditions		Dermal contact Inhalation of soil/vapours Ingestion of soil	Site users	Moderate (nitric acid) High (UDMH)	<ul style="list-style-type: none"> <li>Localized investigation and analysis of deeper soil and groundwater in areas where impact has been recorded</li> <li>Localized remedial work (if necessary) combined with removal of hazardous chemicals from the site</li> </ul>
			Consumption of crops grown on site/ingestion of soil	Site users	High (locally adjacent to UDMH)	<ul style="list-style-type: none"> <li>Restrict local inhabitants growing crops in or around hydrazine-impacted areas</li> <li>Localized investigation and analysis of deeper soil and groundwater in areas where impact has been recorded</li> <li>Localized remedial work (if necessary) combined with removal of hazardous chemicals from the site</li> </ul>
			Consumption of livestock grazing on site	Site users	Low	<ul style="list-style-type: none"> <li>None proposed</li> </ul>
		Residual shallow groundwater conditions	Inhalation of vapours	Site users	Low to moderate	<ul style="list-style-type: none"> <li>Localized investigation and analysis of deeper soil and groundwater in areas where impact has been recorded</li> <li>Localized remedial work (if necessary) combined with removal of hazardous chemicals from the site</li> </ul>

Table 6.2: Summary of risks (continuation)

## 7. Recommendations

### 7.1 General

The investigation established pollutant linkages between the localized ground contamination recorded on site and several receptors. On this basis, corrective action should be driven by the following key aspects:

- the protection of site users, and
- the mitigation of risks for the underlying aquifer and the Panjshir River down hydraulic gradient from the site.

As there is no national legislation or guidance material regarding acceptable levels of risk from hazardous waste or contaminated land, the following recommendations are based largely on professional judgement and general guidance literature for the remediation of contaminated sites.

### 7.2 Short-term risk reduction measures

The assessment identified a number of risks warranting remedial action in the short term. These include:

#### 1. Removal of UDMH storage containers

**Scope of work:** the removal of UDMH from the site will eliminate the risks for surrounding environmental and human receptors, while preventing further looting of container lids. It is recommended that the containers be moved to a secure compound (i.e. fenced and locked) with impermeable ground cover and appropriate spill control measures. Safe handling and emergency response precautions should be provided inside the storage compound in Dari, Pashto and English.

(Note: an appraisal of disposal options is provided in section 7.3).

Appropriate lifting equipment should be used to remove the containers, which should then be transported from the site on heavy vehicles (e.g.

ANBP KAMAZ vehicles). These vehicles must be able to cross the Panjshir River to access and return from the site.

Prior to removal, each container should be inspected to ensure that it is properly sealed and that the outer skin of the vessel is not damaged in any way. Containers should only be lifted using the eyebolts provided. If there are none, or if they appear corroded or damaged, a sling should be used to support both ends of the vessel during lifting. Container should then be tied down appropriately to prevent them from moving during transport.

**Volume estimate:** the initial 'poor case' estimate of UDMH to be removed from the site is 45 m<sup>3</sup>, or 87 sealed containers. Indeed, while 107 containers were found during the inspection, 20 had had their lids removed and were relatively empty.

**Responsible party:** the responsible party for this work should be the MoD and ANBP. Given the environmental and human health risks involved, however, it is recommended that the MoD/ANBP collaborate with specialists from UNEP.

**Precautions:** due to the hazardous nature of UDMH, specialist expertise is required to remove it from the site. High-level Personal Protective Equipment (PPE) – including suitable masks, gloves, boots and protective suits to prevent unnecessary dermal and inhalation exposure – should be provided for all workers involved in this activity. It is also recommended that MoD/ANBP undertake the appropriate risk assessments (COSHH<sup>vi</sup> or an equivalent) to ensure that the lifting, transportation and temporary storage of these materials are properly controlled.

#### 2. Removal of nitric acid storage containers

**Scope of work:** the removal of nitric acid from the site will eliminate the risks associated with leaching into the soil and groundwater. Furthermore, early removal will prevent these containers from being buried by the accumulation of soil from the steep slopes to the south of the site. It is recommended that these containers be moved to a secure compound (i.e. fenced and locked) with impermeable ground cover and appropriate spill control measures. Safe

handling and emergency response precautions should be provided inside the storage compound in Dari, Pashto and English.

(Note: an appraisal of disposal options is provided in section 7.3).

The protocols described above to lift and transport the UDMH containers should also be applied for the removal of the nitric acid containers on site. Additionally, an excavator may be required to expose the partially buried containers. It is recommended that a toothless excavation bucket be employed to prevent rupturing containers during the removal operation, and that a reasonable amount of lime ( $\text{CaCO}_3$ ) be available to neutralize any spills or previously impacted soil.

**Volume estimate:** the initial estimate of nitric acid to be removed from the site is approximately 10 m<sup>3</sup>, or 46 individual containers, though it is possible that more containers are buried at site 4 due to the soil accretion in the area.

**Responsible party:** the responsible party for this work should be the MoD and ANBP. Given the environmental and human health risks involved, however, it is recommended that the MoD/ANBP collaborate with specialists from UNEP.

**Precautions:** due to nitric acid's hazardous nature, specialist expertise is required to remove it from the site. High-level Personal Protective Equipment (PPE) – including suitable masks, gloves, boots and protective suits to prevent unnecessary dermal and inhalation exposure – should be provided for all workers involved in this activity. It is also recommended that MoD/ANBP undertake the appropriate risk assessments (COSHH or an equivalent) to ensure that the lifting, transportation and temporary storage of these materials are properly controlled.

### 3. Removal and destruction of unexploded ordnance

**Scope of work:** an assessment is required to determine whether it is safe to move warheads from the site. If so, stockpiles of warheads should be transported to a secure compound in accordance

with existing DDR protocols. If the ordnance on site is judged to be too unstable to transport, or the risks associated with the transportation of warheads through the Panjshir Valley are considered unacceptable, an appraisal of the following destruction options will be required:

- controlled detonation,
- dissolution or dilution by a solvent, or
- chemical destruction.

**Volume estimate:** the initial 'poor case' estimate of unexploded ordnance to be removed from the site is approximately 4 800 kg, or 32 individual missile warheads.

**Responsible party:** given the nature of these materials, the responsible party for carrying out this work should be the ANBP-DDR.

### 4. Removal of radioactive substances

**Scope of work:** elevated levels of radiation were recorded from broken helicopter instruments inspected in site 4. The removal of these materials will prevent site users from being exposed to the radiation. It is recommended that all helicopter instruments be collected and stored in properly sealed containers. Each container should then be transported to a secure compound.

The collection of these materials can be carried out using mainly manual labour under the supervision of ANBP-DDR representatives.

**Volume estimate:** it is estimated that there are between 100 and 300 instrument panels surrounding the large containers in site 4.

**Responsible party:** the responsible party for this work should be the MoD and ANBP. Given the radiological risks involved, however, it is recommended that the MoD/ANBP collaborate with specialists from UNEP.

**Precautions:** radiation was only detected in instrument panels that were broken or damaged. Care should hence be taken to prevent damaging additional instrument panels during collection. Each container used to store these panels should

bear suitable safety labels. It is also recommended that each container be individually numbered and that an inventory of the contents and levels of radiation measured during the collection be maintained.

## **7.3 Short- to medium-term actions**

### **7.3.1 Locally impacted soil conditions**

Areas of localized contamination were identified in superficial soil, most notably in areas where UDMH, and to a lesser extent nitric acid, were stored. While the short-term risk reduction measures outlined in Section 7.2 will eliminate the potential for further impact to environmental and human receptors, locally impacted soil conditions can continue to pose risks to site users, the underlying aquifer and the Panjshir River in the medium term, albeit from a diminishing and finite contaminant source.

Further evaluation of the degree of the risk is required to determine the level of remedial action needed. At this stage, the following recommendations can be made:

1. On-site soil conditions should be investigated after the removal of hazardous chemicals, with a particular focus on areas where superficial contamination was recorded. Using an excavator to obtain soil samples from deeper within the soil profile would help to confirm the vertical extent of the impact of UDMH in site 2 and of nitric acid in site 4. On-site techniques could be employed to determine the depth of impact during excavation (e.g. PID, pH field test kits), thus avoiding the need to resample and test in overseas laboratories.
2. As abiotic mechanisms appear to be the primary degradation process for hydrazine compounds, the excavator could also be used to turn over any hydrazine-impacted soil, in order to promote and enhance the volatilization of hydrazine and its degradation products.
3. If indicators of impact from nitric acid leaks were observed, the excavator could be used to mix lime into the soil to neutralize soil pH.

The above plan provides the framework for a remedial plan in case indications of elevated concentrations of UDMH or nitric acid were observed during or after the removal of hazardous chemicals from the site. This strategy would also form part of a contingency plan if significant accidental spillage occurred during the removal of these chemicals.

### **7.3.2 Appraisal of disposal options for hazardous substances**

The recommended strategy to mitigate the risks associated with the hazardous chemicals stored on site consists, in the short term, of a 'removal and secure containment' approach. Longer-term strategies, however, need to be developed to manage these substances. The preliminary disposal and management options listed in the table below were identified through comprehensive research into the existing literature. Each option was evaluated based on the availability or applicability of local resources and facilities. Recommendations are provided in the paragraphs following Table 7.1.

#### **Management of UDMH fuel**

The table on the right lists as many as four options for the management of the UDMH fuel. However, options 2 and 3 are both constrained by the limitations of the local sewage treatment facilities, while chemical oxidation (option 3) can result in other potentially harmful bi-products for the sewage treatment processes and receiving watercourses downstream. Moreover, not only would option 4 generate potentially toxic emissions for receptors downwind of the combustion site, but the residual ash would also be a waste product requiring additional treatment or segregation, given that incomplete combustion of these compounds is highly likely in an open-pit scenario.

On this basis, it is recommended that negotiations be pursued with Ecolog, a company currently operating a high temperature incinerator in Kabul, to dispose of the UDMH fuel (option 1). The negotiations should be led by UNEP to ensure that:



- (i) the Ecolog incineration plant can operate at a high enough temperature to destroy the UDMH material;
- (ii) the filters/scrubbers within the plant minimize the potential for the release of toxic emissions from the plant; and
- (iii) the appropriate plans are in place to manage the residual ash generated by this process.

The possibility of transporting the UDMH containers directly to the Ecolog plant in Kabul – thereby

removing the need to store them temporarily somewhere else – should also be explored during the negotiations.

### UDMH containers

Two options were considered for the management of the UDMH containers.

The first was to thoroughly clean the containers and issue them to the local community for re-use. It was noted, however, that once these containers were handed over to the community, ANBP/UNEP

Substance	Disposal/management Options	Considerations/constraints
UDMH fuel	1. Incinerate at high temperature <sup>(1)</sup> (Ecolog Plant, Kabul)	<ul style="list-style-type: none"> <li>• Availability of appropriate incineration plant</li> <li>• Whether incinerator plant burns at high enough temperature to destroy hydrazine compounds</li> </ul>
	2. Dispose to sewer after diluting with water to <400 g/L solution, and neutralize with dilute sulphuric acid <sup>(1)</sup>	<ul style="list-style-type: none"> <li>• Very dilute hydrazine solutions of 0.1 mg/L can be toxic for aquatic life</li> <li>• Constraints of local sewer/treatment system to be assessed</li> </ul>
	3. Dilute with water to <20 g/L solution, and oxidize with hydrogen peroxide, calcium hypochlorite, or sodium hypochlorite before draining to sewer <sup>(1)</sup>	<ul style="list-style-type: none"> <li>• Very dilute hydrazine solutions of 0.1 mg/L can be toxic for aquatic life</li> <li>• Constraints of local sewer/treatment system to be assessed</li> </ul>
	4. Incinerate in an open pit after adding a hydrocarbon solvent <sup>(1)</sup>	<ul style="list-style-type: none"> <li>• Localized air emissions</li> <li>• Possible hydrazine compounds present in ash after incomplete combustion</li> </ul>
UDMH containers	1. Provide cleaned containers to local community. Wash containers with hydrogen peroxide, calcium hypochlorite, or sodium hypochlorite prior to re-use <sup>(1)</sup>	<ul style="list-style-type: none"> <li>• Possible public relation sensitivities associated with re-use within local population</li> </ul>
	2. Melt and destroy metal storage containers	<ul style="list-style-type: none"> <li>• Availability of appropriate smelting facility</li> </ul>
Nitric acid	1. Use as feedstock at fertilizer plant	<ul style="list-style-type: none"> <li>• Availability of fertilizer plant</li> <li>• Presence of corrosion inhibitors may preclude the use of this material in fertilizer</li> </ul>
	2. Use as ingredient in other industrial processes (e.g. manufacturing chemicals and polymers, metallurgy, etching steel, photo-engraving)	<ul style="list-style-type: none"> <li>• Lack of suitable industry base</li> <li>• Presence of corrosion inhibitors may preclude the use of this material in fertilizer</li> </ul>
	3. Dilute with water with a strong base (e.g. sodium carbonate) to neutralize acid before draining to sewer for treatment	<ul style="list-style-type: none"> <li>• Presence of corrosion inhibitors and their effects on sewage treatment processes downstream need to be taken into account</li> </ul>
Radioactive instrument panels	1. Prolonged storage in safe compound	<ul style="list-style-type: none"> <li>• Availability of storage space</li> </ul>
	2. Re-use/recycle	<ul style="list-style-type: none"> <li>• The damaged instrument panels show the highest levels of radiation</li> <li>• Lack of a suitable end-user</li> </ul>

Table 7.1: Disposal and management options for hazardous chemicals

Notes: (1) Source: IRPTC (1985)

would have little control over how they were used. Yet certain uses may well be unadvisable: for example, while cleaning would eliminate most of the UDMH fuel, modifications to these containers (such as welding, cutting or drilling) may result in the emission of hazardous fumes; furthermore, the use of these containers for water storage may unduly expose the community to potentially harmful residual compounds. Ultimately, any unexpected illness in the end-user community (whether related to UDMH or not) could be blamed on ANBP/UNEP, damaging relations with the local population.

On this basis, it is recommended that option 2 – to melt and destroy each container – be pursued.

### **Management of nitric acid**

Nitric acid is commonly used as feedstock for the production of nitrogen-based fertilizers. As this first option was deemed a sustainable solution for recycling the material found on site, ANBP/UNEP approached the fertilizer plant in Mazar e Sharif (Balkh Province), but personnel there indicated that the nitric acid stored at the Astana site was not suitable for use in that plant.

While it may not have been possible to recycle this material locally, it was noted that the Organization for Security and Cooperation in Europe (OSCE) had recently implemented programmes in Armenia and Azerbaijan to recycle military-grade nitric acid (commonly known as “melange”) as liquid fertilizer to be used by local farmers. It is hence recommended that ANBP/UNEP initiate negotiations with the OSCE/NATO to explore the possibility of recycling the nitric acid found at Astana in such a programme.

Nitric acid is also used as an ingredient in many other industrial processes, such as the

manufacturing of chemicals and polymers (i.e. for adipic acid to make nylon, and toluene diisocyanate to make polyurethane). Other industries that rely on nitric acid include metallurgy, steel etching, and photo-engraving. At this stage, however, it is not certain that those industries currently operate in Afghanistan.

A third option is the chemical neutralization of nitric acid, which can be achieved through dilution and addition of a strong base, such as sodium carbonate. However, discharging the resulting solution into a sewer may overload treatment processes downstream and pose unacceptable risks for the receiving watercourse. The presence of chemical inhibitors within the nitric acid on site may also preclude this option. Further research is required if ANBP wishes to pursue this alternative.

Finally, should the recycling of this waste through the OSCE programme – or through similar pacific means – become unfeasible, the option remains to initiate negotiations with Coalition Forces currently present in Afghanistan to help manage this military-grade material.

### **Management of radioactive aircraft instrument panels**

Two options were identified to manage the radioactive instrument panels found on site, namely: recycling/re-use and prolonged storage. The possibility of recycling or re-using these panels is not only limited by the fact that the highest levels of radiation were recorded from those that were broken or damaged, but also by the lack of a suitable end-use market for such objects. Thus, from a risk perspective, prolonged storage remains the most feasible option.

## 8. Conclusions

The subject site is an open and undeveloped parcel of land in Astana, a small village situated in the Panjshir Valley, in Afghanistan. The site is currently used by local inhabitants to graze livestock.

The site was used as a helicopter base by the Russian army during the 1980's, and by the Afghan Northern Alliance as storage ground for stockpiles of military hardware in the 1990's. Hazardous chemicals and other miscellaneous materials associated with the fuelling, arming and firing of SCUD missiles remain on site. Research, supporting fieldwork and laboratory analysis of soil and water samples identified the following inventory

of hazardous substances stored at Astana (see table below):

In its current state, the Astana site represents **high** risks for a number of environmental and human receptors. The principle risks identified relate to the storage of the above hazardous substances and, to a lesser extent, to the locally impacted soil conditions recorded on site. In the absence of national guidance on the management of contaminated land, recommendations have been made to mitigate the risks identified in accordance with guidance from internationally recognized regulatory bodies.

Substance	Summary of findings
Unsymmetrical dimethylhydrazine (UDMH)	<ul style="list-style-type: none"> <li>• UDMH is a conventional rocket propellant commonly used in Russian SCUD missiles.</li> <li>• It is estimated that up to 45 m<sup>3</sup> of UDMH currently remain on site.</li> <li>• Anecdotal evidence indicates that looters are removing UDMH container lids to sell as scrap metal.</li> <li>• UDMH is a probable human carcinogen.</li> <li>• Hydrazine compounds were recorded in soil and in water samples recovered from two locations on site.</li> </ul>
Nitric acid	<ul style="list-style-type: none"> <li>• Nitric acid is a strong oxidizing agent which is mixed with UDMH fuel in the launching process of SCUD missiles.</li> <li>• Approximately 10 m<sup>3</sup> of nitric acid remain on site. Additional nitric acid containers may still be buried.</li> <li>• While relatively neutral pH values were recorded in soil surrounding the nitric acid storage area, elevated concentrations of nitrates were detected in specific locations, which is potentially indicative of past spills or leaks of nitric acid.</li> </ul>
Radioactive materials	<ul style="list-style-type: none"> <li>• Elevated levels of radiation were recorded in damaged helicopter instruments found on site. It is expected that the source of radiation is radium or tritium within the instruments themselves.</li> <li>• It is estimated that between 100 and 300 instrument panels remain on site.</li> <li>• Radiation above laboratory detectable limits was not recorded in any soil or water samples recovered from the site.</li> </ul>
Unexploded ordnance	<ul style="list-style-type: none"> <li>• It is estimated that up to 4 800 kg of unexploded ordnance remain on site in the form of 32 missile warheads.</li> <li>• The majority of these warheads are stored in protective casings or cradles, but a few remain exposed.</li> <li>• Analysis of the soil surrounding the warheads revealed significantly high levels of the explosive compounds RDX and TNT.</li> </ul>

# Appendix A: Generic Assessment Criteria

## A.1 Soil Generic Assessment Criteria

The following Generic Assessment Criteria (GAC) were used to evaluate soil quality in this assessment. These criteria were selected from internationally recognized institutions and regulatory bodies for an 'Open Space' end-use, as this was thought to best correspond to the current and future uses of the site. When no criteria were available for an 'Open Space' end-use scenario, a more conservative 'Residential' value was selected.

Determinant	Soil (mg/kg)	Reference
pH	>5, <9	UK Environment Agency
<b>Explosive compounds</b>		
TNT	95	United States Environmental Protection Agency (USEPA) Region 3 Risk-Based Concentrations Industrial/Open Space end-uses
RDX	26	
HMX	51,000	
NG	200	
2,4-DNT	2000	
2,6-DNT	1000	
EGDN	10000	Human Health Med. Screening Levels-Residential (USEPA Region 6)
Tetryl	240	Human Health Med. Screening Levels-Residential (USEPA Region 6)
<b>Hydrazine compounds</b>		
Hydrazine	0.16	United States Environmental Protection Agency (USEPA) Region 6 Human Health Medium Specific Screening Levels (2006) Note: Value for hydrazine used for a residential end-use scenario
Methyl hydrazine	0.16	
1,2-Dimethylhydrazine	0.16	
<b>Alkyl amine compounds</b>		
Methylamine	23	United States Environmental Protection Agency (USEPA) Region 6 Human Health Medium Specific Screening Levels (2006) Note: Value for alkyl amines used for a residential end-use scenario
Dimethylamine	23	
Trimethylamine	23	
<b>Hydrocarbon compounds</b>		
Extractable petroleum hydrocarbons (C <sub>10</sub> -C <sub>40</sub> )	50	Dutch Threshold Value for Mineral Oil
<b>Heavy metals/metalloids</b>		
Vanadium	78	Human Health Med. Screening Levels-Residential (USEPA Region 6)
Chromium (total)	30	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)
Cobalt	43	Dutch Human Health Serious Risk Concentration (RIVM, 2001)
Nickel	75	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)
Copper	8600	Dutch Human Health Serious Risk Concentration (RIVM, 2001)
Zinc	46100	Dutch Human Health Serious Risk Concentration (RIVM, 2001)
Arsenic	20	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)
Molybdenum	1300	Dutch Human Health Serious Risk Concentration (RIVM, 2001)
Cadmium	30	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)
Antimony	31	Human Health Med. Screening Levels-Residential (USEPA Region 6)
Thallium	5.5	Human Health Med. Screening Levels-Residential (USEPA Region 6)
Lead	450	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)
Uranium	N/A	
Mercury	15	Soil Guideline Value - Residential Without Plant Uptake (DEFRA, UK)

Table A.1: Soil Generic Assessment Criteria

## A.2 Water Generic Assessment Criteria

The following Generic Assessment Criteria (GAC) were used to evaluate water quality in this assessment. Given the proximity of the Panjshir River, criteria that were considered protective of freshwater ecological receptors were selected from internationally recognized institutions and regulatory bodies. When no freshwater criteria were available, drinking water standards were applied.

Determinant	Water (µg/l)	Reference
pH	<5, >9	UK Freshwater Environmental Quality Standard
<b>Hydrazine compounds</b>		
Hydrazine	0.022	United States Environmental Protection Agency (USEPA) Region 6 Drinking Water Limit (2006)
Methyl Hydrazine	0.022	
1,2-Dimethylhydrazine	0.022	
<b>Hydrocarbon compounds</b>		
Extractable Petroleum Hydrocarbons (C <sub>10</sub> -C <sub>40</sub> )	10	UK Drinking Water Standard
<b>General inorganic</b>		
Nitrate	50	UK Freshwater Environmental Quality Standard
Nitrite	50	UK Freshwater Environmental Quality Standard
Ammoniacal Nitrogen	210	Tap Water Standard (USEPA Region 6)
<b>Heavy metals/metalloids</b>		
Vanadium	37	Tap Water Standard (USEPA Region 6)
Chromium (Total)	250	UK Freshwater Environmental Quality Standard
Cobalt	730	Tap Water Standard (USEPA Region 6)
Nickel	40	UK Freshwater Environmental Quality Standard
Copper	12	UK Freshwater Environmental Quality Standard
Zinc	50	UK Freshwater Environmental Quality Standard
Arsenic	50	UK Freshwater Environmental Quality Standard
Molybdenum	180	Tap Water Standard (USEPA Region 6)
Cadmium	5	UK Freshwater Environmental Quality Standard
Antimony	15	Tap Water Standard (USEPA Region 6)
Thallium	2.6	Tap Water Standard (USEPA Region 6)
Lead	20	UK Freshwater Environmental Quality Standard
Uranium	15	WHO Drinking Water Standard
Mercury	1	UK Freshwater Environmental Quality Standard
Aluminium	37000	Tap Water Standard (USEPA Region 6)

Table A.2: Water Generic Assessment Criteria

## Appendix B: Explosive Compounds

### B.1 Explosive compounds

Each soil sample recovered from the site was screened for the following explosive compounds at BAE Systems Laboratory, in Chorley, United Kingdom.

Explosives abbreviated names	Chemical name
NC	Nitrocellulose
HMX	Cyclo-1,3,5,7-Tetramethylene-2,4,6,8-Tetranitramine
RDX	Cyclo-1,3,5-Trimethylene-2,4,6-Trinitramine
EGDN	Ethylene Glycol Dinitrate
Tetryl	Trinitro-2,4,6-Phenylmethylnitramine
NG	Nitroglycerine
TNT	2,4,6-Trinitrotoluene
2,6-DNT	2,6-Dinitrotoluene
2,4-DNT	2,4-Dinitrotoluene
PETN	Pentaerythritol Tetranitrate
HNS	Hexanitrostilbene
Picrite	Nitroguanidine
Picric Acid	2,4,6-Trinitrophenol

## Appendix C: Laboratory Test Results

### Heavy Metals in Soil Samples Nitric Acid Leaching (EPA Standard Procedures 3051/6020)

UNEP Code	V [µg/g]	Cr [µg/g]	Co [µg/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	As [µg/g]	Mo [µg/g]	Cd [µg/g]	Sb [µg/g]	Hg [µg/g]	Tl [µg/g]	Pb [µg/g]	U [µg/g]
Site 2; Sample 1	74	142	23	133	67	80	131	1.6	0.53	0.92	1.60	1.01	63	1.4
Site 2; Sample 2	71	95	22	87	53	134	59	0.72	0.49	0.23	0.50	0.58	82	4.8
Site 2; Sample 3	66	83	20	74	57	65	66	0.44	0.23	0.20	<0.5	0.39	40	1.0
Site 2; Sample 4	67	96	19	78	53	101	66	0.84	0.38	0.10	<0.5	0.36	52	1.3
Site 2; Sample 5	75	107	23	103	62	135	77	0.56	0.56	0.22	<0.5	0.62	96	3.1
Site 1; Sample 1	78	90	34	100	86	119	163	0.57	0.66	0.12	<0.5	0.44	72	1.1
Site 1; Sample 2	90	141	34	137	76	107	97	0.79	0.39	0.11	<0.5	0.52	65	1.2
Site 1; Sample 3	82	109	20	87	50	141	46	0.63	0.49	<0.1	<0.5	0.50	66	1.8
Site 3; Sample 1	70	73	27	81	76	95	127	0.50	0.28	0.22	<0.5	0.51	44	2.6
Site 4; Sample 1	76	87	33	101	89	91	204	0.60	0.87	0.15	<0.5	0.43	39	1.1
Site 4; Sample 2	75	68	22	63	62	67	117	0.33	0.28	0.13	<0.5	0.37	24	1.0
Site 4; Sample 3	80	113	26	108	65	236	108	0.87	1.18	<0.1	<0.5	0.43	58	1.4
Site 4; Sample 5	63	900	22	102	59	5300	115	0.70	0.94	0.18	<0.5	0.47	3300	1.1
Riverbank; Sample 1	75	73	15	47	31	84	20	0.46	0.22	<0.1	<0.5	0.47	32	2.3
Riverbank 2; slurry	64	68	13	38	27	70	22	0.44	0.25	<0.1	<0.5	0.33	48	5.0

Concentration expressed on a dry-weight basis (constant weight at 105 °C).

**Heavy Metals in Soil Samples  
Real Total Acid Digestion  
(EPA Standard Procedures 3052/6020)**

Element Sample Code	V [µg/g]	Cr [µg/g]	Co [µg/g]	Ni [µg/g]	Cu [µg/g]	Zn [µg/g]	As [µg/g]	Mo [µg/g]	Cd [µg/g]	Sb [µg/g]	Tl [µg/g]	Pb [µg/g]	U [µg/g]
Site 2; Sample 1	135	193	22	147	63	88	125	2.0	0.53	7.2	1.8	63	2.3
Site 2; Sample 2	124	146	21	91	50	148	66	1.1	0.53	4.5	1.3	86	5.5
Site 2; Sample 3	125	134	20	85	56	78	77	0.85	0.26	7.7	1.1	45	2.2
Site 2; Sample 4	124	154	21	95	56	127	85	1.5	0.46	3.8	1.1	65	2.7
Site 2; Sample 5	120	157	22	106	58	152	88	0.9	0.59	5.7	1.4	101	4.4
Site 1; Sample 1	132	130	29	91	75	125	174	1.1	0.66	4.3	1.2	73	2.4
Site 1; Sample 2	145	182	31	145	70	118	108	1.7	0.41	6.5	1.3	69	3.0
Site 1; Sample 3	112	142	19	87	44	152	49	1.1	0.52	3.0	1.2	72	2.7
Site 3; Sample 1	145	137	27	83	74	106	140	1.0	0.28	3.8	0.53	49	3.7
Site 4; Sample 1	162	160	33	106	89	106	227	1.2	0.91	4.2	0.53	45	2.6
Site 4; Sample 2	137	117	22	64	62	77	129	1.1	0.30	4.1	0.36	27	2.6
Site 4; Sample 3	140	173	27	118	65	255	117	1.5	1.2	3.7	0.47	66	2.7
Site 4; Sample 5	122	900	20	102	55	5300	121	1.1	0.95	3.7	0.39	3300	2.1
Riverbank; Sample 1	103	101	16	50	29	101	21	0.69	0.25	1.6	0.36	45	2.8
Riverbank 2; slurry	97	112	15	42	26	94	25	0.77	0.27	2.6	0.22	62	5.7

Concentration expressed on a dry-weight basis (constant weight at 105 dC).

**Heavy Metals in Water Samples  
Dissolved Contents  
(EPA Standard Procedures 200.8/6020)**

Element	Site 4; water 1 [µg/L]	Riverbank; water 1 [µg/L]	Riverbank 2; slurry [µg/L]
Al	321	<10	<10
V	1.2	<1	<1
Cr	3.7	10	<1
Co	3.0	<0.1	4.1
Ni	6.9	<1	4.7
Cu	10	4.4	0.79
Zn	6.8	2.9	<1
As	51	1.5	19
Cd	0.45	<0.1	<0.1
Hg	<0.1	<0.1	<0.1
Sb	0.41	<0.2	0.50
Pb	0.70	0.20	<0.2
Tl	<0.1	0.13	<0.1
U	0.13	1.5	11



## Anions in Water Samples

UNEP Code	Fluoride [mg/l]	Chloride [mg/l]	Nitrite [mg/l]	Bromide [mg/l]	Nitrate [mg/l]	Sulfate [mg/l]	Phosphate [mg/l]
UA-2006-11-14	<0.1	3.7	<0.1	<0.1	<0.1	4.1	0.3
UA-2006-11-16	<0.1	37.2	<0.1	<0.1	3.1	31.1	<0.1
UA-2006-11-17	<0.1	61.4	<0.1	0.5	<0.1	19.3	<0.1

## Soil Reaction - pH

UNEP Code	pH
Site 2; Sample 1	4.1
Site 2; Sample 2	7.1
Site 2; Sample 3	6.7
Site 2; Sample 4	7.2
Site 2; Sample 5	7.3
Site 1; Sample 1	7.4
Site 1; Sample 2	7.6
Site 1; Sample 3	7.3
Site 3; Sample 1	7.0
Site 4; Sample 1	7.3
Site 4; Sample 2	7.4
Site 4; Sample 3	7.3
Site 4; Sample 5	6.9
Riverbank; Sample 1	7.3
Riverbank 2; slurry	7.9

## Appendix D: Figures

Testing laboratory for the determination of main and trace elements and selected air pollutants	<b>TEST REPORT</b>
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<b>Test report no.:</b>	UA-2006-11	Page 1/3
Customer:	United Nations Environment Programme (UNEP), Post Conflict Branch (PCoB), Dr. Mario Burger, Senior Expert / Project Coordinator	
Order:	<b>UNEP Mission Afghanistan - ASTANA - Determination of heavy metals, selected anions and pH in water and soil samples</b>	
Summary:	<p>Soil samples were dried, homogenized and digested according to the standard procedures EPA 3051 (nitric acid leaching) and EPA 3052 (total digestion) using microwave digestion technique. Water samples were filtered and digested according to EPA 200.8. ICP-MS-technology was applied for the determination of the heavy metals in the filtered and diluted sample solutions. Selected anions in the water samples were measured by ion chromatography. The soil reaction (pH) was accomplished according DIN ISO 10390.</p> <p>The results are summarized in the annexes 1-4 of this test report.</p>	
Speiz, 29 September 2006 (Speicherdatum) 00465 / JK		
Approved:	Author:	
SPIEZ LABORATORY Physics The Head	SPIEZ LABORATORY Physics Environmental Analysis	
Dr. P. Roder	A. Jakob	
<b>Annexes:</b>	- ANNEX 1-4 -	

<b>Copy to:</b>	- Customer (Adress see chapter 1) - SPIEZ LABORATORY: JK → SAR → QS-Dok STS 101 - RPE ⇒ Reg



STS 101

The contents of this test report refer only to the test samples. It may be published in full without consent, however partial publication requires permission from SPIEZ LABORATORY.



## 1 ORDER MANAGEMENT

Date of order: 2006-04-12

Order by: Letter

Postal Address :

United Nations Environment Programme (UNEP)

Post Conflict Branch (PCoB)

Dr. Mario Burger, Senior Expert / Project Coordinator

Ch. Des Anémones 15, CH-1219 Châtelaine (Genève), Switzerland

## 2 ORDER NUMBER AND TEST PLAN

SOP: L 101 006 01

Order number: UA-2006-11

Test plan: UA-2006-11

## 3 SAMPLING

Sample(s) taking by: Customer

Sampling plan: UNEP - Afghanistan, ASTANA (Military Waste Site)

## 4 SAMPLE(S) AND CODE

SOP: L 101 011 01

LS Code	UNEP Code	Visible Check	Date
UA-2006-11-01	Site 2 - Sample 1, soil	i.O.	April 4th, 2006
UA-2006-11-02	Site 2 - Sample 2, soil	i.O.	April 4th, 2006
UA-2006-11-03	Site 2 - Sample 3, soil	i.O.	April 4th, 2006
UA-2006-11-04	Site 2 - Sample 4, soil	i.O.	April 4th, 2006
UA-2006-11-05	Site 2 - Sample 5, soil	i.O.	April 4th, 2006
UA-2006-11-06	Site 1 - Sample 1, soil	i.O.	April 4th, 2006
UA-2006-11-07	Site 1 - Sample 2, soil	i.O.	April 4th, 2006
UA-2006-11-08	Site 1 - Sample 3, soil	i.O.	April 4th, 2006
UA-2006-11-09	Site 3 - Sample 1, soil	i.O.	April 5th, 2006
UA-2006-11-10	Site 4 - Sample 1, soil	i.O.	April 5th, 2006
UA-2006-11-11	Site 4 - Sample 2, soil	i.O.	April 5th, 2006
UA-2006-11-12	Site 4 - Sample 3, soil	i.O.	April 5th, 2006
UA-2006-11-13	Site 4 - Sample 5, soil (sampling form for sample 4)	i.O.	April 5th, 2006
UA-2006-11-14	Site 4 - Water 1	i.O.	April 5th, 2006
UA-2006-11-15	Riverbank - Sample 1, soil	i.O.	April 5th, 2006
UA-2006-11-16	Riverbank - Water 1	i.O.	April 5th, 2006
UA-2006-11-17	Riverbank 2, soil - water slurry	i.O.	April 5th, 2006

## 5 SAMPLE PREPARATION

SOP: L 101 040 02, L 101 043 02, L 101 061 01, DIN ISO 10390

Methode: Dry (40°C) / Dry (105°C) / Homogenisation / Digestion / Filtration

- **Water Samples:** The original water samples were homogenized by hand shaking and filtered through a 0.45  $\mu\text{m}$  filter. For the determination of the heavy metals 10 mL of the filtered water sample was post digested by adding of 0.2 ml nitric acid (30%) and 10  $\mu\text{L}$  citric acid (10%) according the standard procedure EPA 200.8.
- **Soil Samples:** The soil samples were dried at 40 dC. For the determination of the heavy metals a representative sample of 0.5 g was digested using microwave digestion technique according the standard procedures EPA 3051 and EPA 3052.

## 6 METHODS OF MEASUREMENTS

SOP: L 101 041 03, L 101 062 02, L 101 021 02

Methode: ICP-MS  
Ion Chromatography  
Potentiometric method

## 7 DATE OF ANALYSIS

Date: April 12th - May 4th, 2006

Test executing staff: JK / WEJ

## 8 ARCHIVING

SOP L 101 013 01

Test Report/Rawdata: 10 years

Sample(s): 1 year

## 9 RESULTS

The results are summarized in the annexes 1 - 4 of this test report.

## 10 STATISTICAL AND MEASUREMENT UNCERTANTY

**Heavy metals in water and soil samples:** From each samples two analyses were performed. The analytical procedure was controlled by analyzing the Standard Reference Materials NIST N° 1640 "Trace Elements in Natural Water" and RTC "Metals on Soil". Based on these control measurements an uncertainty ( $p=0.95$ ) of  $\pm 10\%$  was estimated for the results.

**Anions, pH:** From each sample two analyses were performed. The analytical procedure was controlled by analyzing Standard Reference Materials. Based on these control measurements an uncertainty ( $p=0.95$ ) of  $\pm 5\%$  was estimated for the results.

Experimental details are available in STS 101 Testing Service "Determination of main and trace elements, their compounds and selected air-pollutants".





FIGURE 2: SITE LAYOUT & KEY AREAS OF INTEREST  
 SITE: ASTANA, AFGHANISTAN  
 SCALE: AS SHOWN

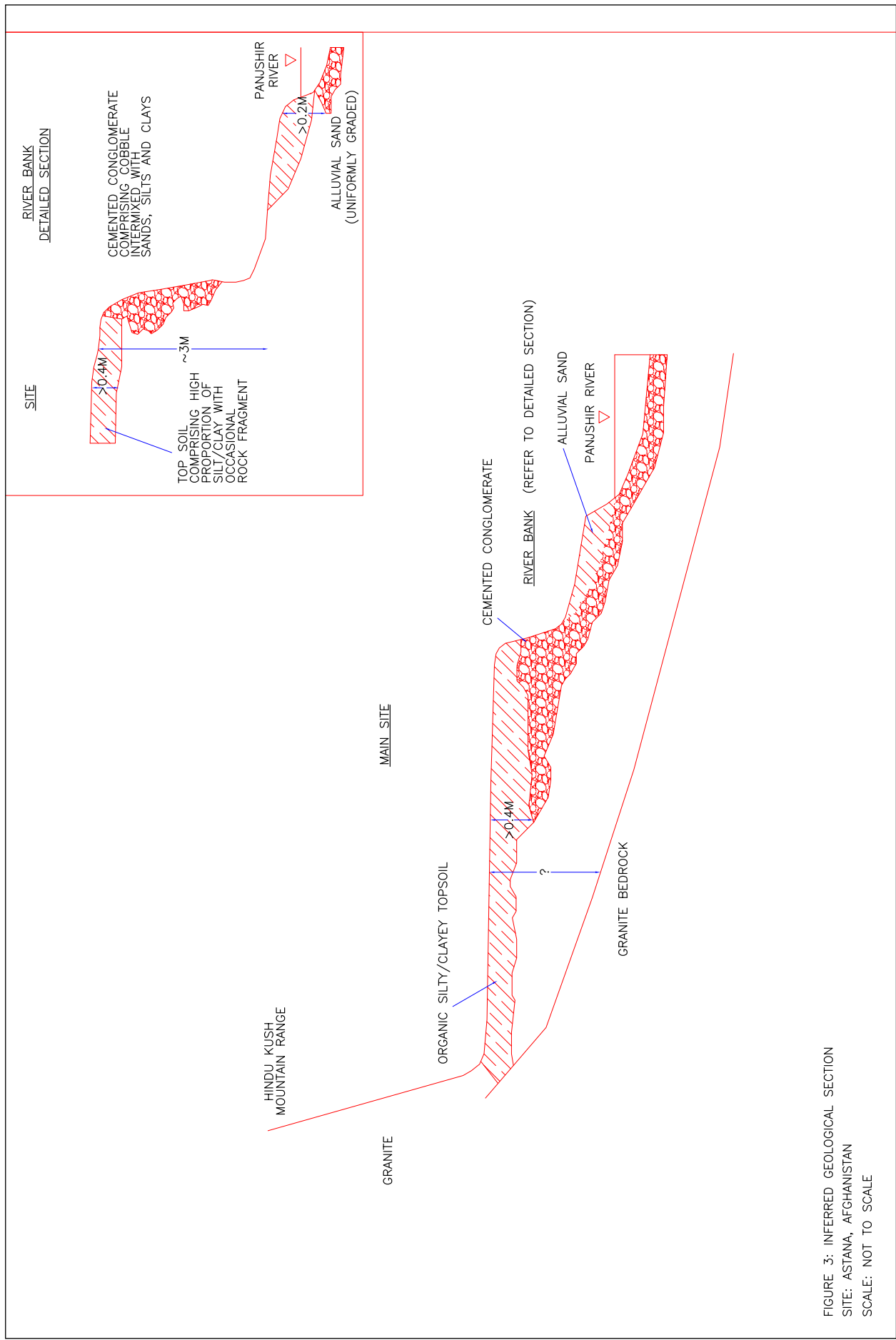
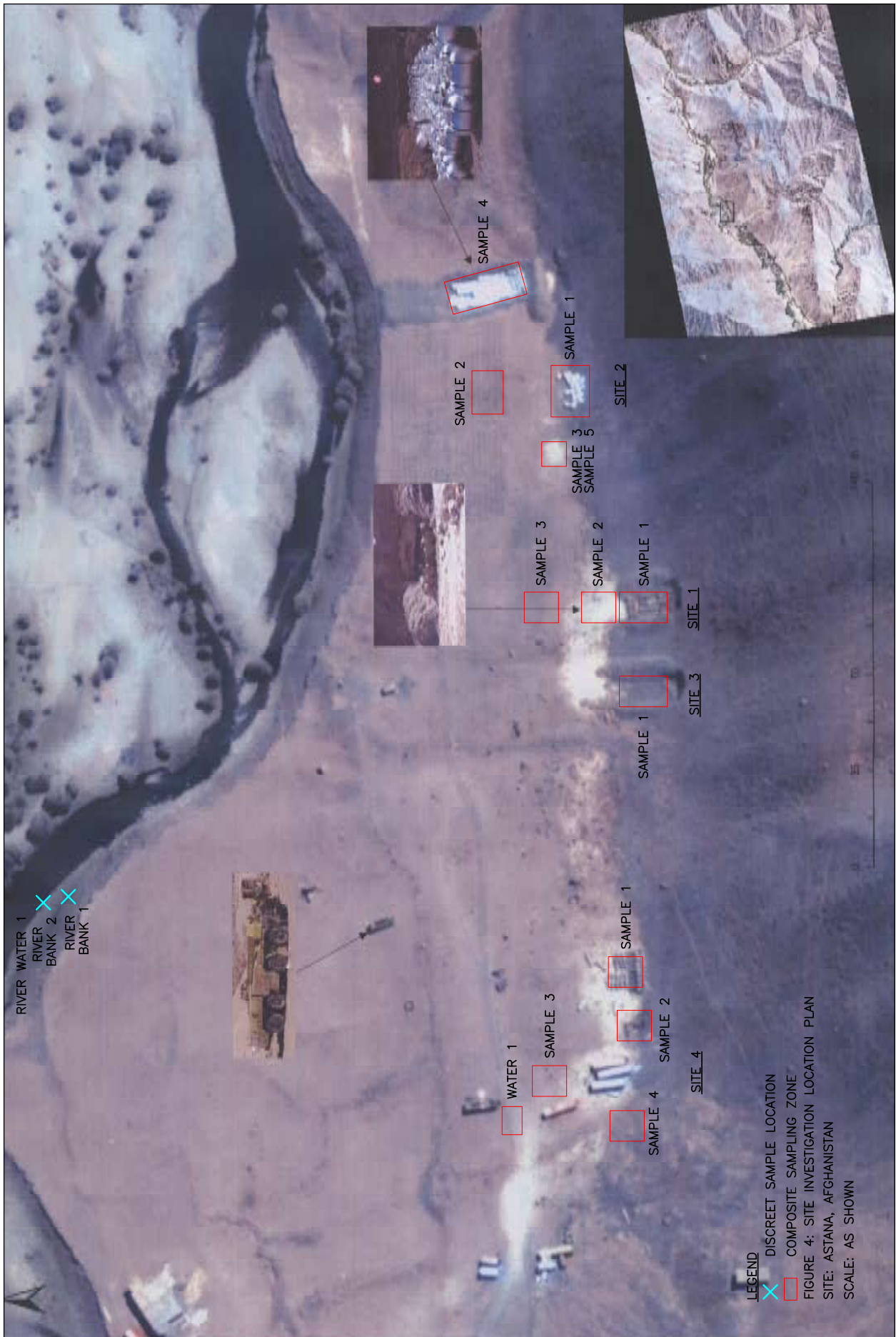


FIGURE 3: INFERRED GEOLOGICAL SECTION  
 SITE: ASTANA, AFGHANISTAN  
 SCALE: NOT TO SCALE







## Appendix E: References

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Watje, W.F. (1978). *Potential of a Hydrazine-type Fuel Spill or Emission during Movement from Supplies to User*. Proceedings of the 1977 Conference on Environmental Chemistry: Hydrazine Fuels, Tyndall Air Force Base, Florida, pp. 19-24 (CEEDO-TR-78-14).

## Appendix F: Notes

- i Further investigation of the likelihood of buried ordnance and rocket components was beyond the scope of this assessment.
- ii 1,1 Dimethylhydrazine is commonly known as unsymmetrical dimethylhydrazine (UDMH).
- iii LC50 refers to the 'Lethal Concentration' that kills 50 per cent of the test animals in a given time (usually four hours)
- iv Bioaccumulate refers to *the increase in the concentration of a substance, especially a contaminant, in an organism or in the food chain over time* (Source: American Heritage Stedman's Medical Dictionary, 2<sup>nd</sup> ed.).
- v This estimate is based on 32 warheads with an approximate weight of 150 kg each.
- vi The Control of Substances Hazardous to Health (COSHH) is an internationally-recognized British process which consists of assessing the risks to health arising from hazardous substances in the workplace, deciding on the precautions to be taken, and ensuring that the appropriate control measures are used, maintained, examined and tested. The COSHH system also ensures that employees are properly informed, trained and supervised.

## **Appendix G: Contributors**

### **UNEP Experts:**

1. George Bouma, EIA Expert, Kabul Office
2. Mario Burger, Senior Expert, Post-Conflict Branch
3. Matt Locke, Health and Safety Officer, Post-Conflict Branch
4. Asif Zaidi, Afghanistan Programme Manager, Kabul Office

### **National Environmental Protection Agency Experts:**

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UNEP also wishes to acknowledge the contribution of other staff of the National Environmental Protection Agency (NEPA) in the implementation of this work.

## **Further information**

*Further technical information may be obtained from the UNEP Post-Conflict Assessment Unit website at:  
<http://postconflict.unep.ch/>*

