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Abstract

This work describes the evaluation of the impacts of the live firing training activities in Cold Lake Air Weapons Range (CLAWR) in Alberta performed during August 02 (Phase I). CLAWR is the biggest air weapon range area in Canada and was the first Canadian Air Force Base to be characterized for explosives and metals. The study was conducted by DRDC-Valcartier in collaboration with the U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research Engineering Laboratory (CRREL), Hanover, NH, and the ERDC Environmental Laboratory (EL), Vicksburg, MS. The problem of Army ranges should be different from that of Air ranges since the Air weapons are different even if filled with the same explosives. Four ranges on the site were visited during August 2002. Alpha, Bravo, Jimmy Lake and Shaver Ranges were sampled for explosives using different strategies. More particularly, intensive efforts were done in the Shaver Range since this range was used mainly for air bombing. A linear transect sampling strategy was used in all ranges to evaluate the progression in explosives concentrations across the ranges. All the samples were built by compositing 20-30 sub-samples. A new circular sampling strategy adapted to the air-bombing situation was achieved by collecting 26 samples around the targets at specific locations. Some soil samples were also collected at different depths in front of the targets. In total, 193 soil samples, 13 biomass samples, and 4 surface water samples were collected during this first phase of the evaluation of this area. Metal analyses were done using Inductively Coupled Plasma /Mass spectrometer (ICP/MS) and explosives concentrations were done using the Gas Chromatography/Electron Capture Detector (GC/ECD) method developed at CRREL.

Résumé

Ce travail décrit l'évaluation de l'impact des activités d'entraînement par tir réel faites au secteur d'entraînement des forces de l'air à Cold Lake (CLAWR) effectuée en août 2002 (Phase I). Le secteur d'entraînement de la base de l'air à Cold Lake est le plus important en surface au Canada et a été le premier à être caractérisé pour la contamination par les explosifs et les métaux. Cette étude a été dirigée par RDDC Valcartier en collaboration avec l'US Army Research and Development Center (ERDC), Cold Regions Research Engineering Laboratory (CRREL), Hanover, NH, et l'ERDC Environmental Laboratory (EL) Vicksburg, MS. La problématique des sites d'entraînement de l'armée devrait être différente de celle de l'air compte tenu qu'ils utilisent d'autres types de munitions, même si celles-ci contiennent les mêmes explosifs. Quatre champs de tir du secteur ont été visités en août 2002. Les champs de tir Alpha, Bravo, Jimmy Lake et Shaver ont été échantillonnés en utilisant différentes stratégies pour les explosifs. Plus particulièrement, des efforts plus intenses ont été faits pour échantillonner Shaver, car celui-ci est principalement utilisé pour le largage de bombes réelles. La stratégie d'échantillonnage par section transversale linéaire a été appliquée à tous les champs de tir pour évaluer la progression des concentrations en explosifs tout au long des champs de tir. Tous les échantillons ont été constitués de 20-30 sous-échantillons. Une nouvelle stratégie d'échantillonnage circulaire qui tient compte de l'approche aérienne dans le largage des bombes a été appliquée autour des cibles en recueillant 26 échantillons à différents endroits. Quelques échantillons de sols ont également été prélevés à différentes profondeurs en face des cibles. Au total, 193 échantillons de sol, 13 échantillons de biomasse et 4 échantillons d'eaux de surface ont été prélevés durant cette première phase de la caractérisation de ce secteur. Des analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les explosifs ont été analysés par la méthode de chromatographie gazeuse/détecteur à capture d'électrons (CG/DCE) développé à CRREL.

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Executive summary

The international context of demilitarization, the closure of military bases and the more stringent aspects of environmental laws, have led to the establishment of new areas for research and development. Many activities of the Canadian Forces such as the firing of ammunition, demolitions, and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment. It is within this context that the Defence Research and Development Canada-Valcartier (DRDC-Valcartier) and the US Army Engineer Research and Development Center (ERDC), Cold regions Research and Engineering Laboratory (CRREL) and the ERDC Environmental Laboratory (EL) initiated research programs to study the environmental impact of energetic materials that are found in the Department of National Defence (DND) and the US Department of Defence (DoD) ammunition stockpiles. The Programmes on site characterization allowed the development of a unique expertise and positioned our departments to better understand the impacts of live fire training and to be in a readiness state to answer any inquiries and take corrective actions if needed. The first training areas to be characterized within the Programme were mainly Army bases such as CFB Chilliwack, Shilo, Valcartier, Gagetown in Canada and, Fort Bliss, Fort Lewis, Yakima, MMR and many others in United States. The Canadian Programme was sponsored by DRDC, DGE, DLE and by a major US Department of Defense (DoD) funding program, the Strategic Environmental R&D Program (SERDP).

During the characterization of CFB Shilo, interest grew from Cold Lake Air Weapon Ranges (CLAWR) to study their training ranges. After discussion with 4-Wing Command unit, preliminary sampling took place in March 2002 followed by the sampling of the main ranges in August 2002. Worldwide, this study represents the first efforts to characterize an entire Air Force Base. Cold Lake Air Weapon Ranges (CLAWR) is located in Alberta and is the largest and the most used air force base in Canada. Therefore, it can be seen as the most representative area for this new area of research. The campaign involved many scientists and contractors, including three scientists from ERDC, who are co-authors of the present report. To understand the potential environmental impacts caused by live firing activities, characterization of the main four ranges was conducted. Soils were sampled using a compositing technique and a new strategy that took into account the different problems coming from the air dropping of munitions. Biomass samples were also collected to ascertain their contamination. On some occasions, surface soils were collected at different depths down to 20 inches to evaluate the profile of explosives in soils. Surface water samples were also collected in nearby rivers and lakes. Samples were analyzed for explosive contamination using a gas chromatography-electron capture detector (GC-ECD) method. Heavy metals concentrations were also assessed. This report explains the approach and strategy taken and presents the results obtained during the preliminary and the first phase of the project. The analyses for explosives and heavy metals revealed localized problems in specific areas.

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Sommaire

Le contexte international de démilitarisation, de la fermeture de bases et de la sévérité croissante des lois environnementales a conduit à l'émergence de nouveaux champs de R&D. Plusieurs activités des Forces armées canadiennes telles que l'entraînement au tir de diverses munitions et la destruction de munitions, jugées désuètes ou en surplus, par brûlage ou détonation extérieure peuvent conduire à la dispersion de matériaux énergétiques et d'autres contaminants dans l'environnement. C'est dans ce contexte que Recherches et développement pour la défense Canada (RDDC)-Valcartier en collaboration avec Cold Regions Research and Engineering Laboratory (CRREL) et Environmental Laboratory (EL) de l'US Army ERDC, ont entrepris des programmes de recherches afin d'étudier les impacts environnementaux des composés énergétiques que l'on retrouve dans le ministère de la défense nationale (MDN) et le Department of Defence (DoD). Les programmes de caractérisation de sites ont permis de développer une expertise unique et ont positionné nos organisations de défense à mieux comprendre les impacts des entraînements à tir réel et à être prêtes à répondre à toute éventualité pour prendre des mesures correctives, si nécessaire. Les premiers sites d'entraînement à être évalués dans le cadre de ce programme étaient des bases de l'armée, telles que BFC Chilliwack, Shilo, Valcartier, Gagetown au Canada et Fort Bliss, Fort Lewis, Yakima, MMR et plusieurs autres aux États-Unis. Le programme canadien a été financé par RDDC, DGE, DLE ainsi que par un programme majeur de fonds américains, le Strategic Environmental R&D Programme (SERDP).

Durant la caractérisation de la BFC Shilo, l'intérêt a grandi pour étudier les secteurs d'entraînement de la base de l'air à Cold Lake. Après discussion avec 4-Wing, un échantillonnage préliminaire a été effectué en mars 2002 et l'échantillonnage principal en août 2002. Mondialement, cette étude représente les premiers efforts pour caractériser une base entière des forces de l'air. La base de l'air à Cold Lake, située en Alberta, est la plus grande au Canada. Ce site peut donc être vu comme étant le plus représentatif pour ce nouveau champ de recherche. Cette campagne a impliqué plusieurs entrepreneurs et scientifiques, dont ceux de CRREL, co-auteurs de ce rapport. Pour comprendre les impacts environnementaux potentiels causés par les activités à tir réel, on a procédé à la caractérisation de quatre sites. Les sols ont été échantillonnés en utilisant la technique des sous-échantillons et une nouvelle stratégie qui tient compte de la problématique différente reliée au largage aérien des munitions. Des échantillons de biomasse ont été ramassés pour évaluer leur contamination. À quelques occasions, des sols de surface ont été recueillis à des profondeurs jusqu'à 20 pouces pour évaluer les profils de concentrations des explosifs dans le sol. Des échantillons d'eaux de surface ont également été prélevés dans les rivières et lacs avoisinants. Les échantillons ont été analysés pour la contamination par les explosifs en utilisant la chromatographie gazeuse avec détecteur par capture d'électrons (CG-DCE). Les concentrations en métaux lourds ont également été évaluées. Ce rapport explique l'approche et la stratégie utilisée et présentent les résultats obtenus durant la phase préliminaire et la première phase du projet. Les analyses pour les explosifs et les métaux lourds ont révélé des impacts locaux dans certains secteurs déterminés.

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1 Introduction

Energetic materials are the main components of gunpowder, explosive warheads and solid rocket propellants and, therefore, can be found in war zones, training ranges or on industrial production sites. During this decade, many needs have already emerged related to the identification, quantification, delimitation and elimination of energetic contaminants dispersed by munitions, or present in explosives dumps, trials or destruction fields, firing areas and production sites [1-25]. The international context of the end of the Cold War resulted in the closing of many military bases and a growing awareness of environmental issues. Within this context the Director Research and Development Branch, through DRDC-Valcartier, has directed some of its resources to assess and develop expertise related to the environmental risks associated with explosive compounds.

Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning/open detonation (OB/OD) ranges, which were used to destroy out-of-specification materials, were highly suspected of being contaminated with energetic substances as described in the literature [1-14]. To evaluate the contamination of Department of National Defence (DND) sites, sampling and characterization of various ranges was performed over the last ten years. A protocol describing the different methods of sampling and the analytical chemistry was developed [15]. This protocol was recently updated in collaboration with CRREL and is presently being reviewed under the auspices of the Technical Cooperation Program (TTCP) by the member nations in a key technical area (KTA 4-28) [16]. Research results to date have demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In the United States, a lot of efforts have been made to develop analytical chemistry, to establish the best sampling procedure and to understand the complex fate of explosives in the environment [3, 4, 6-12, 17-25].

The selection of CLAWR in CFB Cold Lake to conduct the first R&D efforts to assess the environmental aspects of live firing activities on an Air Base was the result of a growing interest by 4- Wing following the characterization of CFB Shilo and also because Cold Lake is the largest Air base in Canada. Being the biggest and the most used area for Air practice with live weapons, it is the area most representative and worthy of study among Air bases. The problem of air bombing is completely different from problems encountered on Army ranges. The weapons used are different, especially in size and content. In Army ranges, unexploded ordnances (UXOs) buried in the ground may corrode and eventually leak their explosives to the groundwater however, many UXOs will be needed to get an important plume to the groundwater. An air-bomb that did not explode may generate a UXO buried deeper in the ground and, following corrosion, perforation and leakage, may result in a bigger problem considering that many kilograms of explosives are released in one location when 500 or 1000 pound bombs are used. Even a low order detonation with such large weapons may result in dramatic impacts to the environment as it was seen in CFB Gagetown. In this base, a 500 pound bomb that underwent low order detonation released its explosive content into a crater that was filled with water. The concentration of TNT was 35 ppm [26]. Also, a lot of Air weapons use rockets that contain ammonium perchlorate, a newly recognized contaminant that is extensively studied in US. When these rockets hit the ground, some of them are not completely burned and can break into pieces following the impact with the ground spreading ammonium perchlorate at the surface. This contaminant is ionic, very water soluble, recalcitrant and goes directly to the groundwater. Even if the expertise of DRDC-Valcartier, CRREL and EL is mainly based on Army ranges, it is directly applicable to Air ranges to understand this new problem that represents a new area of research.

The ultimate goal of this sampling campaign was to assess global contamination related to explosives and heavy metals dispersed at the surface. The contamination patterns of surface soils around targets and across the ranges were evaluated. The extent of biomass contamination in the worst-case scenario locations was assessed, and, finally, the surface water quality was also evaluated to a limited extent due to limitations in time and funds available. In previous DRDC-Valcartier studies, both energetic materials and metals contaminated surface soils have been found in training ranges [1, 2, 13-14].

To better understand and assess the contamination and characterize an area, an appropriate definition and understanding of the hydrogeological context of the site are required. Characterizing the groundwater quality, especially on such large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in groundwater, presenting a threat to human health and to the environment. Large sites can be seen as big filters for the contamination and managers or site owners must ensure that no contamination migrates off site. Soil surface sampling may point out specific areas where the contamination occurs, but the final answers will be obtained following the hydrogeological study. Groundwater flow has to be carefully assessed by determining its velocity and direction. The quality of the groundwater has also to be evaluated. Groundwater is often used as a drinking water source by the base, to sustain aquatic ecosystems and also serves for irrigation on some occasions. Consequently, any contamination could impact human health and aquatic ecosystems. In fact, groundwater flowing under CLAWR discharges into Primerose and Jimmy Lakes and also in rivers such as Shaver River. All are highly sensitive areas for wildlife and humans receptors. Consequently, it is imperative that a hydrogeological study be conducted in Cold Lake to assess the impacts of the activities.

Biomass has also proven to bio-accumulate both metals and energetic materials [10]. Therefore, prairie grass or other flora could represent a high potential intake source of these compounds for wildlife like bears. Finally, since wildlife has access to the surface water, surface water quality has to be verified.

This report describes the work carried out during the preliminary phase in March 2002 and Phase I performed in August 2002. The preliminary phase consisted in collecting some samples in winter 2002, but most of the study was accomplished in August 2002. This report will concentrate on the results obtained during the first phase. The approach and the strategy were adapted to the new context of air-dropping and the results obtained from this sampling campaign are described. Four ranges, Alpha, Bravo, Jimmy Lake and Shaver Ranges, were sampled during the August 2002 event. A lot of efforts were made to characterize Shaver River range, which was the one most used for air-dropping of live weapons. Background samples were also collected to compare and assess the natural and anthropogenic contribution. Biomass samples were collected in the four ranges. Four surface water samples were also collected. In total, 193 soils, 13 biomass and 4 surface water samples were collected. A deficiency of this study was the low number of background samples collected during August 2002; this will be corrected at the next sampling campaign in August 2003.

This study was performed under the work breakdown element 12NY01, "Characterization of DND Sites Contaminated with Energetic Materials," and was sponsored mainly by 4-Wing and by the Strategic Environmental R&D Programme (SERDP) for the sampling of the surface soils. All work was done in collaboration with U.S. Army Engineer Research and development Center (ERDC) Scientists from CRREL and EL under the umbrella of Canada-United States Test and Evaluation Programme (CANUSTEP). This joint venture between Canada and the United States was initiated to evaluate the fate of explosives in live firing ranges under the auspices of the Strategic Environmental Research and Development Program (SERDP), a major funding program in the U S DoD. Defence Construction Canada (DCC) was responsible of hiring the analytical laboratory, providing manpower, logistic and making the link with range control personnel.

2 Range History/Description

Four Wing – Cold Lake is situated in the remote northeastern corner of Alberta on the border with Saskatchewan. It was opened in 1954 to be used as an air weapons training base, and still performs that function today.

The Cold Lake area was settled in the early 1900's. The early community was largely composed of French Canadians and European immigrants drawn by the possibilities of the area's extensive natural resources. Prior to their arrival, the Chipewyan Indian nation inhabited the area. There were exceptional possibilities for trapping, forestry and fishing, and over time a considerable agricultural base was established as well.

Because of its remote location, following World War II, Cold Lake was chosen as the site for Station Cold Lake, the first flying station to be built for Royal Canadian Air Force (R.C.A.F.) fighters. A spur line from the Canadian National Railway was built in 1951 to bring in building materials, and in 1952 construction began on the base itself. The main runway and two hangars were useable by the spring of 1954. The entire infrastructure of the base had to be constructed from scratch over a period of several years including water supply lines, sewage, housing and roads, at an overall cost of $30,000,000.

Imperial Oil began exploration of the Cold Lake area in 1964. The area has extensive oil sands, and production began in the 1980's. The Cold Lake production project accounts for half of Imperial Oil's annual production, averaging 40-45 million barrels per year. In 2002, Imperial proposed a 1 billion dollar expansion of its Cold Lake project. The injection of money from petroleum production has decreased the community's dependence on the military as a primary employer.

Over 3000 military personnel, 3200 dependents and 470 civilian employees live at Cold Lake, making it both the biggest and the busiest fighter base in Canada. It is home to three tactical fighter squadrons flying the CF-18 aircraft: 410 "Cougar" Squadron, 416 "Lynx" Squadron, and 441 "Silver Fox" Squadron. In addition, Cold Lake has a tactical training squadron, 419 "Moose" Squadron, and a combat support squadron, the 417. Cold Lake is also home to the Aerospace Engineering Test Establishment (AETE), which is responsible for flight-testing all aircraft, weapons and avionics systems destined for use in military aircraft.

Four Wing also takes care of the nearby Cold Lake Air Weapons Range (CLAWR), one of the most sophisticated facilities of its type in the world. It is the only tactical bombing range in Canada, and incorporates over 100 target areas with over 700 individual targets ranging from disused vehicles to dummy surface-to-air missile sites and airfields. CLAWR has been designated a supersonic range, with pilots able to fly their aircraft at speed down to 30 meters altitude. The CLAWR is heavily used during the annual Maple Flag exercise, which brings together several NATO air forces for six weeks of intensive flying above the Cold Lake pine forests.

CLAWR covers an area of approximately 180 Km by 65 Km and is approximately 54 Km northeast of CFB Cold Lake at the junction with Saskatchewan having Primerose

Lake as a boundary. This beautiful lake is used for commercial fishing and also serves as an area to approach the ranges. There are four main ranges in CLAWR, Alpha and Bravo ranges that are part of the Primerose Lake Evaluation Range (PLER), Jimmy Lake and Shaver river ranges. Alpha and Bravo ranges are located, respectively, from South to North following the southwest shoreline of Primerose Lake (see Map Appendix A), while the Jimmy Lake range is located between Jimmy Lake and Primerose Lake. The Shaver range is remote to the Lakes and close to the Shaver River. This range is the one most dedicated to live firing using air bombing with 500 pounds. All ranges in CLAWR contain several ground target complexes for bombing training. Both the Jimmy Lake and Shaver ranges are licensed for live weapons use up to 2,000 lbs general purpose bombs and live firing missiles. The Primerose Lake water zones are called drop zones Charlie, Delta and Echo and are used to analyse the performance of stores such as dispenser or cluster munitions.

Preliminary sampling at CLAWR was conducted by D.A. Westwood & Associates in 1993. They reported some trends with metals such as cadmium, barium, copper, vanadium and lead. Defence Construction Canada also performed a study of the soils, and of sediments in the lakes. They recommended a thorough investigation of the flora such as lichen, fish tissue and water samples. No investigation prior our current study examines the potential for explosives contamination. This was the main objectives of this sampling campaign, to determine the explosives concentrations in soils in the different CLAWR ranges. A second objective was to evaluate the metal concentrations in the ranges.

3 Experimental

3.1 Contractors Involved

Defence Construction Canada (DCC) was responsible for collecting soils samples during the preliminary phase in March 2002. The DCC partial report for this activity can be found in Appendix B. They were also responsible of hiring the analytical laboratory and for supplying all of the analytical tools, solvents, bottles, etc., and the manpower to assist DRDC-Valcartier, CRREL and EL for the sampling of soils, biomass and surface water samples during the first phase in August 2002. The analytical work for metals was sub-contracted to Enviro-Test Laboratory (ETL) in Edmonton, Alberta, for the analyses of the samples collected during the preliminary phase. For Phase I, the analytical chemistry for metals was performed on all samples by Maxxam Analytics, Inc. in Calgary, Alberta. All of the energetic materials analyses were performed for both phases by DRDC-Valcartier. Furthermore, the energetic materials analyses for the samples collected during Phase I were also performed by CRREL to evaluate the heterogeneity of the samples and to validate the methods of analysis in both laboratories. DCC was responsible of the shipment of all samples to the laboratories.

3.2 Parameters Monitored and Analytical Methods

Soil, biomass and surface water samples were analysed for metals and energetic materials. Metals were analysed by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) by the external laboratory (ETL) and Maxxam Analytics, Inc. All of the parameters available by this method were included in the study. For soils and surface water samples, energetic materials were analysed at DRDC-Valcartier using the Gas Chromatography/Electron Capture Detector, a method that can produce a 0.004 ppb detection limit. In our study, a quantification limit of 0.01 ppb for all analytes was obtained based on interferences peaks in the chromatograms. Analyses were performed with a GC HP6890 equipped with an electron capture detector (ECD), an auto-injector HP7683 at an injection temperature of 250 ºC. A capillary column based on phenylmethyl siloxane HP-5 (HP19095J-121) of 10.0 m x 0.53 mm was used under helium carrier gas. The temperature run used was as follows: 100 ºC/ 2 minutes, ramp of 10ºC/ minute until 200 ºC, ramp of 15º C/minute until 280 ºC, and a pause of 4 minutes at 280 ºC. This method was based on recent work published in the U.S. [22-23].

Soil samples were dried in the dark, homogenized by adding acetone to form a slurry which was then evaporated. Soils were sieved through 25 mesh sieves and extracted at DRDC-Valcartier according to the following procedure. Four grams of soil were mixed in acetonitrile (10 mL) and a vortex was applied for one minute, followed by a sonication period of 18 hours after which the samples were left to settle for 30 minutes. The mixture was then filtered on a 0.45 microns filter and these extracts were shipped to CRREL. The extracts were then analysed by CRREL using the following procedure.

Soil extracts were maintained at 4°C until analyzed by GC-ECD. The auto sampler vials containing the acetonitrile soil extracts were placed into GC auto sampler trays that were continuously refrigerated by circulating 0°C glycol/water through the trays. The samples were injected into a HP-6890 GC equipped with a Ni63 cell micro-electron capture detector (GC-µECD). Results were obtained according to the general procedure outlined in EPA SW846 Method 8095 (Draft, www.epa.gov). Direct injection of 1-µL of soil extract was made into a purged packed inlet port, maintained at 250°C, that was equipped with a deactivated Uniliner from Restek Corporation, Bellefonte, PA. Primary analysis was conducted on a 7-m x 0.53-mm ID fused-silica column, with a 0.5-µm film thickness of 5%-(phenyl)-methylsiloxane (Rtx-5MS from Restek). The GC oven was temperature programmed as follows: 100°C for 2 min, 10°C/min ramp to 270°C, 2 min hold. The carrier gas was hydrogen at a constant flow of 10 mL/min (linear velocity approximately 95 cm/sec). The detector temperature was 300°C. The ECD makeup gas was nitrogen flowing at 45 mL/min.

If a peak was observed in the retention window for a specific signature compound, the extract was reanalyzed on a confirmation column, 6-m X 0.53-mm ID having a 1.0-µm film thickness of a proprietary phase (Rtx-TNT2 from Restek). The GC oven was temperature programmed as follows: 130°C for 1 min, 10°C/min ramp to 160°C, 30°C/min ramp to 270°C, 2 min hold. The carrier gas was hydrogen at a constant flow of 15 mL/min (linear velocity approximately 150 cm/sec). The detector temperature was 300°C. The ECD makeup gas was nitrogen flowing at 45 mL/min. Concentrations were estimated against commercial multianalyte standards (from Restek) from peak heights. Where analyte concentrations exceeded the highest standard, appropriate dilutions of the extract were made and the diluted extract re-analyzed. If analyte concentrations were within the linear range of the ECD, concentrations reported were taken from the determination on the primary column, unless co-elution with another compound was evident. In such cases, reported concentrations were taken from the determination of the confirmation column. At DRDC-Valcartier, no confirmation analyses were done using a second column system, since no second column was available.

The quantification limits obtained for energetic materials in the present study varied between 0.5 and 12.5 ppb for soils depending on the analyte. No biomass samples were analysed for energetic materials, since no explosives were detected in another study [27-28]. For all the samples collected in Shaver range, we also used the HPLC method EPA 8330 using High Pressure Liquid Chromatography (HPLC) that is good for higher explosive concentrations. See the EPA method 8330 found on their internet site (www.epa.gov) for a complete description of this method.

3.3 Sample Handling and Treatment

Explosives are not volatile compounds, and, therefore, no specific precautions, such as the use of sealed containers, had to be taken during sampling of media containing explosives. Soil samples were composites based on a minimum of 20 random sub samples and were stored in polyethylene bags. The bags were immediately stored on ice in coolers in the dark to avoid photodegradation of light-sensitive compounds. The use of polyethylene bags decreased the space needed for storing samples and reduced shipping costs. The soil samples were shipped frozen to Maxxam who split the samples into two sub samples after a thorough hand homogenization. One set of frozen samples was sent to DRDC-Valcartier for explosives analysis and the other was digested and analyzed for metals by Maxxam. Surface water samples for metals analyses were collected in standard 500-ml polyethylene bottles, and acidified to a pH of 2. These water samples were not filtered on site since they are surface water and particles can be ingested by wildlife. Biomass samples were collected in polyethylene bags, kept frozen in the dark, and sent to Maxxam. The samples were then cut in small pieces, homogenized, digested and analyzed for metals by Maxxam.

3.4 Sample Nomenclature

All samples were named according to the following five-parts labelling system during Phase I:

First part: sample type

S: Soils
SW: Surface Water
B: Biomass (Prairie Grass and other species)

Second part: Location by range

AL: Alpha
BR: Bravo
JL: Jimmy Lake
SR: Shaver River
RIF: Rifle Range
BG: Background Sample

Third part: Identification of the sample source

Target number (1 and 2) or
Firing Position (FP) or
Background location (ex: North of target) or
Background location by GPS or
LS for linear sampling at XX% of the range
where XX%=% of the overall range length or
open detonation area like in Shaver (OD-1, 2 or 3)

Fourth part: Identification of the sample

Linear sampling at xx % (A or B): A being the right side of the road access and B the left side; 0% is at the beginning of the road towards the target at 100 %
Systematic target sampling (A1, B2 C3 etc according to Figure 1, see section 3.7)
In rifle ranges: X-Y where X is the left target and Y the right target or the position of the firing position ex. 100 or 200 m.

3.5 QA/QC

Quality assurance and quality control programs were included in this study. Background soil and background biomass samples were collected away from the ranges. Analyses were done twice for energetic materials (lab replicates), but were done only once for the other parameters. Furthermore, each energetic analysis was repeated by CRREL for inter laboratory study. Ten percent of field replicates were also sent for analysis. The contracted laboratory reported their QA/QC including surrogates and blanks, detection limits, and quantification limits. Trip blanks and field blanks were also included in the QA/QC plan.

3.6 Safety and Emergency Plan

The sampling of an UXO-contaminated area represents an increased level of risk for personnel. The Range Control Officers gave a safety briefing to people involved in the sampling program. This briefing explained the precautions to be taken to avoid contact with UXOs on the ranges and also described the various types of UXOs that may be found on ranges. A safety and emergency plan was also put in place for any incident that could have occurred while sampling water, soils, and biomass. This plan was under the responsibility of the CLAWR Range Control unit. When on site for sampling, personnel were always equipped with radios to contact range control in case of an emergency. Walkie-talkies were available to communicate between the teams. Range control personnel were always accompanying the sampling team.

3.7 Sampling Strategy

During the preliminary phase, DCC sampled in Alpha, Bravo, Jimmy Lake and Shaver ranges to provide preliminary results for energetics and metals. Unfortunately, the metals analyses will not be included in the present report. For the energetic materials, DCC used a circular pattern to collect soils around targets in the ranges. A complete description of this work can be found in Appendix B. During Phase I, soil, biomass and surface water sampling was conducted by DRDC-Valcartier, CRREL, EL and DCC. A total of 193 soil, 16 biomass and 4 surface water samples were collected during Phase I. The surface water samples were collected in Primerose Lake, Jimmy Lake, Shaver River, and a last one in a pond containing ammunition and water in Shaver range. For statistical analyses and quality evaluation, 8 backgrounds and 18 field duplicates (9%) were collected for soil analyses. All samples were analyzed for metals (193), while a limited number was analyzed for energetic materials (131 soils - 12 field duplicates (9%)). All of the analyses for energetic materials were performed by both DRDC-Valcartier and CRREL following the drying, homogenization, sieving and splitting of the samples. This was done to compare the results between laboratories and also to validate the results. Samples collected in Alpha, Bravo and Jimmy Lake were analysed using the GC-ECD method, while most of the samples collected in Shaver range, which was suspected to be more contaminated in explosives, were analysed using the HPLC method EPA 8330. For biomass samples, only two background samples were collected and this was a deficiency in this study that will be corrected during Phase II in August 2003. Biomass samples were collected in all four ranges.

Background soil samples are critical for establishing the anthropogenic contribution versus the natural contribution for all metal parameters. The background composite samples were collected in a random manner, in a circular pattern of approximately 20 meters in different locations inside and outside the base. A minimum of 30 sub samples was collected to form each background sample. A statistical analysis was done with the results. This statistical analysis allows the identification of a mean background concentration and to define a limit for a value that can be considered abnormal. Samples located at the extremity of the lognormal curve were identified, the limits were chosen for a probability of 97.72% (2 times the standard deviation). The probability of finding a result with a value higher than this limit is 2.28 %. When the analytical laboratory did not detect metals, we used a value at half of the detection limit for the purpose of our analysis.

The initial strategy planned for soil sampling was based on systematic sampling around a representative number of targets in ranges and also around hot spots (broken casings, UXOs or debris, etc.). Usually, surface soils are collected at depth of 0-5 cm. This strategy was used in previous studies on antitank ranges, which showed very distinct patterns of contamination around targets [2]. However, the nature and type of firing exercises conducted in the Air ranges were different from those conducted in antitank ranges in the sense that the plane, which is the firing point, is moving fast and represents a different situation compared to static firing positions or targets in Army ranges. Even if some air weapons are laser guided and, consequently, very precise, many air-dropped weapons are not guided and precision around targets can be more difficult to achieve. For these reasons, we used mainly two sampling approaches, both based on the collection of composite samples, in order to decrease the high level of heterogeneity usually observed with explosives residues in such scenarios [2, 6].

The first sampling approach consisted in using a linear sampling pattern. This approach was used to evaluate whether the level of contamination by metals or energetic materials was following a pattern with distance from the target in the ranges. If firing activities led to the accumulation of contaminants in soils, higher concentrations should be found around targets, since most of the ammunitions fired were supposedly fired at these targets. Therefore, composite samples were collected at distances of 20, 40, 60, 100, 120 % and 140% of the distance from the entrance of the range to the target. Most of the time, there was an access road going directly to the targets in the middle of the ranges. This road was used for maintenance and clean-up so, we used that road to build transects (right and left of centerline) that was perpendicular to the road. Twenty or more increments were taken to build each composite. Transects were fixed with the help of the Global Positioning System (GPS). The GPS locations are reported in Table I. The linear samples corresponded to the % of the distance between the range entrance and the target. As an example, at 20% of the distance, we collected on each side of the road walking perpendicularly to the road using a GPS to keep on a straight line. A minimum of 20 surface sub samples taken at 0-2 cm depth were collected to build each composite sample A and B corresponding to the right and left side of the road. The composites were built by walking 100-200 meters. In some occasions such as hot spots or other artefacts of interest, we used composite sampling that consisted in building the sample using discrete samples around the hot spot (20 minimum).

The second sampling strategy is a new approach and consisted of sampling around targets by compositing samples taken in a circular pattern. This strategy, based on the circular sampling used at CFB Shilo, was used for specific target evaluation. The strategy was modified to adapt to the specific context of air-to-ground targets and was designed to allow a comparison of the relative concentrations in front of and behind a target. A semi-circular pattern was used to collect composite samples at specific distances from the targets. This is illustrated in Figure 1. Twenty-six (26) soil samples were collected around targets, one within each of the cells around the target. Three circles located at 10, 30 and 50 m radius of the target define these cells. Two composite samples (A1 & A2) collected in hemispheres of first 10-m diameter ring (Front and Back of Target). Eight equal-sized rectangles sampled between 10 and 30 m (B1-B8), and 16 between 30 and 50 m (C1-C16). Twenty or more increments were collected to build 800 g to 1.5 kg composite samples.

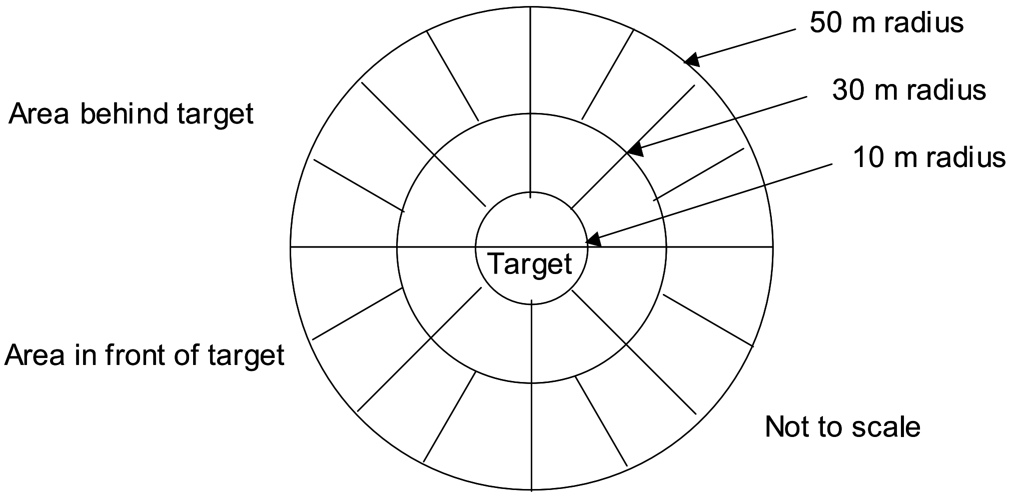

Figure 1: New circular soil sampling pattern designed for air-to-ground targets.
The total number of samples is 26 around a target.

Wherever biomass samples were collected, the method consisted of building composite samples of indigenous living plants by randomly cutting various types of plants. A minimum of 20-30 sub samples of mixed biomass material was collected to build the different biomass samples, around targets, in transects or in rifle ranges. Only the upper part of the plants (without roots) was collected, since grazing animals rarely eat the roots of the plants as verified by consulting an expert from Environment Canada (Lucie Olivier, Environment Canada-Montréal). Metals could bio-accumulate either in the upper plant system or in the roots, depending of the solubility of the metals. Metals were evaluated by digesting the biomass samples using a standard procedure in nitric acid.

In Jimmy Lake range, a practice target was used for the circular sampling and the linear sampling strategy was used for the 20-mm firing range. Composite soil samples were collected behind three targets in transects that were split into A and B (west and east) sections. Transects were perpendicular to targets at distances of 20, 40, 60, 80, and 100% of a 120 m range. In addition, samples of vegetation were taken just beyond the 120 m distance and at about 30 m in front of targets. The soil samples collected in this range were comprised of fine grained sand.

In Shaver River range, air dropping of 250, 500, and 1000 lbs high explosive (HE) bombs at stationary target is done on a regular basis. Again, the circular strategy was applied. Also, three duplicates, one each taken within each of the three rings was collected. Down range from the target, transects were made at 100, 200, 300, 400, and 500 m. Transects were split into two halves (A on one side of the road and B on the other side) and composite samples were collected over a 100-m transect on each side of a line running perpendiculary to the road going to the target. The wheel sampling pattern was also used to collect surface samples some 12 ft away from the tank target, in composite domain A1 (W samples) [2]. Three depth samples were taken below sample W1 in the center of the wheel and were named W1 D1, D2 and D3 at depths between 5 to 10 cm, 10 to 15 cm, and 15 to 20 cm, respectively. Depth sampling was not performed until a large area had been cleared. Surface samples were taken between 0 and 5 cm. Small discrete samples were also collected at the surface using the wheel pattern and were named W2, W3, W4, W5, W6 and W7. As for the other ranges, the surface was covered with fine grained sands; however, several chunks of HE that were tentatively identified by dissolution in acetone, were picked up around the target. Some chunks were thought to be Tritonal (TNT and aluminum) and others TNT or Composition B. Burn areas on both sides of road leaving the Shaver range were also sampled. Two composite samples named S-SR-OD were collected in an old burn area on the North side and one on the South side of that road. Again fine sands dominated the samples.

The Alpha range, in front of Primerose Lake, is a practice range for dropping bombs. This range was lightly covered with grasses growing in fine grained sand. The concentric domain sampling approach was performed around the stationary target, which included composite sample duplicates, and composite vegetation samples from each ring (A, B and C made from C4 and C13). Linear sampling was performed along transects (100m each side of the access road) in front of the target going from the entrance of the range to the target at distances of 0, 200, 400, 600, 800, 1000, and 1200 m. Two biomass samples were taken at 800 m (LS 80 %).

The Bravo range in front of Primerose Lake is also a practice range for dummy bombs and rockets. Six dummy bombs and 4 rockets (CRV7) (2.75 in diameter) rockets were dropped/fired at target just prior to sampling. Concentric domain sampling was performed around the target (Note: all shots that we observed during the live firing were hitting the ground within 50 m of the target, 2 within 10 ft.). Three soil duplicates in the three circles (A, B and C) were collected along with two biomass samples in rings A and B. Linear transects were collected at 40, 60, 80, 100, 120, and 140% from the entrance of the range to the target, this target being considered the 100%, for a 110 m range. Two hot spots that perhaps had propellant on the surface were sampled. One was a crater some 40 m up range, and the other was material on the surface in the A1 domain.

A specific sampling strategy was used in the rifle range. The rifle range in CLAWR consisted of a series of numbered targets having conventional sand butts (berms) in front of them. Surface soils and one biomass sample were collected in front of the targets. Surface soils were collected from 0 to 10 cm deep, using stainless steel spoons. Five composite surface soil samples were built of at least 20 sub samples and were collected in front of groups of three nearby targets (15 targets sampled). The biomass sample was collected by compositing at least 30 sub samples in the area in front of a group of four close targets (1-4). In addition two composite samples were collected along firing point positions some 10 and 100m up range.

4 Results and Discussion

In our evaluation of the results, the mean values for background samples were the mean of all collected backgrounds for each parameter measured. When results lower than detection limits were encountered for specific parameters in some samples, half value of the detection limit for this parameter was chosen as the result for the calculation of the mean value and for the comparison of all results with the background mean values. The results obtained in training areas were compared to the mean value of the background to which was added twice the standard deviation. This allowed the selection of results having values greater than the background means, while being statistically representative. Results are presented for each parameter instead of per sample to facilitate the analysis of the results, since trends can be easily seen for each parameter. Backgrounds were always tabulated first with mean, standard deviation, mean plus twice the deviation standard and Canadian Council of Ministers of Environment (CCME) threshold criteria values for each metal. Then, results for samples collected in the training areas were tabulated. Surface soil samples were compared to the most stringent agricultural CCME threshold levels for metals that were included in the latest published CCME quality guideline (see www.ccme.ca). For metals that were not included in the CCME list, results were compared to the mean values added to twice the standard deviation of all soil backgrounds samples and results exceeding this value were highlighted in blue font in Table II. Even if not applicable to DND properties, the CCME agricultural soil criterion is the most stringent reference, and, therefore, it shows where contamination should be looked at first and monitored. When metal concentrations were above the agricultural criteria, they were also compared to the industrial soil criterion, which is the most permissive criterion. These results were highlighted in red fonts in the tables. For biomass, there are no CCME criteria. Results higher than the mean values added to twice the standard deviation were highlighted in blue font in Table III. Metals concentrations in surface water samples exceeding the CCME Water criteria were highlighted in red font and are presented in Table IV. In these instances, the CCME aquatic life threshold criterion is the most appropriate value to use.

A total of 193 soil, 16 biomass and 4 surface water samples were collected during Phase I in August 2002. The parameters analyzed in soils were as follows: Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, Sn, U, V, and Zn. The parameters analyzed in biomass were as follows: Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn. The parameters analyzed in surface water were as follows: Al, Sb, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, Se, Ag, Sr, Tl, Sn, Th, Ti, U, V, Zn and Zr. Thus, a total of 4,053 analyses were conducted for soils and 320 for biomass and 108 for surface water samples. The results for plants correspond to the total amount of metals both bio-accumulated and deposited on the plants, since digestion of the total plants was accomplished. Analyzing leachates to discriminate between metals in and on plants was not judged necessary, since wildlife ingest the metals, in both cases by eating the entire plants. A total number of 56 soil samples were collected by DCC during Phase 0 in March 2002.

For Phase I, the analytical results obtained for the parameters tested in all types of samples showed no major environmental impacts related to the training activities. In soils, the accumulation of some heavy metals associated with ammunition was observed in some parts of ranges, but concentrations did not reach levels of concern. Phase I results clearly demonstrated no major problems associated with soil contamination except in a few locations.

Out of the 193 soils samples, 131 samples were analysed for energetic materials. Ten parameters were screened for explosives, including the most common explosives RDX, HMX and TNT, using the HPLC method, while 9 parameters were screened using the GC/ECD method. No biomass samples were analysed for explosives during Phase I, but some analyses will be performed with biomass samples during Phase II August 03.

Analyses for energetics were done at CRREL and at DRDC-Valcartier by GC/ECD SW 846 Method 8095, or for higher concentrations samples, RP-HPLC SW 846 Method 8330. The GC-ECD method provides detection limits in the low microgram/kg (ppb) levels for explosives analytes; however, the quantification limits for our soil samples were slightly higher based on interference peaks present in the soils extracts. The detection limit of this method and the reporting limits for both methods are provided in Table V.

All samples were thoroughly homogenised and analysed in duplicates (one replicate was extracted and analysed at DRDC-Valcartier and the other at CRREL) to verify the sample homogenization efficiency. Means and standard deviations were calculated for all sets of replicate measurements. Suspect individual measurements were flagged on the basis of extreme values of the relative standard deviation (RSD) and inconsistencies in the overall pattern for that sample or analyte. More than 80 % of the laboratory replicates showed a relative standard deviation (RSD) < 30 %, which indicates that the approach taken for soil homogenization by adding acetone after the drying step was quite efficient. However, for some parameters RSD values as high as 155% were still observed.

Analyses for energetics were also performed using the HPLC EPA method 8330 at CRREL and DRDC-Valcartier for the Shaver range, which was suspected to be contaminated at higher explosive concentrations. The reporting limit of this method is 100 ppb for all analytes except for DNB, tetryl and PETN, for which limits were slightly higher (Table V). During the preliminary phase in March 2002, 59 samples were analysed for energetic materials according to the sampling described in section 3.7. These samples were analysed at DRDC-Valcartier using the GC/ECD method. The GPS locations for all these samples can be found in Table I. No energetic materials were found in these samples with the exception of samples ssr-bombcirc-50m A and B and ssr-bombcirc-25m A in Shaver. These samples were composite samples collected in a circular pattern at 25 and 50 m radius from the Shaver river range target. TNT, amino TNT and tetryl were found at levels between 0.3-2.0 ppb in these samples.

Results for energetic materials are presented in Table VI. In the four ranges, both linear transect patterns (between 20 and 140% of the range length at each 20% interval) and circular patterns around targets were done. Samples were analysed for explosives. Moreover, “hot spot” samples (HS) were collected where munitions, or munitions debris were encountered. These samples were named HS with the GPS locations where they were collected. All samples were composite samples built of at least 20 sub samples either in linear transects, circles around targets or circles around the hot spots. When munitions were visually observed, the samples were collected as near as possible to the UXO with sub samples around it.

4.1 Alpha Range

The Alpha Range is located in front of Primerose Lake and was roughly 1.0 Km long. This range was lightly covered with grasses growing in fine grained sand. The concentric domain sampling approach was performed around the stationary target, which included composite sample duplicates, and composite vegetation samples from each ring (A, B and C made from C4 and C13). Linear sampling was performed along transects (100m each side) in front of the target going up range at distances of 0, 200, 400, 600, 800, 1000, and 1200 m. Two biomass samples were taken at 800 m (LS 80 %). In Alpha Range, 46 soil samples and 5 biomass samples were collected.

Soils

If one examines Table II A, B and C, some parameters are seen to exceed the background level value added to twice the standard deviation (BGL) and are in blue font. Of the 21 parameters analysed, only Be, Mo, Se, Ag, Tl and Sn were not detected at values higher than the BGL in any samples collected in Alpha Range. All the other parameters were detected at values higher than the BGL. Out of the 46 soil samples, Sb (7 samples, 15% of all samples), As (27, 59%), Ba (3, 6.5%), Cd (2, 4.3%), Cr (12, 26%), Co (2, 4.3%), Cu (3, 6.5%), Fe (8, 17%), Pb (4, 8.7%), Hg (1, 2.2%), Ni (13, 2.8%), Sr (1, 2.2%), U (2, 4.3%), V (12, 26%) and Zn (1, 2.2%) concentrations were higher than the BGL added to twice the standard deviation. No metals were detected at concentrations higher than the CCME agricultural soil criteria. For each parameter having blue hits, a mean of these values was calculated and compared to the BGL added to twice the standard deviation (BGL) and also to the CCME Agriculture Soil Quality Guideline (ASQGL) to figure if the levels of concentrations were closer to the BGL or to the CCME criteria. A complete list of these tendencies is as followed:

-Sb: mean 0.23: 1.8 X > BGL and 87 x < CCME ASQGL
-As: mean 1.8: 1.6 x > BGL and 6.6 x < CCME ASQGL
-Ba: mean 60.2: 1.1 x > BGL and 12.5 x < CCME ASQGL
-Cd: mean 1.04: 2.9 x > BGL and 1.3 x < CCME ASQGL
-Cr: mean 12.8: 1.3 x > BGL and 5 x < CCME ASQGL
-Co: mean 5.0: 1.2 x > BGL and 8 x < CCME ASQGL
-Cu: mean 11.2: 1.6 x > BGL and 5.1 x < CCME ASQGL
-Fe: mean 10560: 1.2 x > BGL, no ASQGL for Fe
-Pb: mean 4.25: 1.3 x > BGL and 16.5 x < CCME ASQGL
-Hg: mean 0.084: 2.4 x > BGL and 79 x < CCME ASQGL
-Ni: mean 7.7: 1.3 x > BGL and 6.5 x < CCME ASQGL
-Sr: mean 22.3: 2 x > BGL, no ASQGL for Sr
-U: mean 0.55: 1.0 x > BGL, no AQGL for U
-V: mean 18: 1.3 x > BGL and 7 x < CCME ASQGL

-Zn: mean 1.8: 1.5 x > BGL and 4 x < CCME ASQGL

As it can be seen, most of the values are at 1-3 times higher than the background levels added to twice the standard deviation, but all parameters respect the agricultural soil criteria. No anomalies were observed for the duplicate samples, i.e., the values for the duplicates were similar to values for the original sample. The impact of the activities is measurable, but at a very low extent. No action is required on this site.

Biomass

The results for the biomass samples are found in Table III. Every biomass sample analysis was done twice, and some parameters are missing in the second analysis. It is probable that the analytical lab repeated some of the analyses on separate sub samples. On many occasions, the values for the same sample are quite different. Nevertheless, the analysis was done even if it was stated earlier that the number of background samples was inadequate to realize a valid statistical evaluation. If one examines Table III, some parameters are seen to exceed the background level value added to twice the standard deviation (BGL) and are in blue font. Of the 20 parameters analysed, only Al, Ba, Cd, Cr Cu, Fe, V and Zn were detected at values higher than the BGL. A complete list of the parameters and the number of hits is as followed:

-Al: 3 out of 5 results exceeded the BGL added to twice the standard deviation
-Ba: 7 out of 10 results exceeded the BGL added to twice the standard deviation
-Cd: 1 out of 5 results exceeded the BGL added to twice the standard deviation
-Cr: 1 out of 10 results exceeded the BGL added to twice the standard deviation
-Cu: 4 out of 10 results exceeded the BGL added to twice the standard deviation
-Fe: 1 out of 5 results exceeded the BGL added to twice the standard deviation
-V: 1 out of 10 results exceeded the BGL added to twice the standard deviation
-Zn: 1 out of 5 results exceeded the BGL added to twice the standard deviation

All of the parameters that exceeded the BGL added to twice the standard deviation in biomass samples also exceeded the BGL in soils. It is highly possible that these metals are preferentially extracted from the soils and may represent a risk for wildlife.

Energetic Materials

For the purposes of this report, we can consider that energetic compounds fall into two classes, those that are related to propellants and those related to high explosives. Nitroglycerine (NG), dinitrobenzene (DNB), dinitrotoluene (DNT) and trinitrobenzene (TNB) are either major ingredients or impurities in various types of propellants such as those used in rocket motors. Usually, rockets use either double based propellants composed of nitrocellulose and nitroglycerine or a thermoset polymeric matrix based on hydroxyl terminated polybutadiene containing ammonium perchlorate as the oxidizer. Perchlorate analyses should be performed in ranges to evaluate impacts by this chemical. However, these analyses are costly. The single-based propellants also contain DNT as a plasticizer and impurities such as DNB and TNB coming from the synthesis of energetic materials starting from toluene containing benzene as an impurity.

High explosives used by both Canada and the United States generally contain either TNT (2,4,6-trinitrotoluene) or mixtures of TNT with RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), or for some older muntitions, tetryl. Most of the air weapons contain TNT with aluminum (tritonal explosives). The most powerful weapons contain composition B (TNT with RDX) or octol (TNT with HMX). When UXOs are found on sites, they are often blown in place (BIP) using C-4, a mixture of RDX with a polymer. These BIP operations often spread explosives into the environment [11]. In Alpha Range most of the samples did not contain detectable concentrations of propellant-related compounds (Table VI A). 2,4-DNT was detected by CRREL in samples around the target in sectors B-3, C-12, C-16 and at LS 100%A at 3, 2, 4 and 3 ppb, respectively. The samples in which 2,4-DNT were found also had much higher concentrations of TNT. The 2,4-DNT detected in these samples is likely to have originated as an impurity in TNT. The concentrations of 2,4-DNT were low and did not represent a problem.

TNT was found in almost all samples collected at the Alpha Range at concentrations varying from 2 to 1100 ppb. RDX was also detected in over half of these samples, but the concentrations were always less than 50 ppb. It is interesting that the highest RDX concentration samples do not correlate with the samples with the highest TNT concentrations possibly indicating that the sources of the two residues were different.

We were surprised that explosives were found in nearly all the Alpha Range samples, since the Alpha Range is supposedly used only for practice bombs. Some practice ordnances have spotting charges, though, and these residues could have resulted from these spotting charges. We expected that if residues were found at this range, the highest concentrations should be near the target in circle A, then in B, then in C. This was not found to be the case because in all three circles, TNT concentrations of the same magnitude were encountered at about 400 ppb. In fact, one of the highest concentrations of TNT for Alpha range samples was found for a sample in the C circle at C 12.

For samples collected using the linear sampling strategy, we expected that the concentrations should increase as you move toward the target. The highest concentrations were found at 100%, which is nearest the target, but for other samples no correlation between concentration and location appears to exist. The concentrations in the linear transects were quite low except at the entrance of the range, which was very surprising. It is possible that an open detonation (OD) operation on an UXO close to this point was done and spread explosives on this side of the range (LS 0% A). In linear transects, the mean concentrations of TNT were around 100 ppb.

RDX was found in almost all samples from the circular approach, but in very few of the transect samples. One explanation, which is also valid for all of the other explosives, is the fact that when the linear transects were built, we walked away from the median of the range, and, doing so, we walk away from the direction of firing. Furthermore, since the samples were collected by walking a 100 m distance, the concentrations were possibly diluted compared to the circular where the samples were collected in a smaller area. RDX concentrations varied from 5 to 57.4 ppb in circular samples, while they varied from 4 to 21 ppb in the transect samples. Amino DNTs, which are the results of TNT degradation, were found at concentrations of 0.98 to 29.74 ppb in circular samples and at concentrations of 7 to 21 ppb in linear samples. The highest concentrations were for the 100% samples, which were near the target. The highest hit for amino DNTs in the linear transect corresponded to the highest hit for TNT, which makes sense since TNT is the parent compound. Tetryl and HMX were not detected except for HMX in LS 80%B at 123 ppb.

In most of the analyses, good correlation between CRREL and DRDC-Valcartier analyses was found, the values being always in the same order of magnitude (Table VI A and B). On some occasions, though, discrepancies occurred between results from the labs, such as in B2 and C8, which shows that the distribution of analytes in the samples was often very heterogeneous. Even with good preparation of the samples with a homogenization process, small chunks of analyte could be found in one part of the sample, while another part did not contain any explosives. This is also particularly true for duplicate samples. In the analyses for LS 100% A and LS 100% A dup, both samples were collected almost at the same locations and TNT results varied from 11 to 1100 ppb, a factor of a hundred difference. The same situation was encountered with sample A2 and A2 dup. This is explained by the fact that while collecting these samples, one might have collected a small explosive chunk in one of the samples, but not in the other, resulting in very different concentrations upon analysis. If we look at the maximum concentrations of explosives at that range, which for TNT was 1,100 ppb, and having in mind that the ecotoxicological threshold criteria developed by the Biotechnology Research Institute (BRI) for TNT is 80 ppm for soils, the Alpha Range concentrations are far below that level, and, therefore, no action is required for that range.

4.2 Bravo Range

The Bravo range is also located in front of Primerose Lake and is composed mainly of sandy soil with vegetation. Live firing was done at this site just before our sampling. Since the weapons hit the ground in front of the target, this confirmed that our strategy for sampling was appropriate. Concentric domain sampling was performed around the target. Three soil duplicates in the three circles (A, B and C) were collected along with two biomass samples in circles A and B. Linear transects were collected at 40, 60, 80, 100, 120, and 140 percent up range, for a 1.1 Km-long range. Two sites that perhaps had propellant on the surface were sampled. One was a crater some 40 m up range (HS- 0560425), and the other was in the A1 domain (HS-0560345).

Soils

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font (Table II A, B and C). Of the 21 parameters analysed, only Sb, Cd, Cu, Pb and V were detected at values higher than the BGL or the ASQGL. Of the 39 soil samples, Sb (3 samples, 7.7% of all samples), Cd (33, 84.6%), Cu (5, 13%), Pb (7, 18%) and V (10, 26%) concentrations were higher than the BGL added to twice the standard deviation or the ASQGL. Cadmium was detected at concentrations higher than the CCME agricultural soil criteria (12 samples). For each parameter having hits, a mean of these values was calculated and compared to the BGL added to twice the standard deviation (BGL) and also to the

CCME Agriculture Soil Quality Guideline (ASQGL) to determine whether the levels of concentrations were closer to the BGL or to the CCME criteria. A complete list of these tendencies is as followed:

-Sb: mean 0.4: 3.1 x > BGL and 50 x < CCME ASQGL
-Cd: mean 1.12: 3.1 x > BGL and 12 samples > CCME ASQGL
-Cu: mean 8.6: 1.2 x > BGL and 7.3 x < CCME ASQGL
-Pb: mean 4.6: 1.4 x > BGL and 15 x < CCME ASQGL
-V: mean 20.9: 1.5 x > BGL and 6.5 x < CCME ASQGL

As can be seen, fewer parameters exceeded the BGL compared to the Alpha Range, but the situation was similar. Most of the values were 1-3 times higher than the background levels added to twice the standard deviation, but all parameters except cadmium respected the agricultural soil criteria. No anomalies were observed for the duplicate samples; values for the duplicates were similar to values for the original sample. The impact of the activities is lower at this site than in the Alpha Range, but a cadmium problem exists. Nevertheless, even if cadmium concentrations were higher than the ASQGL criterion, concentrations exceeded neither the residential nor the industrial soil criterion. No action is required on this site.

Biomass

Every biomass sample was analysed twice. Not only were values for the same samples often quite different, but, some parameters detected in one analysis were undetected in the second analyses (Table III). These data illustrate the extreme heterogeneity in the distribution of contamination. Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font. Of the 20 parameters analysed, only Al, Ba, Cd, Cr Cu, Fe, Ni, V and Zn were detected at values higher than the BGL. A complete list of the parameters and the number of hits is as followed:

-Al: 2 out of 2 results exceeded the BGL added to twice the standard deviation
-Ba: 4 out of 4 results exceeded the BGL added to twice the standard deviation
-Cd: 2 out of 2 results exceeded the BGL added to twice the standard deviation
-Cr: 1 out of 4 results exceeded the BGL added to twice the standard deviation
-Cu: 2out of 4 results exceeded the BGL added to twice the standard deviation
-Fe: 2 out of 2 results exceeded the BGL added to twice the standard deviation
-Ni: 2 out of 4 results exceeded the BGL added to twice the standard deviation
-V: 4 out of 4 results exceeded the BGL added to twice the standard deviation
-Zn: 2 out of 4 results exceeded the BGL added to twice the standard deviation

All of the parameters that exceeded the BGL added to twice the standard deviation in biomass samples also exceeded the BGL in soils. It is highly possible that these metals are preferentially extracted from the soils. The situation in Bravo Range is almost identical to the one in Alpha Range, except for cadmium. These two ranges are located very close to each other, and the same types of activities were very likely conducted on these two ranges.

Energetic Materials

Analytical results for analysis of explosives- and propellant-related compounds are given in Table VII. Of the propellant-related compounds, only nitroglycerin (NG) was detected by CRREL for samples near the target (samples A-1, B-2, B-4, B-6, and B-8). NG was also detected in one other location that was suspected of containing propellants. The concentrations were, respectively, 27, 18, 22, 27, 39 and 19 ppb. The highest hit was found at B-8, which is close to the target. These concentrations are low and do not represent a problem.

TNT was found in almost all samples from Bravo Range at concentrations ranging from 3 to 298 ppb. This is similar to the Alpha Range results, but the TNT concentrations were lower and only one sample had a detectable concentration of RDX. It is interesting to note that unlike the Alpha Range sample, no detectable levels of the amino-DNT transformation products were observed. This may indicate that the residues of TNT detected at the Bravo Range were very recently deposited and had no time to transform prior to sample collection. As noted above, live fire training occurred just prior to our sampling, and this training probably was the source of these residues.

The results for energetic compounds at the Bravo Range correspond well with the results for metals analyses, which demonstrated that this site was similar to Alpha Range, but contaminated at a lower extent. The same situation is also observed for explosives indicating that this site is less used than the Alpha Range. Again the concentrations in the circular samples were higher than in the linear transect samples indicating that the contamination is restricted to the area around the target, and not spread everywhere on the range. In this case, the C circle seems to contain more TNT than the B or A circles. TNT concentrations in the C circle were around 100-150 ppb. One of the highest hits was found into the C-15 sample. Sampling a D circle at our next visit to see if concentrations are decreasing farther away from the target seems prudent. If we look at the linear sampling strategy, the concentrations were lower than in the circular samples with the highest TNT concentration at again 100%. However, if we look at all of the results, we do not see any progression while going towards the target. In linear transects the mean concentrations were around 20 ppb, which is five times lower than on Alpha Range.

RDX was detected in only one sample at 100 %A by DRDC at a concentration of 5 ppb. CRREL did not detect RDX in this or any other Bravo Range samples. Since DRDC-Valcartier did not have the confirmation column for the GC analyses, the RDX detected by RDDC was possibly an interference rather than RDX. Tetryl and HMX were not detected by either laboratory for Bravo Range samples. Based on these results, no action is required at this range.

4.3 Jimmy Lake Range

In Jimmy Lake Range a practice target was used for the concentric circular sampling and the linear sampling strategy was used for the 20-mm firing range. Composite soil samples were collected behind three targets in transects that were split into A and B (west and east) sections. Transects were perpendicular to targets at distances of 20, 40, 60, 80, and 100% of a 120-m range. In addition, samples of vegetation were taken just beyond the 120 m and at about 30 m in front of targets. The soil samples collected in this range were comprised of fine grained sand. The Jimmy Lake Range is located between Jimmy Lake and Primerose Lake. In Jimmy Lake Range, 43 soil samples and 6 biomass samples were collected.

Soils

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Tables IIA, B, and C. Of the 21 parameters analysed, only Be, Hg, Tl and Sn were not detected at values higher than the BGL in any samples collected in Jimmy Lake Range. All of the other parameters were detected at values higher than the BGL or the ASQGL, and in some occasions were higher than the Industrial Soil Criteria. In the 43 soil samples, Sb (2 samples, 4.7% of all samples), As (38, 88%), Ba (25, 58%), Cd (29, 67%), Cr (29, 67%), Co (1, 2.3%), Cu (43, 100%), Fe (17, 39.5%), Pb (29, 67.4%), Hg (1, 2.2%), Mo (1, 2.3%), Ni (29, 67.4%), Se (1, 2.3%), Ag (2, 4.7%), Sr (1, 2.3%), U (23, 53%), V (29, 67%) and Zn (29, 67%) concentrations were higher than the BGL added to twice the standard deviation or the ASQGL or the Industrial Soil Criteria. For each parameter having hits, a mean of these values was calculated and compared to the BGL added to twice the standard deviation (BGL) and also to the CCME Agriculture Soil Quality Guideline (ASQGL) to determine whether the concentrations were closer to the BGL or to the CCME criteria. These tendencies were as follow:

-Sb: mean 0.20: 1.5 x > BGL and 100 x < CCME ASQGL
-As: mean 1.73: 1.5 x > BGL and 6.9 x < CCME ASQGL
-Ba: mean 62: 1.1 x > BGL and 12 x < CCME ASQGL
-Cd: mean 8.5: 23.6 x > BGL and 6 x > CCME ASQGL, (29 samples exceeded)
-Cr: mean 14.6: 1.5 x > BGL and 4.4 x < CCME ASQGL
-Co: mean 5.0: 1.2 x > BGL and 8 x < CCME ASQGL
-Cu: mean 58: 16 samples at 1.2 to 2.4 x > CCME ASQGL and 5 samples at 1.1 to 1.7 x> industrial soil criteria
-Fe: mean 9138: 1.1 x > BGL, no ASQGL for Fe
-Pb: mean 10: 3.1 x > BGL and 7 x < CCME ASQGL
-Mo: mean 0.8: 1.2 x > BGL and 6.3 x < CCME ASQGL
-Ni: mean 13.3: 2.2 x > BGL and 3.8 x < CCME ASQGL
-Se: mean 1.0: 1.8 x > BGL and equal to CCME ASQGL
-Ag: mean 3.0: 2 x > BGL and 6.6 x < CCME ASQGL
-Sr: mean 16.9: 1.3 x > BGL, no ASQGL for Sr
-U: mean 0.55: 1.1 x > BGL, no AQGL for U
-V: mean 68: 4.9 x > BGL and 1.9 x < CCME ASQGL
-Zn: mean 89: S-JL-T1-C15 concentration is at 1.8 x > CCME ASQGL and 1.04 x industrial soil criteria.

Most of the values were 1-23.6 times higher than the background levels added to twice the standard deviation. 29 samples had cadmium concentrations higher than the ASQGL, 16 had copper concentrations higher than the ASQGL with 5 higher than the Industrial Soil Criteria. One sample had zinc concentrations higher than the Industrial Soil Criteria. The impacts of training activities on Jimmy Lake are clearly important; therefore, more sampling will be done to complete the evaluation at this range.

Biomass

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Table III. Of the 20 parameters analysed, only Al, Ba, Cd, Cr Cu, Fe, Mo, Ni, Th, U, V and Zn were detected at values higher than the BGL. A complete list of the parameters and the number of hits was as follows:

-Al: 3 out of 5 results exceeded the BGL added to twice the standard deviation
-Ba: 1 out of 11 results exceeded the BGL added to twice the standard deviation
-Cd: 3 out of 6 results exceeded the BGL added to twice the standard deviation
-Cr: 1 out of 11 results exceeded the BGL added to twice the standard deviation
-Cu: 7 out of 11 results exceeded the BGL added to twice the standard deviation
-Fe: 3 out of 6 results exceeded the BGL added to twice the standard deviation
-Mo: 2 out of 6 results exceeded the BGL added to twice the standard deviation
-Ni: 1 out of 11results exceeded the BGL added to twice the standard deviation
-Th: 1 out of 6 results exceeded the BGL added to twice the standard deviation
-U: 1 out of 6 results exceeded the BGL added to twice the standard deviation
-V: 5 out of 11 results exceeded the BGL added to twice the standard deviation
-Zn: 2 out of 6 results exceeded the BGL added to twice the standard deviation

All of the parameters that exceeded the BGL added to twice the standard deviation in biomass samples also exceeded the BGL in soils. It is highly possible that these metals are preferentially extracted from the soils. Biomass has a great tendency to accumulate the same parameters in Alpha, Bravo and Jimmy Lake Ranges, but at higher concentrations in Jimmy Lake, which is normal since the levels of metals concentrations are higher in Jimmy Lake.

Energetic Materials

On Jimmy Lake Range, most of the samples contained the propellant-related compound nitroglycerin (NG) (Table VII). Concentrations in samples from the Jimmy Lake Range varied from 21 to 816 ppb. These results indicate propellant residues deposited on the site near Jimmy Lake. DNT was also detected in B2 and C12 at 3 and 2 ppb, respectively, which was quite low. TNT was detected in all of the samples from the Jimmy Lake Range with concentrations varying from 2 to 216 ppb. CRREL did not detect any other explosives in Jimmy Lake samples, but DRDC-Valcartier found RDX in one sample, C-12, at 81 ppb, and amino DNT in another sample at 8 ppb. Since these peaks were not confirmed, these small hits were possibly interferences from the soil matrix. Tetryl and HMX were not detected by either laboratory. The Jimmy Lake Range will be sampled more intensively at our next visit in August 03.

4.4 Shaver Range

Shaver River Range is located close to the Shaver River and is remote from Jimmy Lake. In Shaver River Range air dropping of 250-, 500-, and 1000-lb HE bombs at stationary target is done on a regular basis. Again, the circular strategy was applied. Also, three duplicates, one taken within each of the three rings, were collected. Down range from the target, transects were made at 100, 200, 300, 400, and 500 m. Transects were split into two halves (A and B) and composites samples were collected over a 100-m transect on each side of the access road perpendiculary to a line running from the entrance of the range to the target. The wheel sampling pattern was also used to collect samples 12 ft from the tank target in composite domain A1 (W sample) [2]. Three depth samples were taken below sample W1 in the center of the wheel. Deep sampling was not performed until a large area had been cleared. Surface samples were taken between 0 and 5 cm and deep samples were taken between 5 to 10 cm, 10 to 15 cm, and 15 to 20 cm. As for the other ranges, the surface was covered with fine-grained sands; however, several chunks of HE, which were tentatively identified by dissolution in acetone, were picked up around the target. Some chunks were thought to be Tritonal (TNT and aluminum) and others TNT or composition B. In Shaver Range, 47 soil samples and 1 biomass sample was collected. In this range the efforts were concentrated mainly on the analyses of energetic materials, since this range was the one mainly used for live firing. The area surrounding the target position at the Shaver River Range was tilled to minimize the vegetation and reduce the chance of the live-fire activities initiating a forest fire.

Soils

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Table II A, B, and C. Of the 21 parameters analysed, only Sb, Cd, Cu, Pb, Hg, and Zn were detected at values higher than the BGL or the ASQGL, and, on some occasions, higher than the Industrial Soil Criteria. In the 47 soil samples, Sb (8 samples, 17% of all samples), Cd (34, 72%), Cu (21, 44.7%), Pb (32, 68%), Hg (1, 2.1%) and Zn (6, 13%) concentrations were higher than the BGL added to twice the standard deviation or the ASQGL or the Industrial Soil Criteria. For each parameter having hits, a mean of these values was calculated and compared to the BGL added to twice the standard deviation (BGL) and also to the CCME Agriculture Soil Quality Guideline (ASQGL) to determine whether the concentrations were closer to the BGL or to the CCME criteria. A complete list of these tendencies is as follows:

-Sb: mean 0.27: 2 x > BGL and 74 x < CCME ASQGL, one hit in S-SR-T-C3 exceeded the industrial soil criteria at 80.80 ppm
-Cd: mean 1.8: 5 x > BGL and 5 x > CCME ASQGL, (23 samples exceeded)
-Cu: mean 12.5: 1.8 x > BGL and 5 x < CCME ASQGL
-Pb: mean 12.3: 3.9 x > BGL and 5.7 x < CCME ASQGL
-Zn: mean 30.91: 1.1 x > BGL and 5.9 x < CCME ASQGL

Most of the values are 1-5 times higher than the background levels added to twice the standard deviation. 23 samples had cadmium concentrations higher than the ASQGL; 1 sample had antimony concentration higher than the Industrial Soil Criterion. This range had fewer metals at concentrations higher than the BGL added to twice the standard deviation, and for most of the hits, they were similar in impact to the ones observed in Alpha Range. Again, cadmium is seen at higher concentrations and antimony had one concentration at a very high concentration; however, this can be an anomaly from the laboratory. This sample will be re-collected in August 2003. The impacts by metals on this range are clearly less important than on the Jimmy Lake Range.

Biomass

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Table III. Of the 20 parameters analysed, only Cd, Cu, Fe, Th, and Zn were detected at values higher than the BGL in the only sample collected in Shaver Range. Cadmium was very high, at a concentration of 10 times the BGL. All these data will have to be re-examined when more biomass background samples are available following the August 2003 sampling event. All of the parameters that exceeded the BGL added to twice the standard deviation in biomass samples also exceeded the BGL in soils, except for Sb and Fe. Thorium was not analysed in soils. More biomass samples will be collected on the Shaver Range at our next visit.

Energetic Materials

All of the soil samples collected at the Shaver Range were analysed for energetic materials. The transect samples from the Shaver Range were analyzed using the GC-ECD method (Table VII) as were those from the Alpha and Bravo Ranges. The soil samples from the target area, however, were analyzed using the RP-HPLC method (Table VIII), because we expected much higher concentrations in these samples.

For the transect samples, fairly low TNT concentrations were found over much of the range, except near the target (80% and 100% samples) where much higher concentrations of TNT were found (Table VII). Where high (ppm) concentrations of TNT were found, detectable concentrations of 2,4-DNT, 2,6-DNT and the amino-DNTs were also found. These compounds are either manufacturing impurities or environmental transformation products of TNT.

The TNT concentrations for the soil samples collected in a circular pattern around the target were much higher than the concentrations found in transects samples (Table VIII, note values in ppm in this table). Concentrations above 50 ppm were found in samples from the A, B, and C rings, with the highest concentration (332 ppm) for sample location C11. Here again, much lower concentrations of TNT-related compounds, such as 2,4-DNT, 2,6-DNT, TNB, 2A-DNT, and 4-ADNT, were found in the these samples. In a few samples for the target area, very low concentrations of RDX and HMX (always less than 1.6 ppm) were found, but neither RDX nor HMX were detected in the samples that contained the highest concentrations of TNT. Thus the source of the small amount of RDX found on the Shaver Range appears to be different from the source of the TNT. The source of TNT at this range is thought to be the tritonal used as the high explosive in Air Force bombs.

Tetryl was also detected in the circular samples at B7, C4 and C7 at concentrations of 130, 320 and 70 ppb, respectively. In linear transect samples, tetryl was detected only in LS-100% B at 98.8 ppb. HMX was detected in many circular samples mainly in B and C circles at concentrations ranging from 130 to 310 ppb. HMX was also found in linear transect samples LS-40% A and LS-100% B at concentrations of 20.4 and 53.8 ppb, respectively. This is strange to find HMX in more samples that RDX. It is possible that anti-tank weapons were fired at the tank target in Shaver Range at some point in the past, and that would explain why HMX is found more frequently than RDX. It should be reemphasized, though, that the concentrations of RDX and HMX are quite low at the Shaver Range, even in the relatively few samples where they were detected.

TNT and the amino-DNTs were detected in every surface wheel samples collected in front of the target and in the depth samples collected in the center of the wheel pattern as well. Surprisingly, the highest TNT concentration in the wheel samples was found in sample D4 at a depth of 15-20 cm. This phenomenon had been observed in other sites and has been explained by suggesting that explosives crystals can move downward by a sieving action due to vibrations from repeated detonations. At Shaver Range, though, the higher concentration at depth may be due to the fact that the soils have been tilled, perhaps depositing crystals of TNT deeper in the profile. Concentrations of TNT in the seven surface samples collected in the wheel pattern vary from 6.6 to 56.4 ppm, a factor or about 9, indicating substantial short-range variability in surface soils concentration because all seven samples were collected within a four-foot circle.

In Shaver Range, the concentrations of explosives (mainly TNT) are much higher than in the other ranges we sampled at Cold Lake. Most of the explosives-related compounds were found in almost all the samples except for RDX and HMX that were found at very low concentrations. TNT was the most important contaminant. If we look at the maximum concentrations of explosives at Shaver range, especially for example TNT at 500 ppm, the concentration is above the ecotoxicological criteria of 80 ppm. Fortunately, TNT has a great tendency to transform into metabolites that react with the organic matter of the soils and the contamination stays stabilized on the site. A hydrogeological study should be done at this site to see if RDX has not already moved towards the groundwater. The absence of RDX in most of the bombs used by the Air Force makes it unlikely.

4.5 Open Detonation Area

The open detonation area is located one Km away from the entrance of Shaver River Range. Burning or detonating of materials is done at two locations. Burn areas on both sides of the road leaving the Shaver range were sampled. Two composite samples were collected in an old burn area on the north side and one on the south side of that road. Again, fine sands dominated the soils.

Soils

No parameters exceeded the background level value added to twice the standard deviation (BGL) (Table II A, B,and C). This is not surprising since this area was quite clean of metal debris.

Biomass

No biomass samples were taken in this area.

Energetic Materials

2,4 DNT was detected in OD-3 at 540 ppb, and NG was detected in OD-1 and OD-2 at 17.8 and 14.9 ppb, respectively (Table VII). The presence of these compounds can be the result of the burning of propellants. Open burning of propellants has been demonstrated to be a dirty process [13]. Discussions with the DND headquarters are presently ongoing to address the problem of open burning of propellants. Solutions were proposed and are under evaluation to solve this problem.

TNT was also found in all three of the OD samples at concentrations of 14 to 400 ppb, which are not very high. Concentrations of amino-dinitrotoluenes were detected in OD-2. These explosives are transformation products of TNT that are likely forming after deposition of TNT. Clearly, this area is not impacted with explosives.

4.6 Rifle range

The rifle range in CLAWR consisted of a series of numbered targets having conventional sand butts (berms) in front of them. A specific sampling strategy was used in rifle ranges. Surface soils and one biomass sample was collected in front of the targets. Surface soils were collected from 0 to 10 cm deep, using stainless steel spoons. Five composite surface soil samples were built of at least 20 sub samples and were collected in front of groups of three nearby targets (15 targets sampled). The biomass sample was collected by compositing at least 30 sub samples in the area in front of a group of four close targets (1-4). In addition two composite samples were collected along firing point position 10 and 100 m up range.

Soils

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Table II A, B, and C. Of the 21 parameters analysed, only As, Be, Cd, Mo, Se, Ag, Sr, Tl, Sn and Zn were not detected at values higher than the BGL in any samples collected in Rifle Range. All of the other parameters were detected at values higher than the BGL. In the 8 soil samples, Sb (3 samples, 37.5% of all samples), Ba (1, 12.5%), Cr (1, 12.5%), Co (1, 12.5%), Cu (2, 25%), Fe (1, 12.5%), Pb (6, 75%), Hg (1, 12.5%), Ni (1, 12.5%), U (1, 12.5%) and V (1, 12.5%) concentrations were higher than the BGL added to twice the standard deviation. No metals were detected at concentrations higher than the CCME agricultural soil criteria. For each parameter having blue hits, a mean of these values was calculated and compared to the BGL added to twice the standard deviation (BGL) and also to the CCME Agriculture Soil Quality Guideline (ASQGL) to determine whether the levels of concentrations were closer to the BGL or to the CCME criteria. These tendencies were as follow:

-Sb: mean 0.67: 5 x > BGL and 30 x < CCME ASQGL
-Ba: mean 62.1: 1.1 x > BGL and 12 x < CCME ASQGL
-Cr: mean 13: 1.4 x > BGL and 4.9 x < CCME ASQGL
-Co: mean 5.0: 1.2 x > BGL and 8 x < CCME ASQGL
-Cu: mean 12.5: 1.8 x > BGL and 5 x < CCME ASQGL
-Pb: mean 12.3: 3.9 x > BGL and 5.7 x < CCME ASQGL
-Hg: mean 0.058: 1.7 x > BGL and 114 x < CCME ASQGL
-U: mean 0.61: 1.2 x > BGL, no AQGL for U
-V: mean 18.7: 1.4 x > BGL and 7 x < CCME ASQGL

Most of the values are 1-5 times higher than the background levels added to twice the standard deviation, but all parameters respect the agricultural soil criteria. No anomalies were observed for the duplicate samples; the values for the duplicates are similar to the original sample. The impact of the activities is measurable, but at a low extent compare to other sites [28]. As usual in rifle ranges, lead concentrations are higher than concentrations of the other metals. No cadmium problem was detected at this range. No action is required on this site.

Biomass

Some parameters exceeded the background level value added to twice the standard deviation (BGL) and are in blue font in Table III. Of the 20 parameters analysed, only Al, Ba, Fe and Pb were detected at values higher than the BGL. All of the parameters that exceeded the BGL added to twice the standard deviation in biomass samples also exceeded the BGL in soils. Nevertheless, the accumulation of these metals was not extensive, being generally 1.4 times the BGL added to twice the standard deviation.

Energetic Materials

No energetic materials analyses were done in this range, since usually; no energetic materials are used in this type of range.

4.7 Surface Water

Four surface water samples were collected in Primerose Lake, in Jimmy Lake, in Shaver River, and a last one in a pond containing ammunition and water in Shaver Range. Some parameters exceeded the CCME water quality guideline (WQGL) and are in red font in Table IV. Of the 27 parameters analysed, only Sb, Cd, Fe, Mn, Se and Ag were detected at values higher than the WQGL. In the 4 surface water samples, Sb (1 samples, 25% of all samples), Cd (4, 100%), Fe (3, 75%), Mn (1, 25%), Se (4, 100%) and Ag (1, 25%) concentrations were higher than the WGQL. When available, the aquatic life criteria were used, but on some occasions, drinking water or irrigation criteria were the only available WQGL criteria (see Table IV footnote). In Jimmy Lake, antimony was detected at 9 ppb, which exceeds a CCME interim concentration value for drinking water. Cadmium and selenium were highlighted in red in Table IV because the WQGL criterion is lower than half the detection limit. Since we used a value half the detection limit when the metals were not detected for the purpose of our evaluation, this resulted in red values but these metals were simply not detected. Iron was detected in all samples, except in Jimmy Lake, at concentrations higher than the aquatic life criteria. However, this can be a characteristic of the region. Since we did not have background surface water for comparison, nothing can be concluded for these detections. Manganese was detected at 1350 ppb in the pond in Shaver Range. This detection represents a local impact not representative of the area, since munitions at the bottom of the pond could be the source of this metal. Finally, silver was found in Jimmy Lake at twice the aquatic life criteria. This value will be verified in August 2003 when more sampling will be done in Jimmy Lake.

4.8 Global Results in all ranges

Generally, the levels of metals in soils in the four ranges were quite low. Most of the metal exceedances were no more than twice the BGL added to twice the standard deviation. Furthermore, concentrations were typically far below the Agricultural Soil Quality Guideline (ASQGL). Some metals that were systematically present at high concentrations, such as cadmium, copper and zinc, can be related to firing activities. Nevertheless, most of the values were quite low. The soil background values at Cold Lake were very low compared to those observed in Québec Province. A comparison of soil background values at Cold Lake with the ones observed in the province of Alberta should prove interesting. The fact that metals concentrations are low in the ranges is the direct result of good management of the sites performed at Cold Lake. During our visit, the sites were clean of debris and large pieces of metal. This removal of metals, which is performed on a regular basis, is an excellent practice and makes a significant contribution to environmental stewardship.

When the ranges are compared, the Jimmy Lake Range is the most impacted site, Bravo is less impacted than Alpha, and Shaver is also less impacted than Alpha. In Shaver, fewer metals were detected and the concentrations were similar to Alpha concentrations. The rifle range is not as contaminated as the rifle ranges evaluated in Army base, which is likely the result of a less intensive use.

The biomass analyses revealed that some metals are phytoremediated from the soils, since direct relations between soil and biomass concentrations were identified in almost all the ranges. It was also seen that not all the metals are phytoremediated and this can be the result of a selective adsorption. More biomass sampling will be performed to evaluate if there is a risk for the wildlife to ingest such biomass especially for biomass contaminated by cadmium.

More surface water will also be sampled during the next sampling in August 2003. Surface water background will be collected and compared to the surface water values on the ranges. In general, the surface water in lakes is not contaminated.

The energetic materials analyses revealed some impacts in all ranges. In Alpha Range, TNT and RDX were the most important contaminants with RDX at very low concentrations. However, TNT concentrations were well below the ecotoxicological criteria for TNT of 80 ppm. No progression in the concentrations was observed in the linear transect samples. In fact the concentrations were more important in the circular samples, meaning that the impacts are quite localized around the target. In Bravo, the situation was similar to the one encountered in Alpha, but at a lower level of concentrations. TNT and RDX were the main contaminants at very low concentrations indicating that this range was less used than the Alpha Range. In Jimmy Lake, surprisingly, a problem with propellant residues was observed, especially with NG. The concentrations in explosives were also low and do not represent a major problem. Generally, no action has to be taken on these sites, except collecting more samples to get a better assessment of the contamination.

In Shaver Range the situation was different. This range was the most impacted area of CLAWR. A progression of the explosive concentrations was observed in the linear sampling. The highest concentrations were observed around the target, especially in the B and C circles. TNT was again the most important contaminant at a concentration maximum of 400 ppm. Curiously, RDX was not found in that site. HMX was present in some samples at low concentrations. In the open detonation area, some explosives were detected, but at low concentrations. Some propellant residues were also detected that probably came from open burning.

5 Conclusion

During March 2002 a preliminary phase was conducted by DCC in CLAWR. Soils were collected to be analysed for metals and energetic materials. The energetic materials analyses were performed at DRDC-Valcartier using the GC-ECD method. No energetic materials were detected in any of the samples except for three in Shaver Range. Metal analyses were, unfortunately, not included in this report. In August 2002 DRDC-Valcartier and CRREL conducted Phase I of the study to characterize the soils, biomass and surface water samples for metals and energetic materials. A total of 193 soil, 16 biomass and 4 surface water samples were collected during Phase I in Alpha, Bravo, Jimmy Lake, Shaver River, open detonation and rifle ranges. The surface water samples were collected in Primerose Lake, Jimmy Lake, Shaver River and in a pond containing ammunition in Shaver Range. For statistical analysis and quality evaluation, 8 background and 18 field duplicates (9%) samples were collected for soil analyses. All samples were analysed for metals (193), while a limited number were analysed for energetic materials (131 soils - 12 field duplicates (9%)). For biomass analyses, an insufficient number of background samples were collected. This situation will be corrected in August 2003. Nevertheless, the evaluation was done and results compared to background values. The energetic materials analyses were performed by DRDC-Valcartier and by CRREL to evaluate the heterogeneity of the samples and to validate the results between laboratories. The GC/ECD method was used to analyse soils from Alpha, Bravo, and Jimmy Lake, while the HPLC method was used for the Shaver Range, which was suspected to be more contaminated by explosives. The HPLC method is more suitable to analysis of samples at higher concentrations of explosives.

Two strategies were used to collect the samples across the ranges. The first consisted in using a linear sampling pattern. This approach was used to evaluate whether the level of contamination by metal or energetic materials was following a pattern with distance from the target in the ranges. Composite samples were collected at distances of 20, 40, 60, 100, 120 and 140 % of the distance from the entrance of the range to the targets. The second sampling strategy was a new approach and consisted of sampling around targets by compositing samples taken in a circular pattern. This strategy based on the circular sampling used at CFB Shilo was used for specific target evaluation. The strategy was modified to adapt to the specific context of air-to-ground targets and was designed to allow a comparison of the relative concentrations in front and behind a target. A semi-circular pattern was used to collect composite samples at specific distances from the targets. Twenty-six (26) soil samples were collected around targets, one within each of the cells around the target. These cells are defined by three circles located at 10, 30 and 50 m radius of the target. Two composite samples (A1 & A2) were collected in hemispheres of the first, 10-m diameter ring (front and back of Target). Eight equal-sized rectangles were sampled between 10 and 30 m (B1-B8), and 16 between 30 and 50 m (C1-C16). Twenty or more increments were collected to build 800 g to 1.5 kg composite samples.

Generally, the impacts by metals in soils in the four ranges were quite low. Most of the time, the metals detected at concentrations higher than the BGL added to twice the standard deviation were at concentrations around 1 to twice the BGL value. Most of the time, concentrations were far below the Agricultural Soil Quality Guideline (ASQGL) except for some metals that were present at higher concentrations, such as cadmium, copper and zinc. These metals can be related to firing activities. Nevertheless, most of the values were quite low. The soil background values at Cold Lake compared to the Québec Province background values were also very low. It should be interesting to compare the soil background values at Cold Lake with the ones observed in the province of Alberta. The fact that metals concentrations are low in the ranges is the direct result of the good management of the sites performed at Cold Lake. During our visit, the sites were clean and no debris or large pieces of metals were observed since the range controls are removing the pieces of metals on a regular basis. This is an excellent practice that must be pursued.

More specifically, for soils in Alpha range, most of the values were 1.1 to 2.9 times higher than the background values, but no concentrations were higher than the CCME ASQGL. While an impact on the range is recognized, the impact is very small. For Bravo Range soils, most of the values were 1.2 to 3.1 times higher than the background values, but no concentrations were higher than the CCME ASQGL, except for cadmium concentrations, which were, however, below the Industrial Soil Criteria. For Jimmy Lake, most of the values were 1.1 to 2.4 times higher than the background values, but 67% of the samples had cadmium concentrations higher than the CCME ASQGL, 12 % of the copper concentrations were higher than the industrial soil criteria, and 2% of the zinc concentrations were also higher than the ISQGL. These data will be re-examined and confirmed at the next sampling event in August 2003. In Shaver Range, fewer metals were detected at values higher than the background values and most of the hits were 1.1-5.9 times higher than the background values. Most of the samples did not have concentrations higher than the ASQGL, except for cadmium, which had 49% of the samples exceeding the ASQGL, and zinc, which had 2%of the samples exceeding the ISQGL. These last data will be confirmed in August 2003. In the open detonation area, no metals had concentrations higher than the background values. In the rifle range, the number of background samples was insufficient for a thorough evaluation. Nevertheless, most of the samples had values 1.1-5 times higher than the background values, indicating a small impact compared to rifle ranges located on Army properties. No sample concentrations were higher than the ASQGL. As usual in rifle ranges, lead was one of the most important parameters that exceed the other metals. In general, even if cadmium concentrations were, on many occasions, higher than the ASQGL in some ranges, this does not represent a problem, since the ranges are not dedicated to agricultural purposes. When industrial criteria are excluded, the situation must be looked at more seriously. This is why more samples will be needed to understand these impacts.

For biomass samples, some metals were preferentially adsorbed into the plants. Metals in plants were usually at higher concentrations than in soils. This is particularly true for cadmium found in plants. Since this metal is very toxic, more biomass samples will be collected in August 2003 to evaluate if this represents a risky situation for wildlife that can ingest these contaminated plants. More biomass background samples will also be collected in August 2003 to validate our statistical evaluation for the metals. For surface water samples, metals demonstrated a no strong impact with a few exceptions. More surface water will also be sampled during the next sampling in August 2003 to have a better idea of the situation. Surface water background will be collected and compared to water sample values on the ranges. In general, the surface water in lakes is not contaminated.

When all of the sampled ranges are compared for metal contamination, the Jimmy Lake Range is the most impacted site, Bravo is less impacted than Alpha, and Shaver is also less impacted than Alpha. In Shaver, fewer metals were detected and the concentrations were similar to Alpha Range concentrations. The rifle range was not as contaminated as the rifle ranges evaluated on Army base. This is the result of less intensive use. No immediate actions are required in all sites.

The energetic materials analyses revealed some impacts in all ranges. In Alpha Range, TNT was the most important contaminant with RDX at low concentrations, but the concentrations were well below the ecotoxicological criteria for TNT at 80 ppm. No progression in the concentrations was observed in the linear transect samples. In fact the concentrations were more important in the circular samples, meaning that the impacts are quite localized around the target. In Bravo Range, the situation was similar to the one encountered in Alpha Range, but at a lower extent. TNT and RDX were the main contaminants at very low concentrations indicating that this range was less used than the Alpha Range. In Jimmy Lake, surprisingly, a problem with propellant residues was observed, especially with NG. The concentrations of explosives were also low and do not represent a major problem. Generally, no action has to be taken on these sites, except collecting more samples to get a better assessment of the contamination.

In Shaver range the situation was different. This range is the most impacted area of CLAWR. A progression of the explosive concentrations was observed in the linear transect sampling. The highest concentrations were observed around the target, especially in the B and C circles. TNT was again the most important contaminant at a concentration maximum of 400 ppm. Curiously, RDX was not found in this site; HMX was present in some samples at low concentrations. In the open detonation area some explosives were detected, but at low concentrations. Propellant residues that would come from open burning were also detected.

In conclusion, this study demonstrated that the ranges have some accumulation of metals due to the firing activities, but the extent of contamination is very low except in Jimmy Lake where cadmium, copper and zinc concentrations were high. The contamination by explosives is also minimal except in Shaver Range where TNT was found at high concentrations. More analyses will have to be done to complete the understanding of these ranges, and a hydrogeological study will have to be performed. More efforts will have to be done to evaluate the accumulation of cadmium in biomass, since this represents a potential problem for the wildlife ingestion of a contaminated food source.

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List of symbols/abbreviations/acronyms/initialisms

AQGL	Aquatic Quality Guideline
ASQGL	Agricultural Soil Quality Guideline
B	Biomass sample
BG	Background sample
BGL	Background Level
BRI	Biotechnology Research Institute
CCME	Canadian Council of Ministers of Environment
CFB	Canadian Force Base
CG/DCE	Chromatographie gazeuse couplée avec un détecteur à capture d'électron
CLAWR	Cold Lake Air Weapons Range
CRREL	Cold Regions Research and Engineering Laboratory
DCC	Defence Construction Canada
DGE	Director General Environment
DLE	Diretor Land Environment
DND	Department of National Defence
DNT	Dinitrotoluene
DoD	Department of Defence
DRDC-Valcartier	Defence Research Establishment-Valcartier
EL	Environmental Laboratory
ETL	Enviro-Test Laboratory
GC/ECD	Gas Chromatrograph coupled with an Electron Capture Detector
GPS	Global Positioning System
ICP/MS	Inductively Coupled Plasma /Mass Spectrometer Detector
ISQGL	Industrial Soil Quality Guideline
LS	Linear Sampling in Battleruns
OB/OD	Open Burning/Open Detonation
PIC/SM	Plasma inductif couple avec spectrométrie de masse
ppb	Parts per Billion
ppm	Parts per Million
QA/QC	Quality Assurance/ Quality Control
RSD	Relative Standard Deviation
S	Soil Sample
SERDP	Strategic Environmental Research and Development Program
SW	Surface Water Sample
TNT	Trinitrotoluene
UXO	Unexploded Ordnances
WQGL	Water Quality Guideline

TABLE I: GPS LOCATIONS OF SAMPLING

Sampling Locations or sample ID	***Sampling Point***	
	X or Northern	***Y or Western***
Alpha		
LS-0%-at the road	0561610	6074117
LS-0%-A	0561658	6074205
LS-0%-B	0561565	6074026
LS-20%-at the road	0561409	6074176
LS-20%-A	Not available	Not available
LS-20%-B	Not available	Not available
LS-40%-at the road	0561221	6074232
LS-40%-A	Not available	Not available
LS-40%-B	Not available	Not available
LS-60%-at the road	0561031	6074288
LS-60%-A	Not available	Not available
LS-60%-B	Not available	Not available
LS-80%-at the road	0560838	6074343
LS-80%-A	Not available	Not available
LS-80%-B	Not available	Not available
LS-100%-at the road	0560643	6074392
LS-100%-A	0560673	6074486
LS-100%-B	0560599	6074300
LS-120%-at the road	0560449	6074408
LS-120%-A	Not available	Not available
LS-120%-B	Not available	Not available
Center of target 1	0560617	6074410
Upper position on the border of C circle (T1)	0560569	6074425
Right position on the border of C circle (T1)	0560629	6074463
Downer position on the border of C circle (T1)	0560667	6074407
Left position on border of C circle (T1)	0560611	6074365
Center of target 2 (S-AL-T2-Middle)	0560264	6074378
In front of target 2 (S-AL-T2-Front)	0560278	6074376
Back of target 2 (S-AL-T2-Rear)	0560256	6074380
DZA-BC	54° 48’ 47’’	110° 03’ 21’’

Sampling Locations or sample ID	***Sampling Point***	
	X or Northern	***Y or Western***
DZA-Bunk	54° 48’ 47’’	110° 03’ 40’’
DZA-Random1	54° 48’ 44’’	110° 03’ 15’’
DZA-Shoreline	54° 48’ 41’’	110° 02’ 15’’
Bravo		
LS-0%-at the road	0560562	6071608
LS-60%-at the road	0560450	6071961
LS-60%-A	Not available	Not available
LS-60%-B	0560440	6071889
LS-100%-at the road	0560562	6071608
Center of target	0560336	6071986
Upper position on the border of C circle (T1)	0560289	6072008
Right position on the border of C circle (T1)	0568363	6077204
Downer position on the border of C circle (T1)	0560387	6071978
Left position on border of C circle (T1)	0560322	6071942
Hot spot	0560425	6071964
Hot spot close to A1	056345	6071989
DZB-Random1	54° 47’ 33’’	110° 03’ 28’’
DZB-BG1	54° 47’ 36’’	110° 04’ 13’’
DZB-BG2	54° 47’ 46’’	110° 04’ 06’’
DZB-BC	54° 47’ 29’’	110° 03’ 38’’
DZB-Old BC	54° 47’ 37’’	110° 03’ 36’’
DZB-Strafe	54° 47’ 40’’	110° 03’ 40’’
DZB-Shoreline	54° 47’ 15’’	110° 03’ 26’’
Jimmy Lake		
Old truck target	0567520	6084356
LS-0%-A	0567039	6084710
LS-0%-B	0567047	6084524
LS-100%-A	0567165	6084710
LS-100%-B	0567158	6084529
JLR-BG1	54° 54’ 01’’	110° 00’ 17’’
JLR-BG2	54° 54’ 07’’	110° 00’ 17’’
JLR- Bomb Circle	Not available	Not available
JLR-VIP	54° 54’ 08’’	109° 57’ 20’’
JLR-Strafe	Not available	Not available

Sampling Locations or sample ID	***Sampling Point***	
	X or Northern	***Y or Western***
JLR-Random 1	Not available	Not available
JLR-Random 2	54° 54’ 18’’	109° 56’ 50’’
JLR-Random 3	Not available	Not available
JLR-Foul Line	54° 54’ 15’’	109° 57’ 43’’
Shaver River		
LS-0%-at the road	0566536	6088345
LS-0%-A	0566495	6088253
LS-0%-B	0566590	6088438
LS-20%-at the road	0566625	6088300
LS-20%-A	0566572	6088211
LS-20%-B	0566674	6088391
LS-40%-at the road	0566713	6088260
LS-40%-A	0566675	6088169
LS-40%-B	0566750	6088347
LS-60%-at the road	0566805	6088222
LS-60%-A	Not available	Not available
LS-60%-B	Not available	Not available
LS-80%-at the road	0566899	6088183
LS-80%-A	0566854	6088090
LS-80%-B	0566952	6088266
LS-100%-at the road	0566998	6088141
LS-100%-A	Not available	Not available
LS-100%-B	Not available	Not available
LS-120%-at the road	0567094	6088089
LS-120%-A	0567039	6088022
LS-120%-B	0566712	6088213
LS-140%-at the road	0567176	6088071
LS-140%-A	Not available	Not available
LS-140%-B	Not available	Not available
Center of target	0567098	6088102
Upper position on the border of C circle	0567052	6088123
Right position on the border of C circle	0567113	6088152
Downer position on the border of C circle	0567142	6088079
Left position on border of C circle	0567081	6088056

Sampling Locations or sample ID	***Sampling Point***	
	X or Northern	***Y or Western***
Water sample in Shaver River	0567157	6088600
Water sample in pound close to target	0567200	6088126
SSR-Bomb Circle	Not available	Not available
SSR-Disposal Area	54° 55’ 28’’	109° 57’ 58’’
SSR-Dump	Not available	Not available
SSR-Tritium Hotspot	54° 55’ 25’’	109° 57’ 55’’
SSR-Random 1	54° 56’ 17’’	109° 57’ 43’’
SSR-Random 2	54° 54’ 50’’	109° 57’ 29’’
SSR-BG	54° 56’ 57’’	110° 01’ 00’’
Open detonation area		
OD-1	0566210	6088821
OD-2	0566200	6086851
OD-3	0566254	6086782
Rifle Range		
Target 1	0565104	6078458
Target 15	0565068	6078522

TABLE II A: METALS CONCENTRATIONS IN SOILS (SB TO CO)

	Sb	As	Ba	Be	Cd	Cr	Co
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-BG-0563365	0.05	0.25	44.30	0.35	0.15	3.00	1.00
Average	0.09	0.36	30.36	0.46	0.21	4.46	1.38
Standard déviation	0.02	0.40	13.04	0.07	0.07	2.53	1.36
(2 x StDev))	0.05	0.80	26.09	0.14	0.15	5.07	2.71
Sum (Ave+(2xStDev)	0.13	1.16	56.45	0.60	0.36	9.53	4.09
CCME (a)	20.00	12.00	750.00	4.00	1.40	64.00	40.00
Alpha							
S-AL-LS-0% A	0.05	1.40	20.40	0.35	0.04	4.00	2.00
S-AL-LS-0% B	0.05	0.90	12.10	0.35	0.01	3.00	1.00
S-AL-LS-20% A	0.05	1.00	21.10	0.35	0.02	4.00	1.00
S-AL-LS-20% B	0.05	1.30	18.90	0.35	0.03	3.00	1.00
S-AL-LS-40% A	0.05	1.30	20.10	0.35	0.02	4.00	2.00
S-AL-LS-40% B	0.05	1.10	18.70	0.35	0.04	3.00	1.00
S-AL-LS-60% A	0.05	1.20	26.80	0.35	0.04	5.00	2.00
S-AL-LS-60% B	0.05	1.50	24.40	0.35	0.02	5.00	2.00
S-AL-LS-80% A	0.05	1.50	26.10	0.35	0.03	5.00	2.00
S-AL-LS-80% B	0.05	1.40	28.70	0.35	0.03	7.00	2.00
S-AL-LS-100% A	0.05	1.30	28.70	0.35	0.07	5.00	2.00
S-AL-LS-100%A (DUP)	0.05	1.40	30.10	0.35	0.07	6.00	3.00
S-AL-LS-100% B	0.05	1.50	27.00	0.35	0.05	6.00	2.00
S-AL-LS-120% A	0.05	1.40	25.70	0.35	0.04	6.00	2.00
S-AL-LS-120% B	0.20	1.30	24.50	0.35	0.03	5.00	2.00
S-AL-T1- A1	0.05	1.40	41.10	0.35	0.08	11.30	4.00
S-AL-T1- A2	0.40	10.00	66.90	0.35	0.18	13.20	3.00
S-AL-T1- A2 (DUP)	0.20	1.40	37.00	0.35	0.10	10.00	3.00
S-AL-T1- B1	0.05	0.50	31.00	0.35	0.06	6.00	2.00
S-AL-T1- B2	0.05	1.10	38.10	0.35	0.10	8.00	3.00
S-AL-T1- B3	0.20	1.60	48.00	0.35	0.12	13.00	4.00
S-AL-T1- B3 (DUP)	0.05	1.60	43.90	0.35	0.10	12.00	4.00
S-AL-T1- B4	0.20	1.30	38.60	0.35	0.10	10.10	4.00
S-AL-T1- B5	0.05	1.90	52.30	0.35	0.07	14.00	4.00
S-AL-T1- B6	0.05	1.60	42.10	0.35	0.10	11.20	3.00
S-AL-T1- B7	0.05	0.80	28.40	0.35	0.06	6.00	2.00

	Sb	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**
Sample			**ppm**	**(mg/Kg)**			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-AL-T1- B8	0.05	0.90	32.70	0.35	0.05	8.00	3.00
S-AL-T1- C1	0.05	0.60	27.10	0.35	0.04	6.00	2.00
S-AL-T1- C10	0.05	1.80	48.00	0.35	0.06	13.30	4.00
S-AL-T1- C11	0.05	0.80	30.60	0.35	0.04	7.00	2.00
S-AL-T1- C12	0.05	1.20	32.70	0.35	0.05	7.00	3.00
S-AL-T1- C12 (DUP)	0.05	1.20	34.10	0.35	0.05	8.00	2.00
S-AL-T1- C13	0.05	1.00	34.20	0.35	0.06	7.00	2.00
S-AL-T1- C14	0.05	0.60	24.70	0.35	0.06	5.00	2.00
S-AL-T1- C16	0.05	1.60	41.40	0.35	0.03	12.00	4.00
S-AL-T1- C2	0.05	0.25	24.70	0.35	0.04	3.00	1.00
S-AL-T1- C3	0.05	0.25	27.40	0.35	0.06	4.00	1.00
S-AL-T1- C4	0.20	0.25	31.20	0.35	0.08	4.00	2.00
S-AL-T1- C5	0.20	0.50	34.40	0.35	0.08	4.00	2.00
S-AL-T1- C6	0.05	1.30	38.50	0.35	0.05	9.00	3.00
S-AL-T1- C7	0.05	0.60	29.30	0.35	0.05	6.00	2.00
S-AL-T1- C8	0.05	0.80	29.80	0.35	0.05	7.00	2.00
S-AL-T1- C9	0.05	2.20	56.90	0.35	0.03	15.90	5.00
S-AL-T2-FRONT	0.05	2.40	56.90	0.35	0.04	17.20	5.00
S-AL-T2 MIDDLE	0.10	0.25	22.40	0.35	0.91	7.00	2.00
S-AL-T2-REAR	0.05	1.00	21.50	0.35	1.16	5.00	2.00
Bravo							
S-BR-LS- 40% A	0.05	0.25	17.30	0.35	0.07	2.00	0.50
S-BR-LS- 40% B	0.05	0.25	19.10	0.35	0.09	3.00	0.50
S-BR-LS- 60% A	0.05	0.25	20.80	0.35	0.15	3.00	1.00
S-BR-LS- 60% B	0.05	0.25	18.60	0.35	0.12	3.00	1.00
S-BR-LS- 100% A	0.05	0.60	19.00	0.35	0.85	3.00	0.50
S-BR-LS- 100% B	0.05	0.25	18.60	0.35	0.39	3.00	0.50
S-BR-LS- 120% A	0.05	0.25	27.30	0.35	0.76	3.00	0.50
S-BR-LS- 120% B	0.05	0.25	23.70	0.35	0.43	3.00	0.50
S-BR-T-A1	0.40	0.50	20.60	0.35	1.70	4.00	0.50
S-BR-T-A1 (DUP)	0.50	0.50	21.40	0.35	1.92	4.00	0.50
S-BR-T-A2	0.05	0.70	24.10	0.35	1.90	5.00	1.00
S-BR-T-B1	0.05	0.50	22.70	0.35	1.47	4.00	1.00
S-BR-T-B2	0.05	0.25	20.40	0.35	1.05	3.00	0.50
S-BR-T-B3	0.05	0.25	19.90	0.35	0.97	3.00	0.50
S-BR-T-B4	0.05	0.70	21.40	0.35	1.14	3.00	0.50

	Sb	As	Ba	Be	Cd	Cr	Co
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-BR-T-B4 (DUP)	0.05	0.25	21.40	0.35	1.23	4.00	0.50
S-BR-T-B5	0.05	0.25	27.90	0.35	1.23	4.00	0.50
S-BR-T-B6	0.05	0.25	24.30	0.35	1.72	4.00	1.00
S-BR-T-B7	0.05	0.60	24.10	0.35	1.68	4.00	0.50
S-BR-T-B8	0.05	0.25	22.00	0.35	1.51	4.00	1.00
S-BR-T-C1	0.05	0.25	18.40	0.35	0.63	3.00	0.50
S-BR-T-C2	0.05	0.25	19.70	0.35	0.56	3.00	0.50
S-BR-T-C3	0.05	0.25	20.60	0.35	0.65	3.00	1.00
S-BR-T-C4	0.05	0.25	18.50	0.35	0.93	3.00	1.00
S-BR-T-C5	0.05	0.50	20.90	0.35	0.86	3.00	0.50
S-BR-T-C6	0.05	0.25	17.20	0.35	0.56	3.00	0.50
S-BR-T-C7	0.05	0.25	16.40	0.35	0.34	3.00	1.00
S-BR-T-C7 (DUP)	0.30	0.25	15.90	0.35	0.34	3.00	1.00
S-BR-T-C8	0.05	0.25	19.60	0.35	0.38	3.00	0.50
S-BR-T-C9	0.05	0.25	19.10	0.35	0.61	3.00	0.50
S-BR-T-C10	0.05	0.25	19.30	0.35	0.94	3.00	0.50
S-BR-T-C11	0.05	0.25	23.60	0.35	1.55	3.00	0.50
S-BR-T-C12	0.05	0.25	25.80	0.35	2.29	4.00	0.50
S-BR-T-C13	0.05	0.25	24.80	0.35	1.84	3.00	0.50
S-BR-T-C14	0.05	0.25	25.30	0.35	1.59	4.00	0.50
S-BR-T-C15	0.05	0.25	20.50	0.35	1.14	3.00	1.00
S-BR-T-C16	0.05	0.25	16.70	0.35	0.78	2.00	1.00
S-BR-HS-0560345	0.05	0.25	18.00	0.35	1.42	3.00	0.50
S-BR-HS-0560425	0.05	0.25	17.80	0.35	0.37	3.00	1.00
Jimmy Lake							
S-JL-LS-0% A	0.05	0.60	19.60	0.35	0.07	5.00	2.00
S-JL-LS-0% B	0.05	0.50	20.30	0.35	0.08	6.00	2.00
S-JL-LS-20% A	0.05	0.50	23.20	0.35	0.09	5.00	2.00
S-JL-LS-20% B	0.05	0.80	26.00	0.35	0.07	7.00	2.00
S-JL-LS-40% A	0.05	0.25	17.40	0.35	0.06	4.00	1.00
S-JL-LS-40% B	0.10	1.80	23.40	0.35	0.08	5.00	2.00
S-JL-LS-60% A	0.10	2.50	23.90	0.35	0.09	6.00	2.00
S-JL-LS-60% B	0.05	1.40	18.70	0.35	0.07	5.00	2.00
S-JL-LS-60%B (DUP)	0.05	1.60	19.20	0.35	0.06	5.00	2.00
S-JL-LS-80%A	0.05	2.10	19.80	0.35	0.07	5.00	1.00
S-JL-LS-80%B	0.05	1.70	21.30	0.35	0.08	5.00	1.00

	Sb	As	Ba	Be	Cd	Cr	Co
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-JL-LS-80% B (DUP)	0.05	1.60	20.20	0.35	0.05	5.00	1.00
S-JL-LS-100% A	0.05	1.60	16.00	0.35	0.05	4.00	1.00
S-JL-LS-100% B	0.05	1.70	18.20	0.35	0.08	4.00	1.00
S-JL-T1-A1	0.05	2.10	65.20	0.35	15.20	14.00	4.00
S-JL-T1-A2	0.05	1.80	68.00	0.35	11.10	15.30	4.00
S-JL-T1-B1	0.05	1.70	57.40	0.35	12.80	18.70	4.00
S-JL-T1-B2	0.05	2.10	64.20	0.35	8.74	14.20	4.00
S-JL-T1-B3	0.05	1.60	54.40	0.35	8.08	14.50	4.00
S-JL-T1-B4	0.05	1.70	60.30	0.35	9.29	14.60	3.00
S-JL-T1-B5	0.05	2.20	67.40	0.35	10.10	13.70	4.00
S-JL-T1-B6	0.05	1.50	69.70	0.35	11.20	15.90	4.00
S-JL-T1-B7	0.05	1.70	69.50	0.35	13.30	16.00	4.00
S-JL-T1-B7 (DUP)	0.05	1.50	65.10	0.35	10.50	16.20	4.00
S-JL-T1-B8	0.05	2.20	68.20	0.35	10.30	13.90	4.00
S-JL-T1-C1	0.05	1.70	57.10	0.35	6.89	13.60	4.00
S-JL-T1-C2	0.05	1.20	55.70	0.35	6.25	14.40	4.00
S-JL-T1-C3	0.20	2.00	58.80	0.35	6.06	13.60	4.00
S-JL-T1-C4	0.05	1.50	58.50	0.35	6.62	14.20	4.00
S-JL-T1-C5	0.05	1.80	57.30	0.35	6.67	13.60	4.00
S-JL-T1-C5 (DUP)	0.05	1.80	55.30	0.35	7.09	13.70	4.00
S-JL-T1-C6	0.05	1.60	57.40	0.35	5.88	14.00	4.00
S-JL-T1-C7	0.05	2.20	58.00	0.35	5.13	11.70	4.00
S-JL-T1-C8	0.05	1.80	54.70	0.35	5.36	11.80	4.00
S-JL-T1-C9	0.05	1.50	57.70	0.35	6.22	12.80	4.00
S-JL-T1-C10	0.05	1.60	60.70	0.35	7.43	14.60	4.00
S-JL-T1-C10 (DUP)	0.20	1.80	65.40	0.35	7.78	14.10	5.00
S-JL-T1-C11	0.05	1.20	59.80	0.35	8.11	13.60	3.00
S-JT-T1-C12	0.10	2.10	64.70	0.35	8.22	12.60	4.00
S-JL-T1-C13	0.05	1.50	63.00	0.35	9.60	16.00	4.00
S-JL-T1-C14	0.05	1.20	56.60	0.35	7.81	13.30	4.00
S-JL-T1-C15	0.05	1.60	61.30	0.35	8.04	24.10	4.00
S-JL-T1-C16	0.05	1.60	58.30	0.35	6.63	13.20	4.00
Shaver River							
S-SR-LS-0%A	0.05	0.80	34.00	0.35	0.04	5.00	2.00
S-SR-LS-0%B	0.05	0.25	24.30	0.35	0.04	3.00	0.50
S-SR-LS-20% A	0.05	0.25	28.70	0.35	0.04	3.00	0.50

	Sb	As	Ba	Be	Cd	Cr	Co
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-SR-LS-20% B	0.05	0.60	26.40	0.35	0.04	2.00	0.50
S-SR-LS-40% A	0.05	0.50	23.70	0.35	0.04	2.00	0.50
S-SR-LS-40% B	0.05	0.70	27.30	0.35	0.07	3.00	0.50
S-SR-LS-60% A	0.05	0.50	26.20	0.35	0.05	3.00	0.50
S-SR-LS-60% A (DUP)	0.05	0.25	25.20	0.35	0.06	3.00	1.00
S-SR-LS-60% B	0.05	0.25	20.30	0.35	0.06	2.00	0.50
S-SR-LS-80% A	0.05	0.25	22.60	0.35	0.15	3.00	0.50
S-SR-LS-80% B	0.05	0.50	28.00	0.35	0.08	3.00	0.50
S-SR-LS-100%A	0.05	0.25	19.80	0.35	0.24	2.00	0.50
S-SR-LS-100%B	0.10	0.60	26.50	0.35	0.93	3.00	1.00
S-SR-LS-100%B (DUP)	0.20	0.70	28.50	0.35	0.90	4.00	0.50
S-SR-LS-120% A	0.05	0.60	21.50	0.35	0.79	3.00	0.50
S-SR-LS-120% B	0.10	0.60	23.30	0.35	2.15	4.00	1.00
S-SR-LS-140% A	0.05	0.60	20.70	0.35	0.35	2.00	0.50
S-SR-LS-140% B	0.05	0.70	21.70	0.35	0.58	3.00	0.50
S-SR-T-A1	0.05	0.60	32.20	0.35	1.99	6.00	1.00
S-SR-T-A1 (DUP)	0.20	1.00	23.60	0.35	2.54	5.00	1.00
S-SR-T-A2	0.70	1.00	25.10	0.35	2.42	6.00	2.00
S-SR-T-B1	0.10	0.80	25.80	0.35	2.33	4.00	1.00
S-SR-T-B2	0.05	0.70	22.70	0.35	2.15	4.00	0.50
S-SR-T-B3	0.20	0.80	25.40	0.35	2.44	6.00	1.00
S-SR-T-B4	0.20	0.70	51.00	0.35	2.83	4.00	2.00
S-SR-T-B5	0.05	0.80	20.40	0.35	1.89	4.00	0.50
S-SR-T-B5 (DUP)	0.05	0.70	19.60	0.35	1.87	3.00	1.00
S-SR-T-B6	0.10	0.80	19.10	0.35	1.48	3.00	1.00
S-SR-T-B7	0.10	0.90	23.10	0.35	2.28	5.00	1.00
S-SR-T-B8	0.20	0.70	22.60	0.35	1.92	4.00	1.00
S-SR-T-C1	0.05	0.70	24.90	0.35	1.30	4.00	1.00
S-SR-T-C2	0.05	0.70	23.90	0.35	1.47	4.00	1.00
S-SR-T-C3	80.80	0.70	20.60	0.35	1.43	4.00	0.50
S-SR-T-C4	0.05	0.80	22.00	0.35	2.15	4.00	1.00
S-SR-T-C5	0.05	0.70	23.20	0.35	2.86	4.00	1.00
S-SR-T-C6	0.05	0.80	23.30	0.35	2.58	4.00	1.00
S-SR-T-C7	0.05	0.60	20.60	0.35	1.91	3.00	1.00
S-SR-T-C8	0.05	0.80	23.10	0.35	2.56	4.00	1.00
S-SR-T-C9	0.05	0.90	24.50	0.35	2.66	5.00	1.00

	Sb	As	Ba	Be	Cd	Cr	Co
Sample			**ppm**	**(mg/Kg)**			
BR-DZB-BG1	0.10	0.10	25.00	0.50	0.25	6.50	0.50
BR-DZB-BG2	0.10	1.00	46.00	0.50	0.25	7.30	1.00
JLR-BG1	0.10	0.10	16.00	0.50	0.25	2.40	0.50
JLR-BG2	0.10	0.10	18.00	0.50	0.25	1.90	0.50
JLR-Foul Line-BG	0.10	0.10	16.00	0.50	0.25	1.30	0.50
SRR-BG	0.10	1.00	36.00	0.50	0.25	6.30	4.00
S-BG-0560641	0.05	0.25	41.60	0.35	0.05	7.00	3.00
S-SR-T-C10	0.05	0.80	24.40	0.35	2.37	4.00	1.00
S-SR-T-C10 (DUP)	0.05	0.70	21.50	0.35	2.32	4.00	1.00
S-SR-T-C11	0.05	0.70	20.90	0.35	1.17	6.00	1.00
S-SR-T-C12	0.20	0.70	21.70	0.35	1.22	3.00	1.00
S-SR-T-C13	0.05	0.70	21.80	0.35	0.79	3.00	1.00
S-SR-T-C14	0.05	0.60	23.20	0.35	1.03	3.00	1.00
S-SR-T-C15	0.05	0.60	22.90	0.35	0.87	3.00	1.00
S-SR-T-C16	0.05	0.80	23.10	0.35	1.21	4.00	1.00
Shaver open detonation Area							
S-SR-OD-1	0.05	0.80	24.20	0.35	0.12	4.00	1.00
S-SR-OD-2	0.05	0.25	15.90	0.35	0.07	2.00	0.50
S-SR-OD-3	0.05	0.50	19.70	0.35	0.11	3.00	0.50
Rifle Range							
S-RIF-T-1-3	1.50	1.10	20.80	0.35	0.02	3.00	0.50
S-RIF-T-4-6	0.05	1.10	20.60	0.35	0.14	3.00	0.50
S-RIF-T-4-6 (DUP)	0.30	0.25	0.35	0.35	0.07	0.50	0.50
S-RIF-T-7-9	0.05	0.25	0.35	0.35	0.06	0.50	1.00
S-RIF-T-10-12	0.05	0.25	18.10	0.35	0.04	3.00	0.50
S-RIF-T-13-15	0.05	0.25	20.70	0.35	0.03	4.00	0.50
S-RIF-FP-10M	0.20	0.25	21.00	0.35	0.04	3.00	0.50
S-RIF-FP-100M	0.05	0.25	62.10	0.35	0.05	13.00	5.00

(a) agricultural soil threshold criteria

(b) half values of the detection limits are used when metals are not detected

TABLE II B: METALS CONCENTRATIONS IN SOILS (CU TO SE)

	Cu	Fe	Pb	Hg	Mo	Ni	Se
Sample	ppm (mg/Kg)						
BR-DZB-BG1	4.00		2.50	0.025	0.50	4.00	1.00
BR-DZB-BG2	4.00		2.50	0.025	0.50	3.00	0.10
JLR-BG1	4.00		2.50	0.025	0.50	1.00	0.10
JLR-BG2	6.00		2.50	0.025	0.50	1.00	0.10
JLR-Foul Line-BG	5.00		2.50	0.025	0.50	1.00	0.10
SRR-BG	6.00		2.50	0.025	0.50	5.00	0.10
S-BG-0560641	2.90	5970	1.50	0.010	0.24	4.00	0.05
S-BG-0563365	1.90	3180	1.50	0.010	0.26	1.00	0.05
Average	4.23	4575	2.25	0.021	0.44	2.50	0.20
Standard déviation	1.43	1973	0.46	0.007	0.12	1.69	0.32
(2 x StDev))	2.85	3946	0.93	0.014	0.23	3.38	0.65
Sum (Ave+(2xStDev)	7.08	8521	3.18	0.035	0.67	5.88	0.85
CCME (a)	63.00		70.00	6.60	5.00	50.00	1.00
Alpha							
S-AL-LS-0% A	1.80	4570	1.50	0.010	0.20	4.00	0.50
S-AL-LS-0% B	0.60	2120	1.50	0.010	0.14	2.00	0.50
S-AL-LS-20% A	1.30	2910	1.50	0.010	0.17	2.00	0.50
S-AL-LS-20% B	0.70	3200	1.50	0.010	0.18	1.00	0.50
S-AL-LS-40% A	1.40	2860	1.50	0.010	0.16	3.00	0.50
S-AL-LS-40% B	1.10	1940	1.50	0.010	0.18	2.00	0.50
S-AL-LS-60% A	1.90	3960	1.50	0.010	0.22	4.00	0.50
S-AL-LS-60% B	1.80	3960	1.50	0.010	0.20	3.00	0.50
S-AL-LS-80% A	1.80	4130	3.00	0.010	0.22	3.00	0.50
S-AL-LS-80% B	2.30	4430	1.50	0.010	0.20	4.00	0.50
S-AL-LS-100% A	2.30	3980	1.50	0.010	0.21	5.00	0.50
S-AL-LS-100%A (DUP)	2.60	4310	1.50	0.010	0.22	4.00	0.50
S-AL-LS-100% B	2.10	4280	1.50	0.010	0.22	3.00	0.50
S-AL-LS-120% A	2.20	3900	3.00	0.010	0.17	4.00	0.50
S-AL-LS-120% B	1.70	3970	1.50	0.010	0.26	4.00	0.50
S-AL-T1- A1	5.00	8420	1.50	0.010	0.16	7.00	0.50
S-AL-T1- A2	12.40	6470	5.00	0.010	0.23	6.00	0.50
S-AL-T1- A2 (DUP)	4.60	7050	1.50	0.010	0.25	7.00	0.50
S-AL-T1- B1	2.70	4420	1.50	0.010	0.20	4.00	0.50
S-AL-T1- B2	3.80	6280	1.50	0.010	0.21	6.00	0.50
S-AL-T1- B3	5.50	9760	1.50	0.010	0.24	8.00	0.50
S-AL-T1- B3 (DUP)	5.10	8690	4.00	0.010	0.21	8.00	0.50
S-AL-T1- B4	4.10	8170	1.50	0.010	0.26	6.00	0.50
S-AL-T1- B5	6.00	11300	1.50	0.010	0.26	9.00	0.50
S-AL-T1- B6	4.80	8850	1.50	0.010	0.18	7.00	0.50

	Cu	Fe	Pb	Hg	Mo	Ni	Se
Sample	**ppm (mg/Kg)**						
S-AL-T1- B7	2.90	5180	1.50	0.010	0.18	4.00	0.50
S-AL-T1- B8	3.00	6600	1.50	0.010	0.18	5.00	0.50
S-AL-T1- C1	2.00	4860	1.50	0.084	0.19	4.00	0.50
S-AL-T1- C2	1.20	3140	1.50	0.010	0.23	1.00	0.50
S-AL-T1- C3	1.50	3670	1.50	0.010	0.20	2.00	0.50
S-AL-T1- C4	2.40	3730	1.50	0.010	0.22	3.00	0.50
S-AL-T1- C5	2.20	3330	1.50	0.010	0.29	3.00	0.50
S-AL-T1- C6	3.40	7420	1.50	0.010	0.20	5.00	0.50
S-AL-T1- C7	2.10	4990	1.50	0.010	0.19	3.00	0.50
S-AL-T1- C8	2.10	5270	1.50	0.010	0.22	4.00	0.50
S-AL-T1- C9	6.70	12700	4.00	0.010	0.20	10.00	0.50
S-AL-T1- C10	5.60	10600	4.00	0.010	0.26	8.00	0.50
S-AL-T1- C11	2.70	5920	1.50	0.010	0.16	4.00	0.50
S-AL-T1- C12	3.00	6330	1.50	0.010	0.18	4.00	0.50
S-AL-T1- C12 (DUP)	3.20	6780	1.50	0.010	0.22	5.00	0.50
S-AL-T1- C13	3.00	5550	1.50	0.010	0.16	4.00	0.50
S-AL-T1- C14	1.90	4250	1.50	0.010	0.18	3.00	0.50
S-AL-T1- C16	4.40	9480	1.50	0.010	0.19	7.00	0.50
S-AL-T2-FRONT	7.60	13100	3.00	0.010	0.20	11.00	0.50
S-AL-T2 MIDDLE	13.60	5270	3.00	0.010	0.25	5.00	0.50
S-AL-T2-REAR	6.60	5230	1.50	0.010	0.19	5.00	0.50
Bravo							
S-BR-LS- 40% A	0.80	2940	1.50	0.010	0.19	2.00	0.50
S-BR-LS- 40% B	1.10	2940	1.50	0.010	0.09	1.00	0.50
S-BR-LS- 60% A	1.10	3620	1.50	0.010	0.20	2.00	0.50
S-BR-LS- 60% B	1.30	3420	1.50	0.010	0.08	1.00	0.50
S-BR-LS- 100% A	3.30	2990	1.50	0.010	0.12	1.00	0.50
S-BR-LS- 100% B	2.00	2250	1.50	0.010	0.07	1.00	0.50
S-BR-LS- 120% A	3.60	1720	1.50	0.025	0.14	1.00	0.50
S-BR-LS- 120% B	1.90	2190	1.50	0.010	0.08	2.00	0.50
S-BR-T-A1	10.80	3090	5.00	0.010	0.24	3.00	0.50
S-BR-T-A1 (DUP)	7.60	3290	4.00	0.010	0.23	3.00	0.50
S-BR-T-A2	7.50	3530	6.00	0.010	0.34	4.00	0.50
S-BR-T-B1	6.00	3250	3.00	0.010	0.18	3.00	0.50
S-BR-T-B2	3.90	2780	1.50	0.010	0.17	2.00	0.50
S-BR-T-B3	4.40	3310	1.50	0.010	0.20	3.00	0.50
S-BR-T-B4	4.10	3330	1.50	0.010	0.13	2.00	0.50
S-BR-T-B4 (DUP)	4.80	3180	1.50	0.010	0.12	3.00	0.50
S-BR-T-B5	3.80	3230	1.50	0.010	0.18	3.00	0.50
S-BR-T-B6	6.70	3520	4.00	0.010	0.12	3.00	0.50
S-BR-T-B7	5.80	3320	5.00	0.010	0.17	4.00	0.50
S-BR-T-B8	5.60	3290	3.00	0.010	0.12	2.00	0.50
S-BR-T-C1	2.60	3170	1.50	0.010	0.07	2.00	0.50

	Cu	Fe	Pb	Hg	Mo	Ni	Se
Sample	**ppm (mg/Kg)**						
S-BR-T-C2	2.20	3180	1.50	0.010	0.08	2.00	0.50
S-BR-T-C3	2.90	3670	1.50	0.010	0.09	2.00	0.50
S-BR-T-C4	3.30	3220	3.00	0.010	0.09	2.00	0.50
S-BR-T-C5	5.00	3440	1.50	0.010	0.18	3.00	0.50
S-BR-T-C6	2.60	2690	1.50	0.010	0.15	2.00	0.50
S-BR-T-C7	1.80	2690	1.50	0.010	0.06	1.00	0.50
S-BR-T-C7 (DUP)	1.50	2630	1.50	0.010	0.18	1.00	0.50
S-BR-T-C8	1.40	2810	1.50	0.010	0.17	2.00	0.50
S-BR-T-C9	2.10	2360	1.50	0.010	0.17	2.00	0.50
S-BR-T-C10	2.90	1860	1.50	0.010	0.18	2.00	0.50
S-BR-T-C11	5.50	2290	1.50	0.010	0.19	3.00	0.50
S-BR-T-C12	9.70	2690	4.00	0.010	0.22	4.00	0.50
S-BR-T-C13	6.80	2760	4.00	0.010	0.17	3.00	0.50
S-BR-T-C14	5.10	3080	1.50	0.010	0.16	2.00	0.50
S-BR-T-C15	3.60	2810	1.50	0.010	0.07	1.00	0.50
S-BR-T-C16	2.30	2640	1.50	0.010	0.06	1.00	0.50
S-BR-HS-0560345	9.80	2740	3.00	0.010	0.08	3.00	0.50
S-BR-HS-0560425	1.30	2950	1.50	0.010	0.08	1.00	0.50
Jimmy Lake							
S-JL-LS-0% A	7.60	4190	1.50	0.010	0.24	4.00	0.50
S-JL-LS-0% B	9.10	4500	3.00	0.010	0.32	5.00	0.50
S-JL-LS-20% A	20.60	4500	1.50	0.010	0.22	4.00	0.50
S-JL-LS-20% B	31.20	5430	1.50	0.010	0.26	5.00	0.50
S-JL-LS-40% A	35.00	3760	1.50	0.010	0.26	3.00	0.50
S-JL-LS-40% B	32.40	4790	1.50	0.010	0.30	3.00	0.50
S-JL-LS-60% A	103.00	5960	3.00	0.010	0.42	4.00	1.00
S-JL-LS-60% B	62.90	4240	1.50	0.010	0.28	3.00	0.50
S-JL-LS-60%B (DUP)	45.40	4750	1.50	0.010	0.39	4.00	0.50
S-JL-LS-80%A	60.40	5260	1.50	0.010	0.31	4.00	0.50
S-JL-LS-80%B	33.40	4770	1.50	0.010	0.37	4.00	0.50
S-JL-LS-80% B (DUP)	37.40	4480	1.50	0.010	0.31	3.00	0.50
S-JL-LS-100% A	28.40	3750	1.50	0.010	0.28	3.00	0.50
S-JL-LS-100% B	22.00	4330	1.50	0.010	0.30	3.00	0.50
S-JL-T1-A1	62.70	9280	20.00	0.010	0.29	14.00	0.50
S-JL-T1-A2	82.80	8560	22.80	0.010	0.50	15.70	0.50
S-JL-T1-B1	86.90	11500	19.80	0.010	0.80	14.30	0.50
S-JL-T1-B2	61.50	9920	14.10	0.010	0.27	13.30	0.50
S-JL-T1-B3	55.10	7970	19.30	0.010	0.44	21.00	0.50
S-JL-T1-B4	86.60	8640	15.90	0.035	0.45	13.70	0.50
S-JL-T1-B5	68.10	9510	18.50	0.010	0.34	13.00	0.50
S-JL-T1-B6	90.60	8760	28.20	0.010	0.42	15.50	0.50
S-JL-T1-B7	77.00	8800	25.30	0.010	0.47	20.80	0.50
S-JL-T1-B7 (DUP)	76.20	8140	22.80	0.010	0.45	15.40	0.50

	Cu	**Fe**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**
Sample	**ppm (mg/Kg)**						
S-JL-T1-B8	100.00	9030	21.90	0.010	0.31	13.20	0.50
S-JL-T1-C1	73.80	8210	13.20	0.010	0.40	11.70	0.50
S-JL-T1-C2	40.50	8230	13.70	0.010	0.46	11.80	0.50
S-JL-T1-C3	42.10	9570	9.00	0.010	0.29	12.00	0.50
S-JL-T1-C4	48.10	8530	9.0	0.010	0.38	12.60	0.50
S-JL-T1-C5	41.60	8820	10.70	0.010	0.37	11.40	0.50
S-JL-T1-C5 (DUP)	35.70	8500	11.90	0.010	0.40	12.10	0.50
S-JL-T1-C6	49.40	8870	15.70	0.010	0.43	12.60	0.50
S-JL-T1-C7	27.60	9030	9.00	0.010	0.30	10.40	0.50
S-JL-T1-C8	41.20	8190	10.20	0.010	0.42	10.70	0.50
S-JL-T1-C9	68.50	8060	12.30	0.010	0.39	11.20	0.50
S-JL-T1-C10	60.70	8380	15.10	0.010	0.39	12.30	0.50
S-JL-T1-C10 (DUP)	49.60	8780	26.90	0.010	0.47	13.40	0.50
S-JL-T1-C11	79.30	7800	15.50	0.010	0.39	12.60	0.50
S-JT-T1-C12	55.20	9170	18.60	0.010	0.44	12.60	0.50
S-JL-T1-C13	111.00	8430	19.90	0.010	0.53	15.00	0.50
S-JL-T1-C14	96.80	7370	15.90	0.010	0.39	11.70	0.50
S-JL-T1-C15	154.00	8570	18.20	0.010	0.41	12.60	0.50
S-JL-T1-C16	74.60	8000	14.30	0.010	0.34	11.50	0.50
Shaver River							
S-SR-LS-0%A	1.90	4720	4.00	0.010	0.15	3.00	0.50
S-SR-LS-0%B	0.50	3500	1.50	0.010	0.11	1.00	0.50
S-SR-LS-20% A	0.50	3730	1.50	0.010	0.12	2.00	0.50
S-SR-LS-20% B	0.40	3460	1.50	0.010	0.12	1.00	0.50
S-SR-LS-40% A	0.40	3150	1.50	0.010	0.08	1.00	0.50
S-SR-LS-40% B	0.80	3590	1.50	0.010	0.09	2.00	0.50
S-SR-LS-60% A	0.50	3360	1.50	0.010	0.10	1.00	0.50
S-SR-LS-60% A (DUP)	0.40	3250	1.50	0.010	0.10	1.00	0.50
S-SR-LS-60% B	0.20	2710	1.50	0.010	0.10	1.00	0.50
S-SR-LS-80% A	0.50	3290	1.50	0.010	0.11	1.00	0.50
S-SR-LS-80% B	0.60	3700	1.50	0.010	0.09	2.00	0.50
S-SR-LS-100%A	1.50	2800	3.00	0.010	0.11	1.00	0.50
S-SR-LS-100%B	4.70	3590	10.00	0.010	0.15	3.00	0.50
S-SR-LS-100%B (DUP)	3.20	3820	1.50	0.010	0.15	2.00	0.50
S-SR-LS-120% A	3.60	3050	5.00	0.010	0.14	1.00	0.50
S-SR-LS-120% B	12.80	4700	12.30	0.010	0.25	3.00	0.50
S-SR-LS-140% A	1.20	3420	1.50	0.010	0.12	1.00	0.50
S-SR-LS-140% B	1.80	3610	1.50	0.010	0.11	2.00	0.50
S-SR-T-A1	16.90	4400	26.90	0.010	0.33	4.00	0.50
S-SR-T-A1 (DUP)	17.90	4980	25.70	0.010	0.62	4.00	0.50
S-SR-T-A2	20.30	4610	53.80	0.010	0.64	5.00	0.50
S-SR-T-B1	11.30	4570	17.60	0.010	0.31	4.00	0.50
S-SR-T-B2	8.80	4700	10.00	0.010	0.25	3.00	0.50

	Cu	Fe	Pb	Hg	Mo	Ni	Se
Sample	ppm (mg/Kg)						
S-SR-T-B3	10.20	4840	12.90	0.010	0.66	3.00	0.50
S-SR-T-B4	13.50	4550	15.80	0.010	0.34	3.00	0.50
S-SR-T-B5	22.50	3900	8.00	0.010	0.26	3.00	0.50
S-SR-T-B5 (DUP)	19.20	3800	8.00	0.010	0.18	4.00	0.50
S-SR-T-B6	8.10	4070	9.00	0.010	0.26	3.00	0.50
S-SR-T-B7	18.20	4590	25.30	0.010	0.27	4.00	0.50
S-SR-T-B8	10.80	4230	26.50	0.010	0.26	3.00	0.50
S-SR-T-C1	6.60	4250	10.60	0.010	0.21	3.00	0.50
S-SR-T-C2	8.80	3980	3.00	0.010	0.16	3.00	0.50
S-SR-T-C3	5.80	5000	5.00	0.010	0.19	3.00	0.50
S-SR-T-C4	5.50	4100	5.00	0.010	0.20	2.00	0.50
S-SR-T-C5	7.20	4680	8.00	0.010	0.20	3.00	0.50
S-SR-T-C6	7.10	4450	6.00	0.010	0.21	3.00	0.50
S-SR-T-C7	7.10	4450	6.00	0.058	0.22	2.00	0.50
S-SR-T-C8	10.50	4650	12.50	0.010	0.20	2.00	0.50
S-SR-T-C9	11.60	5100	12.80	0.010	0.43	3.00	0.50
S-SR-T-C10	8.70	4600	9.00	0.010	0.19	3.00	0.50
S-SR-T-C10 (DUP)	10.70	4790	11.40	0.010	0.21	3.00	0.50
S-SR-T-C11	6.00	3970	6.00	0.010	0.58	4.00	0.50
S-SR-T-C12	3.70	4190	7.00	0.010	0.17	2.00	0.50
S-SR-T-C13	3.40	3700	4.00	0.010	0.12	2.00	0.50
S-SR-T-C14	4.20	4470	5.00	0.010	0.17	2.00	0.50
S-SR-T-C15	3.60	4050	5.00	0.010	0.22	3.00	0.50
S-SR-T-C16	6.40	4190	9.00	0.010	0.21	3.00	0.50
Shaver Open detonation Area							
S-SR-OD-1	2.50	4210	1.50	0.010	0.13	3.00	0.50
S-SR-OD-2	1.30	2720	1.50	0.010	0.10	1.00	0.50
S-SR-OD-3	0.70	3200	1.50	0.010	0.11	1.00	0.50
Rifle range							
S-RIF-T-1-3	15.80	3140	16.90	0.010	0.16	1.00	0.50
S-RIF-T-4-6	2.60	3170	8.00	0.010	0.14	1.00	0.50
S-RIF-T-4-6 (DUP)	0.20	0.50	5.00	0.010	0.17	1.00	0.50
S-RIF-T-7-9	0.20	0.50	11.40	0.039	0.11	2.00	0.50
S-RIF-T-10-12	1.30	2560	1.50	0.010	0.08	1.00	0.50
S-RIF-T-13-15	1.30	3290	1.50	0.010	0.20	3.00	0.50
S-RIF-FP-10M	1.70	3390	7.00	0.010	0.12	1.00	0.50
S-RIF-FP-100M	18.30	11200	69.20	0.020	0.10	11.30	0.50

(a) agricultural soil threshold criteria

(b) half values of the detection limits are used when metals are not detected

TABLE II C: METALS CONCENTRATIONS IN SOILS (AG TO ZN)

	Ag	Sr	Tl	Sn	U	V	Zn
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-BG-0560641	0.15	8.50	0.06	0.50	0.54	11.50	16.70
S-BG-0563365	0.15	4.10	0.01	0.50	0.16	4.90	22.00
Average	0.41	6.30	0.38	2.00	0.15	7.05	19.84
Standard deviation	0.16	3.11	0.22	0.93	0.18	3.31	5.54
(2 x StDev))	0.32	6.22	0.43	1.85	0.36	6.62	11.08
Sum (Ave+(2xStDev)	0.74	12.52	0.82	3.85	0.51	13.67	30.91
CCME (a)	20.00		1.00	5.00		130.00	200.00
Alpha							
S-AL-LS-0% A	0.15	3.00	0.04	0.50	0.38	6.80	14.20
S-AL-LS-0% B	0.15	1.90	0.01	0.50	0.18	3.50	8.60
S-AL-LS-20% A	0.15	3.00	0.03	0.50	0.18	5.70	8.70
S-AL-LS-20% B	0.15	1.80	0.01	0.50	0.15	4.70	12.20
S-AL-LS-40% A	0.15	3.20	0.04	0.50	0.24	5.60	9.00
S-AL-LS-40% B	0.15	3.10	0.03	0.50	0.18	4.90	11.30
S-AL-LS-60% A	0.15	3.90	0.05	0.50	0.23	8.50	13.10
S-AL-LS-60% B	0.15	3.60	0.04	0.50	0.24	7.80	11.50
S-AL-LS-80% A	0.15	3.80	0.04	0.50	0.24	7.70	12.70
S-AL-LS-80% B	0.15	4.90	0.05	0.50	0.27	9.90	14.00
S-AL-LS-100% A	0.15	3.90	0.03	0.50	0.25	7.60	13.60
S-AL-LS-100%A (DUP)	0.15	4.30	0.04	0.50	0.25	8.20	15.70
S-AL-LS-100% B	0.15	4.60	0.05	0.50	0.26	8.80	13.10
S-AL-LS-120% A	0.15	4.30	0.04	0.50	0.26	7.90	11.80
S-AL-LS-120% B	0.15	3.70	0.03	0.50	0.24	8.00	11.40
S-AL-T1- A1	0.15	7.00	0.08	0.50	0.44	16.30	19.30
S-AL-T1- A2	0.15	22.30	0.06	0.50	0.33	13.00	20.50
S-AL-T1- A2 (DUP)	0.15	6.10	0.07	0.50	0.34	14.10	19.60
S-AL-T1- B1	0.15	4.50	0.04	0.50	0.29	8.60	13.90
S-AL-T1- B2	0.15	5.90	0.06	0.50	0.35	11.40	18.50
S-AL-T1- B3	0.15	8.00	0.10	0.50	0.43	19.40	23.20
S-AL-T1- B3 (DUP)	0.15	7.30	0.10	0.50	0.44	15.30	25.60
S-AL-T1- B4	0.15	5.90	0.08	0.50	0.37	15.00	19.60

	Ag	Sr	Tl	Sn	U	V	Zn
Sample			**ppm**	**(mg/Kg)**			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-AL-T1- B5	0.15	7.90	0.10	0.50	0.46	20.80	28.60
S-AL-T1- B6	0.15	7.10	0.08	0.50	0.43	16.40	20.40
S-AL-T1- B7	0.15	4.20	0.04	0.50	0.33	9.50	13.90
S-AL-T1- B8	0.15	4.90	0.06	0.50	0.30	12.20	15.80
S-AL-T1- C1	0.15	3.80	0.05	0.50	0.25	9.00	13.80
S-AL-T1- C2	0.15	2.60	0.03	0.50	0.25	5.70	11.90
S-AL-T1- C3	0.15	3.00	0.03	0.50	0.31	6.80	12.90
S-AL-T1- C4	0.15	3.40	0.04	0.50	0.29	7.00	15.40
S-AL-T1- C5	0.15	3.10	0.03	0.50	0.22	6.10	15.00
S-AL-T1- C6	0.15	6.80	0.07	0.50	0.35	13.90	18.40
S-AL-T1- C7	0.15	3.90	0.05	0.50	0.29	9.20	15.70
S-AL-T1- C8	0.15	4.50	0.07	0.50	0.31	10.00	13.90
S-AL-T1- C9	0.15	9.10	0.12	0.50	0.52	22.70	25.90
S-AL-T1- C10	0.15	7.80	0.11	0.50	0.44	19.80	23.00
S-AL-T1- C11	0.15	4.60	0.05	0.50	0.31	11.50	13.50
S-AL-T1- C12	0.15	5.10	0.05	0.50	0.34	11.60	15.90
S-AL-T1- C12 (DUP)	0.15	4.80	0.06	0.50	0.39	12.50	15.20
S-AL-T1- C13	0.15	5.20	0.05	0.50	0.32	10.90	14.20
S-AL-T1- C14	0.15	3.70	0.03	0.50	0.30	8.30	12.50
S-AL-T1- C16	0.15	6.60	0.09	0.50	0.38	16.90	21.00
S-AL-T2-FRONT	0.15	9.80	0.14	0.50	0.58	25.50	27.00
S-AL-T2 MIDDLE	0.15	10.60	0.05	0.50	0.02	8.00	49.10
S-AL-T2-REAR	0.15	7.50	0.05	1.00	0.27	6.60	21.00
Bravo							
S-BR-LS- 40% A	0.15	1.70	0.01	0.50	0.37	4.80	10.80
S-BR-LS- 40% B	0.15	2.60	0.03	0.50	0.20	5.30	12.90
S-BR-LS- 60% A	0.15	1.40	0.01	0.50	0.16	6.30	12.90
S-BR-LS- 60% B	0.15	1.90	0.02	0.50	0.18	6.00	10.30
S-BR-LS- 100% A	0.15	6.10	0.05	0.50	0.23	9.90	11.80
S-BR-LS- 100% B	0.15	2.00	0.02	0.50	0.17	5.90	12.30
S-BR-LS- 120% A	0.15	4.50	0.03	0.50	0.18	3.80	9.10
S-BR-LS- 120% B	0.15	3.20	0.03	0.50	0.18	4.60	12.40
S-BR-T-A1	0.15	2.10	0.02	0.50	0.17	36.50	23.10
S-BR-T-A1 (DUP)	0.15	2.00	0.02	0.50	0.15	29.10	22.30
S-BR-T-A2	0.15	2.00	0.02	0.50	0.20	16.30	17.50
S-BR-T-B1	0.15	2.10	0.02	0.50	0.19	17.00	16.10
S-BR-T-B2	0.15	1.80	0.01	0.50	0.18	17.60	14.70

	Ag	Sr	Tl	Sn	U	V	Zn
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-BR-T-B3	0.15	1.70	0.02	0.50	0.20	18.90	15.40
S-BR-T-B4	0.15	2.30	0.02	0.50	0.21	12.10	15.20
S-BR-T-B4 (DUP)	0.15	2.30	0.02	0.50	0.19	14.80	16.70
S-BR-T-B5	0.15	2.10	0.03	0.50	0.18	10.40	14.30
S-BR-T-B6	0.15	2.40	0.03	0.50	0.22	13.20	16.70
S-BR-T-B7	0.15	2.10	0.01	0.50	0.27	13.60	16.10
S-BR-T-B8	0.15	2.20	0.02	0.50	0.21	13.30	15.80
S-BR-T-C1	0.15	1.90	0.02	0.50	0.19	6.70	12.20
S-BR-T-C2	0.15	1.70	0.01	0.50	0.20	7.80	12.30
S-BR-T-C3	0.15	1.90	0.02	0.50	0.19	10.60	12.50
S-BR-T-C4	0.15	1.60	0.02	0.50	0.18	18.20	14.60
S-BR-T-C5	0.15	1.70	0.01	0.50	0.18	19.00	19.20
S-BR-T-C6	0.15	1.40	0.01	0.50	0.14	7.70	12.30
S-BR-T-C7	0.15	1.30	0.01	0.50	0.18	5.90	10.50
S-BR-T-C7 (DUP)	0.15	1.10	0.01	0.50	0.19	6.10	10.60
S-BR-T-C8	0.15	1.90	0.02	0.50	0.16	6.40	12.60
S-BR-T-C9	0.15	1.60	0.01	0.50	0.14	5.50	11.90
S-BR-T-C10	0.15	2.70	0.01	0.50	0.14	5.70	11.40
S-BR-T-C11	0.15	2.30	0.02	0.50	0.17	6.50	13.70
S-BR-T-C12	0.15	2.60	0.03	0.50	0.17	10.10	17.50
S-BR-T-C13	0.15	2.20	0.01	0.50	0.17	8.10	13.80
S-BR-T-C14	0.15	2.30	0.03	0.50	0.21	8.10	14.00
S-BR-T-C15	0.15	1.90	0.02	0.50	0.19	6.20	11.00
S-BR-T-C16	0.15	1.50	0.01	0.50	0.17	5.40	10.30
S-BR-HS-0560345	0.15	2.00	0.02	0.50	0.17	22.20	18.00
S-BR-HS-0560425	0.15	1.30	0.02	0.50	0.15	7.70	11.80
Jimmy Lake							
S-JL-LS-0% A	0.15	3.50	0.05	0.50	0.26	6.40	10.80
S-JL-LS-0% B	0.15	5.20	0.05	0.50	0.39	7.10	12.10
S-JL-LS-20% A	0.15	4.00	0.05	0.50	0.36	6.90	12.50
S-JL-LS-20% B	0.15	6.80	0.05	0.50	0.42	8.80	15.70
S-JL-LS-40% A	0.15	6.30	0.04	0.50	0.26	5.70	14.90
S-JL-LS-40% B	0.15	7.80	0.05	0.50	0.28	6.60	14.70
S-JL-LS-60% A	3.00	5.70	0.05	0.50	0.34	8.50	26.10
S-JL-LS-60% B	0.15	5.30	0.04	0.50	0.26	6.30	18.20
S-JL-LS-60%B (DUP)	0.15	5.30	0.04	0.50	0.25	6.80	16.50
S-JL-LS-80%A	0.15	4.10	0.04	0.50	0.32	7.10	18.00

	Ag	Sr	Tl	Sn	U	V	Zn
Sample			ppm	(mg/Kg)			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-JL-LS-80%B	0.15	8.10	0.04	0.50	0.27	6.30	16.60
S-JL-LS-80% B (DUP)	0.15	5.60	0.04	0.50	0.28	6.10	13.80
S-JL-LS-100% A	0.15	3.40	0.04	0.50	0.26	5.50	12.60
S-JL-LS-100% B	0.15	4.40	0.03	0.50	0.26	5.80	14.70
S-JL-T1-A1	0.15	16.90	0.09	0.50	0.48	101.00	82.20
S-JL-T1-A2	3.00	10.30	0.20	0.50	0.50	85.80	107.00
S-JL-T1-B1	0.15	9.60	0.11	0.50	0.54	72.10	108.00
S-JL-T1-B2	0.15	10.80	0.09	0.50	0.52	97.70	86.70
S-JL-T1-B3	0.15	9.30	0.10	0.50	0.52	80.80	71.90
S-JL-T1-B4	0.15	10.00	0.10	0.50	0.57	66.40	84.80
S-JL-T1-B5	0.15	10.20	0.09	0.50	0.54	75.10	80.30
S-JL-T1-B6	0.15	10.00	0.09	0.50	0.54	79.50	97.20
S-JL-T1-B7	0.15	9.80	0.09	0.50	0.47	79.10	98.40
S-JL-T1-B7 (DUP)	0.15	9.70	0.09	0.50	0.54	82.70	95.80
S-JL-T1-B8	0.30	9.90	0.09	0.50	0.55	79.10	101.00
S-JL-T1-C1	0.15	11.30	0.09	0.50	0.51	56.30	77.90
S-JL-T1-C2	0.15	9.50	0.11	0.50	0.58	57.10	56.10
S-JL-T1-C3	0.15	10.30	0.09	0.50	0.53	67.70	63.80
S-JL-T1-C4	0.15	10.00	0.10	0.50	0.58	78.60	74.10
S-JL-T1-C5	0.15	10.40	0.11	0.50	0.59	74.80	63.50
S-JL-T1-C5 (DUP)	0.15	10.20	0.09	0.50	0.62	76.50	53.20
S-JL-T1-C6	0.15	10.70	0.11	0.50	0.54	54.00	57.50
S-JL-T1-C7	0.15	10.70	0.09	0.50	0.54	47.30	48.70
S-JL-T1-C8	0.15	9.30	0.10	0.50	0.49	45.50	48.20
S-JL-T1-C9	0.15	10.20	0.10	0.50	0.51	39.20	70.20
S-JL-T1-C10	0.15	10.00	0.09	0.50	0.52	51.70	78.20
S-JL-T1-C10 (DUP)	0.15	10.20	0.10	0.50	0.57	53.60	65.40
S-JL-T1-C11	0.15	9.10	0.10	0.50	0.50	59.70	79.00
S-JT-T1-C12	0.15	9.80	0.12	1.00	0.54	61.00	74.50
S-JL-T1-C13	0.15	9.10	0.09	1.00	0.48	67.50	133.00
S-JL-T1-C14	0.15	8.90	0.09	0.50	0.52	60.40	85.20
S-JL-T1-C15	0.15	9.30	0.09	0.50	0.58	56.90	377.00
S-JL-T1-C16	0.15	9.20	0.12	0.50	0.54	44.20	72.20
Shaver River							
S-SR-LS-0%A	0.15	4.00	0.04	0.50	0.19	8.60	14.50
S-SR-LS-0%B	0.15	1.90	0.02	0.50	0.12	5.90	14.70
S-SR-LS-20% A	0.15	2.10	0.03	0.50	0.16	6.10	14.00

	Ag	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
Sample			**ppm**	**(mg/Kg)**			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-SR-LS-20% B	0.15	1.80	0.02	0.50	0.17	5.20	13.90
S-SR-LS-40% A	0.15	1.50	0.02	0.50	0.15	4.90	17.40
S-SR-LS-40% B	0.15	2.30	0.03	0.50	0.18	5.80	14.60
S-SR-LS-60% A	0.15	1.80	0.03	0.50	0.21	5.00	18.10
S-SR-LS-60% A (DUP)	0.15	1.50	0.02	0.50	0.17	4.80	14.90
S-SR-LS-60% B	0.15	1.20	0.01	0.50	0.12	4.30	10.50
S-SR-LS-80% A	0.15	1.60	0.02	0.50	0.17	5.40	12.70
S-SR-LS-80% B	0.15	2.10	0.03	0.50	0.20	5.90	15.30
S-SR-LS-100%A	0.15	1.30	0.01	0.50	0.22	3.70	12.90
S-SR-LS-100%B	0.15	2.60	0.02	0.50	0.18	5.10	18.50
S-SR-LS-100%B (DUP)	0.15	2.30	0.03	0.50	0.18	5.80	16.20
S-SR-LS-120% A	0.15	2.10	0.02	0.50	0.13	4.10	16.10
S-SR-LS-120% B	0.15	2.30	0.03	0.50	0.20	5.80	27.00
S-SR-LS-140% A	0.15	1.30	0.01	0.50	0.14	4.60	11.40
S-SR-LS-140% B	0.15	2.10	0.03	0.50	0.27	5.20	12.20
S-SR-T-A1	0.15	3.80	0.03	0.50	0.18	5.60	34.70
S-SR-T-A1 (DUP)	0.15	3.50	0.05	2.00	0.21	5.10	35.70
S-SR-T-A2	0.15	3.40	0.03	2.00	0.23	6.10	33.40
S-SR-T-B1	0.15	2.90	0.03	1.00	0.20	5.40	28.10
S-SR-T-B2	0.15	2.80	0.03	2.00	0.24	5.10	24.60
S-SR-T-B3	0.15	2.30	0.03	2.00	0.21	5.60	25.20
S-SR-T-B4	0.15	3.40	0.02	2.00	0.24	5.60	33.00
S-SR-T-B5	0.15	2.00	0.02	3.00	0.18	4.80	21.30
S-SR-T-B5 (DUP)	0.15	2.20	0.02	0.50	0.20	4.60	21.10
S-SR-T-B6	0.15	2.30	0.05	0.50	0.23	5.00	21.30
S-SR-T-B7	0.15	8.10	0.04	0.50	0.27	6.00	34.10
S-SR-T-B8	0.15	2.90	0.04	1.00	0.24	5.40	26.40
S-SR-T-C1	0.15	2.50	0.03	0.50	0.24	5.60	20.20
S-SR-T-C2	0.15	2.10	0.03	0.50	0.16	5.10	33.50
S-SR-T-C3	0.15	2.60	0.02	0.50	0.24	6.10	25.60
S-SR-T-C4	0.15	2.20	0.03	0.50	0.23	5.30	20.30
S-SR-T-C5	0.15	2.00	0.03	2.00	0.20	5.30	21.80
S-SR-T-C6	0.15	2.00	0.03	1.00	0.28	6.00	24.00
S-SR-T-C7	0.15	1.70	0.01	0.50	0.17	5.30	20.50
S-SR-T-C8	0.15	2.10	0.02	0.50	0.20	5.40	28.40
S-SR-T-C9	0.15	2.80	0.03	0.50	0.23	6.30	30.20
S-SR-T-C10	0.15	3.10	0.02	0.50	0.18	6.00	26.00

	Ag	**Sr**	**Tl**	**Sn**	**U**	**V**	**Zn**
Sample			**ppm**	**(mg/Kg)**			
BR-DZB-BG1	0.50		0.50	2.50	0.20	7.00	10.00
BR-DZB-BG2	0.50		0.50	2.50	0.20	11.00	20.00
JLR-BG1	0.50		0.50	2.50	0.02	7.00	20.00
JLR-BG2	0.50		0.50	2.50	0.02	3.00	20.00
JLR-Foul Line-BG	0.50		0.50	2.50	0.02	3.00	30.00
SRR-BG	0.50		0.50	2.50	0.02	9.00	20.00
S-SR-T-C10 (DUP)	0.15	2.80	0.02	0.50	0.22	5.80	26.20
S-SR-T-C11	0.15	2.30	0.02	0.50	0.26	5.30	18.40
S-SR-T-C12	0.15	2.00	0.03	0.50	0.26	5.50	15.40
S-SR-T-C13	0.15	2.00	0.02	0.50	0.28	5.50	14.70
S-SR-T-C14	0.15	2.10	0.02	0.50	0.17	5.40	16.00
S-SR-T-C15	0.15	2.50	0.02	0.50	0.23	6.00	15.60
S-SR-T-C16	0.15	2.10	0.02	0.50	0.17	5.60	19.30
Shaver Open detonation area							
S-SR-OD-1	0.15	2.80	0.02	0.50	0.18	6.90	11.90
S-SR-OD-2	0.15	1.70	0.01	0.50	0.20	4.30	8.90
S-SR-OD-3	0.15	2.50	0.01	0.50	0.23	5.00	9.80
Rifle range							
S-RIF-T-1-3	0.15	2.40	0.02	0.50	0.21	5.70	11.60
S-RIF-T-4-6	0.15	2.80	0.02	0.50	0.26	6.00	13.10
S-RIF-T-4-6 (DUP)	0.15	0.20	0.04	0.50	0.18	0.90	0.40
S-RIF-T-7-9	0.15	0.20	0.04	0.50	0.20	0.90	1.20
S-RIF-T-10-12	0.15	3.00	0.02	0.50	0.20	4.50	6.40
S-RIF-T-13-15	0.15	3.20	0.02	0.50	0.28	5.70	7.70
S-RIF-FP-10M	0.15	2.70	0.02	0.50	0.34	6.00	8.80
S-RIF-FP-100M	0.15	10.80	0.10	0.50	0.61	18.70	28.20

(a) agricultural soil threshold criteria

(b) half values of the detection limits are used when metals are not detected

TABLE III A: METALS CONCENTRATIONS IN BIOMASS SAMPLES (AL TO CO)

	Al	As	Ba	Be	Cd	Cr	Co
Sample			ppm	(mg/Kg)			
B-BG-0560641	46.40	0.25	23.80	0.35	0.03	0.50	0.50
B-BG-0560641			31.50	0.01		2.80	0.07
B-BG-0563365	47.40	0.25	23.80	0.35	0.14	0.50	0.50
B-BG-0563365			31.10	0.01		2.80	0.14
Average BG	46.90	0.25	27.55	0.18	0.09	1.65	0.30
Standard deviation	0.71	0.00	4.33	0.20	0.08	1.33	0.23
(2 x StDev)	1.41	0.00	8.67	0.39	0.16	2.66	0.46
Sum (Ave+(2xStDev)	48.31	0.25	36.22	0.57	0.24	4.31	0.76
Alpha Range							
B-AL-LS-80%A	49.90	0.25	30.60	0.35	0.03	0.50	0.50
B-AL-LS-80%A			37.90	0.01		2.50	0.05
B-AL-LS-80%B	41.40	0.25	33.50	0.35	0.05	0.50	0.50
B-AL-LS-80%B			39.20	0.01		2.20	0.04
B-AL-T1-A1	29.00	0.25	43.00	0.35	0.11	0.50	0.50
B-AL-T1-A1			54.20	0.01		2.50	0.05
B-AL-T1-B4	70.90	0.25	27.00	0.35	0.42	2.00	0.50
B-AL-T1-B4			38.90	0.01		3.30	0.06
B-AL-T1-C4/C13	168.00	0.25	48.10	0.35	0.17	3.00	0.50
B-AL-T1-C4/C13			71.00	0.01		4.80	0.11
Bravo range							
B-BR-T-A	164.00	0.25	62.50	0.35	6.77	2.00	0.50
B-BR-T-A			75.50	0.01		2.80	0.23
B-BR-T-B	195.00	0.25	48.30	0.35	19.60	3.00	0.50
B-BR-T-B			57.70	0.01		3.90	0.21
Jimmy Lake							
B-JL-LS-NORTH A	55.20	0.25	14.30	0.35	0.07	0.50	0.50
B-JL-LS-NORTH A			19.40	0.01		2.80	0.13
B-JL-LS-NORTH B	83.10	0.25	29.80	0.35	0.26	1.00	0.50
B-JL-LS-NORTH B			35.70	0.01		2.60	0.15
B-JL-LS-SOUTH A	34.90	0.25	16.40	0.35	0.04	0.50	0.50
B-JL-LS-SOUTH A			22.80	0.01		3.20	0.12
B-JL-LS-SOUTH B	44.70	0.25	18.10	0.35	0.06	1.00	0.50
B-JL-LS-SOUTH B			23.60	0.01		2.90	0.05

	Al	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**
Sample			**ppm**	**(mg/Kg)**			
B-BG-0560641	46.40	0.25	23.80	0.35	0.03	0.50	0.50
B-BG-0560641			31.50	0.01		2.80	0.07
B-BG-0563365	47.40	0.25	23.80	0.35	0.14	0.50	0.50
B-BG-0563365			31.10	0.01		2.80	0.14
B-JL-T1-NORTH		0.25	44.30	0.35	10.80	2.90	0.53
B-JL-T1 SOUTH	188.00	0.25	28.30	0.35	3.67	1.00	0.50
B-JL-T1 SOUTH			36.10	0.01		2.90	0.18
Rifle Range							
B-RIF-1-4	163.00	0.25	38.90	0.35	0.05	0.50	0.50
B-RIF-1-4			51.10	0.01		1.90	0.11
Shaver range							
B-SR-LS-100%A		0.25		0.35	2.81	1.90	0.34

TABLE III B: METALS CONCENTRATIONS IN BIOMASS SAMPLES (CU TO SE)

	Cu	Fe	Pb	Mn	Mo	Ni	Se
Sample			ppm	(mg/Kg)			
B-BG-0560641	3.30	61.90	1.50	29.40	5.50	1.00	0.50
B-BG-0560641	3.29		0.15			1.04	
B-BG-0563365	4.20	79.90	1.50	61.90	1.33	1.00	0.50
B-BG-0563365	3.78		0.14			2.07	
Average BG	3.64	70.90	0.82	45.65	3.42	1.28	0.50
Standard Deviation	0.44	12.73	0.78	22.98	2.95	0.53	0.00
(2 x StDev)	0.87	25.46	1.56	45.96	5.90	1.06	0.00
Sum (Ave+(2xStDev)	4.52	96.36	2.39	91.61	9.31	2.33	0.50
Alpha Range							
B-AL-LS-80%A	2.20	58.50	1.50	87.80	0.52	1.00	0.50
B-AL-LS-80%A	2.59		0.08			0.81	
B-AL-LS-80%B	4.10	57.60	1.50	43.40	0.39	1.00	0.50
B-AL-LS-80%B	4.07		0.10			0.88	
B-AL-T1-A1	6.70	65.90	1.50	0.50	0.57	1.00	0.50
B-AL-T1-A1	6.47		0.15			1.01	
B-AL-T1--B4	3.90	70.60	1.50	54.20	0.69	1.00	0.50
B-AL-T1--B4	3.96		0.11			1.47	
B-AL-T1-C4/C13	4.80	138.00	1.50	75.40	0.63	1.00	0.50
B-AL-T1-C4/C13	4.98		0.26			1.60	
Bravo range							
B-BR-T-A	4.20	166.00	1.50	19.40	0.40	1.00	0.50
B-BR-T-A	4.06		0.31			2.17	
B-BR-T-B	5.80	179.00	1.50	45.30	0.56	4.00	0.50
B-BR-T-B	5.77		0.27			3.87	
Jimmy Lake							
B-JL-LS-NORTH A	4.70	80.20	1.50	21.10	7.78	1.00	0.50
B-JL-LS-NORTH A	5.31		0.12			1.28	
B-JL-LS-NORTH B	8.70	111.00	1.50	27.10	11.80	1.00	0.50
B-JL-LS-NORTH B	7.58		0.12			2.30	
B-JL-LS-SOUTH A	3.50	48.80	1.50	18.10	5.27	1.00	0.50
B-JL-LS-SOUTH A	3.63		0.07			1.14	
B-JL-LS-SOUTH B	2.60	62.30	1.50	42.80	14.00	1.00	0.50
B-JL-LS-SOUTH B	2.99		0.13			0.72	
B-JL-T1-NORTH	11.50	812.00	1.64	49.40	6.90	2.48	0.50
B-JL-T1 SOUTH	10.90	175.00	1.50	35.00	2.89	1.00	
B-JL-T1 SOUTH	11.00		0.43			1.79	

	Cu	Fe	Pb	Mn	Mo	Ni	Se
Sample			**ppm**	**(mg/Kg)**			
Rifle Range							
B-RIF-1-4	3.10	137.00	1.50	41.70	0.12	1.00	0.50
B-RIF-1-4	3.06		3.18			0.93	
Shaver range							
B-SR-LS-100%A	7.10	508.00	0.41	0.50	0.73	2.19	0.50

TABLE III C: METALS CONCENTRATIONS IN BIOMASS SAMPLES (AG TO ZN)

	Ag	***Sr***	***Th***	***U***	***V***	***Zn***
Sample			***ppm***	***(mg/Kg)***		
B-BG-0560641	0.15	10.70	0.02	0.02	0.30	11.50
B-BG-0560641					0.50	
B-BG-0563365	0.15	19.10	0.02	0.02	0.30	22.30
B-BG-0563365					0.50	
Average	0.15	14.90	0.02	0.02	0.40	16.90
Standard Deviation	0.00	5.94	0.00	0.00	0.12	7.64
(2 x StDev))	0.00	11.88	0.00	0.00	0.23	15.27
Sum (Ave+(2xStDev)	0.15	26.78	0.02	0.02	0.63	32.17
Alpha Range						
B-AL-LS-80%A	0.15	4.30	0.02	0.02	0.30	19.60
B-AL-LS-80%A					0.40	
B-AL-LS-80%B	0.15	9.40	0.02	0.02	0.30	17.00
B-AL-LS-80%B					0.30	
B-AL-T1-A1	0.15	7.00	0.02	0.02	0.30	35.00
B-AL-T1-A1					0.40	
B-AL-T1-B4	0.15	5.30	0.02	0.02	0.30	13.50
B-AL-T1-B4					0.60	
B-AL-T1-C4/C13	0.15	8.50	0.02	0.02	0.30	16.90
B-AL-T1-C4/C13					0.90	
Bravo range						
B-BR-T-A	0.15	19.80	0.02	0.02	1.00	37.40
B-BR-T-A					1.20	
B-BR-T-B	0.15	9.80	0.02	0.02	1.10	73.80
B-BR-T-B					1.30	
Jimmy Lake						
B-JL-LS-NORTH A	0.15	8.10	0.02	0.02	0.30	15.80
B-JL-LS-NORTH A					0.50	
B-JL-LS-NORTH B	0.15	24.40	0.02	0.02	0.30	27.80
B-JL-LS-NORTH B					0.63	
B-JL-LS-SOUTH A	0.15	14.20	0.02	0.02	0.30	7.90
B-JL-LS-SOUTH A					0.63	
B-JL-LS-SOUTH B	0.15	3.50	0.02	0.02	0.30	10.90
B-JL-LS-SOUTH B					0.50	
B-JL-T1-NORTH	0.15	23.40	0.93	0.05	6.50	44.90
B-JL-T1 SOUTH	0.15	11.60	0.02	0.02	1.50	55.60
B-JL-T1 SOUTH					2.20	

	Ag	Sr	Th	U	V	Zn
Rifle Range						
B-RIF-1-4	0.15	17.40	0.02	0.02	0.30	16.80
B-RIF-1-4					0.50	
Shaver range						
B-SR-LS-100%A	0.15	71.70	0.18	0.02	0.30	62.00

TABLE IV: METALS CONCENTRATIONS IN SURFACE WATER SAMPLES

	Al	Sb	As	B	Ba	Be	Cd
Sample			ppb	(μg/L)			
SW-JL	36.00	9.00	2.50	60.00	5.50	0.10	0.10
SW-PL	40.00	1.30	2.50	70.00	50.60	0.10	0.10
SW-SR-05667200	15.00	0.40	2.50	30.00	49.50	0.10	0.10
SW-SR-0567157	50.00	0.50	2.50	80.00	33.40	0.10	0.10
CCME	5 - 100 (a)	6.0 (b)	5.0 (a)	5000 (b)	1000 (c)	100 (d)	0.017 (a)

Metals Concentrations in Surface Water Samples (Cr to Mn)

	Cr	Co	Cu	Fe	Pb	Li	Mn
Sample			ppb	(μg/L)			
SW-JL	5.00	0.20	0.30	190.00	0.50	2.00	34.00
SW-PL	5.00	0.20	0.60	400.00	0.40	2.00	53.00
SW-SR-05667200	6.00	1.50	1.10	4490.00	3.70	2.00	1350.00
SW-SR-0567157	6.00	0.20	1.40	1210.00	0.50	6.00	181.00
CCME	50 (c)	50 (d)	2 - 4 (a)	300 (a)	1 - 7 (a)	2500 (d)	200 (d)

Metals Concentrations in Surface Water Samples (Mo to Sn)

	Mo	Ni	Se	Ag	Sr	Tl	Sn
Sample			ppb	(μg/L)			
SW-JL	2.50	0.60	3.50	0.20	23.00	0.10	6.00
SW-PL	1.20	1.10	3.50	0.10	101.00	0.10	3.00
SW-SR-05667200	0.80	4.10	3.50	0.05	138.00	0.10	2.00
SW-SR-0567157	1.70	2.00	3.50	0.10	130.00	0.10	2.00
CCME	73 (a)	25 - 150 (a)	1 (a)	0.1 (a)		0.8 (a)	

Metals Concentrations in Surface Water Samples (Th to Zr)

	Th	Ti	U	V	Zn	Zr
Sample			**ppb**	**(µg/L)**		
SW-JL	0.15	4.00	0.90	0.50	12.30	8.60
SW-PL	0.15	0.50	0.20	0.50	12.70	3.30
SW-SR-05667200	0.15	0.50	0.20	0.50	26.60	1.10
SW-SR-0567157	0.15	0.50	0.20	0.50	15.00	3.20
CCME			10 (d)	100 (d)	30 (a)	

(a): criteria for aquatic life in freshwater
(b): Interim Maximum Acceptable Concentrations in Drinking Water
(c): Maximum Acceptable Concentrations in Drinking water
(d): criteria for irrigation and/or livestock
(e): half values of the detection limit are used when metals are not detected

TABLE V: EXPLOSIVES DETECTION LIMITS FOR SOIL

analyte	Soil, Microgram/Kg (ppb)			
	RP-HPLC		GC-ECD	
	Detection limit	Reporting limit	Detection limit	Reporting limit
HMX	26	100	26	50
RDX	34	100	3	5
TNB	16	100	3	5
TNT	16	100	1	2
2,6-DNT	19	100	0.8	2
2,4-DNT	28	100	0.8	2
2-ADNT	38	100	2.5	5
4-ADNT	32	100	1.6	5
NG	20	100	2	5
DNB	100	200	0.7	2
TETRYL	600	1000	20	50
PETN	500 (est.)	500	16	50

TABLE VI A: EXPLOSIVES IN ALPHA RANGE SOILS BY GC/ECD IN PPB (NG TO TNB)

Sample	**NG**	**1,3-DNB**		**2,6-DNT**		**2,4-DNT**		**1,3,5-TNB**	
	CRREL	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Alpha									
S-AL-T1-A1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.98	n.d.	n.d.
S-AL-T1-B3 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C12 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.16	n.d.	n.d.
S-AL-T1-C13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.56	n.d.	n.d.
S-AL-LS-0% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-0% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-20% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-20% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-40% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-40% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-60% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-60% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-80% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	**NG**	**1,3-DNB**		**2,6-DNT**		**2,4-DNT**		**1,3,5-TNB**	
	CRREL	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Alpha									
S-AL-T1-A1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.98	n.d.	n.d.
S-AL-T1-B3 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-80% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-100% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-100% A DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.44	n.d.	n.d.
S-AL-LS-100% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-120% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-120% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T2-FRONT	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T2-REAR	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

TABLE VI B: EXPLOSIVES IN ALPHA RANGE SOILS BY GC/ECD IN PPB (TNT TO HMX)

Sample	**TNT**		**RDX**		**AMINO's**		**TETRYL**		**HMX**	
	RDDC	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Alpha										
S-AL-T1-A1	74.65	73.00	17.13	24.40	n.d.	n.d	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2	16.00	14.40	22.32	24.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2 DUP	256.43	394.00	44.29	23.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B1	69.04	80.60	17.56	15.80	4.53	6.36	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B2	n.d.	352.00	55.12	57.40	13.72	17.54	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B3	121.96	182.00	35.94	23.80	10.70	13.22	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B3 DUP	125.88	122.00	32.22	20.40	11.49	14.04	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B4	n.d.	71.40	26.66	37.00	14.08	8.76	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B5	31.18	41.20	6.89	7.34	6.09	2.30	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B6	22.71	18.30	13.48	20.20	7.52	9.96	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B7	22.49	33.20	18.85	11.90	3.07	7.06	n.d.	n.d.	n.d.	n.d.
S-AL-T1-B8	16.46	15.70	6.52	11.10	7.58	11.22	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C1	18.24	4.32	9.87	18.10	3.12	3.19	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C2	88.25	46.40	13.06	4.76	1.53	0.98	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C3	19.32	17.70	16.79	9.54	2.52	1.17	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C4	55.43	70.60	18.53	13.60	8.58	5.10	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C5	28.52	43.20	30.08	26.60	5.10	8.38	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C6	50.20	74.60	5.30	8.66	4.06	4.74	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C7	284.43	406.00	7.64	4.38	5.09	6.26	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C8	70.38	14.40	6.89	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C9	12.73	11.80	7.10	3.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C10	26.38	14.50	6.66	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C11	6.83	4.20	18.55	17.70	3.29	4.68	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C12	456.54	722.00	4.81	5.38	14.36	11.58	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C12 DUP	221.12	272.00	5.55	8.20	9.77	10.16	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C13	129.04	34.00	19.96	24.00	26.09	29.74	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C14	12.74	10.20	6.10	11.10	1.07	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C15	71.38	41.20	2.43	5.76	11.55	16.40	n.d.	n.d.	n.d.	n.d.
S-AL-T1-C16	174.80	96.60	3.16	3.68	1.16	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-0% A	477.64	564.00	16.71	3.38	5.13	4.40	n.d.	n.d.	n.d.	n.d.
S-AL-LS-0% B	22.98	n.d.	7.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-20% A	6.58	2.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-20% B	40.29	10.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-40% A	15.46	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-40% B	10.44	11.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-60% A	13.98	9.94	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-60% B	10.84	16.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-80% A	n.d.	69.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	**TNT**		**RDX**		**AMINO's**		**TETRYL**		**HMX**	
	RDDC	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Alpha										
S-AL-T1-A1	74.65	73.00	17.13	24.40	n.d.	n.d	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2	16.00	14.40	22.32	24.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T1-A2 DUP	256.43	394.00	44.29	23.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-80% B	77.73	71.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	107.30	123
S-AL-LS-100% A	59.56	11.00	21.16	11.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-100% A DUP	965.44	1100.00	21.31	10.60	24.68	33.00	n.d.	n.d.	n.d.	n.d.
S-AL-LS-100% B	69.31	44.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-120% A	87.20	58.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-LS-120% B	19.34	20.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T2-FRONT	25.03	8.78	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-AL-T2-REAR	436.43	482.00	n.d.	n.d.	7.72	12.98	n.d.	n.d.	n.d.	n.d.

TABLE VII A: EXPLOSIVES IN ALL OTHER RANGES SOILS BY GC/ECD IN PPB (NG TO TNB)

Sample	NG	1,3-DNB		2,6-DNT		2,4-DNT		1,3,5-TNB	
	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL
Bravo									
S-BR-T-A1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A1 DUP	26,8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B2	18,3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B4	21,8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B4 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B6	26,6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B8	38,8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C7 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-40% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-40% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-60% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-60% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-100% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-100% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-120% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-120% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-HS-0560345 6071989	18,9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	NG	1,3-DNB		2,6-DNT		2,4-DNT		1,3,5-TNB	
	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL
Bravo									
S-BR-T-A1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A1 DUP	26,8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B2	18,3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-HS-0560425 6071964	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Shaver range									
S-SR-LS-0% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.28	n.d.	n.d.
S-SR-LS-0% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-20% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-20% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-40% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-40% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% A DUP	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-80% A	n.d.	n.d.	n.d.	n.d.	6.52	n.d.	25.40	n.d.	n.d.
S-SR-LS-80% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-100% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-100% B	n.d.	n.d.	n.d.	n.d.	3.58	n.d.	17.1	n.d.	n.d.
S-SR-LS-100% B DUP	n.d.	n.d.	n.d.	n.d.	2.82	n.d.	12.8	n.d.	n.d.
Open detonation									
S-SR-OD-1	17,8	n.d.	n.d.	n.d.	n.d.	n.d.	2,62	n.d.	n.d.
S-SR-OD-2	14,9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-OD-3	n.d.	n.d.	n.d.	n.d.	n.d.	540,0	n.d.	n.d.	n.d.
Jimmy Lake									
S-JL-T1-A1	388,0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-B2	816,0	n.d.	n.d.	n.d.	n.d.	n.d.	2.5	n.d.	n.d.
S-JL-T1-B5	652,0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-B8	296,0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C3	21,4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C12	532,0	n.d.	n.d.	n.d.	n.d.	n.d.	2.14	n.d.	n.d.

TABLE VII B: EXPLOSIVES IN ALL OTHER RANGES SOILS BY GC/ECD IN PPB (TNT TO HMX)

Sample	TNT		RDX		AMINO's		TETRYL		HMX	
	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL	RDDC	CRREL
Bravo										
S-BR-T-A1	22.17	17.10	n.d.	n.d.	1.77	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A1 DUP	8.37	10.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A2	3.44	2.68	n.d.	n.d.	1.19	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B1	32.01	25.80	n.d.	n.d.	0.60	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B2	108.36	105.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B3	9.16	4.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B4	n.d.	9.18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B4 DUP	28.10	31.00	n.d.	n.d.	1.63	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B5	n.d.	3.68	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B6	51.85	22.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B7	2.72	2.84	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-B8	n.d.	3.54	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C1	87.55	114.00	n.d.	n.d.	0.22	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C2	24.63	9.36	2.73	n.d.	0.38	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C3	n.d.	20.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C4	n.d.	24.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C5	98.54	43.40	n.d.	n.d.	1.58	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C6	45.04	49.40	1.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C7	10.40	19.00	1.15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C7 DUP	66.94	74.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C8	90.56	101.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C9	n.d.	3.18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C10	18.85	13.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C11	43.82	41.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C12	101.34	91.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C13	11.82	20.00	n.d.	n.d.	2.32	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C14	n.d.	4.82	1.46	n.d.	2.16	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C15	163.59	298.00	n.d.	n.d.	1.92	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-C16	135.78	125.00	n.d.	n.d.	3.34	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-40% A	12.04	12.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-40% B	3.83	4.82	n.d.	n.d.	3.31	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-60% A	17.01	8.72	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-60% B	n.d.	21.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-100% A	22.66	5.88	5.33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-100% B	31.66	31.40	n.d.	n.d.	1.36	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-120% A	19.48	23.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-LS-120% B	40.37	30.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-HS-0560345 6071989	133.47	89.20	n.d.	n.d.	0.33	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	**TNT**		**RDX**		**AMINO's**		**TETRYL**		**HMX**	
	RDDC	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Bravo										
S-BR-T-A1	22.17	17.10	n.d.	n.d.	1.77	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A1 DUP	8.37	10.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-T-A2	3.44	2.68	n.d.	n.d.	1.19	n.d.	n.d.	n.d.	n.d.	n.d.
S-BR-HS-0560425 6071964	223.44	246.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Shaver range										
S-SR-LS-0% A	9.75	13.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-0% B	26.12	10.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-20% A	15.11	20.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-20% B	n.d.	3.84	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-40% A	13.86	8.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	19.45	20.40
S-SR-LS-40% B	n.d.	8.30	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% A	48.34	35.40	1.38	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% A DUP	11.43	7.24	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-60% B	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-80% A	545.54	10900	n.d.	n.d.	n.d.	1734	n.d.	n.d.	n.d.	n.d.
S-SR-LS-80% B	53.13	40.20	n.d.	n.d.	n.d.	5.68	n.d.	n.d.	n.d.	n.d.
S-SR-LS-100% A	37.03	23.40	n.d.	n.d.	n.d.	11.14	n.d.	n.d.	n.d.	n.d.
S-SR-LS-100% B	995.56	14500	120.04	288.00	n.d.	305.00	n.d.	98.8	n.d.	53.80
S-SR-LS-100% B DUP	65.43	298.00	75.91	n.d.	153.05	234.00	n.d.	n.d.	n.d.	n.d.
Open detonation										
S-SR-OD-1	8.08	14,3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-OD-2	530,0	516,0	n.d.	n.d.	n.d.	4,96	n.d.	n.d.	n.d.	n.d.
S-SR-OD-3	3860,0	65,8	820,0	196,0	4.59	n.d.	330,0	n.d.	n.d.	n.d.
Jimmy Lake										
S-JL-T1-A1	93.09	69.80	n.d.	n.d.	7.77	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-B2	250.49	216.00	n.d.	n.d.	1.16	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-B5	60.90	76.40	n.d.	n.d.	1.08	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-B8	18.01	15.00	n.d.	n.d.	1.14	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C3	0.51	2.90	n.d.	n.d.	1.44	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C7	17.77	2.44	n.d.	n.d.	0.61	n.d.	n.d.	n.d.	n.d.	n.d.
S-JL-T1-C12	145.79	202.00	8.11	n.d.	0.90	n.d.	n.d.	n.d.	n.d.	n.d.

TABLE VIII A: EXPLOSIVES IN SHAVER RANGE SOILS BY HPLC IN PPM (NG TO TNB)

Sample	**NG**	**1,3-DNB**		**2,6-DNT**		**2,4-DNT**		**1,3,5-TNB**	
	CRREL	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Shaver Range									
S-SR-T-A1	n.d.	n.d.	n.d.	n.d.	n.d.	0.33	0.15	0.07	0.06
S-SR-T-A1 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	0.32	0.15	0.19	0.12
S-SR-T-A2	n.d.	n.d.	n.d.	n.d.	n.d.	0.37	0.19	0.79	0.09
S-SR-T-B1	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	0.20	0.67	0.10
S-SR-T-B2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	0.53	0.12
S-SR-T-B3	n.d.	n.d.	n.d.	n.d.	n.d.	0.35	0.17	n.d.	n.d.
S-SR-T-B4	n.d.	n.d.	n.d.	n.d.	n.d.	0.41	0.30	0.49	n.d.
S-SR-T-B5	n.d.	n.d.	n.d.	n.d.	n.d.	0.46	0.36	0.48	n.d.
S-SR-T-B5 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	0.73	0.20	0.51	0.49
S-SR-T-B6	n.d.	n.d.	n.d.	n.d.	n.d.	0.67	0.13	n.d.	n.d.
S-SR-T-B7	n.d.	n.d.	n.d.	n.d.	n.d.	0.69	0.20	0.68	0.21
S-SR-T-B8	n.d.	n.d.	n.d.	n.d.	n.d.	0.18	0.15	4.81	n.d.
S-SR-T-C1	n.d.	n.d.	n.d.	n.d.	n.d.	0.20	0.15	n.d.	0.52
S-SR-T-C2	n.d.	0.45	n.d.	n.d.	n.d.	0.65	0.14	0.83	n.d.
S-SR-T-C3	n.d.	n.d.	n.d.	n.d.	n.d.	0.56	0.37	0.86	0.49
S-SR-T-C4	n.d.	0.30	n.d.	n.d.	n.d.	0.04	0.07	0.29	0.15
S-SR-T-C5	n.d.	n.d.	n.d.	n.d.	n.d.	0.35	0.31	0.61	0.19
S-SR-T-C6	n.d.	0.31	n.d.	n.d.	n.d.	0.07	n.d.	0.15	0.18
S-SR-T-C7	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	3.04	0.70
S-SR-T-C8	n.d.	n.d.	n.d.	n.d.	n.d.	0.24	0.19	0.15	0.19
S-SR-T-C9	n.d.	n.d.	n.d.	0.27	n.d.	0.27	n.d.	0.57	0.13
S-SR-T-C10	n.d.	0.28	n.d.	n.d.	n.d.	0.50	0.23	1.45	n.d.
S-SR-T-C10 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	0.38	0.23	1.33	n.d.
S-SR-T-C11	n.d.	n.d.	n.d.	n.d.	n.d.	0.38	n.d.	n.d.	n.d.
S-SR-T-C12	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	0.16	0.28	0.20
S-SR-T-C13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-T-C14	n.d.	0.55	n.d.	n.d.	n.d.	0.47	n.d.	n.d.	n.d.
S-SR-T-C15	n.d.	n.d.	n.d.	n.d.	n.d.	0.76	n.d.	n.d.	n.d.
S-SR-T-C16	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	n.d.	n.d.	n.d.
S-SR-LS-120% A	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	0.09	n.d.	n.d.
S-SR-LS-120% B	n.d.	n.d.	n.d.	n.d.	n.d.	0.45	0.23	n.d.	n.d.
S-SR-LS-140% A	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-LS-140% B	n.d.	n.d.	n.d.	n.d.	n.d.	0.29	n.d.	n.d.	n.d.
S-SR-T-W1-SURF	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,13	n.a.	0,10
S-SR-T-W1-D2	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.
S-SR-T-W1-D3	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,17	n.a.	0,18
S-SR-T-W1-D4	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,58
S-SR-T-W2	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,13	n.a.	0,09
S-SR-T-W3	n.d.	n.d.	n.d.	n.d.	n.d.	0.46	0,23	0.85	n.d.
S-SR-T-W4	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,28
S-SR-T-W5	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,24
S-SR-T-W6	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,25

Sample	**NG**	**1,3-DNB**		**2,6-DNT**		**2,4-DNT**		**1,3,5-TNB**	
	CRREL	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Shaver Range									
S-SR-T-A1	n.d.	n.d.	n.d.	n.d.	n.d.	0.33	0.15	0.07	0.06
S-SR-T-A1 DUP	n.d.	n.d.	n.d.	n.d.	n.d.	0.32	0.15	0.19	0.12
S-SR-T-A2	n.d.	n.d.	n.d.	n.d.	n.d.	0.37	0.19	0.79	0.09
S-SR-T-B1	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	0.20	0.67	0.10
S-SR-T-B2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	0.53	0.12
S-SR-T-B3	n.d.	n.d.	n.d.	n.d.	n.d.	0.35	0.17	n.d.	n.d.
S-SR-T-B4	n.d.	n.d.	n.d.	n.d.	n.d.	0.41	0.30	0.49	n.d.
S-SR-T-W7	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	n.d.	n.a.	0,22

n.d.: not detected
n.a.: not analysed

TABLE VIII B: EXPLOSIVES IN SHAVER RANGE SOILS BY HPLC IN PPM (TNT TO HMX)

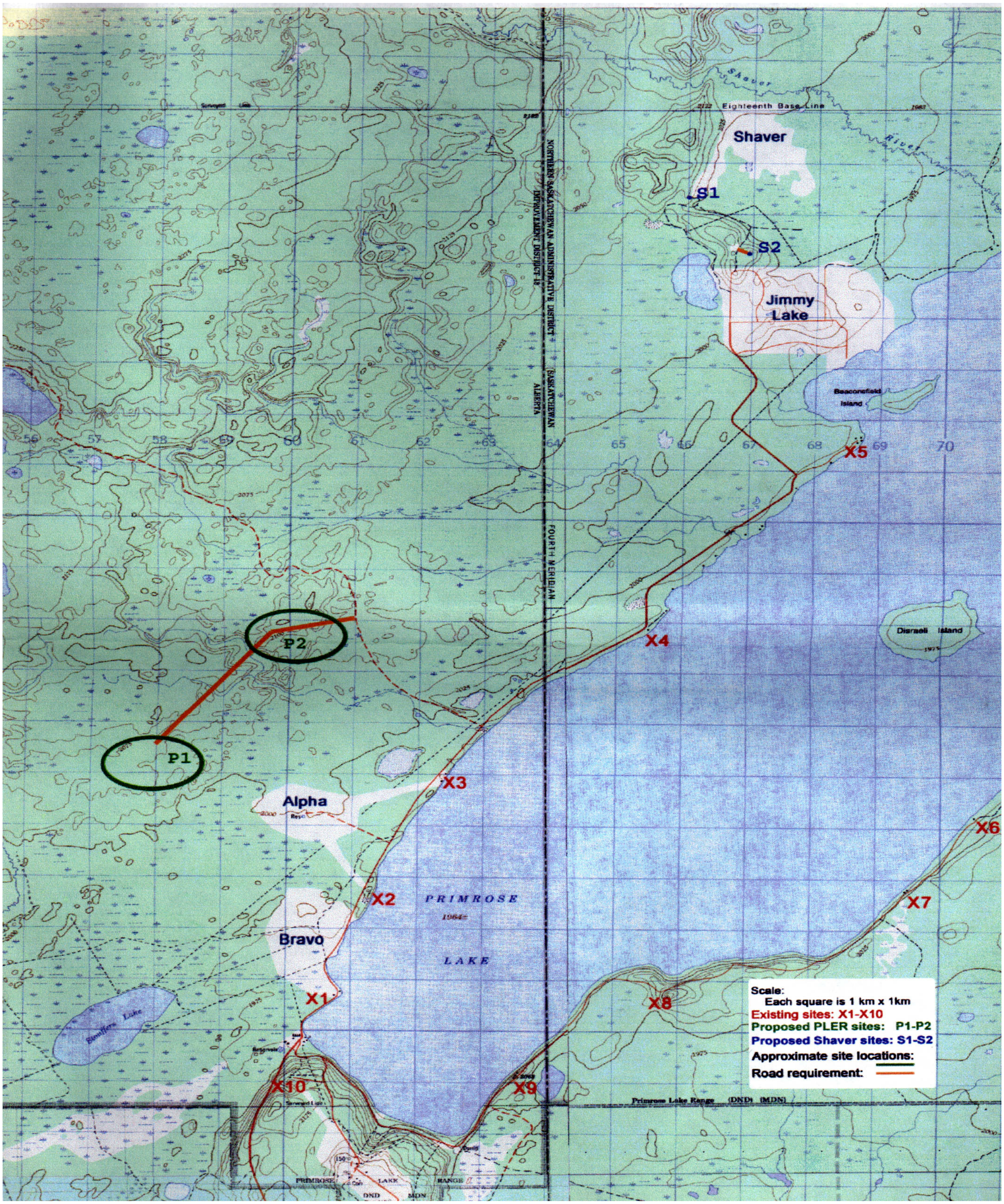
Sample	**TNT**		**RDX**		**2-Amino-DNT**		**4-Amino-DNT**		**TÉTRYL**		**HMX**	
	RDDC	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Shaver Range												
S-SR-T-A1	35.26	58.20	n.d.	n.d.	1.60	1.50	1.12	1.02	n.d.	n.d.	n.d.	n.d.
S-SR-T-A1 DUP	59.71	60.40	n.d.	n.d.	1.97	1.84	1.43	1.33	n.d.	n.d.	n.d.	n.d.
S-SR-T-A2	5.23	6.14	n.d.	n.d.	1.90	2.05	1.31	1.26	n.d.	n.d.	n.d.	n.d.
S-SR-T-B1	12.68	15.40	n.d.	n.d.	1.19	1.32	0.88	0.93	n.d.	n.d.	0.25	0.22
S-SR-T-B2	10.73	19.62	n.d.	n.d.	1.02	1.07	0.62	0.70	n.d.	n.d.	0.28	n.d.
S-SR-T-B3	126.46	149.00	n.d.	n.d.	1.56	1.23	0.80	0.75	n.d.	n.d.	n.d.	n.d.
S-SR-T-B4	88.62	138.00	n.d.	n.d.	1.97	2.06	1.34	1.24	n.d.	n.d.	n.d.	n.d.
S-SR-T-B5	119.85	151.00	n.d.	n.d.	4.06	2.06	1.41	1.35	n.d.	n.d.	n.d.	n.d.
S-SR-T-B5 DUP	111.19	197.00	n.d.	n.d.	1.38	1.34	1.78	0.77	n.d.	n.d.	n.d.	n.d.
S-SR-T-B6	63.57	70.60	n.d.	n.d.	4.42	0.75	1.36	0.44	n.d.	n.d.	n.d.	n.d.
S-SR-T-B7	18.14	25.40	3.00	n.d.	2.05	1.57	1.43	0.93	3.39	0.13	0.56	0.25
S-SR-T-B8	85.71	97.40	1.50	n.d.	1.00	1.06	1.28	n.d.	n.d.	n.d.	n.d.	n.d.
S-SR-T-C1	75.54	92.00	n.d.	n.d.	1.58	0.94	1.96	0.60	n.d.	n.d.	1.46	n.d.
S-SR-T-C2	5.25	3.58	0.83	n.d.	1.65	0.55	1.00	0.44	n.d.	n.d.	0.79	0.12
S-SR-T-C3	500.95	408.00	n.d.	n.d.	0.81	0.49	0.69	0.28	n.d.	n.d.	n.d.	n.d.
S-SR-T-C4	2.42	2.20	0.56	n.d.	1.10	0.57	1.04	0.40	0.32	n.d.	0.40	0.13
S-SR-T-C5	12.38	19.80	n.d.	n.d.	1.10	1.00	0.85	0.53	n.d.	n.d.	n.d.	n.d.
S-SR-T-C6	67.26	70.40	n.d.	n.d.	2.86	1.44	0.49	0.72	n.d.	n.d.	n.d.	n.d.
S-SR-T-C7	65.25	99.20	n.d.	n.d.	2.15	0.91	1.08	0.50	n.d.	n.d.	n.d.	n.d.
S-SR-T-C8	35.71	50.00	n.d.	n.d.	1.33	1.49	0.90	0.74	n.d.	0.07	0.42	0.31
S-SR-T-C9	25.00	29.00	n.d.	n.d.	2.11	1.67	1.17	0.79	n.d.	n.d.	0.29	n.d.
S-SR-T-C10	41.56	58.00	0.15	n.d.	2.19	1.85	1.43	1.07	n.d.	n.d.	0.30	n.d.
S-SR-T-C10 DUP	28.50	41.00	0.26	n.d.	1.63	1.23	1.05	0.90	n.d.	n.d.	n.d.	n.d.

Sample	**TNT**		**RDX**		**2-Amino-DNT**		**4-Amino-DNT**		**TÉTRYL**		**HMX**	
	RDDC	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**	**RDDC**	**CRREL**
Shaver Range												
S-SR-T-A1	35.26	58.20	n.d.	n.d.	1.60	1.50	1.12	1.02	n.d.	n.d.	n.d.	n.d.
S-SR-T-A1 DUP	59.71	60.40	n.d.	n.d.	1.97	1.84	1.43	1.33	n.d.	n.d.	n.d.	n.d.
S-SR-T-A2	5.23	6.14	n.d.	n.d.	1.90	2.05	1.31	1.26	n.d.	n.d.	n.d.	n.d.
S-SR-T-C11	234.73	332.00	n.d.	n.d.	1.38	1.32	0.97	0.79	n.d.	n.d.	n.d.	n.d.
S-SR-T-C12	131.12	153.00	n.d.	n.d.	1.02	0.76	0.63	0.45	n.d.	n.d.	n.d.	n.d.
S-SR-T-C13	84.76	92.60	n.d.	n.d.	0.92	0.79	1.49	0.52	n.d.	n.d.	n.d.	n.d.
S-SR-T-C14	38.89	53.80	0.42	n.d.	1.12	1.21	1.08	0.87	n.d.	n.d.	n.d.	n.d.
S-SR-T-C15	20.95	25.40	0.35	n.d.	0.42	0.64	1.54	0.58	n.d.	n.d.	n.d.	n.d.
S-SR-T-C16	19.16	16.14	n.d.	n.d.	1.23	1.00	0.98	0.63	n.d.	n.d.	0.21	n.d.
S-SR-LS-120% A	127.47	145.00	n.d.	n.d.	0.65	0.32	0.48	0.20	n.d.	n.d.	n.d.	n.d.
S-SR-LS-120% B	45.77	55.60	0.22	n.d.	2.08	1.42	1.27	0.72	n.d.	n.d.	n.d.	n.d.
S-SR-LS-140% A	19.50	21.60	n.d.	n.d.	0.73	0.32	0.53	0.22	n.d.	n.d.	n.d.	n.d.
S-SR-LS-140% B	92.84	106.00	n.d.	n.d.	1.25	1.03	0.88	0.62	n.d.	n.d.	n.d.	n.d.
S-SR-T-W1-SURF	n.a.	6,62	n.a.	1,58	n.a.	1,32	n.a.	0,94	n.a.	n.d.	n.a.	0,39
S-SR-T-W1-D2	n.a.	88,4	n.a.	n.d.	n.a.	1,69	n.a.	0,86	n.a.	n.d.	n.a.	n.d.
S-SR-T-W1-D3	n.a.	8,08	n.a.	n.d.	n.a.	1,74	n.a.	1,11	n.a.	n.d.	n.a.	n.d.
S-SR-T-W1-D4	n.a.	182,0	n.a.	n.d.	n.a.	1,48	n.a.	0,66	n.a.	n.d.	n.a.	n.d.
S-SR-T-W2	n.a.	6,72	n.a.	n.d.	n.a.	1,47	n.a.	1,04	n.a.	n.d.	n.a.	n.d.
S-SR-T-W3	16.70	21.40	0.23	0.13	1.71	1.48	1.27	0.95	n.d.	n.d.	0.28	0.22
S-SR-T-W4	n.a.	62,0	n.a.	n.d.	n.a.	1,72	n.a.	0,83	n.a.	n.d.	n.a.	n.d.
S-SR-T-W5	n.a.	56,4	n.a.	n.d.	n.a.	1,30	n.a.	1,01	n.a.	n.d.	n.a.	n.d.
S-SR-T-W6	n.a.	26,2	n.a.	n.d.	n.a.	1,33	n.a.	0,87	n.a.	0,10	n.a.	0,19
S-SR-T-W7	n.a.	14,3	n.a.	n.d.	n.a.	1,57	n.a.	0,97	n.a.	n.d.	n.a.	0,23

n.d.: not detected
n.a.: not analysed

Appendix A

MAP OF CLAWR


Eighteenth Base Line
Shaver
Shaver River
S1
S2
Jimmy Lake
Beaconsfield Island
NORTHERN SASKATCHEWAN ADMINISTRATIVE DISTRICT
IMPROVEMENT DISTRICT 18
SASKATCHEWAN
ALBERTA
FOURTH MERIDIAN
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
X5
X4
Disraeli Island
P2
P1
Alpha
X3
X6
X2
PRIMROSE
1964
LAKE
X7
Bravo
X1
X8
X10
X9
Primrose Lake Range (DND) (MDN)
PRIMROSE LAKE RANGE
DND MDN
Scale:
Each square is 1 km x 1km
Existing sites: X1-X10
Proposed PLER sites: P1-P2
Proposed Shaver sites: S1-S2
Approximate site locations:
Road requirement:

APPENDIX B

DCC REPORT FOR THE PRELIMINARY PHASE

Introduction:

In 2002, Defence Construction Canada was retained by Defence Research and Development Canada (DRDC - formerly Defence Research Establishment Valcartier) to assist with the characterization of the Cold Lake Air Weapons Range (CLAWR). The characterization involved identifying potential contamination of the CLAWR by energetic materials, metals and related compounds at 4 Wing Cold Lake. The Base Environmental Officer and the Commanding Officer at 4 Wing Cold Lake supported the project on the basis of sustainable development and training for the CLAWR.

The proposed program to fully characterize the range utilizes a systematic approach whereby phasing the project into a five year program. This report was developed to summarize the proceedings of phase O of the IV phase program.

Description of Phase O:

As described in the proposal submitted by DRDC, Phase O included the assessment of metals and energetic materials (E.M) in a limited number of soil samples at areas of main concern within the CLAWR. The assessment was required to provide DRDC with preliminary soil quality data for the CLAWR. This preliminary data helped with the derivation of the subsequent phases of the program.

Prior to collecting soil samples, personnel from DRDC, DND and DCC conducted an initial inspection of the range. DRDC provided their professional opinion on the key locations (i.e., suspect areas of concern) that should be evaluated as part of the Phase O assessment. The main focus areas within the CLAWR were identified as Alpha, Bravo sites within the Primrose Lake Evaluation Range and Jimmy and Shaver River sites within the Jimmy Lake Range. Once prioritized locations were determined, DCC initiated the proceedings of Phase O.

Field Sampling:

Due to the time of year, remoteness of the CLAWR and limited available funding for the year, it was deemed most cost effective for DCC to conduct the field sampling for Phase O. Field work commenced on 05 March, 2002 with the assistance of 4 Wing's Range Control, who provided proofing requirements prior to soil sampling. Fifty-six samples were collected and analyzed for CCME Metals, 11 samples were submitted for physical soil characterization and 29 samples were submitted for energetic compounds. The CCME metals and physical characteristics of soil samples were submitted to an independent laboratory (Enviro-Test in Edmonton, Alberta) and the energetic samples were sent to DRDC for analysis. It should also be noted that approximately 12% of the samples were duplicated as part of the QA/QC program.

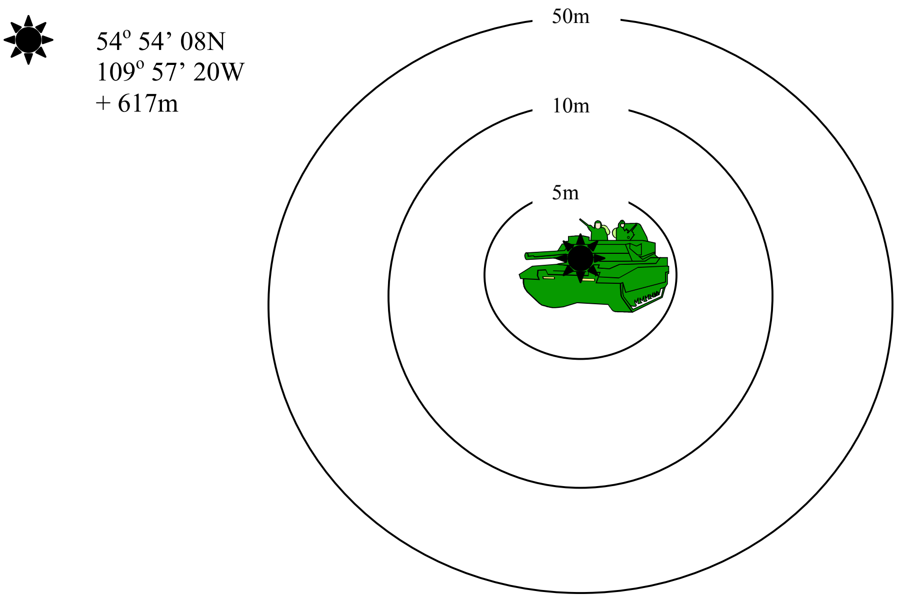
Prior to the commencement of sampling, all equipment was cleaned and sterilized. Physical sampling was done using stainless steel trowels and samples were placed into clean bags as provided by Enviro-Test Laboratories. New, powderless nitrile gloves were worn during each sampling event as well.

The locations of sampling points were GPS referenced using a handheld Gerber GPS unit provided by Range Control. The following is a rendition of the sampling locations with respect to each specified Bombing Range.

Sampling Schematics

Prior to the commencement of sampling, the target located at the center of the circle was pinpointed and referenced using GPS coordination. Once the center of the target was determined, a measurement rope was used to locate sampling distances around the target in a 360° circumference. This was the basis of the sampling at all the target locations. The only variation was the distances that were sampled from the center/target. At these points, grab samples were taken at a minimum of 10 locations surrounding the tank (on the line) to provide a representative sample. Refer to Figure 1:1 below for example diagram of sapling distances from the target.

Figure 1:1 – Example of VIP Sampling Schematics



The remainder of the samples were taken at pinpoint locations with referencing GPS locations. The following table highlights the locations of samples throughout the range.

Sampling Locations:	Sample ID	GPS	Analysis	Comments
BRAVO Range				
Random	DZB-Random1	54°47’33”N 110°03’28”W +605m	CCME	
Background 1	DZB-BG1	54°47’36”N 110°04’13”W +605m	CCME, Physical, Energetics	
Background 2	DZB-BG2	54°47’46”N 110°04’06”W +620m	CCME	
Bombing Circle	DZB-BC	54°47’29”N 110°03’38”W +607m	CCME, Energetics (1.5, 25, 50m)	Samples taken @ 1.5, 25$^{(dup)}$ and 50m intervals
Old Bombing Circle	DZB-Old BC	54°47’37”N 110°03’36”W +605m	CCME, Physical (10m), Energetics (1.5m)	Samples taken @1.5$^{(dup)}$, 10 and 25m intervals
Strafe Pit	DZB-Strafe	54°47’40”N 110°03’40”W +618m	CCME	Samples taken before, after and a composite of both.
Shoreline	DZB-Shoreline	54°47’15”N 110°03’26”W +603m	CCME	Duplicate sample taken.
ALPHA Range				
Bombing Circle	DZA-BC	54°48’47”N 110°03’21”W +613m	CCME, Physical (50m), Energetics (1.5, 25, 50m)	Samples taken @ 1.5, 25, 50m$^{(dup)}$ intervals
Bunker	DZA-Bunk	54°48’47”N 110°03’40”W +615m	CCME, Energetics (1.5, 25m)	Samples taken @ 1.5 and 25m intervals
Random	DZA-Random1	54°48’44”N 110°03’15”W +610m	CCME, Energetics	
Shoreline	DZA-Shoreline	54°48’41”N 110°02’15”W +603m	CCME, Energetics	
Jimmy Lake Range				
Background 1	JLR-BG1	54°54’01”N 110°00’17”W +625m	CCME, Physical	
Background 2	JLR-BG2	54°54’07”N 110°00’17”W +626m	CCME, Physical	

Bombing Circle	JLR- Bomb Circle	Not Available	CCME, Energetics (1.5, 10, 50m)	Samples taken @ 1.5, 10 and 50m intervals
VIP Tank	JLR-VIP	54°54’08”N 109°57’20”W +617m	CCME, Energetics (5, 10, 50m)	Samples taken @ 1.5, 5$^{(dup)}$, 10 and 50m intervals
Jimmy Strafe Range	JLR-Strafe	Not Available	CCME, Physical (Strafe 4)	Samples taken as composites throughout each lanes (1-4) and before the lanes$^{(dup)}$.
Random 1	JLR-Random 1	Not Available	CCME, Physical	
Random 2	JLR-Random 2	54°54’18”N 109°56’50”W +625m	CCME, Energetics	
Random 3	JLR-Random 3	Not Available	CCME, Physical, Energetics	
Foul Line	JLR-Foul Line	54°54’15”N 109°57’43”W +617m	CCME	Taken near Jimmy Lake, towards strafe lanes.
Shaver River Drop Zone				
Bombing Circle (live)	SRR-Bomb Circle	Not Available	CCME, Physical (50m), Energetics (1.5, 25, 50, 100m)	Samples taken @ 1.5, 25, 50, 100m intervals
Disposal Area	SRR-Disposal Area	54°55’28”N 109°57’58”W +630m	CCME, Energetics (1.5, 25, 50m)	Samples taken @ 1.5, 25$^{(dup)}$, 50m
Old Dump Area	SRR-Dump	Not Available	CCME, Energetics	Located West of Bombing Circle
Tritium Hotspot	SRR-Tritium Hotspot	54°55’25”N 109°57’55”W +628m	CCME, Energetics	
Random Range 1	SRR-Random 1	54°56’17”N 109°57’43”W +625m	CCME, Physical	Approximately 100m on West cut line.
Random Range 2	SRR-Random 2	54°54’50”N 109°57’29”W +619m	CCME	South of bombing circle in middle of SRR.
Background 1	SRR-BG	54°56’57”N 110°01’00”W +643m	CCME, Physical	West of Shaver River Range

* CCME- Samples were analyzed in accordance with the Canadian Council For Ministry of the Environment metal scan via ICP/MS Gas Chromatography SW846-3051/6020 methodologies

*Physical- Select samples were submitted for Cation Exchange Capacity, Total Carbon, and Particle Size

* Energetics- Select samples were submitted to Defence Research and Development Canada (Formerly DREV) for analysis of Energetic Materials

Conclusion:

Sampling was completed by Defence Construction Canada 07 March, 2002. A total of fifty-six samples were collected and analyzed by Environ-Test Laboratories from Edmonton, Alberta. All the samples were analyzed for total metals using CCME methodologies and eleven samples were analyzed for physical parameters. Twenty-nine select samples were also sent to DRDC in Valcartier, Quebec for analyses of energetic materials. All sample results from Enviro-Test were compiled by DCC and delivered to DRDC Valcartier for their interpretation.

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This work describes the evaluation of the impacts of the live firing training activities in Cold Lake Air Weapons Range (CLAWR) in Alberta performed during August 02 (Phase I). CLAWR is the biggest air weapon range area in Canada and was the first Canadian Air Force Base to be characterized for explosives and metals. The study was conducted by DRDC-Valcartier in collaboration with the U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research Engineering Laboratory (CRREL), Hanover, NH, and the ERDC Environmental Laboratory (EL), Vicksburg, MS. The problem of Army ranges should be different from that of Air ranges since the Air weapons are different even if filled with the same explosives. Four ranges on the site were visited during August 2002. Alpha, Bravo, Jimmy Lake and Shaver Ranges were sampled for explosives using different strategies. More particularly, intensive efforts were done in the Shaver Range since this range was used mainly for air bombing. A linear transect sampling strategy was used in all ranges to evaluate the progression in explosives concentrations across the ranges. All the samples were built by compositing 20-30 sub-samples. A new circular sampling strategy adapted to the air-bombing situation was achieved by collecting 26 samples around the targets at specific locations. Some soil samples were also collected at different depths in front of the targets. In total, 193 soil samples, 13 biomass samples, and 4 surface water samples were collected during this first phase of the evaluation of this area. Metal analyses were done using Inductively Coupled Plasma /Mass spectrometer (ICP/MS) and explosives concentrations were done using the Gas Chromatography/Electron Capture Detector (GC/ECD) method developed at CRREL.

Ce travail décrit l'évaluation de l'impact des activités d'entraînement par tir réel faites au secteur d'entraînement des forces de l'air à Cold lake (CLAWR) effectuée en août 02 (Phase I). Le secteur d'entraînement de la base de l'air à Cold Lake est la plus important en surface au Canada et a été le premier à être caractérisé pour la contamination par les explosifs et les métaux. Cette étude a été dirigée par RDDC-Valcartier en collaboration avec le US Army Research and Development Center (ERDC), Cold Regions Research Engineering Laboratory (CRREL) Hanover NH et le ERDC Environmental Laboratory (EL) Vicksburg MS. La problématique des sites d'entraînement de l'armée devrait être différente de celle de l'air compte tenu qu'ils utilisent d'autres types de munitions même si celles-ci contiennent les mêmes explosifs. Quatre champs de tir du secteur ont été visités en août 2002. Les champs de tir Alpha, Bravo, Jimmy Lake et Shaver ont été échantillonnés en utilisant différentes stratégies pour les explosifs. Plus particulièrement, des efforts plus intenses ont été faits pour échantillonner Shaver car celui-ci est principalement utilisé pour le largage de bombes réelles. La stratégie d'échantillonnage par section transversale linéaire a été appliquée à tous les champs de tir pour évaluer la progression des concentrations en explosifs tout au long des champs de tir. Tous les échantillons ont été construits de 20-30 sous-échantillons. Une nouvelle stratégie d'échantillonnage circulaire qui tient compte de l'approche aérienne dans le largage des bombes a été appliquée autour des cibles en recueillant 26 échantillons à différentes locations. Quelques échantillons de sols ont également été prélevés à différentes profondeurs en face des cibles. Au total, 193 échantillons de sols, 13 échantillons de biomasse et 4 échantillons d'eaux de surface ont été prélevés durant cette première phase de la caractérisation de ce secteur. Des analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les explosifs ont été analysés par la méthode de chromatographie gazeuse/détecteur à capture d'électron (CG/DCE) développé à CRREL.

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