DEVELOPMENT OF METHODOLOGIES AND TECHNOLOGY FOR SUPPORTING CLEARANCE OF LANDMINES AND UNEXPLODED ORDNANCE IN VIET NAM

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Front cover legend - see overleaf.

Front Cover:

1) Children in the Aluoi Valley.
2) UXO collected near the former US Special Forces base, A So, Aluoi Valley.
3) Deminer in the Aluoi Valley.
4) Cluster bomb victim, Aluoi Valley.
5) Bombing target coordinates over Indochina during the Viet Nam conflict (each dot represents a bombing event).

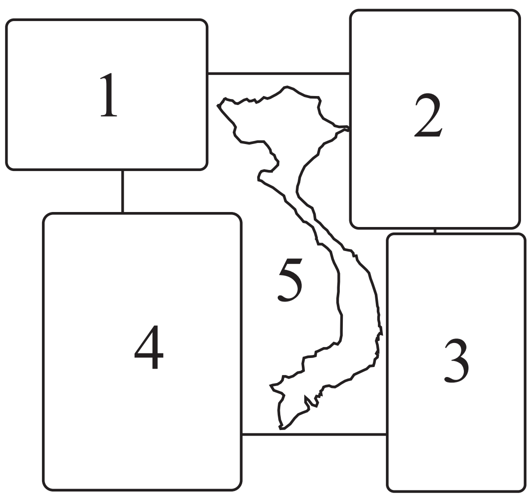

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Photo #2 - Dave McCracken.
Image #5 - Federal Resources Corporation Ltd., Washington D.C.

Cover Design - L. Wayne Dwernychuk, Hatfield Consultants Ltd.

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The politics of Agent Orange/dioxin and unexploded ordnance (UXO) cleanup in Viet Nam have produced only limited results to date. Very large areas of the country remain contaminated.

During our earlier Agent Orange investigations, it became clear that UXO was a significant issue in the Aluoi Valley. As a result, our team initiated a project to develop methods to assist deminers when working in chemically contaminated soils.

As outlined in our report, an average of 2,000 people per year are casualties of accidental UXO encounters in Viet Nam. Approximately 65,000 Vietnamese (primarily children and family bread winners) have been victims of UXO detonations since the end of the war. Approximately 40,000 of these incidents have resulted in death, 25,000 in maiming.

The US military had such superior fire power during the conflict that the vast majority of the UXO left in Viet Nam is of American origin. The most destructive weapons over time are the cluster bombs, containing 700 to 800 bomblets (like small hand grenades) which were scattered over the countryside from each cluster bomb that was dropped. The bomblets of these "slow weapons of mass destruction", as some people have called them, were developed by academics in the Physics Department of Princeton University.[1]

The maximum destructive power of cluster bombs for human killing and maiming was perfected by, among other things, exploding prototypes near anesthetized cats. This was undertaken in order to determine penetration distance, necessary explosive loads and tissue damage caused by their metal pellets. These experiments could be precisely evaluated to increase killing efficiency. This killing efficiency continues, 30 years later.

The ongoing carnage caused by UXO in Viet Nam, and the continuing increased risk to human health caused by Agent Orange dioxin, is morally indefensible.

The contamination by dioxin and UXO is a current problem, not an historical war-time issue. Positive changes to the way many people in the world perceive US actions would likely result from the implementation of serious cleanup programs of both types of war-time contamination in Viet Nam. It is widely recognized that the poorest segments of societies in many post-conflict countries continue to be victims of actions taken long ago by rich and powerful nations, particularly the US. If, for ideological or political reasons, such a cleanup becomes a component in the "War on Terrorism", and results in an improved global image of the US and the west, in general, then so be it, but lets get on with it!

Chris Hatfield, CEO
Hatfield Consultants Ltd.

[1] Prokosch, E. 1995. The Technology of Killing - A Military and Political History of Antipersonnel Weapons. Zed Books. London. 224 p.

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- Mr. Christopher Hatfield, Chief Executive Officer and Senior Biologist;
- Dr. Wayne Dwernychuk, Senior Vice President and Senior Environmental Scientist;
- Mr. Tom Boivin, President and Senior Environmental Specialist;
- Mr. Grant Bruce, Vice President and Senior Environmental Chemist;
- Mr. John Villamere, Senior Environmental Engineer;
- Mr. Martin Davies, Senior Environmental Specialist;
- Mr. Andrew Allan, Environmental Biologist;
- Mr. Garth Taylor, Environmental Biologist;
- Ms. Susan Stanley, GIS/AutoCAD Specialist; and
- Ms. Gaetane Claude, report production assistant.

BACKGROUND

> *"Not only do these abominable weapons lie buried in silence and in their millions, waiting to kill or main innocent women and children; but the presence – or even the fear of the presence – of a single landmine can prevent the cultivation of an entire field, rob a village of its livelihood, place yet another obstacle on a country's road to reconstruction and development."*
>
> *UN Secretary General of the United Nations, Kofi Annan describing the world UXO/landmine situation. (UN 1999)*

Residents of post-conflict areas of the world often continue to suffer from the impacts of war, long after the guns have been silenced. Highly visible impacts such as damaged or destroyed buildings, bridges, roads, etc., are fairly easy to assess and rectify. It is the economic, social and environmental impacts resulting from war that are far more difficult to quantify and mitigate. These less visible impacts are often not properly considered during post-conflict remediation. Unexploded ordnance (UXO) and chemical contamination are insidious threats that need to be properly integrated into reconstruction efforts. These hidden threats create an atmosphere of fear and uncertainty among local residents and potential investors, which inhibits rehabilitation and agricultural/economic development of impacted lands or increases the cost of remediation to unreasonable levels. Proper planning and integration of environmental considerations at an early stage can significantly reduce the time and cost required to restore environments impacted by war.

(Source: D. McCracken)

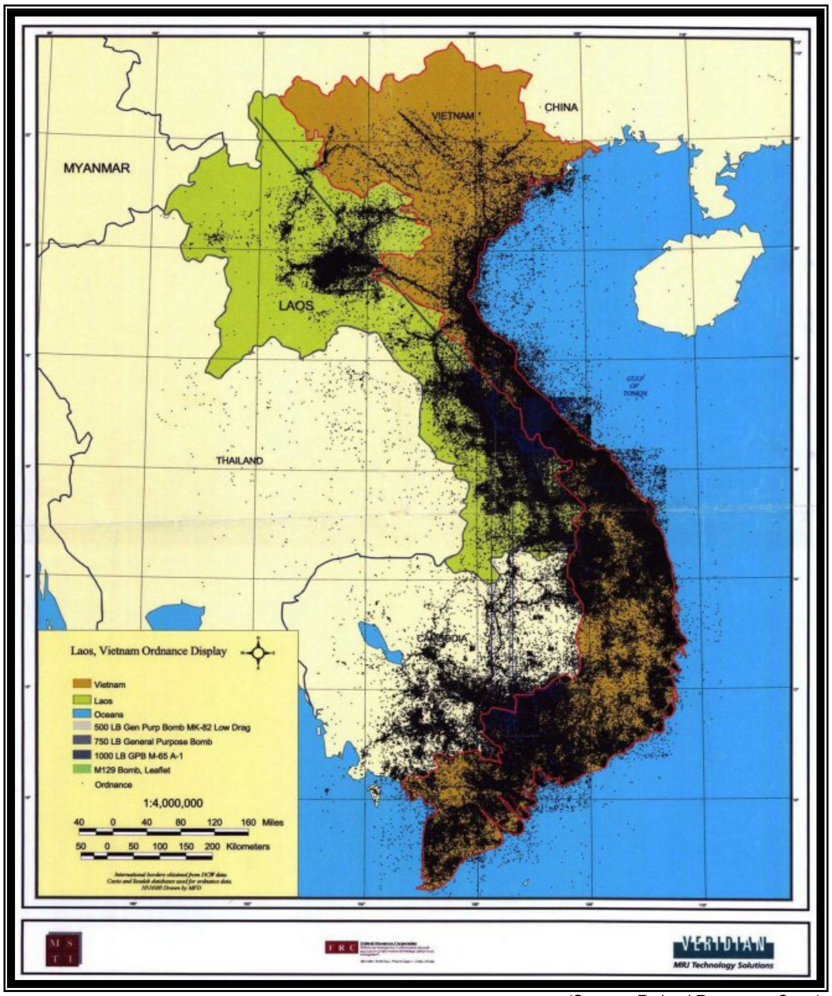
Anti-personnel (AP) mines uncovered during clearance operations near Hong Thuong Commune.

This project focused on the development and testing of methods which should be incorporated into current protocols for UXO removal in Viet Nam and elsewhere; these include: (i) novel mapping and data integration techniques using historical, declassified, and modern information to allow better definition of UXO contamination areas and types of UXO likely present; (ii) locally-relevant slope stabilization, site remediation, and environmental monitoring techniques for use in UXO clearance, to ensure land may be fully returned to productive use after UXO removal; and (iii) assessment and screening procedures to determine risk of exposure and contamination from dioxins residual in the environment from war-era applications of herbicide (specifically Agent Orange). Application of these approaches in future UXO programs should result in: (a) better-defined and more cost-effective UXO survey and removal programs; (b) more secure livelihoods for local people in UXO clearance areas through effective land rehabilitation; and (c) protection of the environment, local people, and deminers themselves from exposure to highly toxic and chemical contaminants that may be carcinogenic.

CONTINUING IMPACTS OF WAR IN VIET NAM

The International Committee of the Red Cross (ICRC) estimates that presently there are in excess of 110 million anti-personnel mines located in 64 countries worldwide, including Viet Nam. The Landmine Monitor Report for 2000 published by the International Campaign to Ban Landmines, reports new landmine victims in 71 different countries in 1999-2000. In addition, unexploded ordnance (UXO) such as bombs, artillery shells, grenades, and other leftover war materiel continue to pose a severe threat to people and livelihoods in post-conflict countries. According to ICRC, approximately 30,000 people are killed or maimed by UXO each year throughout the world; of this figure, 10,000 may be fatalities.

Viet Nam remains highly contaminated with UXO and landmines, almost thirty years after the end of the US-Viet Nam Conflict (1961-1975). Approximately eight million tons of ordnance were dropped on Indochina during the Viet Nam war, compared to four million tons dropped by US and UK forces in World War II in all theatres. More than half of this total was dropped on South Viet Nam, approximately one million tons on North Viet Nam, and two million tons on Lao PDR and Cambodia. In addition, approximately eight million tons of US artillery was used in South Viet Nam. It is estimated that 350,000 tons of UXO remain hidden in the country.



(Source: Federal Resources Corp.)

Aerial bombing coordinate data for Viet Nam, Lao PDR and Cambodia.

The Landmine Monitor Report also estimated that at least 5% of Vietnamese territory has been affected by landmines and UXO, or a total of 16,478 km^2 (5,932 squares miles). Most ordnance fell in jungle and rural areas rather than cities. UXO is scattered throughout all 61 provinces and major cities. According to a nationwide survey conducted in 1999 by the Ministry of Labour, War Invalids and Social Affairs, over 38,000 people have been killed and more than 64,000 have been injured by landmines and UXO since the end of the Viet Nam War, which is equivalent to approximately 180 casualties per month.

Despite extensive efforts since the end of the war, only a fraction of the land area containing landmines and UXO have been thoroughly cleared and are considered safe for human habitation and use. To complicate the problem, demining and/or UXO clearance may be carried out in soils contaminated with war-related chemicals. Studies have shown that many of these chemicals are harmful to human health and local environments. In Viet Nam, widespread soil contamination results from herbicide applications (e.g., Agent Orange contaminated with dioxin), anti-personnel agents, and residual blast munitions used during the war. Contamination is generally most severe in or near the many former US and South Vietnamese military bases, and battle fields. Local farmers and minority people now inhabit many of these impacted areas; these people are often the poorest members of society, who have little alternative but to reside in or near areas of UXO or chemical contamination.

(Source: E.W. Pfeiffer)

C-123 aircraft applying herbicide over upland forest in Viet Nam,

PROJECT GOALS: ENHANCING APPROACHES TO MINE ACTION

In Viet Nam, the goal of poverty reduction through assessment and mitigation of war-related impacts is shared by many. Vietnamese government agencies, foreign aid organizations, international finance institutions, NGOs and most of all, impacted communities, all stand to benefit from the development of well designed methodologies for assessing and mitigating the environmental impacts of war. Given that approximately 50% of all developing countries are in a conflict or post-conflict situations, and that landmines, UXO and chemical contamination remain threats long after hostilities end, there is an urgent need to develop methodologies and technologies to assist deminers deal with this enormous problem.

Landmine and UXO clearance is time-consuming and costly. Deciding priority areas for clearance is essential to ensure effective use of limited financial resources. In Viet Nam, schools, health clinics, markets and other public areas have been cleared on a priority basis. Land for agriculture and rural development projects can only be cleared as funding permits. Out of necessity, most UXO clearance in Viet Nam has had to be performed on a limited budget, using outdated technology. At present, civilians who discover a mine or bomb are instructed to inform the local military, which then clears the site. However, the response time is often slow, and demand for their services is high. In some cases, local people take the situation into their own hands, and dispose of the UXO or landmines themselves, or call on the numerous scrap collectors and do-it-yourself deminers. The consequences are all-too-often fatal.

No nationwide UXO survey has been conducted in Viet Nam, given lack of budget. The Vietnamese National Ministry of Defense estimates that complete clearance would take several decades, at a cost of $4 to $15 billion US. The Vietnamese Government states they have expended approximately $10 to $50 million US per year on military UXO clearing since the end of the war (ICBL 2000). It is estimated that 15-20% of explosives left by the war have been cleared to date, accounting for 7-8% of the country's total land area.

Effective clearance of unexploded ordnance requires knowledge of where UXO may exist, the quantity and type of UXO located in an area, prevailing natural conditions in target areas (e.g., land cover and physical conditions), and the characteristics and activities of people living in UXO-contaminated areas. Without such knowledge and understanding, problems of UXO contamination, and how to address them, may be overwhelming, particularly in countries such as Viet Nam, where large amounts of UXO remain dispersed over large areas.

With the overall goal to improve landmine and UXO clearance activities in Viet Nam, Hatfield Consultants Ltd. (HCL) of Canada, in association with the 10-80 Division of the Viet Nam Ministry of Health and the Hue Provincial Department of Planning and Investment (DPI), undertook this project in 2002. Primary objectives were to develop and test methodologies to better define landmine, UXO and chemically contaminated areas in the Aluoi District (Thua Thien Hue Province), and to better integrate environmental and social considerations into mine action activities. The intent of this project was to provide a systematic, integrated approach to UXO/landmine clearance. Mine action teams need to be aware of the possible presence of toxic chemicals in UXO and landmine contaminated soil. Our team therefore developed mitigation procedures that will help protect landmine clearance personnel, and prevent the re-mobilization of dioxin into the environment.

The key goals for this project were to:

- protect clearance teams from increased risk to health, which may be caused by chemical contamination in areas being cleared of UXO and landmines;
- reduce the risk of increased chemical contamination of the environment which in-turn may prevent further contamination of agricultural soils, water resources, food sources and eventually human tissues;
- develop methods to better identify and define the extent and distribution of UXO contamination, through use of novel mapping and spatial data integration techniques;
- introduce methods of erosion control and site rehabilitation that will allow local residents to re-settle UXO contaminated land once it has been cleared; and
- enable local residents to make land use decisions with the prospect for an increased level of self-sufficiency (i.e., to help break the cycle of poverty).

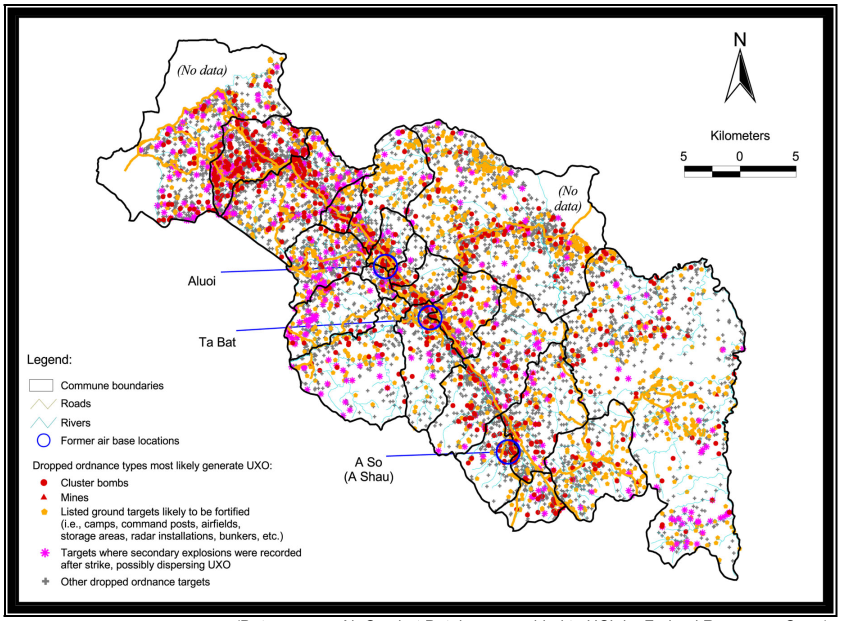
The tools and technologies developed under this project were designed to: assist mine clearance teams identify and delineate UXO/landmine and chemically contaminated areas; facilitate procedures for clearing UXO and landmines in soils which are chemically contaminated; and present methods for the rehabilitation of cleared areas for future land uses. Project results and information collected were displayed using advanced geographic information systems (GIS), a tool which can be used by demining teams to better plan and execute mine action programs in this area of Viet Nam in future. The GIS integrated a variety of data sources related to the landmine/UXO and chemical contamination issue in Aluoi Valley, including: historical data on military activities and impacts (from declassified US army records and war-era information); modern satellite remote sensing imagery collected from the study area; results of detailed community interviews with Aluoi residents, describing UXO presence and impacts; and environmental information to assist with demining activities and remediation of two test sites in Aluoi District.

The key outcomes of the project were:

- creation of GIS outputs (i.e., maps, images and charts) indicating areas of potentially high UXO and chemical contamination in relation to present land use activities in Aluoi District;
- development and implementation of a UXO/landmine awareness and education program for Aluoi District;
- development of an appropriate environmental management (i.e., soil screening and site selection procedures) and site rehabilitation plans for UXO clearance activities in Aluoi District;
- training of Vietnamese personnel in the applications of these methodologies and technologies; and
- field-testing of methodologies developed; two 1 hectare (ha) sites in Aluoi District were screened for dioxin contamination, cleared of UXO, rehabilitated to prevent

soil erosion and re-vegetated with agricultural crops.

Viet Nam is a conducive test area for assessment of the effectiveness of novel approaches and technologies to support UXO removal activities for various reasons, including an active government infrastructure with a clear, directed interest in addressing UXO concerns and supporting UXO-related activities, highly-educated technical personnel with the capacity to understand and implement any valuable new approaches tested, existence of extensive baseline geographical, sociological, and physical data that may be used in the project, and, significantly, extensive and accessible historical American military records documenting war-time activities, facilities, and conditions in Viet Nam.



(Data source: Air Combat Database, provided to HCL by Federal Resources Corp.)

Air combat targets by category of ordinance and target descriptions.

The Extent of UXO and Chemical Contamination in Aluoi District, Viet Nam

Landmines, Unexploded Ordnance and Other War Materiel

Aluoi District, in central Viet Nam's Thua Thien Hue Province, covers 116,642 ha. Its main feature is the Aluoi Valley, which is approximately 30 km long, 3 to 6 km wide and surrounded by mountains ranging in height from 700 m to more than 1,000 m. There is no industrialization in the Aluoi Valley; agricultural pesticides are seldom used. While portions of the valley floor are utilized for agriculture, many areas with potential for agricultural development remain unused due to the presence of UXO. However, with an increasing shortage of available land, local inhabitants are farming unsafe areas out of necessity. The area has an agriculture-based economy, and includes numerous minority groups including Pa Co, Ta Oi and Ca Tu, as well as increasing numbers of Kinh people.

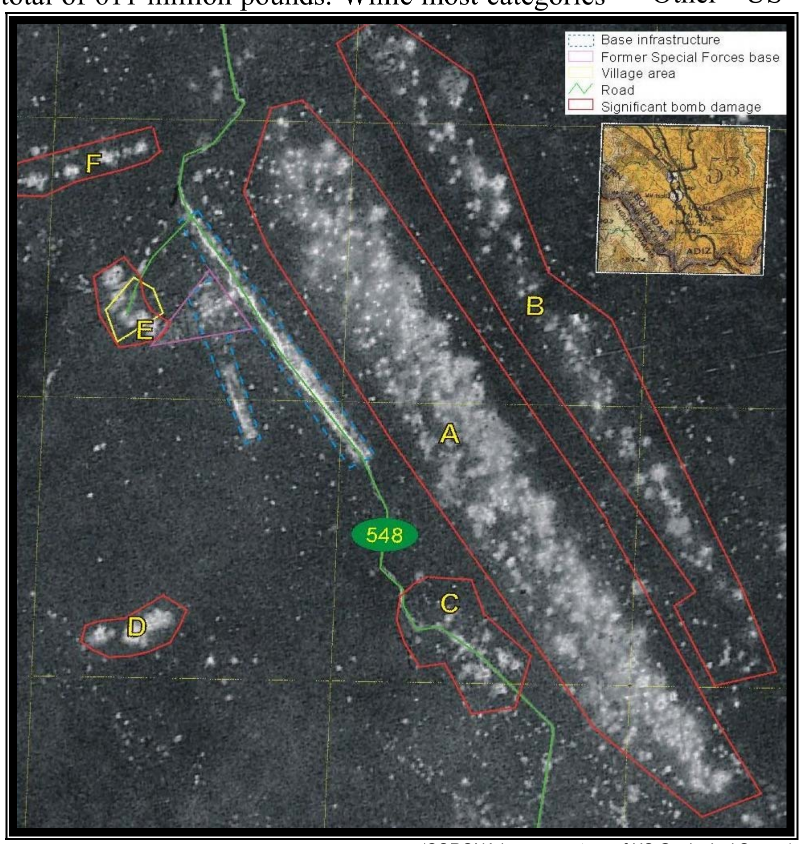
Prior to the war, many affected areas within the Aluoi Valley contained ecologically diverse ecosystems, including extensive forest and natural habitats. These ecosystems were substantially altered or destroyed as a result of military operations, including extensive use of Agent Orange herbicide. The strategic importance of the Aluoi Valley on the Ho Chi Minh trail (which passed through a series of road and trail networks in North and Central Viet Nam, as well as eastern Lao PDR and Cambodia) resulted in this area receiving extensive military activity throughout most of the US-Viet Nam war period.

The occupation of Aluoi Valley by American troops (1963 to 1966) consisted of three American Special Forces (SF) camps and airfields at Aluoi (near modern Aluoi town centre), Ta Bat (near modern Hong Thuong Commune) and A So (near modern Dong Son Commune). Though numerous operations were mounted in the valley by US forces, the NVA never relinquished complete control, and all US SF camps and airfields were closed by March 1966 due to military pressure.

For two years after March 1966, the Aluoi Valley was almost completely under NVA control. However, starting in May 1968 and continuing until March 1971, US forces (1st Calvary and 101st Airborne Divisions) began a number of operations directed at stemming the flow of soldiers and supplies along the Ho Chi Minh Trail. The most notable conflicts of this period were the battles at Bloody Ridge (Dong A Tay) in March 1969, and Hamburger Hill (Dong Ap Bia) in August 1969. No further major ground combat actions were undertaken by American/South Vietnamese forces in the area after this time, although aerial bombardment of the valley by American forces increased significantly.

An analysis of declassified historical US air combat data revealed that a total of 20,611 air combat missions were conducted over Aluoi District between 1965 and 1973. These air combat missions involved 38,258 aircraft flights, which utilized 302,091 pieces of ordnance, weighing a total of 611 million pounds. While most categories of ordnance targeted at Aluoi District increased in total pieces and weight from 1969 to 1972, cluster bombs and, in particular, large general purpose bombs, increased greatly in their use over this time, consistent with increased use of B-52 strategic bombers carrying larger, heavier loads. Likely targets of these large bombs and cluster munitions were NVA troops and materials traveling through Aluoi Valley along its portion of the Ho Chi Minh Trail.

Based on GIS analysis of the air combat database alone, these records suggest that the central and northern Aluoi valley, and Hong Van commune in particular, likely contain the largest number of unexploded bombs, cluster bomblets, and other air ordnance in Aluoi District. Of all categories of air combat ordnance listed in the air combat database, cluster bombs and air-dropped mines likely pose the greatest threat of creating hazardous, accidental encounters between local people and UXO.



(CORONA image courtesy of US Geological Survey)

Declassified Corona Imagery of A So (A Shau) Special Forces base (abandoned), acquired 20 March 1969.

Other US historical war records (including informal, general or anecdotal information) were identified and accessed and used to guide UXO assessment and removal efforts. These include historical aerial photography, Corona spy satellite imagery, civilian earth-observation data from the early 1970s, military grid coordinate data describing installation, fire support base, and landing zone locations, and operations reports, including an after-action report related to the battle for the A So (A Shau) base in Aluoi Valley. Through compilation, integration and comparison, this information was extremely valuable for defining the likely scope and scale of UXO contamination issues in Aluoi District.

The identified spatial data sources and mapping methods developed in this project likely could be applied equally effectively throughout Viet Nam and in other war-affected areas of the globe.

Community Surveys and Landmine/UXO Awareness Programs

Given the numerous potential sources of UXO contamination from ground and artillery activities, and the lack of precise information on risk areas in some former combat zones, it is essential that field surveys and community interviews be undertaken to verify the extent of the problem in any given area. Our project therefore also included detailed community surveys in all 21 communes in Aluoi District to better delineate the extent of the UXO and landmine problem in the area.

(Source: 10-80 Division)

Aluoi Valley resident participating in the UXO Awareness and Education Program (May 2001).

Results of the community survey included the following:

- most residents of Aluoi District have seen UXO, and over 1,000 UXO accidents involving local residents were reported;
- UXO are seen in all areas in the valley, with the majority of UXO sighted in agricultural and forested land, but a proportion observed near homes and along roads;
- generally, UXO of all possible types used in the American war have been observed by Aluoi residents, in almost all communes of the District; and
- approximately 50% of all types of UXO observed in Aluoi District are air combat ordnance, with other ordnance being related to ground combat or position defense (e.g., mortars, grenades, mines) or artillery.

This last point strongly underscores the extent of the UXO problem in Aluoi District. Given 611 million pounds of air ordnance was targeted at Aluoi District during the war, and that air ordnance constitutes approximately half of all UXO reports in Aluoi valley, the magnitude of the UXO contamination problem in Aluoi District is huge.

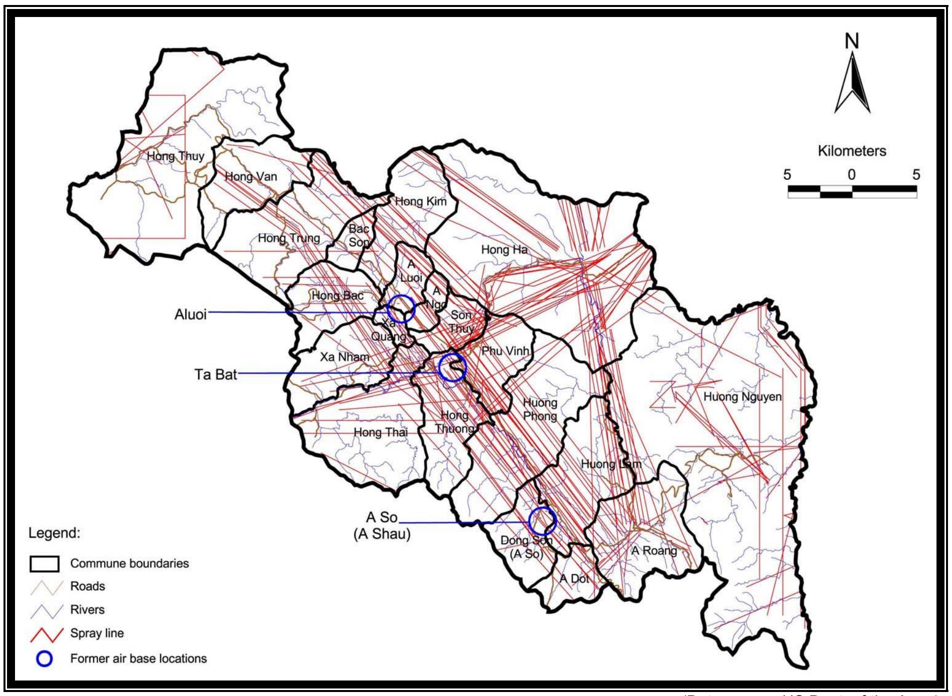
To ensure local residents understood the extent of the problem in Aluoi District, we conduced a Landmine/UXO Awareness Program according to UNICEF's International Guidelines for Landmine and Unexploded Ordnance Awareness Education. A District-wide UXO awareness and education program (UAEP) was designed to target community members most at risk, while identifying the social and economic situations that may be the source of high risk behavior. The UAEP provided educational information and emphasized effective dissemination of knowledge to all Aluoi District communes. Media products produced for the Aluoi District UAEP included pictorial booklets, posters, billboards and video/cassette tapes, and was well received in the District.

The Agent Orange Dioxin Problem in Aluoi District

Approximately 76 million litres of herbicides were sprayed over 10-14% of southern Viet Nam during the US-Viet Nam war, primarily to remove forest cover, but also to destroy rice crops used by NVA. Agent Orange, a 50/50 mixture of 2,4,5-T and 2,4-D herbicides, was the most heavily utilized, accounting for 61% of the total volume expended from 1962 to 1971. Dioxin (2,3,7,8–tetrachlorodibenzo-*p*-dioxin or TCDD) was a contaminant by-product of the manufacturing process present in Agent Orange. Dioxins are a family of chemicals that have been associated with serious health effects in humans.

Ten provinces in southern Viet Nam received an estimated 47% of all Agent Orange herbicide applications, with Song Be, Thua Thien Hue (which includes the Aluoi valley) and Binh Dinh being the most targeted provinces. Aluoi valley received 224 of the 606 missions in Thua Thien Hue province, which resulted in a change of dominant land cover from dense forest to open grass and shrubland in much of Aluoi District. Previous investigations by Hatfield Consultants Ltd. and 10-80 Division in Aluoi District have revealed persistent and on-going contamination of soil, biota, and humans with dioxins, that is most likely associated with exposure to Agent Orange. When consideration is given to demining in Aluoi District, and other areas of southern Viet Nam, it is therefore important to address potential residual dioxin contamination, in order to minimize potential exposure of deminers and local people to this contaminant. Furthermore, if precautions are not taken, demining activities also may remobilize dioxins currently trapped in soil into the environment and food chain.

Based on our previous studies, there appears to be two major types of dioxin contamination in Aluoi District due to herbicide application: first, low-level contamination in areas that received aerial applications of herbicides during the war; and second, potentially high contamination in areas surrounding war-era Special Forces bases, where ground application and storage of herbicides may have occurred.



(Data source: US Dept. of the Army)

Aerial herbicide applications in Aluoi Valley, 1965-1973.

A hazard map was developed for Aluoi District describing potential risks to demining activities from residual dioxin contamination from herbicide applications. Areas that received aerial application of herbicides were considered to pose a moderate risk to demining activities from residual dioxin contamination, while areas of highest potential risk were in the vicinity of the former Special Forces bases of A So (A Shau), Ta Bat, and Aluoi, where high levels of dioxins in soils have been documented. Deminers should use caution and protective clothing when working in contact with soils in these areas, particularly in areas near the former US bases.

This generalized herbicide contamination risk map can be used as part of a General Mine Action Assessment to determine areas where additional risks may exist for deminers, and to help set priorities and approaches to demining these areas.

Demining and Site Remediation of Pilot Sites in Aluoi District

As part of this project, two pilot sites were selected in Aluoi District to test for dioxin contamination, UXO presence/absence, and environmental remediation / land rehabilitation techniques. The pilot sites were located in Hong Thuong commune (near the former Ta Bat base) and Dong Son commune (near the former A So base).

Ta Bat and A So were selected for pilot sites for this project because:

- there was a perceived threat of UXO/landmine and chemical contamination by local inhabitants; subsequent investigations during the impact/risk assessment showed that there was a real threat of UXO/landmine and chemical contamination; and
- the land was not being used for domestic purposes (agricultural or residential) due to the above threats.

Soil samples collected from the two pilot sites were analyzed for dioxin contamination. Due to the high risk of UXO and landmine contamination, soil sample cores were taken from the edge of well-traveled sections within the 1 ha boundary for each pilot site. Samples were collected and analyzed prior to commencement of UXO clearance activities. Although risk of dioxin contamination at the two pilot sites was deemed to be low, the following is recommended to minimize risk exposure of demining crews and local populations to chemical contaminants in Aluoi District.

1. A soil sampling 'screening' program should be included in any UXO clearance project.
2. Depending upon the findings of the screening program, appropriate mitigative strategies should be considered during the planning stages of any UXO/landmine clearance and land rehabilitation program.

The Hue Defense Department (HDD) was responsible for the UXO clearance/demining work undertaken for the project. The demining crew consisted of 13 deminers and two supervisors. UXO and landmines cleared and collected by the HDD demining crew included:

- M18 directional fragmentation anti-personnel (AP) mines (claymore);
- M16 bounding fragmentation AP mines;
- unused M79 (rifle grenades) still in plastic casing;
- a US military issue hand grenade;
- unidentified cluster munitions;
- US Military issue mortar shells;
- miscellaneous rifle bullet rounds; and
- various scrap metal and larger bomb fragments.

Hue Agriculture University (HAU) personnel were responsible for the land rehabilitation component of the project. Reclamation of the two pilot sites was part of an overall agricultural infrastructure re-building program instituted after the floods that decimated large areas of central Viet Nam in the fall of 2000. The Vietnamese agriculture specialists refer to the land reclamation/erosion program used in the Aluoi Valley as the Sloping Agricultural Land Techniques (SALT) system.

> *"This (SALT) is expected to diversify products, increase income for farmers, improve soil conditions, prevent land erosion, limit slash-and-burn practice and increase ecological environment protection particularly in areas affected by UXO and toxic chemicals."*
>
> *An excerpt from the Vietnamese SALT Guidebook.*

After a four-month monitoring period, it was evident that the program was successful in returning non-productive, UXO contaminated parcels back into economically viable agricultural land base. According to objectives set out by the local Peoples' Committees, long-term goals for the two plots include continued agricultural crops and/or plantings of trees for the pharmaceutical and forestry industries.

The 'cycle of poverty' associated with these two small plots of land has been broken (i.e., socio-economic, human health and environmental problems due to the impacts of UXO, landmines and residual chemicals have been resolved). Local residents in the vicinity of the pilot plots are in a better position to understand the hidden dangers of chemical contamination as a result of awareness raising activities undertaken by the project team, and can now work towards providing for themselves in an environment that is safer and more productive. The pilot sites for this project were small, as were the numbers of people positively impacted. However, the training and knowledge that project participants gained can be expanded to include many other areas in Aluoi District and throughout Viet Nam.

CONCLUSIONS AND RECOMMENDATIONS

The goals of this project were to develop methods and technology to support landmine and unexploded ordnance (UXO) clearance activities in Viet Nam. The following discussion is based on field experience and information gained during Impact/Risk Assessment, UXO/landmine Clearance and Land Rehabilitation components of this project.

Utilizing Historical Data and New Mapping Technologies

GIS provides a natural environment for quantitative assessment of data pertaining to UXO presence and risks, and opportunities for removal. Using GIS to combine and analyze remote sensing information, historical spatial data, and other map data, a wide variety of novel and powerful approaches may be developed for supporting UXO assessment and removal activities to make UXO removal programs better informed, safer, more efficient, and more cost-effective.

This approach may be particularly effective in Viet Nam, where the amount of available spatially-referenced historical data and descriptive information, primarily from declassified American sources, is large and continually increasing. In particular, declassified Corona and Keyhole spy satellite imagery, geo-referenced aerial bombardment data, and facility location and layout information, are highly effective data sets for use in defining the spatial extent and distribution of UXO contamination.

Approaches developed in this project provide a better understanding of the spatial, temporal, and behavioural dimensions of UXO contamination and related or confounding issues in Aluoi District than can be achieved using current survey methods. Project maps, databases, and other outputs directly benefit all residents of Aluoi District, particularly those living in areas where more detailed study was undertaken (i.e., Dong Son and Hong Thuong communes). It is expected that the approaches and tools developed also will be applicable to other areas that are striving to address their own, unique UXO problems.

Managing Risk in Chemically Contaminated Areas

In many area of southern Viet Nam and for the Aluoi Valley project in particular, UXO clearance activities can be confounded chemically contaminated soils. Aside from chronic exposure problems for local inhabitants, the existence of chemical contaminants can result in acute exposure risks to UXO/landmine clearance crews and support workers.

During the course of UXO clearing activities in soils potentially contaminated with chemicals, the following activities were proven beneficial and should be implemented in consideration of protecting human health:

- identification of the potential for soils to be chemically contaminated in the area to be cleared of UXO;
- determination of extent and type of chemical contamination in the area;
- development of site specific protocols and mitigation measures for clearance crews;
- develop disposal plans for point source chemical contaminants; and
- post-UXO clearance monitoring for chemical contamination in the area.

Implementing Effective Land Management and Rehabilitation

The primary goals of land management and rehabilitation procedures are to ensure the ability of land to support productive agriculture and foster the development of sustainable/diverse ecosystems subsequent to UXO/landmine clearance. The Vietnamese SALT system appears to be an appropriate model for agricultural and infrastructure development in Aluoi District. However, continued bi-annual monitoring of the program at the two pilot site locations is required to ensure long-term environmental and socio-economic goals are met. It would also be useful to provide a set of 'SALT' type systems for use in agricultural areas throughout Viet Nam. These systems would have to be designed for a variety of social, agricultural, climatic and geomorphological conditions.

The key guidance document for any comprehensive land rehabilitation project is the land rehabilitation plan. This plan should include all information on pre-clearance conditions, predicted impacts and timetables for land rehabilitation, monitoring, and maintenance activities. Major considerations for a land rehabilitation project include:

- the collection of pre-clearance data on locations and topography, watercourses and drainage, climate, soils and vegetation, current and future land uses;
- project assessment and implementation involving the review of pre-clearance data the development of an impact assessment; and
- monitoring and maintenance during and after land rehabilitation activities.

The UXO/landmine clearance and reclamation methodologies and technology introduced in this document could also be expanded to include infrastructure and industrial development. The threat of UXO or chemical contamination is present throughout Viet Nam, regardless of the proposed future land use, and UXO clearance crews need to be educated about these risks. Finally, international support of Vietnamese demining capabilities should be expanded. Future efforts include the supplying of Vietnamese demining teams with personal protection, general first aid, and updated detection equipment and training.

In order to better understand the degree to which these explosive and chemical remnants of war are burdening the people of Viet Nam, a nation-wide Impact/Risk Assessment is needed that addresses both the UXO/landmine and chemical contamination issues. International funding agencies and Vietnamese authorities can subsequently use the information gained to direct resources to areas and populations most in need.

The methods and technologies discussed in this report facilitated the development of an integrated approach to UXO/landmine clearance activities in Aluoi District, which included the following key elements for each clearance area:

- an inventory of the bio-physical environment;
- identification of the socio-economic impacts and constraints;
- risk characterization of UXO and landmine contamination;
- risk characterization of chemical contamination; and
- identification of future land use and land rehabilitation goals.

This project provided the training and implementation of a systematic assessment, clearing and remediation process involving two UXO/landmine contaminated and potentially chemically contaminated plots of land. All aspects of the project involved in-country institutional and 'grass roots' strengthening from the federal agency level down to local inhabitants.

Given the site specific biophysical, socio-economic, and technical nature of each mine action activity, the assessment and procedural methods presented in this report are not intended to provide a stringent approach to mine action. Alternatively, they are intended to provide a systematic, step-by-step planning approach which will allow mine action planners to realize and act upon land rehabilitation and chemical contamination issues within the framework of a specific UXO and landmine clearance program.

(Source: HCL)

The rehabilitated A So pilot site, four months after UXO/landmine clearance.

> ***Four killed by Vietnam war-era shell***
>
> *HANOI (AFP) – Four people, three of them schoolboys, were killed and another seriously injured when a Vietnam war-era device exploded in the central province of Thua Thien Hue, official media said.*
>
> *The accident occurred in the Aluoi District last Wednesday [June 19, 2002] when three schoolboys aged around 15 'played' with a US-made shell abandoned since the end of the conflict in 1975, the Nhan Dan newspaper said.*
>
> *The three were attempting to dismantle the device's detonator when it exploded, the report added.*
>
> *(AFP June 23, 2002)*

The human impact of unexploded ordnance (UXO) on families that have members injured or killed is difficult to assess. All one really requires is to consider the truncated future of these Vietnamese families to fully appreciate the rationale and objectives of this project. The reporting of these two incidents, one in the popular press and one at the local level, provides sufficient justification for the advancement of UXO and landmine clearance activities in Viet Nam.

1.1 PROJECT OBJECTIVES

Armed conflicts often result in vast areas of UXO contamination in former strategically significant areas, military bases and important infrastructure facilities (e.g., trails, roads, bridges, tank farms, power plants). Given that many of these areas often encompass remote and culturally distinct communities, compiling and updating socio-economic and environmental information can be a major stumbling block to the mine clearance process.

To complicate the problem, demining and/or UXO clearance may be carried out in soils contaminated with war-related chemicals. Studies have shown that many of these chemicals are harmful to human health and local environments. In Viet Nam, soil contamination from herbicide applications (e.g., Agent Orange contaminated with dioxin), anti-personnel agents, and residual blast munitions used during the war are present in many former military bases and battle areas. This combination of chemical and UXO contamination is particularly concentrated in border areas of Viet Nam, Lao PDR and Cambodia where herbicide spraying, aerial and artillery bombardment were common along the Ho Chi Minh Trail corridor.

UXO deactivation programs may actually increase the contaminant burden in an area by distributing chemically contaminated soil, or leaving the area exposed to soil erosion. Activities such as vegetation removal, *in situ* UXO detonation (Plate 1.1), and mechanized destruction, can exacerbate this problem. Deminers, local residents or residents who may be resettled into UXO cleared areas could be affected by these chemicals, if appropriate mitigative strategies are not implemented.

> *" ...the urgency of UXO removal and demining projects was sadly evident when in January of 2002, while clearance operations were proceeding for this project, two brothers (six years and four years) were killed while handling an UXO in the neighbouring commune of Huong Lam in Aluoi District. "*
>
> *(HCL staff personal account, January 2002).*

(Source: HCL)

Plate 1.1
UXO collected for detonation, Phu Bai Airport, Hue, Viet Nam.

1.2 REMNANTS OF THE US-VIET NAM CONFLICT

The United Nations defines unexploded ordnance (UXO) as "explosive munitions which have not yet been set off" (UNICEF 1999). UXO may have been fired, dropped, or launched but it has failed to detonate as intended. These munitions may include, but are not limited to, submunitions, tank shells, artillery ammunition, bombs, rockets, mortars, hand grenades, rifle grenades and illumination flares.

The International Mine Action Standards (IMAS) defines landmines (including anti-personnel [AP] and anti-tank [AT]) as munitions designed to be placed under, on, or near the ground or other surface area to be exploded by the presence, proximity or contact by a person or vehicle (UNMAS 2001).

Although the fundamental military purpose of ordnance differs greatly from that of landmines, once ordnance lands and does not detonate (i.e., UXO), their future role in the post-conflict arena is essentially the same as a landmine; namely, they are indiscriminant once deployed, victim-triggered, and persistent in that their effects continue indefinitely after a war ends.

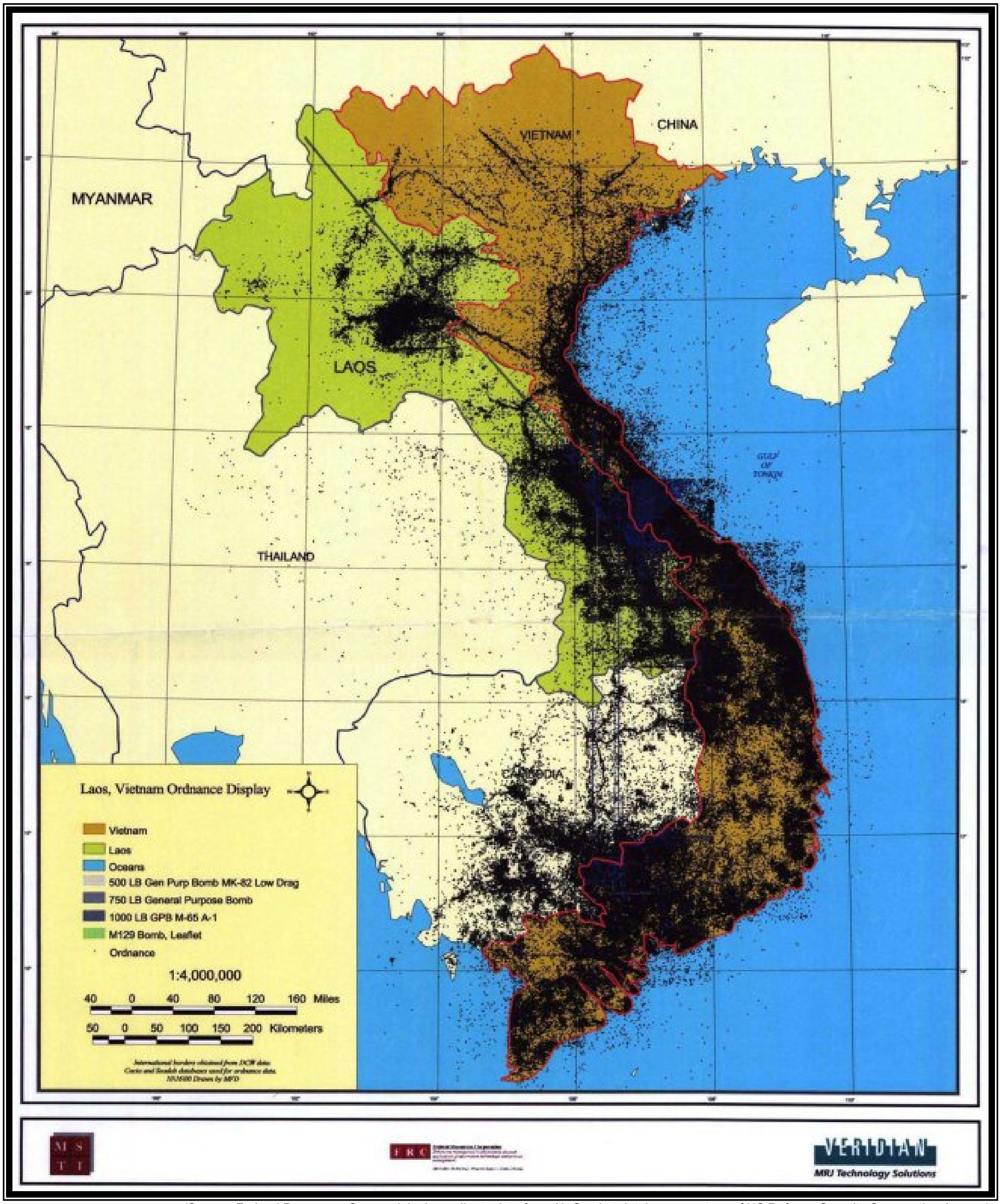
The inclusion of chemical agents in this discussion of UXO and landmine clearance is in relation to the potential health risk to deminers and local populations from exposure to harmful residual chemicals. This risk includes the acute threat to mine action teams and the chronic threat to inhabitants re-establishing themselves in a cleared area. For the purpose of this risk assessment, chemical agents have been grouped into three categories based on purpose and method of deployment. The categories include herbicides, anti-personnel agents and munitions.

1.2.1 UXO and Landmines

Viet Nam remains highly contaminated with UXO and landmines, almost thirty (30) years since the end of the US-Viet Nam Conflict (1961-1975). UXO is scattered throughout all 61 provinces and major cities. US 40 mm M-79 grenades and BLU 26/36 cluster bombs or "bombies" are considered the most deadly and responsible for a significant number, if not the majority, of recent casualties. It is estimated that UXO comprises 97-98% of the total munitions debris. Landmines make up the 2-3% of the remainder in limited areas (e.g., former military bases) (ICBL 2000).

The Landmine Monitor Report (ICBL 2000) also estimated that at least 5% of Vietnamese territory has been affected by landmines and UXO, or a total of 16,478 km^2 (5,932 squares miles). Most ordnance fell in jungle and rural areas rather than cities. Approximately eight (8) million tons of bomb ordnance was dropped on Indochina during the Viet Nam war (Figure 1.1), compared to four (4) million dropped by US and UK forces in World War II in all theatres. More than half of this total was dropped on South Viet Nam, ±1 million tons on North Viet Nam and two million tons on Lao PDR and Cambodia. In addition, approximately eight million tons of US artillery was used in South Viet Nam. It is estimated that 350,000 tons of UXO remain hidden in the country (ICBL 2002).

Certain areas that were heavily bombed (e.g., Cu Chi district outside Ho Chi Minh City, Highway 5 between Hanoi and the port of Haiphong, the former Ho Chi Minh Trail [including Aluoi Valley] and areas around former military bases near the former DMZ) contain much higher concentrations of UXO than elsewhere; however, bombs and shells can turn up almost anywhere.



(Source: Federal Resources Corp.; original coordinate data from Air Combat database, courtesy of US Defense Security Cooperation Agency)

Figure 1.1

Aerial bombing coordinate data for Viet Nam, Lao PDR and Cambodia.

1.2.2 Chemicals

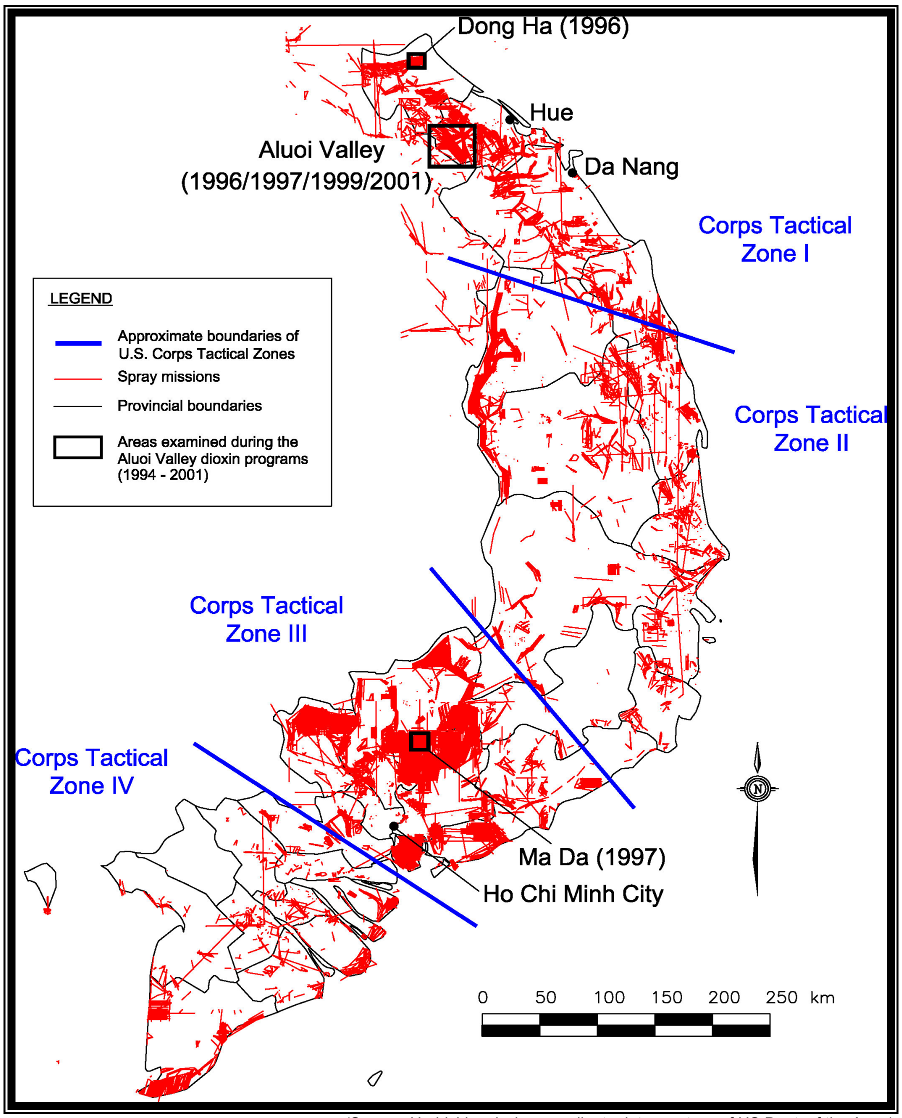
The following section summarizes chemical compounds and agents that are of greatest concern during UXO and landmine clearance programs in Viet Nam. This list is not all inclusive and should be updated as more information on persistent war-related chemical contamination becomes available. More detail on the characteristics of the key chemical compounds discussed is provided in Appendix A1.

Herbicides

Herbicides include chemical compounds that were used as defoliants and vegetation/crop destruction between 1965-1971 in Viet Nam. Herbicide agents (e.g., Agent Orange, Agent Blue and Agent White) were delivered aerially from fixed wing aircraft and helicopter, manually with backpack units, and pressurized from boats and trucks.

Approximately 76 million litres of herbicides were sprayed over 10-14% of southern Viet Nam during the US-Viet Nam war (Figure 1.2). The herbicides, were code named by the US Military as "Orange", "White" and "Blue" based on the colour of the painted band around the 45 gallon barrels of herbicide. Forest destruction was generally accomplished through the use of Agents Orange and White, whereas Agent Blue was usually used to damage rice crops. Agent Orange, a 50/50 mixture of 2,4,5-T and 2,4-D herbicides, was the most heavily utilized accounting for 61% of the total volume expended from 1962 to 1971 (SIPRI 1976). Dioxin (2,3,7,8–tetrachlorodibenzo-*p*-dioxin or TCDD) was a contaminant by-product of the manufacturing process present in Agent Orange. Dioxins are a family of chemicals which have been associated with serious health effects in humans.

Agent Blue (dimethyl arsinic acid), representing 11% of the total volume sprayed during the Viet Nam conflict, contained arsenic. However, studies have shown that the environmental persistence of



(Source: Herbicide mission coordinate data courtesy of US Dept. of the Army)

Figure 1.2
Aerial herbicide spray missions in southern Viet Nam, 1965-1971
(Source: US Dept. of the Army).

arsenic is low (Westing 1989), and there seems to be no food chain concentration of arsenic and/or arsenic compounds to toxic levels (Isensee *et al*. 1973).

With respect to mine action risk assessment, the major concern is the chronic health effects that may be associated with long term exposure of inhabitants to persistent toxins and short term exposure by mine clearance teams.

Extensive discussion on the assessment and effects of herbicide-related chemicals in Viet Nam is presented in HCL/10-80 Committee (1998; 2000) and Dwernychuk *et al*. (2002).

(Source: HCL)

Plate 1.2
Excavated barrels of CS at a dump site in Qui Nhon, Viet Nam.

Anti-personnel Agents

Anti-personnel or incapacitating agents were used in large amounts and in various ways by the United States military during the US-Viet Nam War. The most widely used chemical was termed "CS" (*o*-chlorobenzalmalononitrile) or "super tear gas" (Neilands 1972). Plate 1.2 is a photograph of an uncovered CS dump site near Qui Nhon, Viet Nam, estimated to include 60 tonnes of CS material.

Other chemicals used in lesser amounts included "CN" (tear gas) and "DM" (vomiting gas) (Neilands 1972). A finely pulverized form of CS called CS1 was used for protracted area denial rendering an area inhospitable for approximately 15 days. An especially non-degradable form called CS2 was developed later which could accomplish the same result for 30 to 45 days. The US Department of Defense has released no information on the amount of CS or other riot control agents used during the US-Viet Nam war. However, procurement figures that are available at least provide an indication of the amount intended for use in Viet Nam. The total quantity of CS procured by the US Department of Defense from 1961 to 1972 was 9×10^6 kg, about four fifths of this in bulk form, and the remainder directly incorporated into munitions (SIPRI 1976).

(Source: HCL)

Plate 1.3
Exposed CS (o-chlorobenzalmalononitrile) crystals excavated at a dump site in Qui Nhon, Viet Nam.

US Army studies state that the risks posed by continued chemical weapon storage, while very small, far exceed the risk of disposal (Noyes 1996). The condition of the stockpile can be expected to degrade with time, increasing the risks posed by continued storage. Plate 1.3 shows the degrading CS bags and exposed chemical that can pose a threat to mine action crews. The greatest risk from a chemical weapons stockpile is to communities located near storage sites.

If impact and risk assessment surveys indicate the possible presence of CS or other riot control agents, clearance teams need to prepare appropriate mitigation and disposal measures. The inadvertent uncovering of chemical weapons munitions during routine mine action activities can be a major health and safety hazard when demining teams are not prepared for (or experienced in) the proper handling of these chemical agents.

Explosive and Conventional Munitions Waste

Explosion, detonation, decomposition or corrosion of UXO and landmines (Plate 1.4) may result in the release of a wide range of chemical compounds that may degrade or pollute the environment. These chemical compounds include explosives, propellants, pyrotechnics, and various heavy metals (Noyes 1996).

(Source: HCL)

Plate 1.4
AP mines and UXO found at a site in Aluoi Valley, Viet Nam.

Medium-and long-term environmental impacts of these substances may include the degradation of soil quality, fouling of surface and ground water supplies, and the persistence and bioaccumulation of certain chemicals (mercury and lead, in particular) (Torres Nachon 1999).

A risk to human health may occur through a variety of soil exposure pathways including dust inhalation, ingestion and dermal absorption. Avoiding exposure to contaminated soils is therefore critical during mine action surveys.

1.3 Residual Impacts

The results of UXO and landmines not only include the immediate impact of death or injury to civilians and military personnel; they also can result in further socio-economic and environmental burdens long after the conflict has ended.

> *"Not only do these abominable weapons lie buried in silence and in their millions, waiting to kill or main innocent women and children; but the presence – or even the fear of the presence- of a single landmine can prevent the cultivation of an entire field, rob a village of its livelihood, place yet another obstacle on a country's road to reconstruction and development."*
>
> *UN Secretary General of the United Nations, Kofi Annan describing the world UXO/landmine situation. (UN 1999)*

The impacts on a society resulting from UXO, landmine and chemical contamination can be broken into three major categories: human health, socio-economic, and environmental. The inter-dependency and inter-action between categories implies that degradation of any one of these categories contributes to degradation of the other two, resulting in a reduction in the overall quality of life. This sequence has been termed "the cycle of poverty" in post conflict areas (Figure 1.3).

In a post-conflict area, UXO, landmines and chemical contamination are major causal factors in the poverty cycle. By independently affecting each category, UXO, landmines and chemical contamination contribute to the overall reduction in the standard of living in a community.

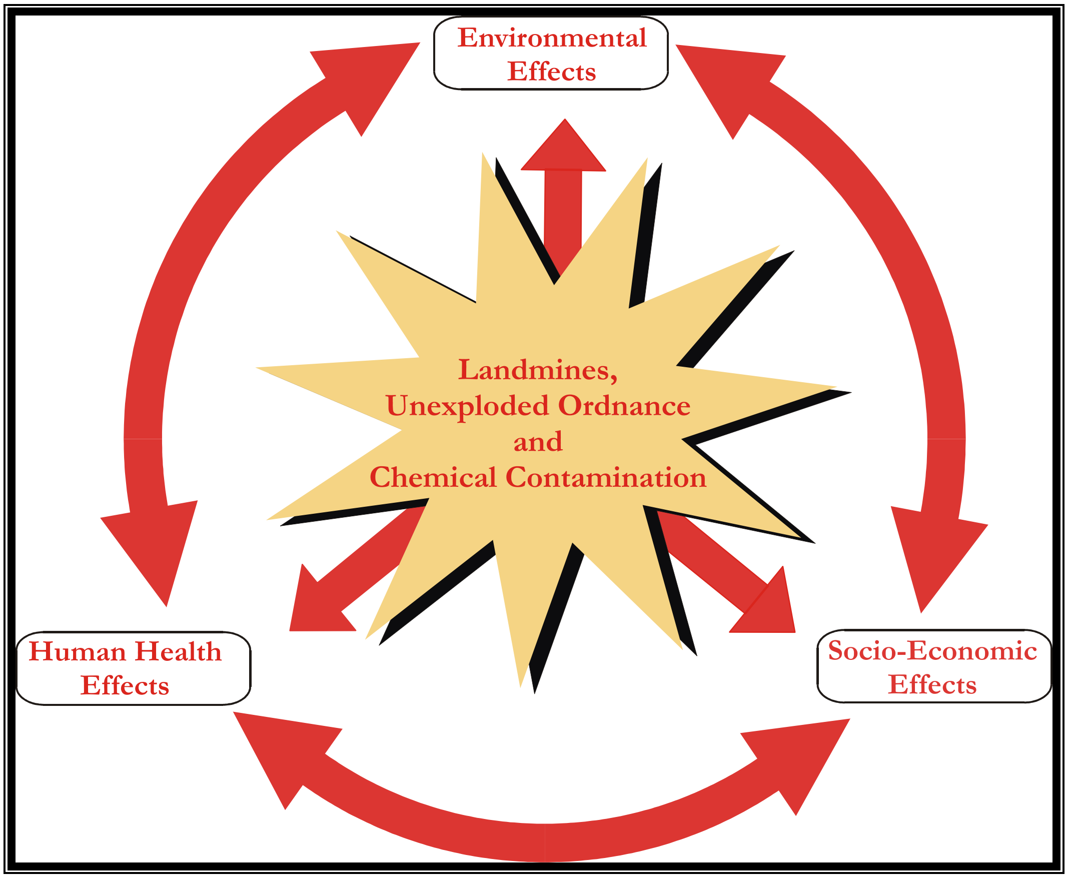


Figure 1.3
The "cycle of poverty" in post-conflict areas.

1.3.1 Human Health Effects

The International Committee of the Red Cross (ICRC) estimates that there are in excess of 110 million anti-personnel mines located in 64 countries worldwide (ICRC 1995). In addition to landmines, there is a large number of other types of UXO present in many countries, including Viet Nam, Lao PDR and Cambodia (i.e., bombs, artillery shells, grenades, etc.). According to ICRC, approximately 30,000 people are killed or maimed by UXO each year throughout the world. Of this number, 10,000 may be fatalities.

The Landmine Monitor Report for 2000 published by the International Campaign to Ban Landmines, reports that from March of 1999 to May of 2000 there were new landmine victims in 71 different countries in just about every major region of the world (ICBL 2000). The highest casualties occurred in Myanmar (1,500), Cambodia (1,012) and Angola (1,004).

In Viet Nam, mine-related injuries account for 15% of the total disabled population (JMA 2001). According to a nationwide survey conducted in 1999 by the Ministry of Labour, War Invalids and Social Affairs, over 38,000 people have been killed and more than 64,000 have been injured since the end of the Viet Nam War, which is equivalent to approximately 180 casualties per month.

A wide range of human health effects are associated with UXO contamination, including direct loss of life, maiming and psychological trauma (e.g., post-traumatic stress disorder or PTSD). The most common physical injuries include loss or serious damage to lower extremities and blinding (Plates 1.5 and 1.6). Both short and long-term psychiatric disorders can be expected following severe physical trauma

(Source: 10-80 Division)

Plate 1.5
UXO victims from the Aluoi Valley, Viet Nam.

resulting from UXO explosions. In addition to post-traumatic stress disorder (PTSD), other psychiatric disorders, such as major depression, generalized anxiety disorders (e.g., loss of self-esteem, embarrassment) and substance abuse, may also follow mine explosion trauma (McGrath 2000).

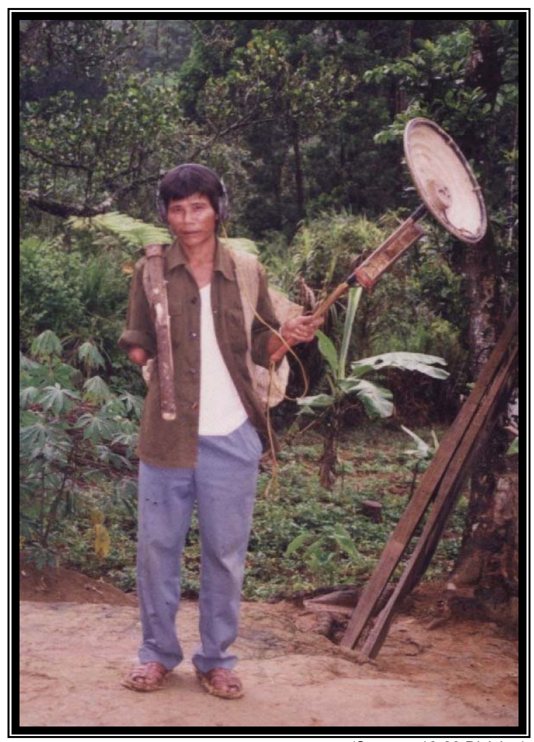
In addition to the direct physical and psychological health consequences, there are a number of indirect public health impacts of UXO/landmines. Table 1.1 summarizes some of the most significant indirect public health effects. It is important to note that most landmine/UXO contaminated countries do not have the medical infrastructure and human resources to respond effectively to the needs of victims. This is especially the case in rural areas of Viet Nam, including Aluoi Valley.

1.3.2 Socio-economic Effects

The victims of landmines/UXO are almost inevitably the poorest and most vulnerable members of society. Even though all family members are vulnerable in UXO contaminated areas, most victims are adult males who are often the principal income earners in the family unit. The loss or injury of a key household member can exacerbate an already tenuous socio-economic situation.

Immediately after a landmine/UXO incident has occurred, financial losses are incurred by the victim and his/her family. There are short-term costs associated with initial treatment of the injury, including hospital care.

While in the hospital, the casualty and dependent family members are losing earned income and household labour, in addition to having to pay hospital costs. Furthermore, since most landmine/UXO related injuries occur in rural areas and most hospital facilities are located in urban centres, it often necessary for an additional family member to stay with the victim on a full-time basis during the recovery period in hospital. This results in a loss of labour and/or income



(Source: 10-80 Division)

Plate 1.6
An UXO-injured scrap metal dealer continues to work in Aluoi Valley, Viet Nam.

Table 1.1 *Major indirect public health effects from UXO/landmine trauma.*

UXO Primary Influence Point	Condition(s) or Altered Behavior	Indirect Public Health Effect
1. Agricultural/aquaculture land, water canals mined/bombed.	Farming activities decrease causing food scarcity.	Malnutrition-related diseases.
2. Access to drinking water and firewood mined/bombed.	Consumption of contaminated drinking water.	Increased incidence of waterborne diseases such as bacterial diarrhea, amoebiasis, Giardiasis, etc.
3. Roads and access to public places mined/bombed.	Mobile vaccination and health teams avoid area, which results in low or no vaccination coverage and may disrupt all public health activities.	Potentially higher incident of major childhood diseases (e.g., polio) and lack of primary health care.
4. Increased amputation and injury requiring blood transfusion.	Increased demand and frequency of blood transfusion.	Contaminated blood transfusion diseases (e.g., HIV, hepatitis).
5. Mined roads prevent food transport between villages.	People must subsist on local food products that may be nutrient (e.g., iodine) deficient.	Iodine deficiency disorders, including high perinatal mortality.

(Source: HDW 2001)

generating potential from two family members over this period. An additional cost to the victim's family often results from the higher price of food encountered in urban versus rural areas. In most instances, food for the victim and his/her family is not supplied by the institution during a hospital stay.

In addition to the shorter-term financial impacts, there can be significant long-term financial burdens experienced by landmine / UXO victims and their families. In particular, there may be costs associated with rehabilitation of the victim, as well as job loss or employment changes. All of the above result in a reduction of income.

Rural families that are unable to earn an adequate income or produce sufficient food due to the loss of key household members and/or displacement from agricultural lands due to landmines/UXO, often move to urban centres where they exert added pressure on already taxed infrastructure and human support systems.

1.3.3 Environmental Effects

Where UXO exist in large numbers, they have had a significant effect on already degraded environments. Populations living with UXO experience limited access to agricultural or grazing lands and are pushed onto increasingly fragile, marginal land, furthering the land's rapid degradation. Where UXO contamination has reached a degree which disrupts traditional lifestyles, such populations may be forced to move into urban environments, thereby contributing to overcrowding, unemployment and other problems.

Apart from the obvious destruction of forest and crop vegetation from the Viet Nam landscape by herbicide applications, deforestation has also been accelerated by landmines and UXO. Where arable land has been subjected to war activity to such a degree that forests become the only source of livelihood, the long-term consequences of selling old forests and fruit trees give way to immediate survival pressures. Deforestation can in turn affect marshlands and water tables, which have an impact on fish and wildlife (Roberts 1995), and result in massive erosion problems (Plate 1.7).

Other forms of environmental damage from UXO, landmine and contamination may be in the form of soil degradation, slope instability resulting in massive sediment transport, and the pollution of water resources and soil with persistent toxic chemicals and heavy metals released from the decomposition of UXO and landmine casings (Torres Nachon 1999).

A discussion of long-term consequences of war on Vietnamese ecosystems may be reviewed online at www.nnn.se/vietnam/environ.htm. This document was compiled for a conference in Stockholm, Sweden (July 2002) and involved representatives from HCL (Appendix A2).

(Source: HCL)

Plate 1.7
Large scale down-slope movement of soil onto a stream bed and road due to the war-related herbicide application and subsequent removal of vegetative cover (Hwy 49).

> *"...It is now universally recognized that mine action is not just about demining, it is about reducing the social, economic and environmental impact of mines. It is about people and societies, and their interaction with land contaminated by mines and UXO..."*
>
> *excerpt from "A Framework of International Mine Action Standards and Guidelines" by Alastair McAslan.*

2.1 CURRENT APPROACHES TO MINE ACTION

The IMAS have been developed by the United Nations Mine Action Service (UNMAS) to provide a framework of international standards in which mine action activities and tasks are conducted. Within these standards are a set of general guidelines for the development and planning of mine action activities. The guidelines provide a framework for the creation of Standing Operating Procedures (SOPs), which in turn detail the manner in which specific mine clearance operations are conducted. However, no two landmine/UXO contamination situations are the same, and the SOPs for each mine action should take into account cultural, environmental and operational variations.

The general guidelines for mine action suggest a series of three activities: impact/risk assessment; technical survey; and post clearance or completion report. A summary of each mine action component is provided below. IMAS guidelines are provided in Appendix A3 (IMAS Guidelines 08.10, 08.20, 08.30).

The terms "mine" and "landmines" are used conventionally throughout the IMAS literature to mean both landmines and UXO. Similarly, the term "demining" is the clearance of contaminated land through detection, removal or destruction of all mine and UXO hazards.

2.1.1 Impact/Risk Assessment

Effective clearance of unexploded ordnance requires knowledge of where UXO may exist, the quantity and type of UXO located in an area, prevailing natural conditions in target areas and the characteristics and activities of people living in UXO-contaminated lands. The IMAS refers to this procedure as the "Impact/Risk Assessment".

An Impact/Risk Assessment gathers general location data and socio-economic impact of mines and UXO on communities in proximity to contaminated areas. The assessment identifies UXO/mine areas, determining impact on the local population and the degree of priority for planners to allocate clearance resources. This will normally be conducted by specially-trained assessment teams with enhanced mine awareness and navigation skills to determine the location of contaminated areas. In addition, these teams are trained in interview techniques and are able to assess socio-economic factors affecting communities.

Survey programs at the local level are key at this stage and are normally conducted by donor supported NGO's and national supporting agencies. These programs should, at a minimum, include:

- an UXO presence survey;
- an UXO/landmine victims survey; and
- an UXO/landmine awareness program.

All of these records form part of the mine survey database and are a major planning tool in the prioritization of tasks and the commitment of mine clearance resources (IMAS 1997 and 2001).

Plate 2.1 shows a local Aluoi District resident engaged in a UXO presence survey interview session with representative from the Hue provincial government.

(Source: 10-80 Division)

Plate 2.1
Interviewing a local inhabitant on the presence of UXO and landmines in the Aluoi Valley, Viet Nam.

2.1.2 Technical Survey

The technical survey is a detailed technical and topographical investigation of known or suspected hazardous areas identified during the impact/risk assessment. The primary aim of this survey is to collect sufficient information to enable the clearance requirement to be more accurately defined, including the area(s) to be cleared, the depth of clearance, suspected types of mine and/or ordnance, local soil conditions and the vegetation characteristics (IMAS 2001).

A Technical Survey is conducted by trained deminers equipped with suitable protective and detection equipment to meet and manage threat conditions. Technical survey teams determine, through additional information gathering and detection techniques, the boundary of contaminated areas.

In the current study, extensive interviews were conducted in Aluoi District to assess current UXO contamination levels, accidents, and to increase awareness of the local population to landmines and UXO

2.1.3 Completion Report

The completion report and associated post clearance documentation is a key step in the handover of cleared land. Often local populations will follow-up and occupy land immediately following clearance in order to confirm ownership by re-establishing historic land rights. The completion report involves the monitoring of the demining organization's management systems and operational procedures before and during the clearance process (quality assurance). It also includes the inspection of cleared land (quality control).

This procedure identifies issues and required tasks which must be completed before the land can be considered formally 'cleared' and available for use. It also aims to clarify the ownership of any residual risk and determine the legal responsibilities and accountability of the donor, national mine action authority and demining organization(s) following handover (UNMAS 2001).

2.2 EXISTING UXO/MINE ACTION IN VIET NAM

No nationwide UXO survey has been conducted in Viet Nam, given lack of budget. The Vietnamese National Ministry of Defense estimates that complete clearance would take several decades, at a cost of $4 to $15 billion US. The Vietnamese Government states they have expended approximately $10 to $50 million US per year on military UXO clearing since the end of the war (ICBL 2000). It is estimated that 15-20% of explosives left by the war have been cleared to date, accounting for 7-8% of the country's total land area.

2.2.1 National Programs

From 1975-1996, Peoples' Army of Vietnam (Service of Defense Division) was responsible for all organized mine and UXO clearance in Viet

Nam. Postwar clearance during that time was relatively superficial, dealing primarily with areas of economic and infra-structure development (i.e., factories and highways) and only with explosive material at the depth required by construction (ICBL 1999).

The Vietnamese Army engineer units continue to be active clearing areas of infra-structure development. Presently, largescale clearing efforts are in place along the construction corridor for the Ho Chi Minh national highway (Hwy 2), which is to directly link communities in western half of the country (including those in the Central Highlands) with Hanoi and Ho Chi Minh City. Vietnamese soldiers working on the project have diffused 18,513 individual items of ordnance, including 84 heavy bombs, between May and October 2001. Partly because of the high level of UXO/landmine contamination encountered along the route, the project is estimated to be 30 to 40 percent behind schedule (ICBL 2002).

UXO clearance is time-consuming and costly. Deciding priority areas for clearance is essential to ensure best-targeted development and benefits. Schools, health clinics, markets and other public areas have been cleared on a priority basis. Land for agriculture and development projects is being cleared as funds allow.

Extensive consultation with local authorities and communes is necessary to determine where clearance has the highest priority and can deliver most benefits. Emergency clearing requests are also responded to by the Vietnamese military where ongoing work is halted or daily life is affected due to the presence of UXO, or where people have already found and marked ordnance.

Out of necessity, most UXO clearance in Viet Nam to date has had to be cheap using outdated technology. At present, civilians who discover a mine or bomb are instructed to inform the local military, who then clear the site. However, the response time is often slow. Newspapers report numerous accounts of residents of various provinces finding explosives, waiting as long as seven months for a clearance team, and then attempting to dispose of the materials themselves. Often, residents call on the numerous scrap collectors and do-it-yourself deminers in the central provinces.

In Quang Tri province (near the former DMZ), up to 4,000 people have been engaged in their own UXO clearance activities since the 1980s. Civilian "wildcat deminers" form a virtual second army in many of the most affected areas.

Little is known regarding the casualty rate among Vietnamese military deminers who have been carrying out most of the more official UXO clearing in Viet Nam to date. Given the near-universal lack of international standard safety equipment in Viet Nam, deaths and injuries are likely relatively high. For example, at least two or three, and probably more, workers were killed in 1999 during construction of the road (Route 9) from Quang Tri to the Laotian border; 37 soldiers were reported killed during demining along Viet Nam's northern border from 1991-98 (ICBL 2000).

According to Vietnamese Land Law, agricultural land allocation in rural Viet Nam is carried out by the commune or village on the basis of family size and need. Land that is cleared of UXO is turned over to local authorities who then decide how best to use it. In one commune in Quang Tri province, there is 170 hectares of arable land, or 15% of the district total, that is currently unusable because of mines and UXO. If local farmers could have full use of the land, a significant obstacle to poverty would be overcome. Such a situation is typical of many areas in the country. In many provinces and districts, intended beneficiaries for resettlement once UXO clearance is complete have been identified.

The Vietnamese government places a high priority on redevelopment and has supported partnerships among clearance groups and development NGOs. UXO awareness programs have been encouraged by Vietnamese authorities, mainly at the local and provincial levels.

2.2.2 Internationally Supported Programs

Prior to 1997, Vietnamese Central Government policy did not allow the Services of Defense to deal directly with any foreign agency that might assist in mine action. After 1997, policy was relaxed to allow for an expatriate presence in an advisory role and by the end of January 1999, the first major foreign funded mine clearance project (sponsored by the Danish government) in Viet

(Source: HCL)

Plate 2.2
Photograph of a GERBERA UXO clearance operation at a former US Military base near Phu Bai Airport, Hue, Viet Nam.

Nam was initiated in Quang Tri's Gio Lihn District. The $1.1 million project was implemented by the provincial People's Committee in collaboration with the UK-based Mines Advisory Group (MAG)(ICBL 1999). The participation of HCL in this program is discussed in Section 5.3.4 of this document.

Since that time, various clearance programs have and are been undertaken in Quang Tri and Thua Thien Hue provinces (Plate 2.2) by foreign demining teams (MAG from Britain, Solidaritaets Dienst [SODI], Potsdam Kommunikation and GEBERA from Germany and Peace Trees Viet Nam and UXB International from the US) mainly near former US and south Vietnamese military sites.

The US State Department signed an agreement with the Viet Nam Veterans of America Foundation (VVAF) to conduct a nationwide, Landmine Impact Survey program in Viet Nam. Negotiations are continuing between the VVAF and the Viet Nam government on the final implementation plan for the US$6 million, three year project (ICBL 2002).

2.3 AN INTEGRATED APPROACH TO MINE ACTION IN VIET NAM

The intent of this project was to provide a systematic, integrated approach to UXO/landmine clearance. Mine action teams need to be aware of the possible presence of toxic chemicals in UXO and landmine contaminated soil. Mitigation procedures that will protect clearance teams and prevent the re-release of dioxin, for example, into the environment, need to be included in action protocols.

The approach involves Geographic Information System (GIS) products designed to assist mine clearance teams identify and delineate UXO/landmine and chemically contaminated areas, procedures for clearing UXO and landmines in soils which are chemically contaminated, and methods for the rehabilitation of cleared areas for future land uses. The key goals for this project were to:

- protect clearance teams from increased risk to health, which may be caused by chemical contamination in areas being cleared of UXO and landmines;
- reduce the risk of increased chemical contamination of the environment which in-turn may prevent further contamination of agricultural soils, water resources, food sources and eventually human tissues;
- introduce methods of erosion control and site rehabilitation that will allow local residents to re-settle UXO contaminated land once it has been cleared; and
- enable local residents to make land use decisions with the prospect for an increased level of self-sufficiency (i.e., break the cycle of poverty).

BETTER DEFINING THE PROBLEM: NEW APPROACHES TO MAPPING UXO-CONTAMINATED AREAS

CHAPTER 3

3.1 CONCEPTUAL APPROACH TO USING REMOTE SENSING, GIS AND HISTORICAL SPATIAL DATA

Effective clearance of unexploded ordnance requires knowledge of where UXO may exist, the quantity and type of UXO located in an area, prevailing natural conditions in target areas (e.g., land cover and physiography) and the characteristics and activities of people living in UXO-contaminated areas. Without such knowledge and understanding, problems of UXO contamination and how to address them may be overwhelming, particularly in countries such as Viet Nam, where large amounts of UXO remain dispersed over large areas.

Types of information required to develop such an understanding typically are spatial (i.e., UXO are unevenly distributed in space), temporal (i.e., UXO contamination and subsequent events are unevenly distributed in time), and behavioral (i.e., people, the ultimate focus of UXO clearance activities, interact with UXO in different ways).

In addition, it is important to bear in mind that with the exception of planned minefields, UXO generally are an unintended outcome of another activity (i.e., UXO are bombs, shells, mortars and other explosive materials that did not function [explode] as intended). This means that clear records do not exist regarding UXO "placement" in any area from the time of conflict, which in turn means that specific UXO problems must be identified and deduced *post-hoc* from secondary information or direct observation. Identification of the appropriate scope, scale, and approach for UXO assessment and removal activities requires creativity in approach, use of numerous and varied data sources, and a detective-like methodology.

Although large-scale war in Viet Nam ended over 25 years ago, widespread problems with UXO persist. Viet Nam is a conducive test area for assessment of the effectiveness of novel approaches and technologies to support UXO removal activities for various reasons, including an active government infrastructure with a clear, directed interest in addressing UXO concerns and supporting UXO-related activities, highly-educated technical personnel with the capacity to understand and implement any valuable new approaches tested, existence of extensive baseline geographical, sociological, and physical data that may be used in the project, and, significantly, extensive and accessible historical American military records documenting war-time activities, facilities, and conditions in Viet Nam.

To effectively use these varied data sets to generate a useful understanding of UXO contamination issues in a given area, they must be combined and interpreted in a consistent analytical environment. This project used geographical information systems (GIS) as this analytical environment. Stated simply, a GIS is a database system in which data records are spatially linked to geographic coordinates. These spatial linkages allow analyses to be undertaken based on the geographic location of data, not only on the content or value of the data themselves.

Using GIS, various spatial and non-spatial data from a wide variety of sources (e.g., satellite imagery, new and historical map information, community health and accident surveys, historical war activity records, environmental contamination data, etc.) can be combined, analyzed, and interpreted quantitatively. This project combined and interpreted such varied data sets, particularly various types of modern and historical remote sensing imagery, to develop approaches, methodologies, and data products of value to UXO removal programs in Viet Nam and elsewhere.

The following sections document different data sources and analytical approaches used in this project, and present results and a critical discussion of these various approaches.

3.2 AVAILABLE HISTORICAL SPATIAL INFORMATION

Approaches to determining the scope and scale of UXO contamination in an area can be described as either indirect or direct. Traditionally, UXO contamination is assessed indirectly, through surveys of local communities regarding prevalence and locations of UXO accidents and local community fears, concerns, and anecdotal understanding of UXO contamination. Based on the number of UXO-related accidents in a given area, estimates of the prevalence of UXO in a particular area may be made.

However, historical UXO contamination may also be assessed more directly, though examination of data sources collected during or near the time of conflict. Particularly in Viet Nam, extensive American war records exist, many recently declassified, that may be accessed to support and inform UXO-related studies. Some of these historical data sources are described below.

3.2.1 Historical War Records

Aerial Herbicide Application Data

Numerous types of previously-classified military records pertaining to the conflict in Viet Nam have been released by the American government in recent years. One such data set, known as the HERBS database, documents aerial herbicide spray missions in Viet Nam from August 1965 to February 1971. This database was created and maintained by the Chemical Operations Division, US Military Assistance Command, Viet Nam, and documents over 6,500 aerial herbicide application missions undertaken in southern Viet Nam from August 1965 to February 1971 (US Institute of Medicine [IOM] 1994).

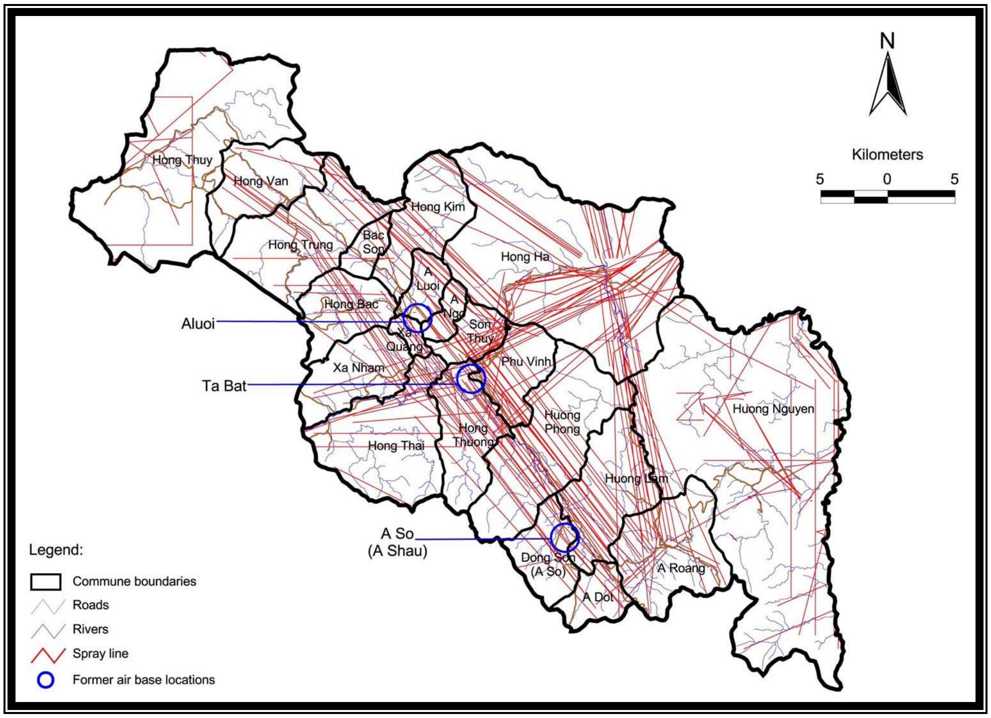
This database contains flight dates, flight coordinates (start and finish), and amounts and types of herbicides applied. Aerial herbicide applications over all of southern Viet Nam, as extracted from the HERBS database, were presented in Chapter 1 (Figure 1.2). Using these data, it is possible to determine areas of intense or repeated herbicide application, which may be contaminated by herbicide-related chemicals (i.e., dioxin from Agents Orange and Purple) and which may be environmentally degraded (i.e., where tree cover and forest communities were destroyed during the war by herbicide application).

It should be noted that the HERBS database only includes records for herbicides that were applied from C-123 aircraft. In addition to these documented applications, other means of herbicide application that are not included in the HERBS aerial application database include: applications from helicopter; backpack or other types of ground-spraying; herbicides applied before or after the HERBS database duration of record; and any herbicides applied, aerial or otherwise, that were not recorded in any database (IOM 1994).

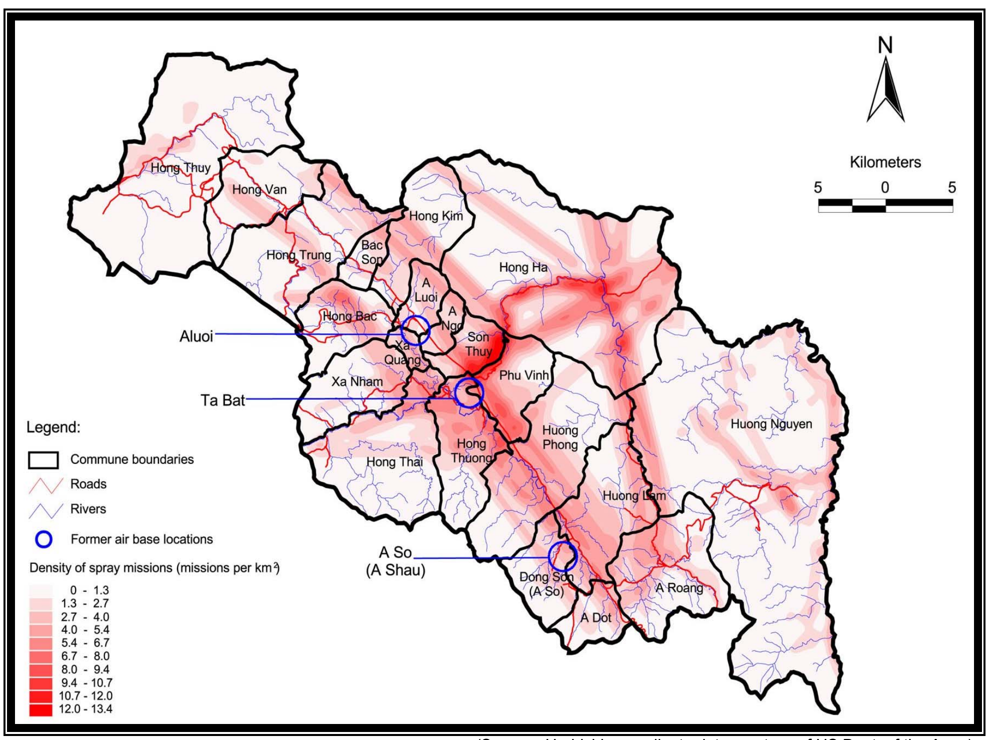
When examining the HERBS mission data spatially, it also is important to note that for the purposes of display, spray missions are illustrated as straight lines progressing from a start coordinate to a stop coordinate. In reality, aerial applications, conducted at low altitudes, likely did not follow such straight lines; rather, herbicide application missions likely followed more complex flight plans, such as following winding river valleys, topographic contours or features, etc. However, detailed in-flight data describing the exact path of these application missions do not exist. Therefore, spray mission flight lines presented in this report and used for analysis are approximations by necessity.

Figure 3.1 illustrates aerial herbicide application data for Aluoi District, using two different presentation methods. Figure 3.1A presents aerial herbicide application mission flight lines (hereafter referred to as "spray lines"). It is apparent from this figure that herbicide applications followed specific physiographic, and militarily strategic, features. Particular areas of

A. Herbicide application flight lines.



B. Spatial density of herbicicde applications.



(Source: Herbicide coordinate data courtesy of US Dept. of the Army)

Figure 3.1

Aerial herbicide applications in Aluoi Valley, 1965-1973.

the district that were heavily sprayed include: (1) the floor of the valley along its axis (i.e., NW-SE); (2) hills adjacent to the valley floor (also along a general NW-SE axis); (3) the Highway 49 right-of-way and associated river course connecting Aluoi to lowland Hue province; and (4) the Bo River valley, which connects the southern valley with the road from Aluoi to the lowlands.

Figure 3.1B presents an interpreted spatial density map of these herbicide application data for Aluoi District. This alternative means of presenting the data shows areas of the district that were heavily sprayed by herbicides, with stronger red colours indicating a greater density of spray lines.

While this dataset may appear less precise geographically than the previous map showing spray missions as start-to-finish line data (as in Figure 3.1A), the imprecision of the straight-line point-to-point data due to in-mission course deviations, may mean that a density-based mapping approach is more realistic and useful for determining areas where risks of residual chemical contamination may be greatest.

Air Combat Database

The Air Combat Database, recently declassified and released by the US government, is a spatial-relational database including records of ordnance types and targets related to daily air combat missions in Viet Nam, Cambodia and the Lao PDR from 1965 to 1975. A general presentation of these data for all of Indochina appears in Figure 1.1 of Chapter 1. This database includes specific mission numbers, type and number of aircraft, target locations (lat/long), ordnance types, number of ordnance dropped, and information regarding downed aircraft. Air Combat Database records covering Aluoi District were provided by Michael Sheinkman and the Lao PDR field office of Federal Resources Corporation Ltd.

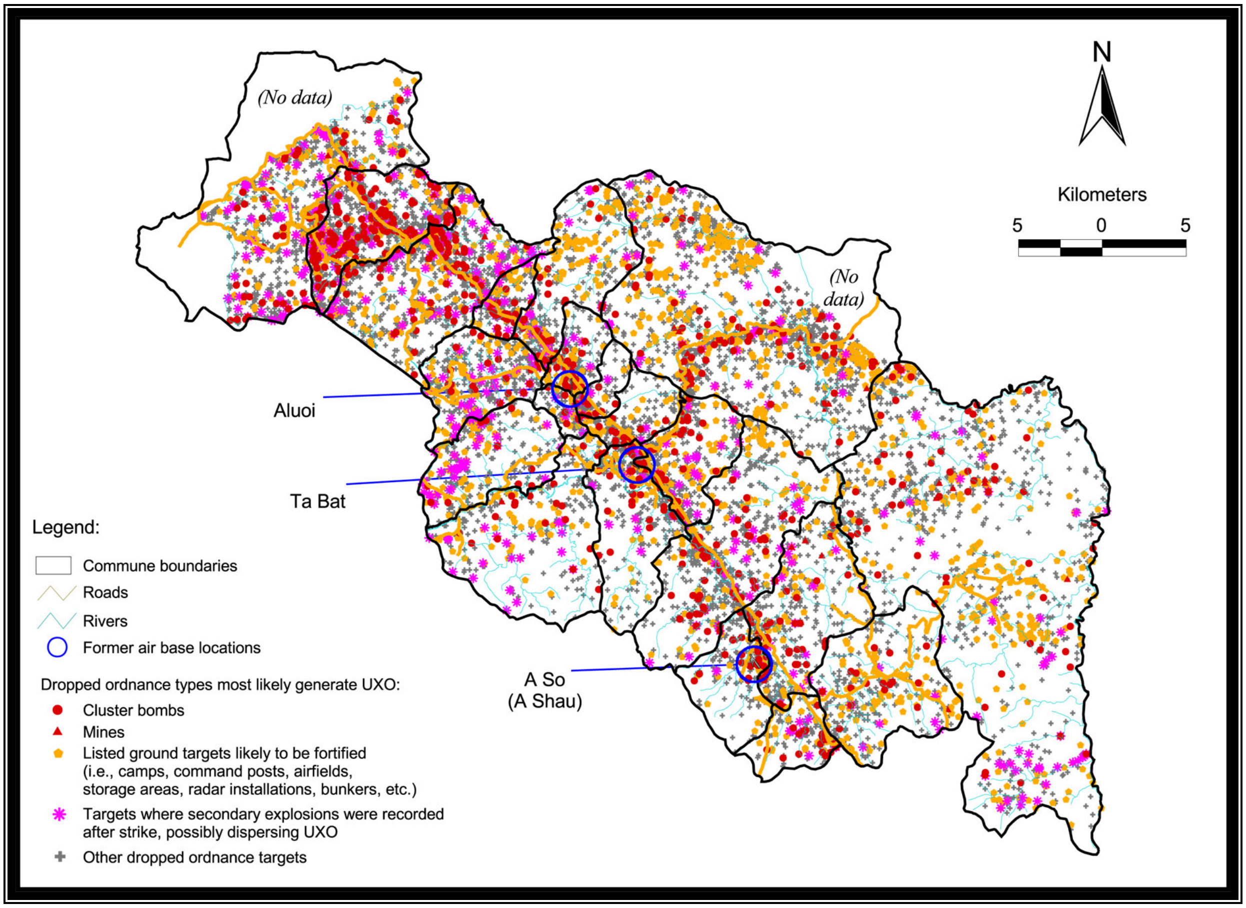
For each air combat mission, this database includes records regarding:

- date of the mission;
- number of aircraft participating in the mission, and the type of aircraft (e.g., A-6, F-4, AC-130, B-52, etc.);
- load of ordnance used, recorded both by total pieces of ordnance and by total weight in pounds;
- type of ordnance used, listed by major categories (i.e., ammunition, cluster bomb, flare, general purpose, incendiary, mine, missile, rocket, and other), general type (e.g., "MK-11/MK-12"), and specific type (e.g., "20 mm M12");
- geographic coordinates of the mission target;
- description of the target type (e.g., "troops", "camp", "command post", etc.); and
- description of any after-action observations (e.g, "destroyed", "secondary explosions", etc.).

When assessing air combat data discussed in this report for Aluoi District, it is important to note that due to some small changes in the borders of Aluoi District over recent years, spatial boundaries of the database record used for this project exclude small portions of two communes: Hong Thuy, the northernmost commune of Aluoi District; and Hong Ha, a large commune along the eastern district border which includes Highway 49 connecting the Aluoi valley to the lowlands of Hue province (complete air combat records for these communes exist, but were not accessed for this project). Therefore, air combat records for these two communes most likely under-report the number of air combat targets and munitions dropped.

A total of 20,611 air combat missions over Aluoi District appear in the database, for the years 1965 to 1973. In total, these 20,611 missions involved 38,258 aircraft flights, which utilized a total of 302,091 pieces of ordnance, weighing 611 million pounds. These data are summarized in tabular format in Appendix A4, and presented and discussed in further detail in Chapter 6.

Figure 3.2 illustrates the spatial distribution of air combat targets in Aluoi District from 1965 to 1973. Different colours and symbols are used to highlight specific mission targets that suggest UXO contamination may be particularly



(Source: HCL; original coordinate data from Air Combat Database, provided to HCL by Federal Resources Corp.)

Figure 3.2

Air combat targets by category of ordnance and target descriptions.

important. These categories include cluster bombs, dropped mines, recorded ground targets that would likely be fortified (and therefore represent possible areas of ground protection or locations of ground battles), and targets with after-action mission records indicating secondary explosions, which may serve to further disperse UXO in an area. Modern commune boundaries in Aluoi District also are included in Figure 3.2.

From this figure, uneven spatial distribution of targets is apparent. Although air combat targets are distributed throughout all sections of the district, areas of target concentration (and therefore likely greatest present-day UXO contamination) occur in the vicinity of the roadway along the valley bottom (Hwy 14), the roadway connecting the valley with lowland Viet Nam (Hwy 589), and along particular valleys connecting Aluoi District with Lao PDR. The roughly diamond-shaped commune of Hong Van, second most northerly commune in the district, exhibits a particular concentration of air combat targets, especially in the narrow valley connecting this commune with Lao PDR. This was a major entry point to the valley for NVA troops traveling along the Ho Chi Minh Trail (*pers. comm*. Hong Van commune leaders, 2001). The concentrated use of anti-personnel cluster bombs in Hong Van and other northern Aluoi District communes (Figure 3.2) suggests that troop interdiction was a key objective of aerial bombardment of this area.

It is important to consider that this air combat dataset does not include information related to naval and ground artillery, ground combat, or air ordnance that may have been dropped by North Vietnamese aircraft in the area. Due to the nature of the combat in Aluoi valley (i.e., defense of air and fire bases, and interdiction of ground forces), UXO contamination resulting from ground artillery and combat likely are also important contributors to accidents and land abandonment in Aluoi District, for which detailed, spatially-referenced military information are not available. To assess the extent of UXO contamination from ground and artillery sources, it is necessary to undertake field or community surveys. Results of community UXO incidence and accident surveys are discussed further in Chapter 6.

Military Base Location, Layout and Operations Information

A variety of other American historical records related to war-time activities in Viet Nam may be found through systematic searches of US National Archives in Washington, DC. Although much of the information in the Archives is textual in nature (e.g., memos, directives, mission assessments, correspondence, herbicide application records, etc.), spatial information such as maps and remote sensing data also can be located.

American topographic and navigation maps of southern Viet Nam created during the war era, and Vietnamese maps of this region created thereafter (modified from original American maps) may be obtained that illustrate locations of war-era infrastructure (e.g., fire bases and air strips) that are not typically marked or listed on more modern maps. They also can provide implied military damage information (e.g., map notations describing many towns and villages as "Destroyed" or "Abandoned"). These maps exist at scales of 1:250,000 and 1:50,000. In addition, physiographic and hydrological data from these maps can be used to allow change detection analyses documenting physical and land cover changes from the war era to the present.

A specific search for information about US Special Forces bases in Aluoi District was undertaken at the US National Archives in April 2001. Several valuable data sets were obtained, including aerial photography of the A So (A Shau) and Ta Bat bases, and a schematic map of the A So base indicating the location and dimensions of buildings and other structures.

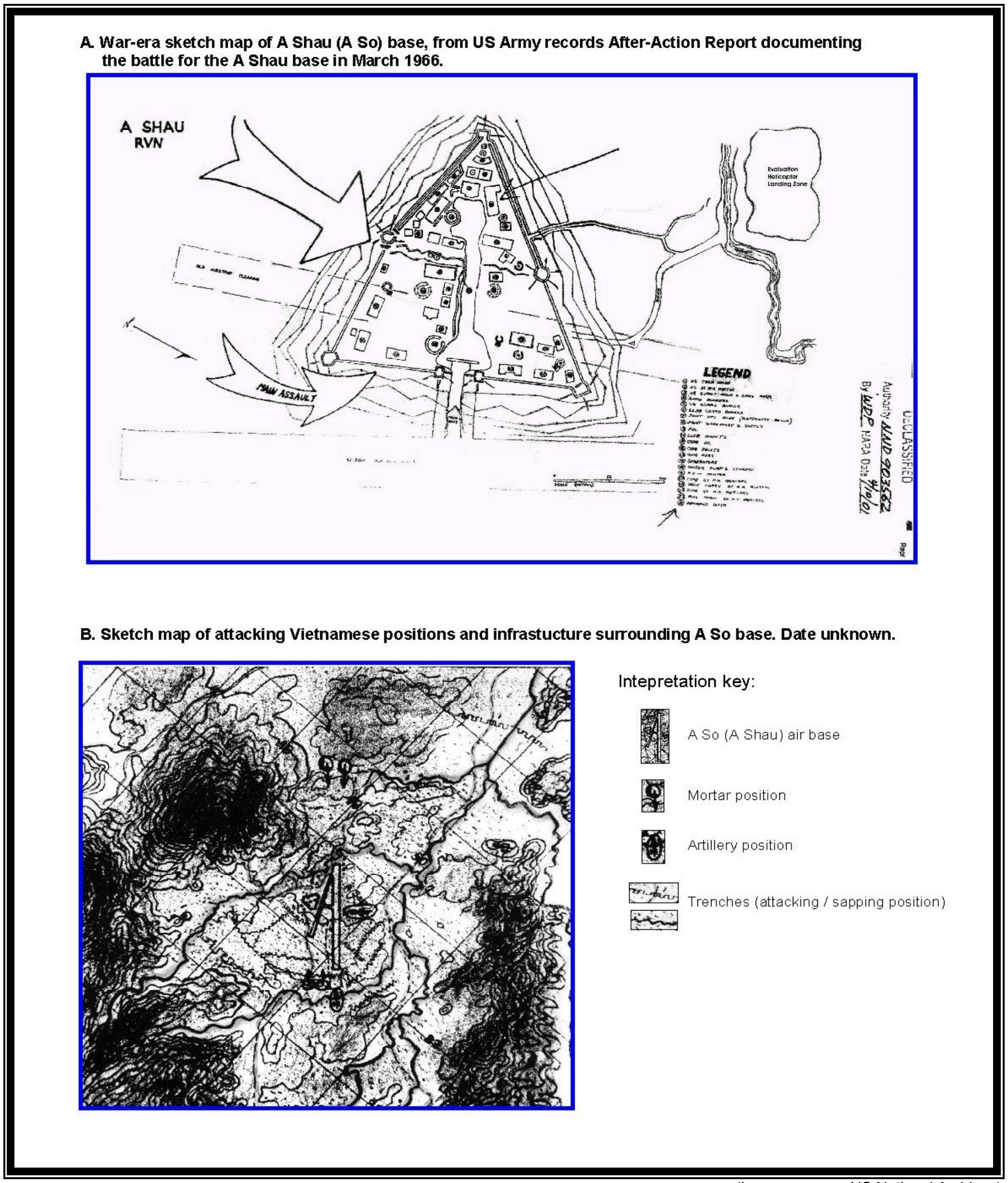
Increasing amounts of recently declassified information regarding locations of US military operations and facilities in Viet Nam is entering the public domain through independent research and much is now available in popular literature and on the Internet. For example, grid locations of US facilities throughout Viet Nam, including air bases, landing zones, fire support bases, and others, have been collated by Kelley (2002). From this source, locations of all US/USVN fire support bases and landing zones in Aluoi District have been collected and combined with other historical spatial data in a GIS environment; these appear and are discussed in Chapter 6.

Three US Special Forces bases existed in Aluoi District in the mid-1960s: Aluoi (established May 1965); Ta Bat (established March 1963); and A Shau (hereafter referred to as A So, established April 1963). Aluoi and Ta Bat supported air strips with small detachments of Vietnamese and American troops; A So (A Shau) was larger, with a fortified triangle-shaped compound and a supporting compliment of US Special Forces and Vietnamese Civilian Irregulars. Aluoi and Ta Bat were abandoned in December 1965; A So (A Shau) was overrun in an intense battle on 12 March 1966 (US Army 1989, Kelley 2002).

Figure 3.3A illustrates a sketch map of the A So (A Shau) base during its operation, including the function of specific structures and buildings. Historical maps such as these allow researchers to identify locations of specific features of interest; for example, perimeter wires that may indicate historical mine fields, on-site storage facilities that may have been used to store herbicides such as Agent Orange, other chemicals, or munitions.

Figure 3.3B illustrates an undated US military sketch map of the area in the vicinity of the A So (A Shau) base area, showing locations of artillery positions, mortar emplacements, and sapping trenches of enemy troops (D. McCracken, Thailand Mine Action Centre, *pers. comm.* 2002).

Detailed information describing war-era conditions is valuable when planning detailed investigations of UXO or chemical contamination at an abandoned military site such as the A So base. When combined with other historical spatial data sets, these data can be used to help construct a



(Image sources: US National Archives)

Figure 3.3
Declassified US Military sketch maps of A So Base layout and defensive/attacking positions.

comprehensive understanding of war-era physical conditions and activity locations. When compared with current data documenting site conditions, such historical data may be used to assess changes over time and current conditions at specific locations of interest due to their war-era histories.

Incidental Information in War Records

Historical military war records also include useful informal, general or anecdotal information that can be accessed and used to guide UXO assessment and removal efforts. These records include monthly operating summaries for base forces or groups, base medical reports, etc. For example, an after-action report related to the battle for the A So (A Shau) base reports that "old mine fields" were located "on the east side of the airstrip and the south side of camp". Such informal information would be helpful to guide UXO detection and clearance operations in the A So base area, particularly related to the safety of UXO detection workers. Although qualitative, such information may still be mapped and included in a GIS system, as described later in this section.

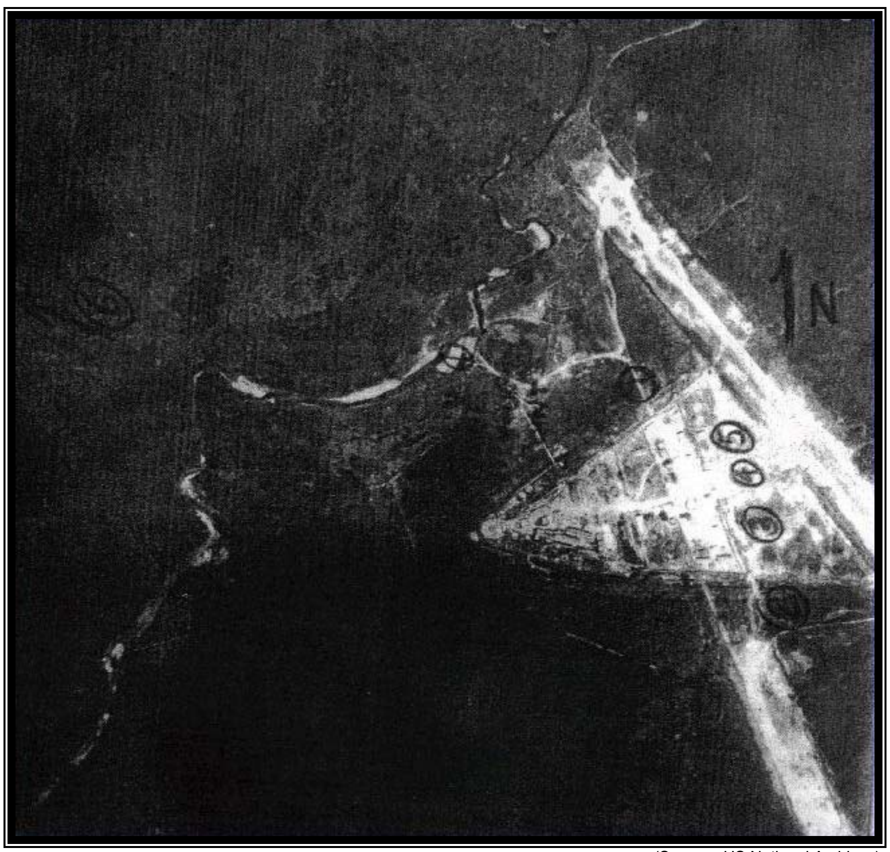
3.2.2 Historical Spatial Data

Aerial Photography

American war records may also include aerial photography of areas of interest in southern Viet Nam. Copies of war-era aerial photography of the A So (A Shau) and Ta Bat bases were found in the US National Archives (Plates 3.1 and 3.2). The date of acquisition of the A So image (Plate 3.1) is unknown; however, base infrastructure appears in the image to be intact, which suggests that the image was acquired before the base was destroyed during its takeover by the North Vietnamese in March 1966. The oblique aerial photograph of Ta Bat, shown in Plate 3.2 taken June 14, 1969, does not show clear evidence of established base infrastructure, although hand-drawn outlines on the archived photograph indicate the location of the base infrastructure (triangular area) and air strip (irregular, rectangular area). The clear evidence of heavy bombardment in the Ta Bat area is consistent with an acquisition date well after base abandonment.

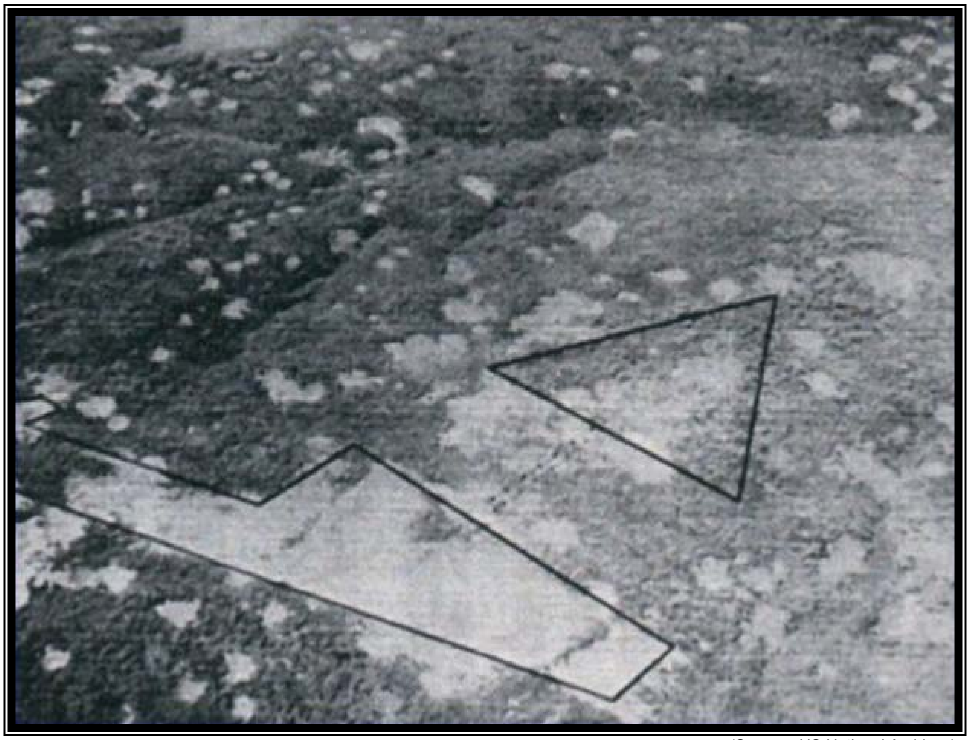
Use of these images to reconstruct war-era conditions in Aluoi valley is limited in two major ways. First, the reproduction quality of these photocopied aerial photographs is poor, which limits the amount of thematic information that can be extracted. Second, these images are not geographically referenced in any way, which means that they are most useful as comparative map products only if they can be co-registered in geographic space to another, geographically accurate data set. This issue is further exacerbated by the fact that most of the imagery is oblique; that is, not collected from directly overhead. Oblique aerial photography results in a spatial distortion in the near-to-far range of the image (known as parallax distortion), as the size of features in the near-range of the image is greater than the size of similar-sized features in the far-range. If pronounced enough, this distortion prevents the direct combination of these images with other maps or imagery.

In the case of the war-era aerial photography of the Aluoi valley bases acquired from the National Archives, this distortion is sufficiently large in the



(Source: US National Archives)

Plate 3.1
US Military aerial photography of A So Special Forces base (date unknown).



(Source: US National Archives)

Plate 3.2

Oblique US Military aerial photography of Ta Bat base, with location of base infrastructure and airstrip outlined (date unknown).

image of Ta Bat to make co-registration of this image with other maps and imagery very difficult. However, distortion in the undated image of the A So base is sufficiently small to allow co-registration and analysis with other spatial information.

Declassified Military Satellite Imagery

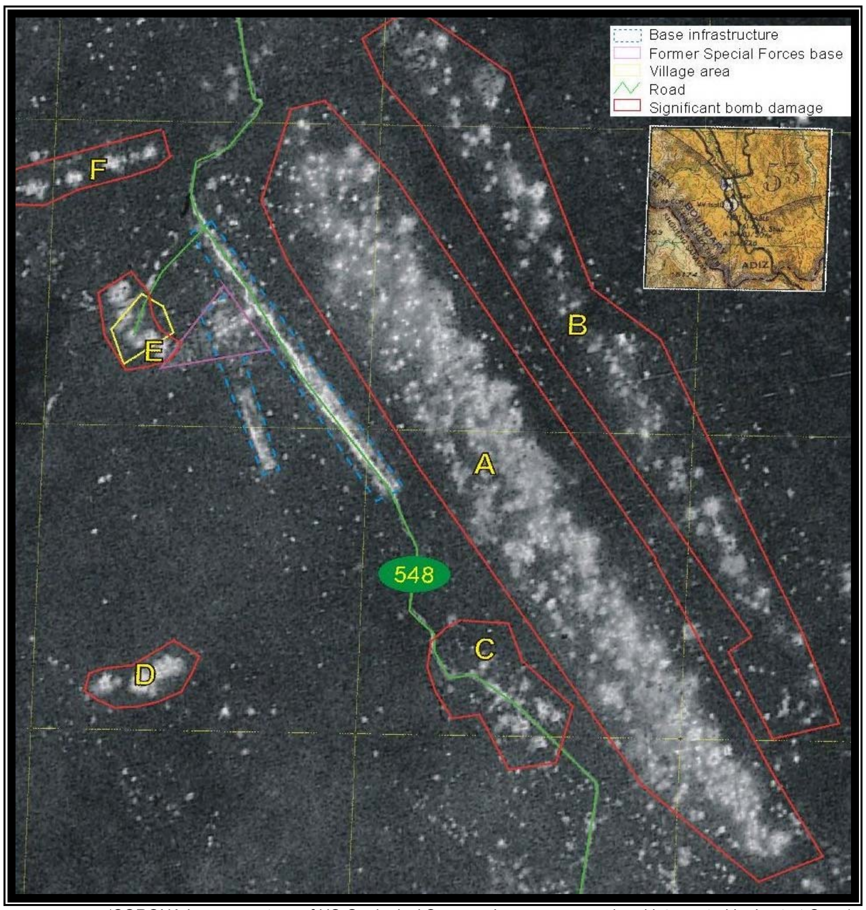
In February 1958, shortly after the Soviet Sputnik satellite was successfully launched, the US government began a program to create and launch military satellites capable of collecting pictures of the earth's surface, or more precisely, activities of countries perceived as military threats to the United States. This program was code-named Corona. The Corona program operated from 1958 to 1972, and successfully collected the first photo reconnaissance from space in August 1960. Over the duration of the Corona program, over 860,000 images of the Earth's surface were collected, on 2.1 million feet of film. The time frame of the Corona program coincides with increasing American involvement in Viet Nam. As a result, a significant amount of Corona imagery exists that was acquired over Viet Nam during the Viet Nam conflict.

Intelligence imagery acquired by the Corona program was declassified on 22 February 1995, and made available to the public. Panchromatic (i.e., black and white) film products were acquired by the satellite, sometimes in stereoscopic pairs. Images were not originally in digital format, so a specific estimate of the ground resolution of Corona imagery is not possible. However, a visible ground resolution of up to two metres was achieved by some series of Corona satellites, which compares favorably with the highest-resolution satellite data available today commercially.

The Corona satellite imagery offers a unique look back in time and offers a considerable amount of data for documenting historical conditions in many areas of the world. The declassified imagery may be used to produce maps, charts and photographic images describing environmental conditions over three decades ago.

In this project, Corona imagery of the Aluoi Valley, particularly areas in the vicinity of former bases, has been scanned, processed and analyzed to identify and delineate former areas of war-era infrastructure (i.e., base locations, orientations, and layouts), and areas that exhibited intense bombing, shelling or combat activity, which may be consistent with areas of high residual UXO contamination.

Corona imagery was interpreted thematically, to extract important features such as base locations and layouts, land cover features, rivers and roads, bombing and shelling evidence, etc. These interpreted features were digitized in a GIS environment as vector (line) and polygon (area) data from the original image, with the vector data overlaid and compared with other historical spatial data and with modern imagery and maps.



(CORONA Image courtesy of US Geological Survey – Image processed and interpreted by Imstrat Corp.)

Figure 3.4

Declassified US Military Corona imagery of A So Special Forces base (abandoned), acquired 20 March 1969.

Figure 3.4 provides an example of processed Corona imagery, acquired on 20 March 1969, showing the A So (A Shau) base area and environs. The airstrip of the A So base can be clearly identified, but the triangular base area is indistinct, suggesting that some vegetation cover had returned to the base area since its abandonment in 1966. Former Highway 548 is visible and has been digitized, running north-south in the image, and numerous bomb craters are clearly evident, particularly in a large NW-SE area to the east and southeast of the A So (A Shau) airstrip. Corona imagery was used to identify roads, rivers, some land cover and topographic features, and other features useful for documenting war-era conditions in the Aluoi valley. Corona imagery analysis in this project was undertaken by a subcontractor to the project, Imstrat Corporation, a firm of former Canadian Department of Defense remote sensing analysts based in Ottawa; Imstrat's report and thematic interpretation of this image appears in Appendix A5.

Imstrat's analysis of the Corona image outlined six areas that received concentrated bombing damage. Two elongated bombing 'runs' (area A and B), running parallel to the airstrip were probably delivered aerially in an attempt to target the airstrip itself. It is unclear if the other four areas of concentrated bomb damage (C, D, E and F) were delivered aerially or from the ground. However, it is apparent (from other military information on the base at A So) that the targets for areas E and F were the base perimeter and helicopter landing area, respectively. It is unclear what the targets were for areas C and D, but they may have been sites of defensive or offensive activity by either the US or North Vietnamese. Regardless of the target, the Corona Imagery provides us with information on areas of bombing concentration and possible presence of UXO.

Although hindered at times by cloud cover issues, like all optical observation satellite data, Corona data have an advantage over war-era aerial photography, in that their high acquisition position (i.e., from space) results in a relatively non-oblique acquisition geometry. This allows for easier geographic registration and comparison between image products and other spatial data sources.

Additional sources of war-era US military imagery may soon be declassified, namely high-altitude aerial photography from U2 intelligence aircraft. Such imagery would also add to available sources of historical spatial and imaging information available for the Viet Nam conflict and others.

Historical Civilian Satellite Imagery

The Landsat Multi-Spectral Scanner (MSS), or Landsat-1, was launched in 1972 by the US government, to provide government and public researchers with digital, visible-spectrum imagery of the earth. Landsat-1 was the first earth observation satellite launched for non-military purposes. Historical Landsat data, such as Landsat-1, has recently been made much less expensive by the US government, to encourage global users to purchase and use these historical satellite data.

Landsat-1 acquires digital imagery of different sections of the visible and near-visible spectrum, in four bands:

- Band 1: 0.50 to 0.60 µm (corresponding to the colour green);
- Band 2: 0.60 to 0.70 µm (red);
- Band 3: 0.70 to 0.80 µm (near-infra-red); and
- Band 4: 0.60 to 0.70 µm (infra-red).

By displaying data from each of three of these bands in red, green, and blue, a false colour image can be created that exhibits a full range of colours in the processed image for interpretation.

The ground resolution of Landsat-1 imagery is 80 m, so one pixel of a Landsat-1 image provides data for a ground area of 80 m x 80 m. One Landsat-1 scene covers a 185 km x 170 km area.

An example of a false colour Landsat-1 image of Aluoi District, acquired on September 11, 1973, appears in Figure 3.5. In this scene, areas of dense forest appear dark green, areas of less dense vegetation cover appear light green, and areas of reduced or minimal vegetation cover, likely mostly agricultural areas, appear pink or purple.

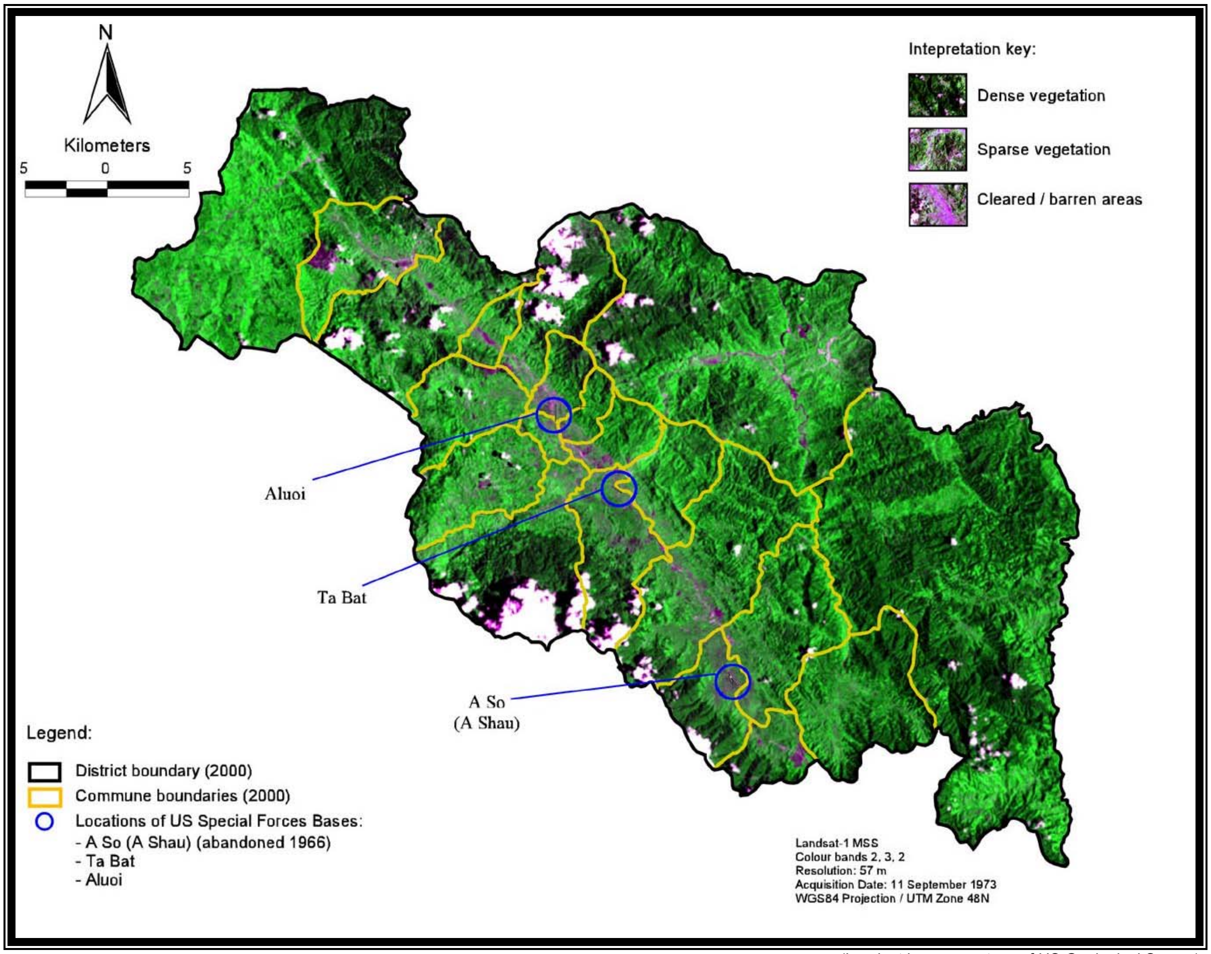
3.2.3 Local Interviews and Surveys

Many older local people in Aluoi District have lived in the area for their entire lives. As such, they have lived through many of the war-era activities and impacts that are of interest to UXO assessment and clearance activities. Through interviews and surveys with local people, war-era events may be reconstructed. Historical spatial information can be collected in this manner, including community mapping exercises to indicate areas within specific communes where major battles occurred, or where infrastructure existed, such as bases, artillery fire bases, airstrips, etc.

Such anecdotal information can be used to support or supplement data gathered from other data sources, and also may provide information that is not available through other sources.

For example, local community leaders at Hong Van commune stated during interviews in May 2001 that an American base existed at the top of a small plateau in the area, which was large enough to allow landing of US Army DC-3 Dakotas. Evidence of intensive human activities (i.e., barren land) on this plateau is apparent in Landsat-1 imagery of the area from 1973 (Figure 3.5); historical information regarding US fire support base (FSB) and landing zone (LZ) locations later revealed this to be LZ/FSB Tiger Mountain. Air combat database records indicate that Hong Van suffered the heaviest aerial bombardment of the war (see Chapter 6, Section 6.2.2., and Figure 3.2); this and other barren areas visible in Hong Van and elsewhere in the 1973 image might indicate intense aerial bombardment by US forces.

Use of varied historical data sources such as satellite imagery, archive material, bombing records and interviews to corroborate each data source allows for a more complete and reliable



(Landsat image courtesy of US Geological Survey)

Figure 3.5
Landsat-1 image of Aluoi District in 1973.

understanding of war-time activities. This in turn provides an important component to support UXO documentation and clearance efforts.

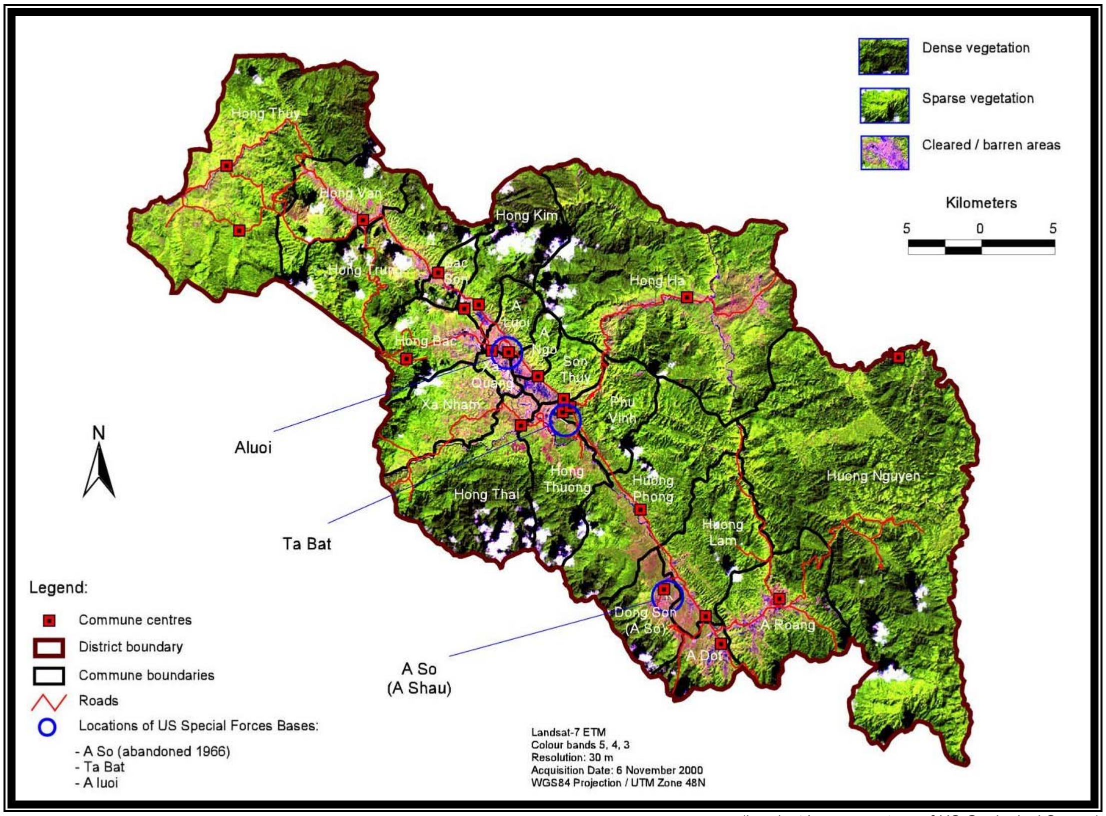
3.3 CURRENT AVAILABLE SPATIAL INFORMATION

3.3.1 Remote Sensing Data

Since the successful start of the Landsat program in 1972, several other earth observation (EO) satellites have been launched that acquire imagery that is publicly and/or commercially available. Particularly in recent years, the number, variety, and precision of EO satellites has increased rapidly. Currently, numerous countries support EO satellites and their activities; major countries active in EO include the United States (though government programs such as Landsat, Terra, and AVHRR, and private initiatives like IKONOS), France (independently and through the European Space Agency), Canada, Japan, and India.

Optical Remote Sensing Data

Optical remote sensing refers to the use of passive sensors on EO satellites to create imagery from light and radiation reflected from the Earth. Typically, data are acquired in and around the visible region of the electromagnetic spectrum. Because these sensors are passive, they require external illumination of a target area in order to create an image. Practically, this means that these optical sensors can only acquire data over an area in daylight hours. Similarly, images cannot be acquired of the Earth's surface where it is covered by high or low cloud. This impact of potential



(Landsat image courtesy of US Geological Survey)

Figure 3.6

Landsat-7 image of Aluoi District in 2000.

cloud cover can be significant in tropical and moist regions of the world, where heat- and moisture-driven cloud cover during daylight hours is very common.

To maximize the likelihood of successfully acquiring a useable scene, optical satellites constantly acquire imagery along fixed orbit paths, and store it in a searchable archive. Users must then search the archive for all imagery of an area of interest, to ascertain whether sufficiently cloud-free imagery of their area of interest exists. Once identified, appropriate scenes are then purchased from the data archive by users.

Although several optical EO satellites are planned for launch in the next few years, currently there are five major optical EO programs globally that could provide data of interest to this project. These are detailed below.

The Landsat program has continued uninterrupted since 1972, and most recently was punctuated by the successful launch of Landsat-7 ETM+ (Enhanced Thematic Mapper Plus) in April 1999. The Landsat-7 sensor is much more advanced than the initial Landsat-1 sensor, and acquires nine bands of information:

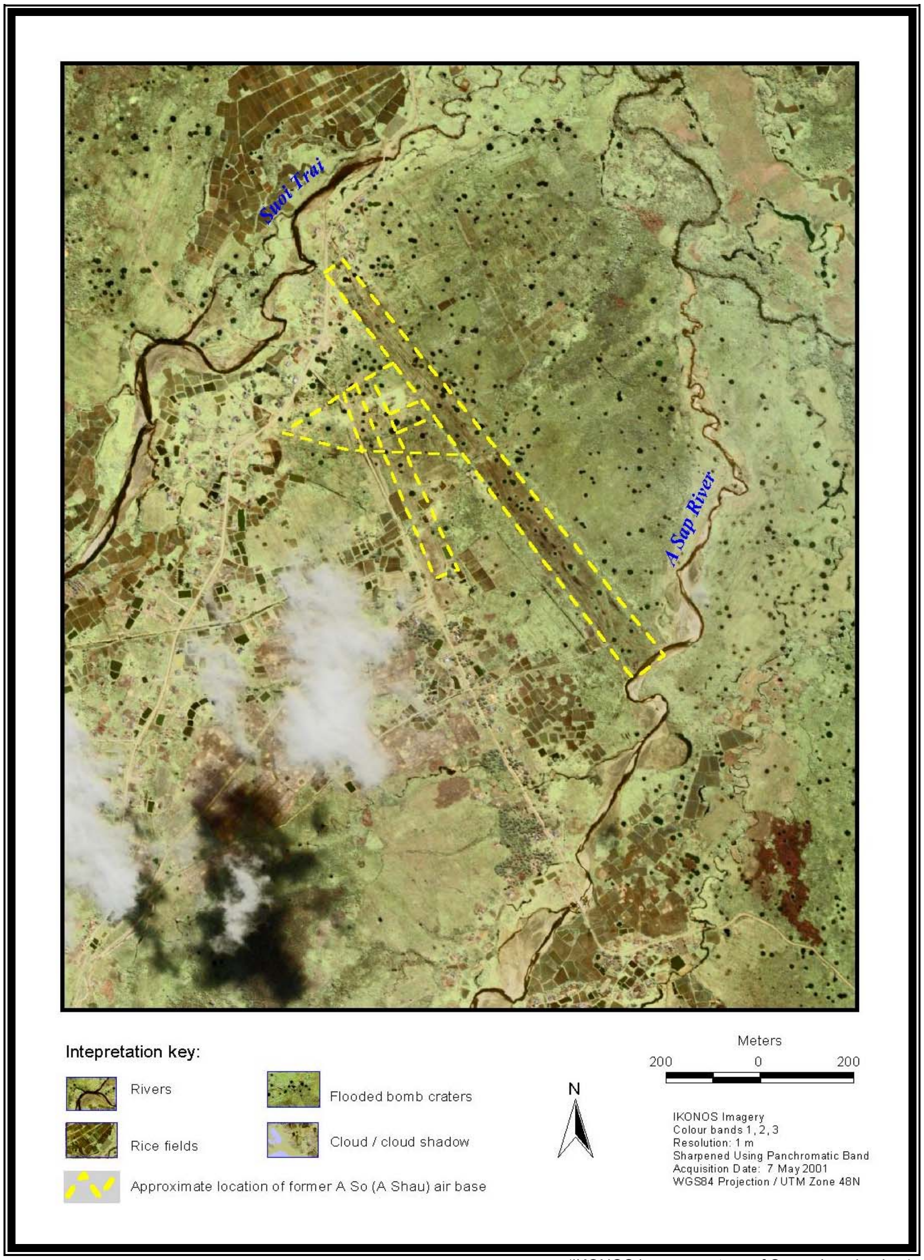
- seven "colour" bands, collected at a spatial resolution of 30 m, corresponding to regions of the visible and infra-red region of the electromagnetic spectrum;
- a panchromatic (black and white) band, collected at a spatial resolution of 15 m, integrating the entire visible spectrum; and
- a thermal band (60 m spatial resolution), which acquires information in the far-infrared region of the electromagnetic spectrum.

Although these data are considered to be relatively low-resolution relative to other current optical satellites, Landsat data has the added advantages of nearly 30 years of research and applications development, as well as the lowest per-image cost of all current EO products. For these reasons, Landsat-7 data of Aluoi District was acquired for this project. A false colour Landsat-7 scene of Aluoi district, created using imagery from bands 5,4, and 3, appears in Figure 3.6.

The French SPOT satellite and the Indian IRS satellite series provide imagery that is currently considered medium to high resolution, respectively. SPOT imagery currently available from the SPOT-4 satellite includes three colour bands of 20 m resolution and one panchromatic band of 10 m resolution. The IRS series of satellites, first launched by India in 1996, were the first commercially-available satellites to provide sub-10 m resolution. The IRS "P" sensor provides panchromatic data of approximately 4.8 m resolution. This imagery is of sufficient resolution to allow mapping at scales of 1:20,000 or better.

In September 1999, the IKONOS satellite was launched by Space Imaging Inc. of Denver, Colorado. This satellite acquires optical EO imagery at very high resolution in one panchromatic band (at 1 m nominal resolution), and four colour bands (at 4 m resolution, corresponding to blue, green, red and near-infrared, and covering wavelength intervals identical to colour bands #1 to #4 in the Landsat 4, 5, and 7 satellites). The very high resolution of IKONOS data allows creation of image products that look similar to aerial photography, and that can identify targets as small as 1 m^2. IKONOS imagery of the southern portion of the Aluoi valley was acquired for this project on May 7, 2001.

Detail from this IKONOS image appears in Figure 3.7, showing the former A So (A Shau) base area. This image exhibits a spatial resolution of 1 m. This



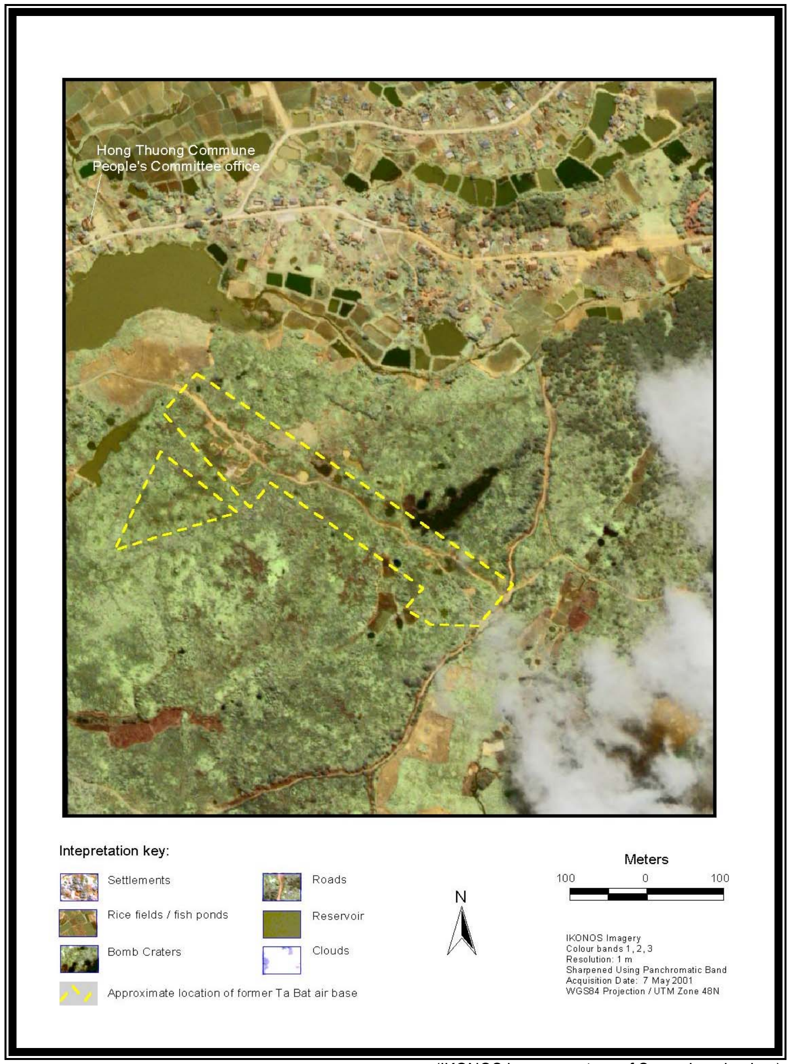
(IKONOS image courtesy of Space Imaging Inc.)

Figure 3.7

Current conditions in the vicinity of the former A So Special Forces base, May 2000.

has been achieved by "sharpening" the red, green and blue colour bands (originally 4 m resolution) with data from the 1-m resolution panchromatic band, to create a colour scene at 1 m resolution. Several features are apparent in this image, including rivers and small streams, roads, agricultural fields (predominantly rice paddy), tall vegetation in some areas, and even specific buildings and structures. Cloud obscures some portions of the south-west quadrant of this scene.

Water-filled bomb craters are evident and widespread in the area, providing evidence of intensive bombing, and suggesting a possibly high UXO risk in this area. The amount of land apparently not under cultivation also implies that the land is unproductive or more likely dangerous due to UXO concerns, or both. Also evident in the scene is the outline of the former A So (A Shau) base air strip, visible as a brownish rectangular feature oriented along a NW-SE axis near the centre of this scene. Through co-referencing and comparison of historical war-era aerial photography of the base itself, an outline of the base and airstrip layout has been overlaid on this image, to indicate the location of these features relative to current conditions on the ground.



(IKONOS image courtesy of Space Imaging Inc.)

Figure 3.8
Current conditions in the vicinity of the former Ta Bat Special Forces base, May 2000.

Figure 3.8 illustrates IKONOS imagery of the former Ta Bat airbase area, at an approximate scale of 1:5,000. Bomb craters are less evident in this scene, likely due to most craters being above the water table and therefore not water-filled and easily distinguished from space at the time of the image acquisition. Both the June 1969 aerial photo and our ground reconnaissance have indicated large numbers of craters exist in the area. A large area of unused or abandoned shrubland occupies much of the area around the presumed former base and air strip (i.e., along the road bisecting the scene from NW to SE). Only very oblique war-era aerial photography of the Ta Bat base area exists (Plate 3.2). This information, and war-era Corona imagery of the area in the vicinity of the base, has been used to help locate the possible base and airstrip position in the scene shown in the overlay.

Radar Remote Sensing Data

Canada entered the group of countries active in space-borne earth observation with the launch of

RADARSAT-1 in 1996. This satellite differs from optical satellites in that it has an active sensor, which creates images through directing a beam of microwave energy (radio waves) at the Earth's surface, and recording the amount of microwave energy that returns from the surface back to the satellite.

Given it is an active sensor, RADARSAT does not require an external illumination source to acquire imagery, and can acquire imagery of the Earth at any time during day or night, and is not affected by cloud cover. These "all-condition" acquisition abilities make RADARSAT data particularly attractive for use in tropical areas where daytime cloud cover greatly limits the ability of optical satellites to acquire imagery. In addition, the unique characteristics of radar, how radar interacts with the Earth's surface, and the slightly oblique angle from which the satellite acquires data, can be exploited to identify and examine specific features that might not otherwise be visible in other types of imagery, such as hydrological features, flooded vegetation, geological features, etc. RADARSAT also has a "flexible targeting geometry", which means that it can acquire imagery at different spatial resolution and area coverage. The highest resolution RADARSAT product, Fine-mode imagery, acquires data with an approximate spatial resolution of 8 m.

RADARSAT imagery of the Aluoi District area was acquired for different purposes during a previous Hatfield Consultants Ltd. project in Viet Nam in 1997 (HCL/10-80 1998). The imagery were found to be useful for delineation of land/water interfaces and for updating vegetation and land cover in war-impacted areas.

3.4 INCORPORATING GIS/REMOTE SENSING INTO MINE ACTION

3.4.1 General Mine Action Surveys

According to the United Nations International Mine Action Standards (IMAS), the objectives of a General Mine Action Assessment are to:

a) assess the scale and impact of the [UXO] problem on the country and individual communities;

b) investigate all reported and/or suspected areas of mine or UXO contamination, quantities and types of explosive hazards; and

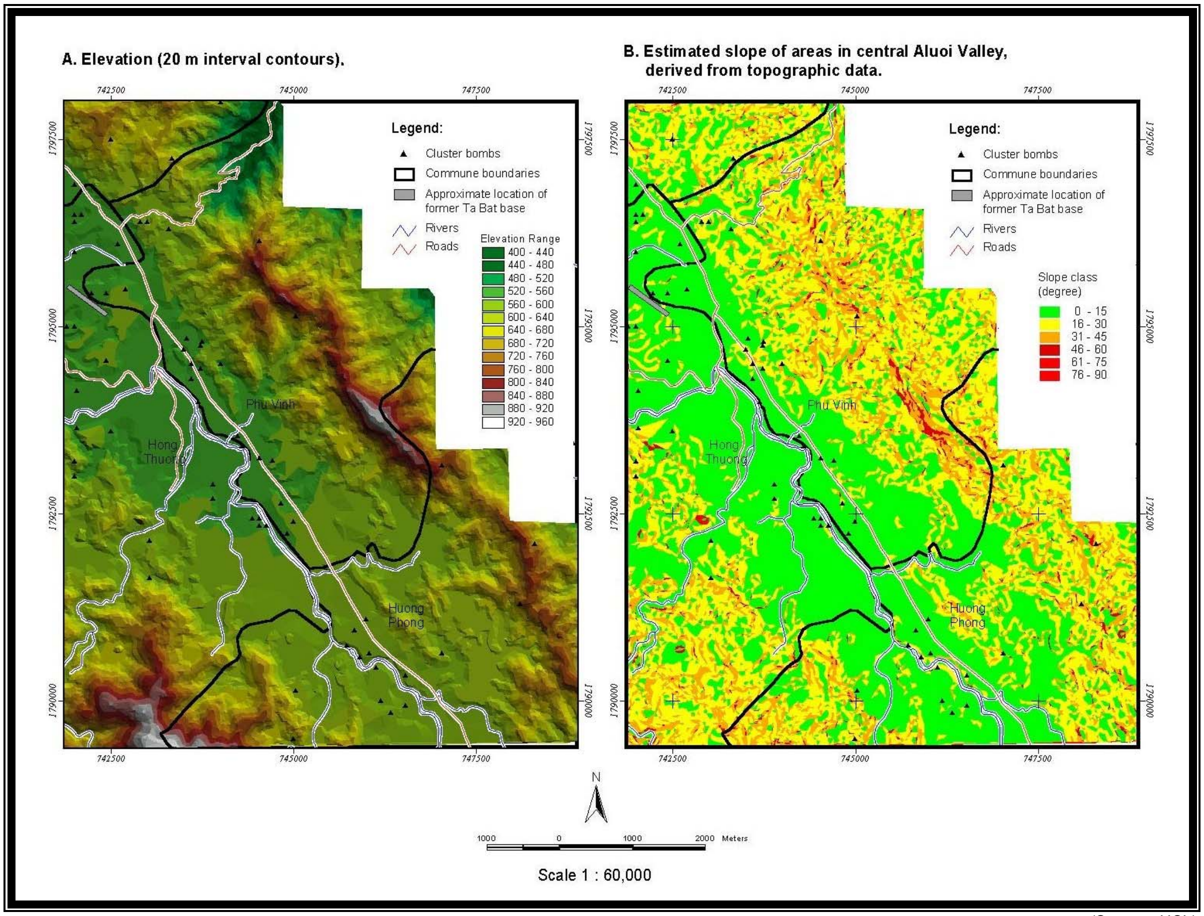
c) collect general information such as the security situation, terrain, soil characteristics, climate, routes, infrastructure, and local support facilities, to assist the planning of future mine action projects.

Previously, this level of assessment was known as a "Level One Mine Action Survey".

GIS and remote sensing technologies, and particularly use and synthesis of historical spatial information with modern data, can support all of these objectives. Several novel approaches utilizing GIS and remote sensing technologies have been used throughout this project for the Aluoi District pilot study area, which are of direct application to a General Mine Action Assessment.

Establishment and Updating Biophysical Conditions

GIS and remote sensing technologies provide a convenient and powerful means of organizing, analyzing, and storing information regarding baseline biophysical conditions. Where accurate spatial data exist and are readily available, GIS allows manipulation and management of these data. For example, topographic information taken from historical maps of Aluoi District were used to create a map illustrating the topography of central Aluoi valley, shown in Figure 3.9A. This topographic information can be further analyzed in a GIS environment to generate a slope map of the area (Figure 3.9B). This slope map can be used to indicate areas where demining activities could be difficult due to steep slopes, or where demining activities should be supported by slope stabilization and drainage management activities (see Chapter 4). In this figure, areas shaded green are relatively flat (i.e., slopes of less than 15º) and likely would require minimal slope stabilization and management; areas shaded yellow (slopes of 16 to 30º) likely would greatly benefit from slope stabilization and drainage management procedures during demining; and areas in red (slopes >45º) would require significant slope stabilization and drainage management.



(Source: HCL)

Figure 3.9

Analysis of topography and slope, central Aluoi Valley.

In addition, areas such as Viet Nam where accurate and current environmental information is difficult to obtain, such information can be extracted from satellite imagery cost-effectively, particularly from Landsat, SPOT, and IKONOS satellite data. From these data, roads, recent development areas, river morphology, and vegetation cover may be extracted and mapped.

Use of historical satellite imagery or aerial photography also can provide information regarding environmental conditions in an area, as shown in the 1973 Landsat-1 scene of Aluoi District (Figure 3.5). Further, comparison of historical and recent satellite imagery can be undertaken to generate a better understanding of environmental changes between war-era and current times. This can be especially useful when working in an area like Viet Nam, where initial UXO contamination occurred almost 30 years ago.

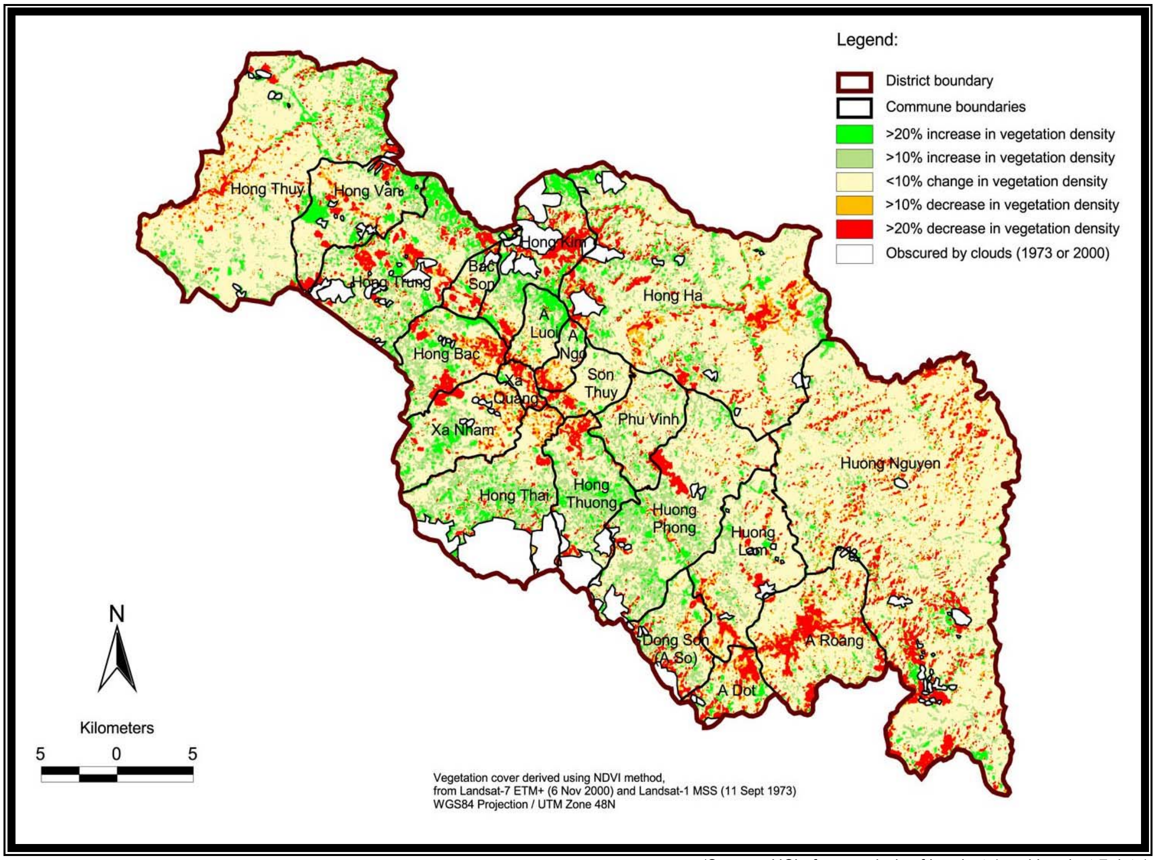
Figure 3.10 illustrates results of a quantitative comparison of vegetation cover in Aluoi District between 1973 and 2000, using Landsat-1 and Landsat-7 imagery, respectively. Through accepted analytical protocols, an index known as the Normalized Density of Vegetation Index (NDVI), was calculated from each image. NDVI provides an estimate of the density of vegetation in an area, based of reflectance values in the red and infra-red bands of Landsat image data.

Comparison of NDVI data from Landsat-1 and Landsat-7 data allows estimation of areas in Aluoi District where vegetation has increased or decreased between 1973 and 2000.

It is important to note that other factors may influence NDVI, such as sun angle and shadow, and crop cycle status during image acquisition, which make these data potentially unreliable when examined in detail. Areas of red in Figure 3.15 correspond to area where a significant decrease in vegetation density likely occurred between 1973 and 2000. Several of these areas correspond to areas of Aluoi District where population density is relatively high (e.g., communes in the north-central valley bottom), as well as southern areas in A Dot, Huong Lam and A Roang communes, and areas along Highway 49. These red areas suggest areas where land clearing and cultivation has occurred, and therefore where human activities have expanded and increased since the war. Regularly-patterned areas of red in Huong Nguyen commune, in the southeast of Aluoi District, may correspond to differences in sun angle and shadow in the hilly areas of this commune, rather than changes in vegetation cover.

Areas of green correspond to areas where vegetation cover may have increased since the war, and may include areas where human activities (including war-related activities, such as combat and intense bombardment) may have been more active in 1973 than 2000. It is possible that these areas also correspond to areas that were formerly used by people, but have been abandoned for various reasons, perhaps including high UXO risk.

Areas where increased vegetation cover are evident include northern communes in the district, such as Hong Van, Hong Thung, Aluoi, Hong Bac, and western and southern communes, such as Hong Thai, Hong Thuong, Huong Phong, and Dong Son (A So).



(Source: HCL, from analysis of Landsat-1 and Landsat-7 data)

Figure 3.10

Estimated changes in vegetation cover in Aluoi District, 1973 versus 2000.

Comparison of remote sensing and other spatial data in a GIS environment can highlight changes in other environmental conditions as well. For example, river morphology and locations of main stream channels in the vicinity of the former A Shau base have changed considerably since the 1960s.

Compilation and Comparison of Community Survey Information

Collation and comparative analysis of spatially organized historical war records in a GIS environment can be a powerful means of visualizing and analyzing war-era conditions, as shown in the analysis of aerial herbicide application data and air combat data discussed above. These data alone provide much of the necessary information to determine likely areas of heavy UXO contamination, and areas where residual herbicide contamination may pose a threat to deminers, local people, and the environment.

Community survey data, collected through interviews in the field, also may be analyzed spatially, and combined with other spatial data sources to facilitate a General Mine Action Assessment. A simple but data-rich summary map of UXO incidence, distribution and accident survey information by commune in Aluoi District is included with detailed discussions of the Aluoi District incidence/accident survey in Chapter 6.

Assessing Residual Herbicide Contamination Risk to Deminers and the Environment

As discussed in other sections of this document, the US military, through its *Operation Ranch Hand*, heavily sprayed portions of southern Viet Nam with various herbicides. Some of these herbicides, Agents Orange and Purple in particular, contained high concentrations of dioxins, a long-lived, extremely toxic compound that has been linked to short- and long-term health problems and birth defects.

Therefore, when considering undertaking demining in southern Viet Nam, it is important to consider potential residual dioxin contamination, in order to minimize potential exposure of deminers and local people to dioxins. Demining activities also may remobilize dioxins currently trapped in soil into the food chain and the environment, if precautions are not taken.

Integration of war-era herbicide application records (i.e., HERBS records) with information gathered through site-specific investigations, may be effectively undertaken in a GIS environment. Results may be useful for indicating areas of high risk to deminers, local residents and the environment from residual dioxin contamination.

Such an analysis has been undertaken for Aluoi District, and is presented and discussed further in Chapter 6.

3.4.2 Technical Mine Action Surveys

According to UN IMAS standards, a Technical Survey is a "detailed technical and topographic investigation of known or suspected hazardous areas." For this study, the area in the vicinity of A So (A Shau) special forces base was chosen as a pilot study area.

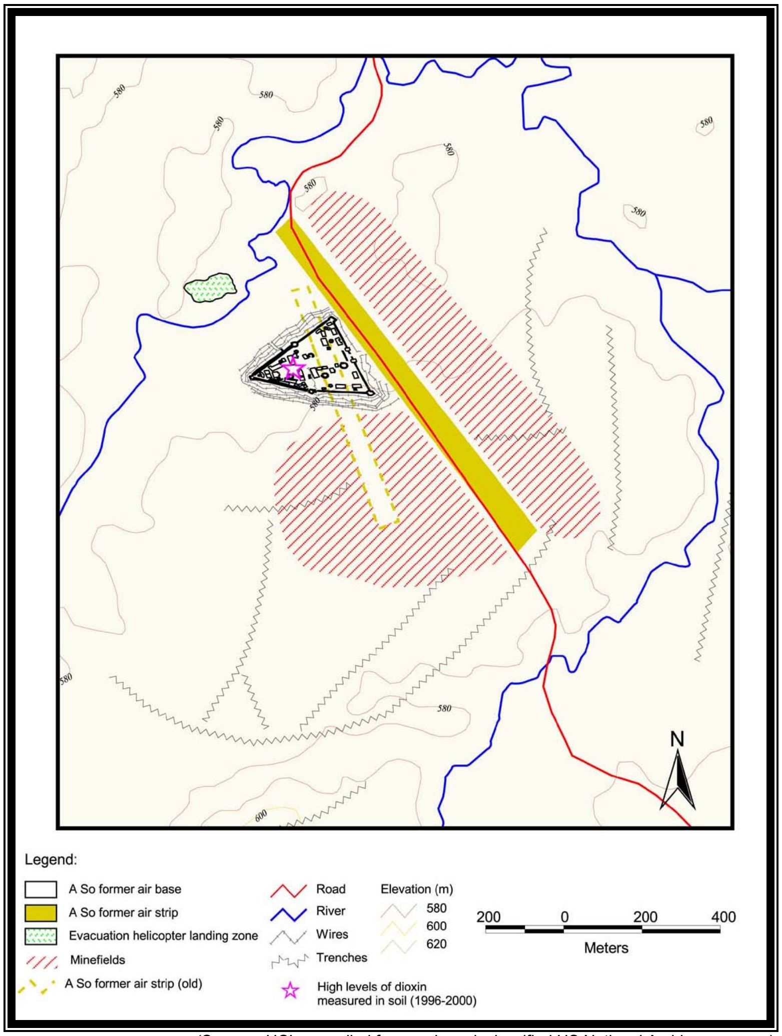
As described previously in this chapter, a wealth of historical (war-era) information can be collected to help demining teams to more fully understand war-era conditions and activities in areas to be demined, so that they can work with maximum knowledge, efficiency, safety, and cost-effectiveness.

Different types of historical information collected during this project were combined, compared, and co-registered into a consistent GIS environment, to help develop a more complete understanding of war-era conditions in the vicinity of the A So (A Shau) special forces base (Figure 3.11). This figure contains information regarding:

- physical features, such as topography and river courses, taking from historical paper maps and historical Corona satellite imagery and military aerial photography;
- the major war-era roadway through the area, taken from Corona satellite imagery;
- location of the air strip(s), taken from Corona satellite imagery and military aerial photography;

- location and layout of the triangular base, taken from military aerial photography and archival schematic drawings from US military archives;
- location and organization of perimeter wires around the A Shau base, taken from archival schematic drawings;
- potential locations of mine fields around the base and airstrip, from anecdotal information in after-action reports from US military archives;
- locations of sapping (attacking position) trenches around the base, taken from archival sketch maps from US military archives; and
- area where intense aerial bombardment was evident by 1969, taken from 1969 Corona imagery of the area.

This map provides a clear idea of the war-era infrastructure, activities, and impacts in this area, which could provide a detailed foundation for planning demining strategies, technical approaches, and logistics for this area.



(Source: HCL, compiled from various declassified US National Archives sources)

Figure 3.11

Compilation map describing war-era conditions in the vicinity of A So Special Forces base.

Such information may be combined with current map or image data for a location to help demining operations to better define specific areas of interest, hazard, and the likely nature of specific UXO problems in key areas (e.g., mines in former tripwire areas, bombs and shells near former artillery installations, etc.). This approach has been applied to the A So (A Shau) base in Chapter 6.

Through the combination of spatially-referenced historical information and modern satellite imagery or aerial photography in a GIS system, it is possible to clearly determine where specific historical features, objects or activities of interest occurred, regardless of what is found at the site today. Additionally, this approach can be used to better understand changes in environmental conditions at a site that are not directly related to war activities, but would influence demining, such as changes in course of local rivers and streams.

3.4.3 Assisting UXO Clearance Activities

GIS and remote sensing technology can also be customized for use in the field stage of a mine or UXO clearing operation. The technology can be used to fulfill the specific requirements of coordinating and performing mine and UXO action activities.

The field application of the technology which can integrate data management, specific mine action standards and visual representations (i.e., maps) would allow the user to record, evaluate and visualize information in real time.

Key steps involved in the field clearance component of a mine action that could utilize a data management and display system are:

- surveying and marking of the exact boundaries of contaminated areas;
- recording the progress of clearance activities;
- recording incidents and accidents which occur during mine action activities (this information builds the basis for most victim assistance programs);
- task and process management for clearance and safety crews; and
- daily log keeping to continuously record important information and decisions.

Reports and maps based on the information entered in the system can be generated. Predefined reports and print maps as well as color overlays can be produced which will give up-to-the-minute visual representation of the field activities on base maps, photographic satellite and/or airphoto projections.

As well as the display and print out digital hazard maps and pictures of mine/UXO infected areas, reports can be created to represent data on mines/unexploded ordnance located and destroyed, area cleared, hours spent per clearance, and total accident and incident statistics.

The quality assurance and quality control (QA/QC) stage of the mine/UXO clearance program can also become integrated into the process. Mine action technical survey and ground survey data entered in one program allows auditors to easily review and plan QA/QC checks in a digital environment. Similar to the field component, the QA/QC work can be updated daily as procedures proceed and can be automated to produce QA/QC reports and maps.

Specific procedures for application of GIS and remote sensing to UXO removal is inappropriate given all UXO-contaminated environments vary geographically and with regard to available spatial, environmental, and socio-economic information. However, this project has demonstrated the site-specific value of this approach, particularly for Risk/Impact Assessment.

PROTECTING THE ENVIRONMENT: LAND MANAGEMENT AND REMEDIATION FOR DEMINING

CHAPTER 4

Land remediation is the final step in the rehabilitation of a UXO/landmine cleared site. The responsibility for site rehabilitation falls heavily on the national, regional and local government agencies of the host country as it is they who make decisions on future land use. These agencies will need to identify goals and strategies, economic instruments and financial requirements for remediation and the institutional framework for implementing remediation projects, including external advice (Richardson 1995).

Land remediation is the process of rehabilitating disturbed land to its original state or to a point allowing for other land uses (i.e., residential, forestry, agriculture, etc.). The primary objective in site remediation is to protect cleared land from excessive erosion/sediment movement in preparation for re-establishment of vegetative cover.

Land rehabilitation planning needs to be site specific given that factors relating to climate, soil type, present and future land use and resources (both human and financial) differ from one mine activity site to the next.

The intent of this section is to provide information regarding the processes and mitigation of erosion and resulting sedimentation from UXO clearing so that environmental and socio-economic impacts can be reduced. It should be used in conjunction with knowledgeable advice of local personnel. This site remediation information will not only assist those involved in land clearing activities as they relate to demining and UXO clearance, but can also be extended to other land development activities (i.e., road building, timber harvesting, agricultural land clearing, etc.).

(Source: HCL)

Plate 4.1
Soil degradation as a result of mine UXO removal activity at Phu Bai Airport, Hue, Viet Nam.

4.1 IMPACTS OF UXO CLEARANCE ACTIVITIES ON LAND CONDITIONS

Direct vegetation removal from chemical defoliants and ordnance barrages are key factors in decreasing the natural ability of the landscape to hold soil and sediment. However, land development activities, such as land clearing associated with demining and UXO clearance, can also result in destruction or burial of protective vegetation cover, exposure of unprotected mineral soils and acceleration in the rates of erosion and sedimentation (Plate 4.1).

Environmental and socio-economic impacts of accelerated soil erosion and sedimentation include:

- pollution of surface water;

- damage to adjacent land;
- degradation of streams and aquatic habitat; and
- increased costs for infrastructure repair and soil rehabilitation.

4.2 EROSION AND SEDIMENT TRANSPORT

Erosion is the detachment and transport of soil materials (including sediment) from place to place. In the natural environment, a thin layer of vegetation and organic mat protects the soil's surface. This organic layer is highly porous, and given its high rainfall infiltration capacity, surface runoff does not usually occur. Soil erosion is a natural process in undisturbed areas happening at almost imperceptible rates if the landscape remains undisturbed (Goldman *et al*. 1986).

Two types of erosion processes exist: surface soil erosion and shallow slope movement. The result of an erosion process is sedimentation (Coulter and Halladay 1997); the key components are defined by the following:

Surface soil erosion involves the removal of particles of soil and transport by water and wind action. For UXO clearing activities wind erosion is less significant; only water erosion is therefore considered in this section.

Shallow Slope Movement (also referred to as mass wasting or slumping) is the movement of soil (which can include water) along a slope. In the present context, it refers to that occurring within approximately a metre or so from the surface (not deep movement that requires geotechnical engineering evaluation).

Sedimentation is the deposition of eroded soil material in water.

In general terms, surface soil erosion is the transport of individual soil particles primarily by the action of water and wind, whereas mass wasting is the movement of larger volumes of soil or rock primarily under the influence of gravity. Surface erosion usually involves a higher water/soil ratio, and greater distance of soil transport, than does slope movement (Goldman *et al.* 1986).

4.2.1 Surface Erosion

Erosion potential is determined principally by:

- rainfall and runoff;
- topography;
- soil erodibility; and
- vegetative cover.

Rainfall and Runoff

Flowing water is a major factor in dislodging soil particles, with the degree of erosion proportional to the amount and velocity of water flowing on soil. Runoff can include water flowing to a cleared site and that generated within the site by rainfall and groundwater sources.

The major factors in producing surface water are the intensity, frequency and duration of rainfall. Local knowledge of weather patterns and timing can provide information to assess the probability of rainfall of a particular intensity and duration occurring at a demining or UXO removal site. This probability is referred to as the *Return Period*, with shorter return periods indicating more frequent occurrence.

Intense heavy rain has high energy and dislodges particles more easily than light rain. High rainfall duration not only leads to greater surface flows, but it also increases water content of a soil and causes:

- decreased stability of soil slopes;
- greater surface flow because of reduced infiltration; and
- easier soil particle dislodgment.

Topography

The shape, size and slope characteristics of the upslope area influence the amount, rate and energy of runoff to a cleared demining or UXO removal site. Minor depressions intersected by a cut slope can result in concentration of runoff.

Erosion potential is directly related to the length and steepness of the slope. For the same vertical height, reducing a slope angle is beneficial, but results in a longer slope. The net effect of slope flattening is, on the whole, slightly advantageous.

The surface texture and minor undulations (humps and hollows) on a slope affects the velocity of flow and penetration of water into the soil. Erosion from a smooth compacted surface may be 50% more than that from a loose surface that has undulations.

Soil Erodibility

Cohesionless soils are those that have little or no adhesion between particles, although sometimes the particles form bonds because of the presence of cementing agents or clay.

The potential for erosion for cohesionless soils increases as particle size decreases. Silt and fine sand particles are the most highly erodible. Finer particles are very easily transported by water and take the longest time to settle out of standing water.

Vegetative Cover

The effect of removing plant cover is easily seen when land clearing begins. Vegetation controls erosion by:

- reducing raindrop impacts on the soil;
- slowing runoff velocity; and
- increasing water infiltration into the soil mass.

Roots in soil provide fibres of high tensile strength within a material of lower strength. The strength of the soil/root system increases in direct proportion to the strength, depth and concentration of the roots. Other forms of cover protection for erodible soils include naturally occurring gravels and coarse outwash deposits.

4.2.2 Surface Erosion Assessment

Assessing the amount of potential erosion for a site can be made by the *Universal Soil Loss Equation*. This was developed for agricultural purposes and has been modified for assessing land development conditions. It shows how the amount of erosion is influenced by changes in the values of the individual factors (rainfall and runoff, topography, soil erodibility and cover condition). The values for each factor are determined for the site and used to estimate the total amount of soil loss (Coulter and Halladay 1997). The equation is:

Soil Loss = A x R x K x LS x VM

where:
A = Area;
R = Rainfall Factor;
K = Soil Erodibility Factor;
LS = Topographic Factor; and
VM = Erosion Cover Factor.

In general, erosion increases as the value of the individual factors increase.

Computing the *rainfall factor* (R) requires detailed statistics of rainfall. Although rainfall is not controllable, the surface runoff may be lowered by excavation of diversion ditches. Both rainfall and runoff should be considered when preparing erosion control plans.

The *soil erodibility factor* (K) ranges from 0.1 to 0.7, with values above 0.3 representing very erodible soil. Soil properties affecting it are:

- particle size distribution, especially the percent silt and very fine sand (0.05 - 0.10 mm), and medium and fine sand (0.10 - 2.0 mm);
- soil structure (very fine granular to blocky);
- permeability (rapid to very slow); and
- percentage of organic matter.

The *topographic factor* (LS) increases as the angle increases, and therefore erosion can be decreased by slope flattening. The benefits of slope flattening are offset, to some extent, by the slope lengthening that increases the *Area*.

The *cover factor* (VM) is a measure of the erosion protection provided by a cover on an erodible material. Covers include vegetation, rock, and man-made materials. Some typical cover factors are shown in Table 4.1.

When other erosion factors remain the same, this table shows that a very large reduction in the amount of erosion can be achieved by using vegetation covers and erosion diminishes significantly as vegetation becomes established.

Table 4.1 Typical cover factors.

Conditions	Factor (VM)	Erosion Change
Cleared Ground		
freshly cleared ground	1.00	-
turned ground	1.30	+ 30%
heavily compacted cleared ground	0.90	- 10%
Grass		
after seeding	0.64	- 36%
after 12 months	0.38	- 62%
Seedlings		
0 to 60 days	0.40	- 60%
60 days to 1 year	0.05	- 95%
after 1 year	0.01	-99%

4.2.3 Shallow Slope Movement

Shallow slope movement involves the mass movement of a soil slope, and includes slumping and flow of the mass. The principal impact is local, as the mass typically comes to rest a short distance from the base of the slope. The mass often enters or blocks drainage courses and ditches. Because the mass is loose, broken and sometimes fluid, it is easily eroded by surface water. Fines can be carried into adjacent watercourses or ponds. Shallow slope movement events often occur in the wet season and in addition to the surface runoff, water may come from groundwater sources. At such times they can lead to significant damage since personnel are not always on site and options to mitigate impacts may be limited (Goldman *et al.* 1986).

Table 4.2 Typical slope angles for various soils.

Material	Slope Angle (horiz:vert)
gravel and sand:	
with <30% silt and clay	1.5:1
with 30 – 50% silt and clay	2 :1 to 2.25:1
silt and sandy silt	2:1 to 2.5:1
silt and clay	2.25:1 to 3:1

Factors in Slope Movement

Shallow slope movement, or failures, are caused by the soil having insufficient strength to stand at the present slope angle. The required slope angle to avoid failure conditions is a function of soil type, moisture conditions and soil density.

For a particular soil type (gravel, sand, silt, clay or mixed soils), stability decreases with a rise in moisture content and a fall in soil density. The geotechnical designer is in the best position to determine the appropriate slope angle for an excavation or fill. Typical required slope angles for compacted soils are given in Table 4.2.

Changes in Soil Strength

Soil strength varies with time, primarily because soil moisture is not constant. For that reason, a slope that has been constructed in summer when moisture conditions are low, may fail in winter as the material becomes wetter.

Groundwater

A high water table may be encountered during excavation. They are usually very obvious in a permeable material (sand or gravel) since the water will seep or flow out of the slope. In silt and clay soils, the effect is less obvious, and a high water table may be noted as sponginess of the soil.

4.2.4 Slope Movement Assessment

Predicting locations where shallow slope movement may occur is difficult. Such predictions are particularly difficult to make when observing an area during dry conditions.

A rise in groundwater after land clearing or demining can lead to failure of excavated slopes below the water table, due to high hydrostatic and seepage forces. Slopes may be constructed during the low water level period in dry seasons without incident. However, these slopes could fail in wet seasons as the groundwater level rises. Excavated slopes that may be below the water table at any time of the year should be designed to prevent sloughing and erosion of the soil.

In high ground water, or potentially high groundwater conditions:

- the slope angles used for normal conditions should be reduced by half (e.g., reduced from 2:l to 3:7), unless adequate groundwater control is provided;
- land clearing procedures should be modified to ensure slope stability is maintained and water flow is controlled as the work proceeds; and
- geotechnical advice should be obtained.

4.3 EROSION CONTROL MANAGEMENT

The effective management of erosion processes during demining or UXO removal includes the development of an Erosion Control Plan (ECP) and the implementation of appropriate erosion control practices.

4.3.1 Erosion Control Plan (ECP)

The environment can be better protected and is often more cost effective to prevent the displacement of fine material by using effective erosion control practices, rather than trying to contain and treat silt laden water (Chilibeck 1992).

An effective way to manage erosion is through preparation of an Erosion Control Plan (ECP), before carrying out demining or UXO removal in sensitive areas. The plan should identify sensitive or potential problem areas and provide a work plan strategy for anticipating and mitigating against erosion during and after clearing. It is important to continually compare actual conditions with those originally anticipated. The plan must be revised to take account of changes that arise. Key features and procedures are provided below.

Planning and Scheduling

- Design and plan land clearing operations with as little soil excavation and disturbance as possible taking into consideration the particular soil conditions and topography of the site.
- Where possible, plan clearing activities during the dry season to avoid potential rain events and delays. In the event of heavy rain, halt clearing activity during periods of heavy precipitation and runoff to minimize soil disturbance.
- Stage the demining activities to allow 'green-up' or re-establishment of vegetation and minimize erosive areas.
- Restricting traffic and equipment access or provide working surfaces/pads.

Soil Retention

- Where possible, minimize the area of clearing and stripping.
- Physically mark clearing boundaries and consider retention of vegetation and/or the top organic soil layer.
- Seed or re-vegetate cleared areas with indigenous grass, shrub and tree species. Where appropriate, agricultural plant species may be an economically beneficial alternative to indigenous plants.
- Cover temporary fills or stockpiles with plastic sheets or tarps.
- Use mulches and other organic stabilizers to minimize erosion until vegetation is established.
- Plan seeding and planting to allow establishment before end of growing season.

Surface Water Management

- Minimize flow over bare areas by diverting overland flows away from land clearing areas.
- Isolate cleared areas with swales, berms, trenches and ditches to direct runoff.
- Avoid steep slopes below rills and gullies.
- Retain natural drainage patterns wherever possible.

Minimizing Runoff Velocities and Erosive Energy

- Maximize the length of flow paths for precipitation runoff to minimize energy of flow.
- Construct interceptor ditches and channels with low gradients to minimize secondary erosion and sediment transport.
- Line unavoidably steep ditches with fabric, rock or plastic to prevent channel erosion.

Designing Clearing Activity for Increased Runoff

- Design ditches and channels for post clearing flows.
- Construct stable, non-erodible ditches, inlet and outlet structures.

Retaining Eroded Sediments Onsite with Erosion and Sediment Control Structures

- Utilize sediment traps and silt fences.
- Provide bed load clean-outs at culverts and ditches.
- Construct and operating sediment control ponds as clearing activity requires.

Planning, Inspecting and Maintaining Erosion and Sediment Control Structures

- Develop and follow a maintenance, inspection and monitoring schedule as part of the development plan. The schedule should encompass a time period before, during and after the development phase.
- Stockpile the required erosion/sediment control materials: filter fabric, rock, seed, culverts, matting, plastic sheeting, used tires, etc.

4.3.2 Erosion Control Methods

The following methods should be employed where necessary to prevent the initiation of surface soil erosion, shallow slope movement and sediment movement from sites where UXO clearing is carried out. The choice of measure(s) is determined by the type of material and the grade of the cleared area.

Conditions and timing of implementation of these erosion and sediment control measures depends upon the weather conditions during the activity. In dry conditions, all cleared slopes and surfaces should have erosion controls implemented within 14 days. In wet conditions, erosion control should be implemented immediately on completion of the demining or UXO removal activity.

Surface Protection

The purpose of these surface protection techniques is to absorb raindrop impact, reduce runoff velocity, improve infiltration, bind soil particles with roots and protect the soil. The rapid establishment of a vegetation cover is generally recognized as the most cost effective form of surface erosion control. Protection of the soil surface with mulches or other materials will provide immediate erosion control until vegetation is established. The smaller vegetation material (grasses, small branches and leaves) cleared during UXO clearance programs can be stock piled on site and used as mulch material. When time is limited or weather conditions are unsuitable, the use of plastic sheeting is recommended (Coulter and Halladay 1997).

For low to moderate slope areas (1:1 to 2:1), soil surfaces to be treated should be rough. The area should be seeded and fertilized and covered with at least 5 cm of vegetative mulch. To prevent the dispersion of the mulch by wind action, pinned netting should hold the material in place until vegetation is established. Steeper slopes (>1:1) and surfaces with highly erodible soils should be treated similarly but need erosion control matting rather than netting. If seedlings are to be incorporated in the revegetation, planting needs to occur after the installation of netting or erosion control matting.

When immediate protection is needed or other protective techniques are not feasible, plastic sheeting or tarps can be used. It should be well anchored to resist wind (e.g., old tires are ideal) and prevent leakage. Breaks in the cover should be repaired immediately. Plastic sheeting is not recommended for use on sites to be left idle for more than two months, unless weather conditions preclude the establishment of vegetation.

Interceptor Ditches

Interceptor ditches are structures designed to intercept and carry clean surface runoff away from erodible areas and slopes, reducing potential surface erosion and limiting the amount of runoff requiring treatment (Chilibeck 1992). Alternatively, they can collect sediment contaminated runoff from cleared areas and carry it, without further erosion, to sediment ponds.

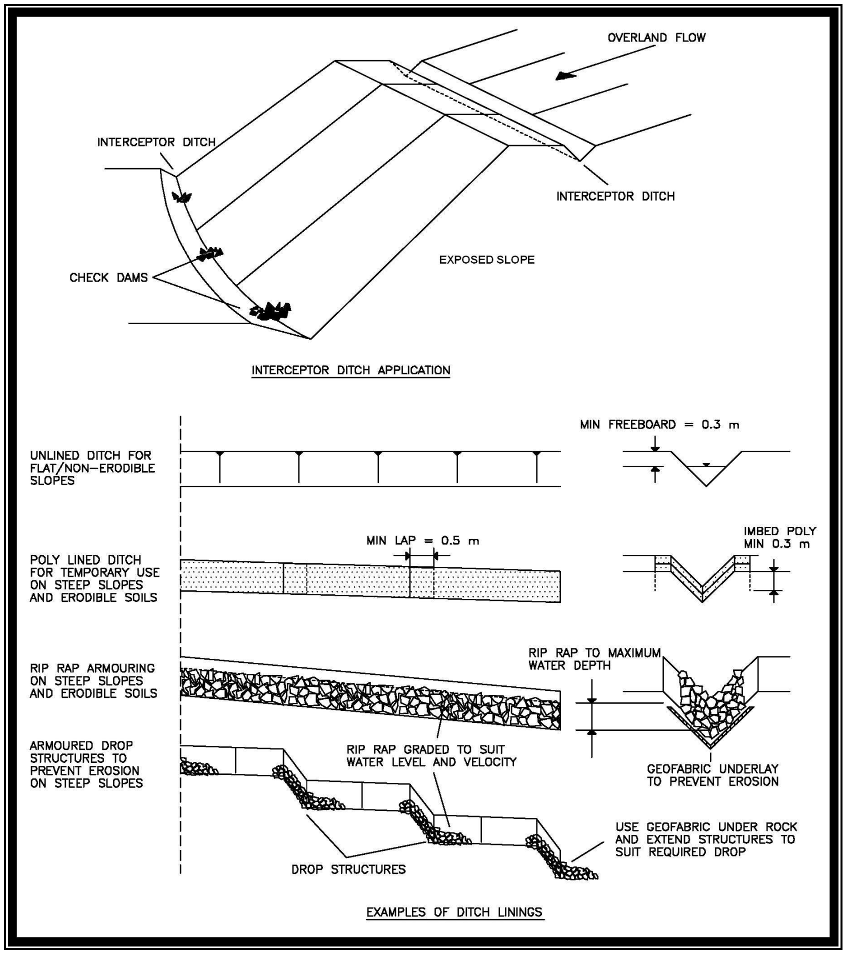


Figure 4.1
Interceptor ditch design features.

Key considerations in the design of interceptor ditches are provided below. Figure 4.1 illustrates some general design features of interceptor ditches.

- The location and access to interceptor ditches should be determined following analysis of the topography, the existing drainage pattern and subgrade conditions.
- Interceptor ditches should be laid out, following contours if possible, and constructed during initial clearing.
- They should be located along the uphill boundaries of clearing sites, the uphill sides of major cut and fill slopes, to intercept and divert overland runoff.
- Side slopes of interceptor ditches should be no steeper than 1:1.
- Depending on the slope, subgrade soil type, and design life, the ditches may require armoring with plastic sheeting or rock.
- Interceptor ditches may require energy dissipaters (weirs built of broken rock, concrete or timber) at changes in grade and elevation.
- Excavated bed load traps or pools formed by gravel berms can be constructed to collect eroded material.
- Side slopes should be seeded to reduce erosion and subsequent maintenance.
- A regular, permanent maintenance program is necessary to keep ditches in good working order. All ditches and structures

should be inspected after periods of heavy or sustained rainfall.

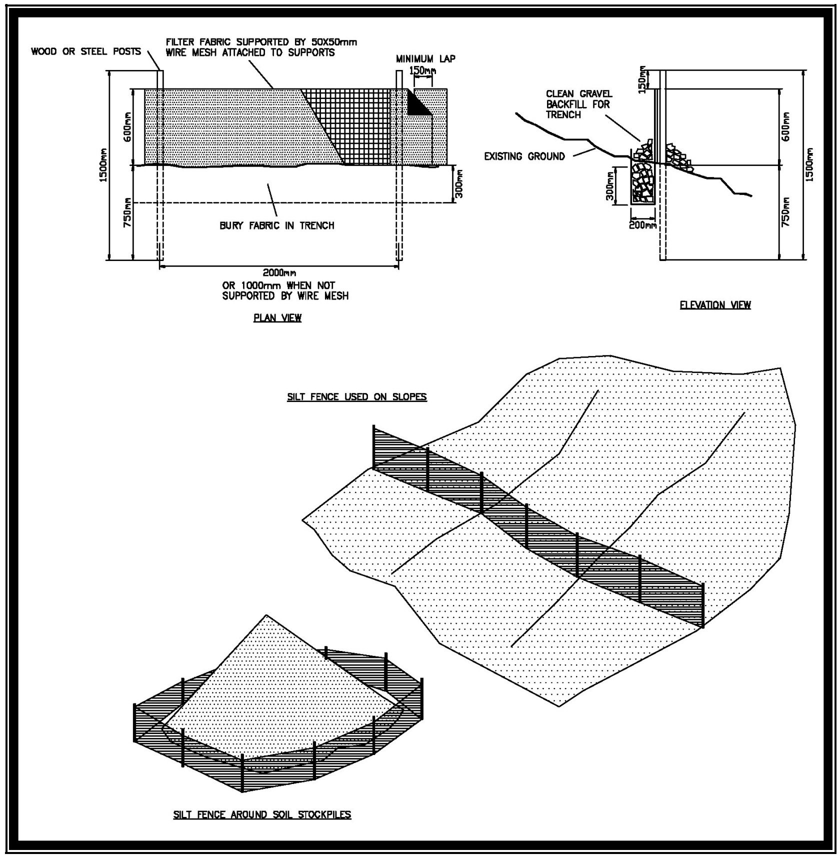


Figure 4.2
Example of proper silt fence design and installation.

Silt Fences

Silt fences and related structures provide an effective filter for sediment-laden runoff eroded from slopes and cleared surfaces. The fine openings do not allow the passage of coarser sediment. Silt fences are effective boundary control devices, trapping the sediment close to the erosion source and preventing mobilization into runoff (Chilibeck 1992). Installation and design parameters for silt fencing are provided below and illustrated in Figure 4.2.

- Silt fences should be installed on the lower perimeter of bare slopes and cleared areas where erodibility is high and/or it is desirable to contain waterborne movement of eroded soils.
- Ideal silt fencing material or fabric is comprised of a pervious sheet of slit film woven polypropylene, nylon, polyester or ethylene yarn.
- Minimum opening size should be 0.15 mm.
- The fencing should be backed by a wire fence supported on posts not over 2.0 m apart. Fabric joints should be lapped at least 0.15 m and stapled. The bottom edge should be anchored in a 0.30 m deep trench to prevent flow under the fence.
- If the filter fabric decomposes or becomes ineffective, it must be replaced and the fence repaired.

Pole Drains and Fascines

Live materials, specifically vegetation, may be used to control erosion and provide geotechnical stabilization to slopes. Pole drains and fascines are examples of erosion control techniques that incorporate the use of locally found vegetative materials. Larger brush cleared as a result of UXO clearance programs can be used in the construction of a pole drain system (McCullah 2000).

A pole drain is a biotechnical and reclamation technique which is intended to drain excess moisture away from an unstable site. Pole drains use bunched and bound branch cuttings bound together into long, tubular bundles or 'fascines'. The plants used to construct the bundles will sprout and grow, with the moisture continuing to drain from the lower end. The bundles of cuttings are placed in shallow trenches in a manner that they intersect and collect excessive slope moisture. That excess water is then allowed to drain onto a stabilized area (Figure 4.3).

The fascines are made from straight, long, and slender branches of shrubs and trees capable of vegetative propagation. Dead branches may be combined into the bundle if they are not brittle.

The cuttings should be long (1 m minimum), straight brushy branches up to 40 mm in diameter. The number of stems varies with the size and kind of plant material. Jute or hemp rope can be used to tie the bundles and those materials will biodegrade with time. Polypropylene tree rope makes a very durable and strong tie material. The retention of the twigs and branches on the cuttings will add bulk and aid drainage. Pole drains require construction stakes and/or live stakes in order to secure them firmly to the slope. Sometimes large rocks may also be used to hold the drains down.

The following procedures should be followed to successfully install a pole drain/fascine erosion control system.

- Install the drains in the areas of seepage, either by excavating a shallow trench or utilizing an existing drainage gully so that the drains intercept and control the excess moisture. Construct side drains as needed.
- The bundles should be tied tightly with twine or rope.
- Place the bundle of cuttings in the trench. It is important to key the bundles into each other by jamming the ends firmly together.
- Use construction stakes and/or live stakes to hold the wattles in place. Insert the stakes adjacent to the rope ties for additional support and stake the pole drains at 1-2 m intervals.
- Lightly backfill the bundles with native soil. Some twigs and branches should be left above the ground as the living material requires some sunlight exposure to grow.

Sediment Traps

Sediment traps should be installed at the lowest point near each clearing excavation. Swales and ditching should convey surface runoff to these

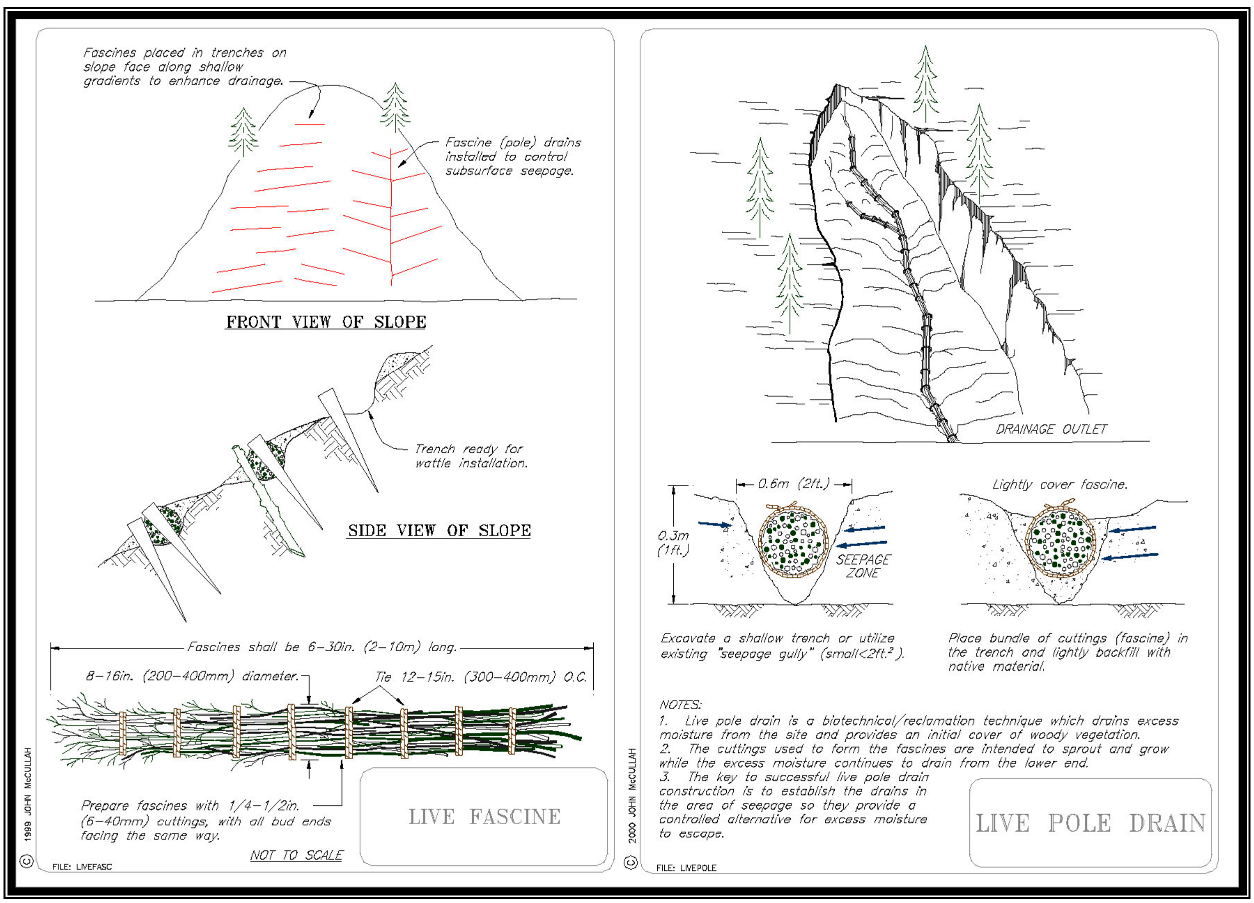


Figure 4.3
An example of fascine and pole drain erosion control systems.

traps prior to discharge from the site. Sediment traps operate like small sediment control ponds by controlling the discharge of sediment offsite.

Swales

Swales are shallow depressions which redirect surface runoff away from erodible sites and reduce the amount of sediment laden runoff generated onsite. They should be constructed of clean, non-erodible granular material with 0.3 m high boundary ridges and have a low gradient to prevent scouring and further sedimentation.

Gravel Berms,
Check Dams and Bale Structures

These should be installed in overland flow paths, swales and other possible locations of concentrated flow to arrest migration of erodible soils. Their number and spacing will depend on estimated precipitation levels and the nature of the clearing activity. They are effective at controlling sediment close to its source.

Culverts

Culverts can be used to contain and direct groundwater seepage and other small flows away from sensitive slopes and cut banks preventing erosion of toe areas and maintaining slope stability. They are also effective for conveying flows down steep slopes where it is impossible to maintain open channels. Culverts can be corrugated metal pipes or half pipes, concrete pipes or wooden flumes.

4.4 STANDARD OPERATING PROCEDURES (SOPS) FOR IMPLEMENTING SITE REHABILITATION

The primary goals of land rehabilitation procedures are to ensure that the ability of land to support productive agriculture lands and foster the development of sustainable/diverse ecosystems subsequent to UXO/landmine clearance. The standard operating procedures provided below should be considered as a set of guiding principals to implement a land rehabilitation program.

Future land use goals will be unique to each mine action. The procedures provided below lay out a framework which will outline key factors to consider when planning land remediation and how to organize a land remediation project. In some cases, if the situation warrants and after expert consultation, certain steps may be overlapped or eliminated altogether.

The key document for any comprehensive land rehabilitation is the land rehabilitation plan. Planning for land remediation forces implementing agencies to 'take stock' of current and future land conditions and focus rehabilitation efforts in the direction of future land use goals. This plan should include all information on pre-clearance conditions, predicted impacts and timetables for land rehabilitation, monitoring, and maintenance activities. The goal of the land rehabilitation planning process is to have one, all inclusive document that will serve as a guide for the project from start to finish. The plan should include reports, maps and schedules that carefully outline what is to be done, by whom and when.

4.4.1 Collecting Pre-clearance Data

The pre-clearance information should be collected onsite through site inspections. A record of site conditions should be kept with photographs and a written record. Aerial photographs or images are useful in gaining an overall perspective. Generally, information should be collected and analyzed by a person qualified or knowledgeable in the areas investigated and could include: biologists, civil engineers, agriculture experts, botanists, geotechnical engineers, hydrologists, etc.

In a UXO/landmine clearance operation, background material will have been collected during the impact/risk assessment phase. The following pre-clearance information should be catalogued and displayed on the pre-clearance map.

Location and Topography

- Create an accurate topographic map to form the basis of any land remediation plan.

- The site map should be accurate and of the appropriate size and scale to show all required features.
- Pre-clearance data and land remediation features will be overlaid onto a base map to provide a visual development plan.
- This map can also be used as a base map for the technical mine action survey.

Watercourses and Drainage

- Overland runoff and channel flow elements should be marked on the map and detailed in the written plan.
- Detail existing streams and channels on the map indicating direction of flow.
- Map and estimate utilization and sensitivity of any key aquatic or terrestrial habitats and features.

Climatic Information

- Collect rainfall data including seasonal timing, intensity, duration and frequency.
- Collect climatic information from the start of mine action activity to end of the monitoring period for land remediation (i.e., long after the work has been completed).

Soils and Vegetation

- Collect and map information on soil types, ground cover and vegetation.
- Outline areas of highly erodible materials and unstable slopes.
- Detail sediment control, erosion control strategies and remedial measures.

Current and Future Land Uses

- Describe the current and future land use of both the site and adjacent areas.
- Record the legal description and registered owner of the clearance area.
- Outline commune or district planning goals for present and future land use of the area.
- Record the total size of the project area.
- Site locations for storm water and sediment control facilities.
- Outline the potential for soil contamination issues as described in Section 5.

4.4.2 Assessment and Implementation

This procedure involves the analysis of pre-clearance information and preparation of the land clearance impact assessment. Once the analysis of the proposed clearance operation is complete (i.e., impact/risk assessment), the following information should be transferred onto an implementation schematic map (Figure 4.4):

- developed and undeveloped terrain, pervious and impervious surfaces;
- building sites, roadways, utility corridors and other land use;
- retained vegetation and leave strips (showing method of distinguishing clearing limits);
- altered drainage and slopes;
- erosion and sediment control features, locations, sizes and capabilities; and
- stormwater management facilities, location, size and capabilities.

In concert with implementation maps, an impact document should be included detailing the following features and activities:

- clearance activities that affect the site and sensitive areas;
- a schedule of activities involved with the clearance and remediation of the site;
- a list and location of all features and provisions for the remediation work cross-referenced to the activity schedule;
- a maintenance program and schedule for the various features including detailing who is responsible for what feature and conditions of maintenance; and
- a contact list of the various parties involved including mine action group, lead agency personnel, and persons responsible for remediation and planting crews.

The land rehabilitation impact assessment should be included as part of the overall work plan for the UXO/landmine clearance project. The completed plan should be distributed to the various parties involved with the mine action. Use and practical implementation of the land remediation plan will require onsite supervision and revision to meet the changing, site-specific conditions encountered.

4.4.3 Monitoring and Maintenance

All projects will require some degree of environmental monitoring and maintenance during clearance and land remediation activities. Depending on the sensitivity of the project area or activity, an environmental monitor may be required to be on site on a permanent basis. The environmental monitor should be fully trained in the purpose, function and maintenance of all site related erosion control and re-vegetation activities. The duties of the environmental monitor include:

- defining environmental standards for the rehabilitation work;
- provide basic environmental education rehabilitation guidelines to all field personnel;
- mapping and marking sensitive areas in advance of work; and
- modify activities and land rehabilitation features where unforeseen circumstances cause environmental problems.

Regular maintenance of land remediation features is also a key step in assuring the success of rehabilitation activities. The environmental monitor is also responsible the maintenance of land remediation features. Depending upon the proposed land use after clearance activities, maintenance may required up to three years after the completion of the project. Key maintenance items include:

- sediment control features (e.g., fencing, surface protection, and ditching network);
- vegetation control and re-vegetation success;
- site waste; and
- site access control.

Generally, after all remediation is complete, weekly monitoring and maintenance visits are required for the first two months and subsequently every two weeks until the site is fully rehabilitated (approximately six months). Additional visits are required during all storm events over this same time period. Detailed notes on each visit should be kept; regular reports to the party responsible (e.g., local Peoples' Committee) for the clearance activity should be made. The reports should include:

- date and time visited;
- personnel present;
- weather conditions;
- water quality data collected;
- success of erosion control features; and
- success of re-vegetation.

All failed erosion control features and dead or dying plants should be noted and a plan and schedule for repair or replacement should be provided.

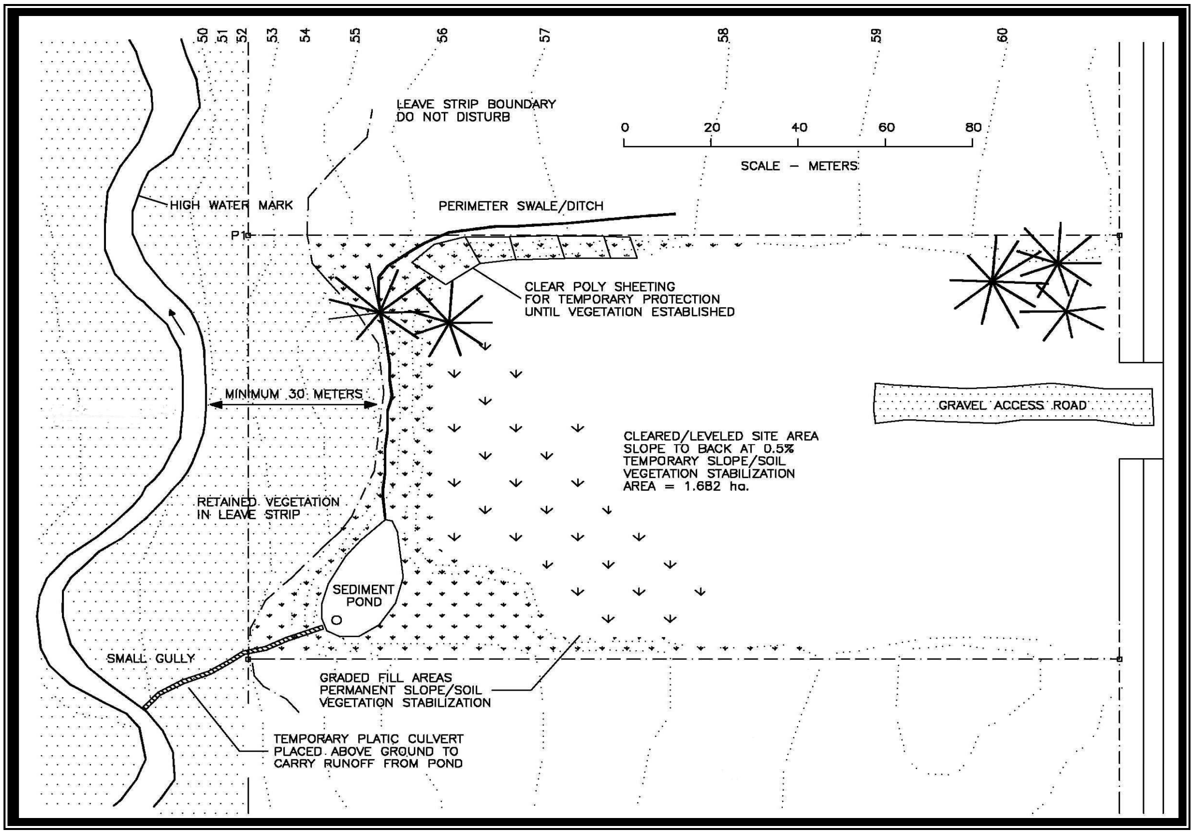


Figure 4.4
An example of a site rehabilitation schematic map.

5.1 GENERAL

Human health risk from toxic pollutants is a function of two measurable factors: hazard and exposure. To cause a risk, a chemical has to present a hazard and be present in the human environment at some significant level. Risk assessment is the combination of hazard identification, dose response information and exposure information (Richardson 1995).

Should the presence of harmful residual chemical agents become evident during the Impact/Risk Assessment, clearance personnel may be exposed to chemicals which could increase their risk to adverse health effects.

During the course of UXO clearing activities in soils potentially contaminated with chemicals, the following activities would be involved:

- identification of the potential for soils to be chemically contaminated in the area to be cleared of UXO/landmines;
- determination of extent of chemical contamination in the area;
- interpretation of chemical data for area soils; and
- post clearing monitoring for chemical contamination in the area.

Figure 5.1 provides a decision framework for determining the level of sampling and mitigation for chemically contaminated areas before initiating UXO/landmine clearance activities.

5.2 ASSESSING THE POTENTIAL FOR CHEMICAL CONTAMINATION

Review of Historical Information

As outlined in Chapter 3, military records (i.e., base layouts, chemicals sprayed on site, chemical burial statistics, military activities, etc.) should be reviewed to determine if, based on historical information, the area of concern may be potentially contaminated.

For example, herbicide spray flight paths and military records could be reviewed for areas to be cleared of UXO in southern Viet Nam, or eastern border areas of Lao PDR and Cambodia. If this information indicated that herbicides were applied over the area during the war, herbicide dioxin could be present in local soils.

Former US, South Vietnamese or other allied military bases, where perimeter herbicide spraying took place or was handled, could also be areas of potential chemical contamination. If, after a review of available information, it is concluded that chemically contaminated soils potentially exist in the specified UXO clean up area, the subsequent activity would be to assess contaminant levels and distribution prior to demining the area.

Review of Soil Types

Preliminary herbicide work done to date in Viet Nam indicates that residual dioxin contamination may be related to certain types of soils. Areas rich in clay and organic matter, appear to have more potential to retain dioxin and other chemical contaminants relative to those which have a high sand content and/or are well drained. Any soil type information available for a site to be cleared of UXO should, therefore, be reviewed during project planning.

5.3 DETERMINING EXTENT OF CHEMICAL CONTAMINATION FROM DEFOLIANT SPRAY PROGRAMS

After determining that a probability of chemical contamination exists, samples should be taken which will, through laboratory analysis, confirm or negate their presence. Depending upon the type and amount of chemical contamination, a soil, and food and/or human tissue sampling program may be appropriate.

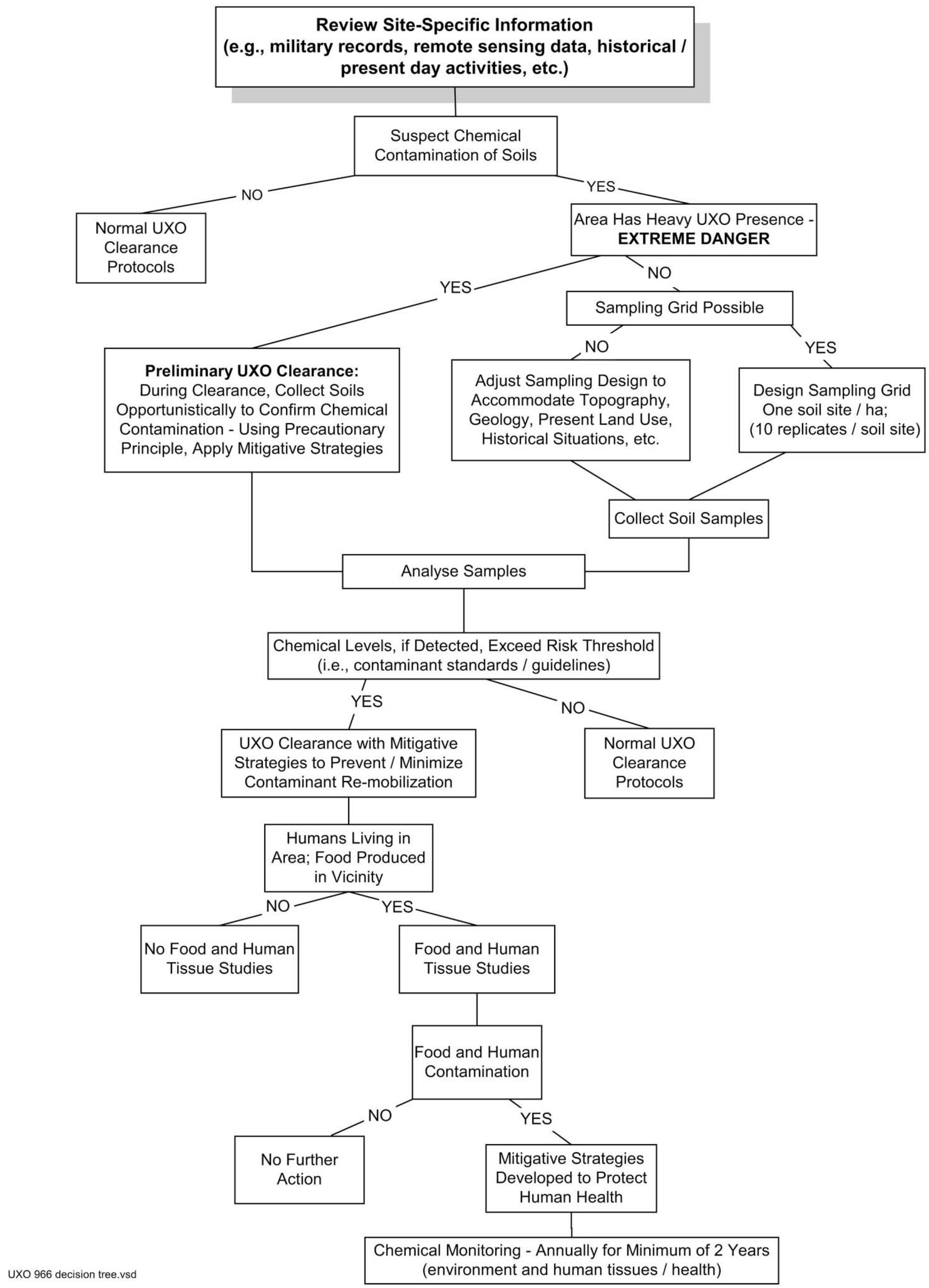


Figure 5.1
Decision tree for contaminated soils and UXO clearance.

Should an area targeted for clearance be assessed as potentially containing contaminated soils, a sampling plan should be devised to collect soil samples within the perimeter of the defined UXO clearance zone. Figure 5.1 provides a series of decision points which should be considered during the process in order to trigger additional sampling (i.e., food stuffs and/or human tissue) and outline mitigative strategies for the protection of human health.

The design of any sampling program should consider the size of the area, future land uses, and proximity of contaminant to human populations.

5.3.1 Soil Sampling

After determining that a probability of herbicide dioxin contamination exists, a number of soil samples should be taken which will, through laboratory analysis, confirm or negate their presence. A sufficient number of samples should be collected to provide a high level of confidence regarding the degree and extent of chemical contamination at the site. It is recommended that each soil sample analyzed should consist of a composite of ten replicate sub-samples to increase sampling power.

The following general protocols for determining the extent and magnitude of soil contamination in an area targeted for UXO clearance. The focus of the discussion will be dioxins; however, considerable approaches can be applied when addressing other contaminants.

Formation of a sampling plan may involve either a regular patterned grid over the entire area, or involve only select geographical areas within the zone that have a significantly higher probability of being contaminated (e.g., previous herbicide storage yards, chemical spills, spray aircraft crash sites, etc.). It may be necessary to apply both a regular patterned grid and/or a site-specific focus within a single area, given available historical information. It is recommended that establishing the number of sampling sites within a zone be based on an approach of a minimum of one sampling station for every two hectares of area within the site to be cleared.

Primary sampling stations should be laid out accordingly. For example, if an area of 40 hectares are to be UXO cleared/investigated, approximately 20 primary sampling stations would be established on the site. Within a 20 m radius of each sampling station, secondary sampling sites (i.e., replicates) would be established. A total of 10 replicate sites should be taken for each primary sampling location. A soil core (0 to 10 cm in depth) should be extracted from each replicate site of the primary location and combined to form a single composite sample which is thoroughly mixed and would constitute the sample for testing in the laboratory. Therefore, in a 40-hectare site, there would be 40 primary sites and 400 secondary sites, resulting in (after compositing) 40 individual soil samples for processing. Other factors such as depth strata may require further sampling at sites having special histories.

Adjustments to the number of primary sampling sites may have to be made to accommodate certain circumstances. For example, it may be necessary to concentrate the number of primary sites in an area that has been determined to be of unique interest (e.g., chemical spill sites). During the sampling process, specific soil core sites must be swept by UXO personnel using metal detectors to ensure each sample site is free of buried ordnance.

If an area has been designated as extremely dangerous due to a very high concentration of known UXO, establishing a regular grid and moving through the area to collect samples may not be possible because of safety considerations. In these instances, only limited direct/opportunistic sampling may be possible during preliminary clearance activities. At such locations, collection sites and in-field movement would be directed and monitored by UXO experts on site, on a case by case basis.

If following laboratory analyses, chemical compounds (e.g., dioxins) exceed threshold standards/guidelines used in the international regulatory community to define contamination, mitigative strategies should be implemented to prevent/minimize the broadcasting and re-mobilization of contaminated soils during UXO clearance. If contaminant levels are low and inconsequential, no alterations in UXO clearance procedures would be necessary.

5.3.2 Food Chain Sampling

During the planning of a UXO clearance program, it may be necessary to determine if chemical contaminants of soil in an area have infiltrated the food chain and local populations (Figure 5.1).

If human food in the area already has significant levels of chemical contamination, UXO clearing protocols will need to be strengthened to ensure more sources of chemicals are not exposed which could be transferred into the food chain. Also, UXO deminers often live in bush camps or small villages in areas to be cleared for months or sometimes years at a time during operations. Locally grown fish, duck, chicken, etc. are often consumed during this time. If these products are chemically contaminated, protocols for avoiding human uptake of such chemicals through food should be followed.

It has been shown that plant materials (e.g., rice and manioc) do not absorb chemicals such as herbicide dioxins (HCL/10-80 Committee 1998, 2000). Vegetables grown beneath the ground's surface, if thoroughly washed and peeled, would pose no threat to human health. However, food sources associated with contaminated pond sediments and water such as fish and ducks have been shown to transfer chemical contamination to humans. Ingestion of contaminated foods is the primary source of human contamination.

If foods are produced in an area which has been determined to show soil contamination and local peoples obtain food products from this area, a sampling program should be designed to determine contaminant levels.

A rapid assessment should be undertaken regarding foods consumed by the local population. This would provide information on the most frequently consumed products.

Target foods that should be sampled for chemical analyses are meats, fish and dairy products. Representative samples of fat, liver and muscle tissues should be collected from animals in the area. If fish aquaculture ponds exist on/near the contaminated site, special effort should be made to sample these fish for testing. Ducks, chickens, cows and pigs should also be considered for testing.

At each fish pond, for example, a minimum of four fish should be collected using a hand seine. All fish should be handled by personnel wearing latex gloves with the sample being placed in clean, well-labelled polyethylene bags. Fish should be dissected within two hours of capture. Length (mm), whole weight (g), and sex (visual inspection of gonads) should be recorded for each specimen. Muscle tissue (skin removed) should be collected from the left side of each fish, above the lateral line, and between the dorsal (top) and caudal (tail) fins. Liver samples should be collected (entire liver should be removed from each specimen); fish fat should also be collected from the viscera. Samples should be placed in individual jars for each type of fish tissue, and frozen immediately following dissection.

Attempts should also be made to collect wild fish if significant natural waterways exist in the area. Large, carnivores (flesh eating) fish species should be the target, using multi-filament gillnets or electroshocking gear.

For livestock, markets in the area could be the source. Liver tissues should be removed from the lower left lobe; fat should be collected from around the chest area. Approximately 50 g of each tissue type should be collected, placed in individual glass jars, and frozen subsequent to collection.

Chicken and ducks could be purchased from local residents in the immediate area. Muscle (breast meat), liver and fat tissues should be collected, weighed (±0.1 g), placed in individual glass jars and frozen.

5.3.3 Human Tissue Sampling

If human populations are in the vicinity of the area to be cleared of UXO, and it is found that the soil and local food stuffs are chemically contaminated, a program to sample human blood and breast milk may be beneficial to assess the levels of contamination that may exist before the UXO clearing program is undertaken. If contaminant levels are already high, special additional UXO clearing protocols should be implemented to reduce risks of increasing this contamination.

Blood samples should be taken from select groups of people according to the following age and sex categories:

- males 25 years of age or older, representing older men;
- males less than 25 years of age (i.e., representing younger men born since the war);
- females 25 years of age or older, representing older females; and
- females less than 25 years of age (i.e., representing younger females born since the war).

Each volunteer donor should be interviewed by the study team to determine name, age and personal geographic residential and medical history. Due to health and cultural issues, it may only be possible to collect small volumes (i.e., 2 ml) of blood using a syringe, and placing these in individual vials (one per patient). Whole blood samples should be kept cool on ice packs during the sampling procedure, and frozen within one hour of collection. Samples to be analysed should be a minimum of 40-50 ml or be made up of composites totaling that volume.

Breast milk samples from first-time mothers (with a single birth) should be collected from volunteer donors. Mothers should provide information on age and number of children which they have breast fed (including children of relatives, etc.). Breast milk sampling should be conducted at the same time as blood sampling; some mothers may donate both blood and breast milk. Volunteer patients should donate approximately 50 cc of milk which should be expressed by individual mothers directly into the sample jar.

Breast milk normally constitutes a significant portion of the diet of infants; therefore, determining the significance of this mode of contaminant transfer is important to the assessment of health risk.

Key components of the human blood sampling and breast milk sampling programs include:

- all potential blood and breast milk donors should be provided with a personal identification number (medical wrist band), which is used to assist the study team identify each individual that was sampled;
- detailed personal information interviews should be conducted with each blood/milk donor prior to collection of samples;
- blood donors should be segregated based on sex and age;
- individual blood samples should be collected from each donor;
- samples should be placed in plastic vacutainer hemoguard tubes with sodium heparin as a preservative;
- samples of the vacutainer tubes should be pre-analyzed for presence of chemical contaminants prior to use;
- individual blood and breast samples should be kept cool on ice packs following sampling and should be frozen within one hour of sample collection; and
- there should be no compositing of blood or milk samples in the field; all compositing that would occur should be performed in the laboratory.

5.3.4 Previous Screening Programs by HCL

HCL has been involved with two previous preliminary soil 'screening' studies in Viet Nam; one humanitarian demining project in Gio Linh District, Quang Tri and one commercial development project at the Dinh Co Gas Terminal near Vung Tao.

Although in each scenario, overall project goals were very different, the application of the soil screening process was successful in assessing risk to human health of herbicide chemical contamination.

Quang Tri

As discussed in Chapter 2, the Mines Advisory Group (MAG) was implementing a mine and UXO clearance project in Gio Linh District, funded by Danida (Danish International Development Agency), which assisted rural development plans for the region. The MAG/Danida demining program is the first large-scale demining program in Viet Nam.

In September 1999, HCL was contracted by the Royal Danish Embassy, Hanoi, to assess the current levels of dioxins and furans in soils (and pond sediments) in areas currently being cleared for landmines and UXO in Gio Linh District, Quang Tri Province, central Viet Nam (HCL 1999).

Gio Linh District is located only 4 km south of the former Demilitarized Zone (DMZ). The area was subject to intense war activity, and was the site of several key battles in the later stages of the war (Turley 1985). The area was of great strategic importance to both the US and north Vietnamese army moving into southern Viet Nam; considerable American efforts were spent to limit the flow of personnel and materiel through this region. To limit the ability of northern troops to move under cover, the area was heavily bombed and sprayed with herbicides between 1965 and 1970.

The results of this sampling program in Gio Linh aided in future development planning, given that precautionary measures were implemented early in the project to manage potential chemical contamination risk to deminers and future residents of the area.

Vung Tau

In January 2001, BP/AMOCO started construction of the 32 ha Dinh Co Gas Terminal as an integral part of the Nam Con Son Gas Project bringing natural gas located in deposits offshore to Dinh Co via underwater and terrestrial pipelines. Following processing at the Dinh Co Terminal, the gas is conveyed by an additional pipeline to an inland power plant As of November 2002, the plant is fully operational.

In view of the uncertain status regarding residual dioxin contamination at the Dinh Co site, BP/AMOCO contracted HCL to undertake a field survey to define residual dioxin contamination. A soil survey was undertaken as an initial risk identification component of a risk analysis to determine and manage the health consequences to workers from residual dioxin exposure (HCL 2001).

5.4 SAMPLING PROTOCOLS FOR OTHER POTENTIAL CHEMICAL CONTAMINANTS

A discussion of non-defoliant chemicals that may be potential sources of contamination in post-conflict areas are provided in Chapter 1 and Appendix A1. The extent to which sampling protocols and planning changes from those designed for defoliant chemicals is provided below.

5.4.1 Non-Defoliants

Similar basic protocols to those for dioxins will apply for other chemicals that are associated with military installations/activities (e.g., pesticides, PCBs, heavy metals). Given these chemicals may be more "site-specific", point source sampling may be all that is required.

Chemicals such as pesticides and heavy metals are generally regarded as materials of lower toxicity compared to dioxins and PCBs in the concentrations that may be expected in local soils from base operations, unless major spills have occurred.

If during the course of site characterization, it is concluded that other non-defoliant persistent chemicals and metals may reside in soils, samples should be collected to confirm presence. Designs outlined in Figure 5.1 and for defoliant dioxins should be applied. The actual number of samples that require analyses may be reduced in number if localization of the contaminant can be determined (i.e., point-source sampling).

5.4.2 Chemicals from UXO/Landmines

Unexploded ordnance materials in artillery shells, bombs and mines or incapacitating agents such as CS gas crystals can also contaminate soils in areas to be cleared of UXO. Energetic (i.e., explosive) materials, that are leaking can usually be visually identified during excavation. Such materials are likely chemicals such as TNT, HMX, RDX, in areas where munitions are identifiable. Emersing a leaking area near the explosive in aqueous sodium hydroxide will neutralize the substance (Noyes 1996). Subsequent to neutralizing the leak, normal

UXO clearance can proceed. If it is necessary to further identify an explosive related chemical sampling, protocols outlined in Section 5.3 should be followed and the samples shipped to specialized laboratories for analysis.

Incapacitating agents (e.g., CN and CS gas crystals) in solid form may be uncovered during clearance activities. Decontamination of local soils recommended by Neilands (1972) consists of the following:

- CN gas crystals – aeration in the open; flushing the area with soda ash solution or alcoholic caustic soda solution; and
- CS gas crystals – flushing the area with water, 5% sodium bisulfite and water rinse.

5.5 INTERPRETING CHEMICAL CONTAMINATION LEVELS

Previous work by HCL and the 10-80 Division have shown the direct relationship between contaminant levels in soils, local foods, and those found in blood and breast milk of local inhabitants (HCL/10-80 1998, 2000, Dwernychuk *et al.* 2001). The use of soil samples as a 'screening' medium for chemical contamination appears to be the quickest and most cost effective method of determining the potential for risk to war-related chemical contaminants.

Table A8.1 (Appendix A8) summarizes the legal soil standards in British Columbia, Canada (BC Waste Management Act 1966). Soil chemical concentrations that are equal to or greater than the levels stated in Table A8.1, indicate the existence of a "contaminated site" for these chemicals. These values can serve as a guide for planning of UXO clearing at sites suspected to be contaminated. Table A8.2 (Appendix A8) summarizes specific chemicals that are categorized as influencing human and environmental health. Levels are set for agriculture and residential land uses.

Most accepted global standards/guidelines for dioxin and other chemicals have been developed for western lifestyles and assume quality housing, low direct contact with soil, availability of a wide variety of food sources, good potable water quality and populations that are relatively free from serious disease, malnutrition or chronic illnesses (e.g., water-borne diseases, vitamin deficiencies, etc.).

Rural people in Viet Nam do not have the lifestyles of most westerners. In fact, they live in continuous close contact with the soil, generally consume a narrow variety of foods grown locally, and experience numerous health problems related to water-borne disease and malnutrition.

Western dioxin standards/guidelines for health and environmental protection are, therefore, likely not conservative enough to protect risk to health in rural Viet Nam. Given the rural Viet Nam socioeconomic situation, such standards should be more stringent. However, developing new standards for application in developing countries where people are still living off the land, would be a long and likely controversial process.

It is recommended, therefore, that existing western standards/guidelines should be initially used to determine when special UXO clearing procedures should be taken in chemically contaminated soils in Viet Nam. Using such an approach will prioritize areas which require the most urgent attention in dealing with the UXO clearing problem in chemically contaminated soils.

A detailed description of chemical contaminant concentrations in various media (soils, food, and human tissue) and how they can be interpreted with regards to the protection of human health is provided in Appendix A9.

5.6 POST UXO CLEARANCE CHEMICAL MONITORING

The primary method of monitoring chemically contaminated media over time is referred to as *trend monitoring*. Studies by HCL and 10-80 Committee in the Aluoi Valley (HCL/10-80 1998, 2000) included trend monitoring of dioxin levels in soils, human blood and human breast milk to determine exposure levels over time in order to better direct remediation efforts for local populations.

Following completion of UXO clearance programs in chemically contaminated areas, samples of soils/sediments, domestic animals and cultured fish tissue and drinking water should be collected over time in order to determine if the contaminant in question has been successfully removed from the human food chain and will not pose a risk to human health. If human blood and/or breast milk has been found to have high chemical loads, these should also be monitored.

A monitoring sampling program should be instituted at least once per year during the dry season for a two-year period, in order to confirm no passage of the chemical contaminant in the local food chain and does not pose any further threat to human health.

5.7 Quality Assurance/Quality Control

An important component of the UXO clearance area chemical contamination assessment and monitoring process is ensuring standard QA/QC protocols are followed during all sample collection activities. Some important QA/QC considerations are:

- using disposable latex gloves dipped in hexane prior to sample collection, to handle all samples; gloves should be changed between samples;
- using stainless steel trays and tools (spoons, forceps, etc.) rinsed in acetone and hexane, before each use and between sample collections;
- using sample jars pre-cleaned by an analytical laboratory prior to use;
- taking duplicate samples at all stations; such duplicate samples can be used as replacements if primary sample jars are broken or more than one laboratory is used for analytical QC/QA checks;
- using 250 ml heat-treated, wide-mouth glass jars, sealed with lids lined with heat-treated aluminum foil; samples should be appropriately labeled and stored in a cool/dark area;
- recording the location of sampling stations using a hand-held GPS unit, still photography and video to verify sampling locations and methodology;
- including field blanks and blind duplicates in the samples to be analyzed;
- not permitting smoking in the vicinity of sampling activities; and
- securing all samples with adhesive tape and clear individual markings to prevent tampering during transport and storage.

5.8 Recommended Mitigation Approaches for UXO Clearing Projects in Chemically Contaminated Soils

5.8.1 Changes in Planning and Procedures

Once the type and extent of chemical contamination is identified, an expert in the management of chemical war-fare agents should be consulted with regards to appropriate procedural strategies for UXO clearance and support personal aimed at reducing or eliminating exposure risks.

Modifications in the demining program can include:

- changes in UXO clearance crew scheduling to avoid undue chemical or heat exposure;
- avoidance of heavily contaminated areas within the clearance boundary; or
- in an extreme situation, not proceeding with the program given that risk to the health of clearance crews is too great.

5.8.2 Personal Protective Equipment

Exposure of UXO clearing personnel to chemicals that may be in soils can result from inhalation, direct contact with skin, with food ingestion, and injection (i.e., chemicals enter the body through puncture wounds). Following determination of the type of chemical that may be in an area of concern, decisions should be made regarding the necessity for personal protective equipment (PPE). Site characterization activities should provide detailed information required to identify specific site hazards, thus enabling selection of appropriate PPE.

Anyone entering a potentially hazardous area should be adequately protected. PPE should shield or isolate individuals from chemical hazards. If health risks exist with respect to inhalation potential, proper respiratory equipment should be selected (i.e., self-contained breathing systems or air purifying respirators) which may be full-face, piece or half masks.

Clothing and accessories may also be necessary in highly contaminated sites. This category of PPE involves any article of clothing that offers skin and/or body protection; these may include full incapsulating suits, non-incapsulating suits, aprons, leggings and sleeve protectors, gloves, and cooling garments, if necessary (National Institute of Occupational Safety and Health 1985).

To enable such equipment to be worn in highly contaminated areas of Viet Nam, UXO clearing programs may have to be carried out during cooler parts of the year in the northern part of the country, or at southern, continuously hot sites at night, on cooler days or in artificially cooled conditions (i.e., shaded, fanned, etc.).

5.8.3 Disposal Plan

If it is determined that the removal of chemically contaminated soil is the preferred course of action, a detailed disposal plan is required. This plan should, at a minimum, address the following issues:

- method of disposal;
- location of disposal facility (interim and/or permanent);
- safety requirements for both clearance crews and local residents;
- disposal of contaminated clothing;
- cleaning of UXO detection and removal equipment;
- disposal and/or cleaning of soil sampling equipment; and
- transportation of contaminated materials and media; and
- long term assessment of exposure risk.

Any disposal plan needs to be developed under the guidance of chemical weapons expert and under the authority of national, provincial and local authorities so that long term land use goals are not compromised by the disposal activities.

6.1 BIOPHYSICAL CHARACTERISTICS

Aluoi District covers 116,642 ha. Its main feature is the Aluoi Valley, which is approximately 30 km in length along a roughly NW-SE axis, 3 to 6 km wide and surrounded by mountains ranging in height from 700 m to more than 1,000 m. Figure 6.1 shows a digital elevation model (DEM) of the key topographical features and waterways of Aluoi District. A DEM is a computer-generated relief map built from cartographic elevation data.

The valley encompasses the headwaters of the A Sap River, which flows across the Laotian border into the Mekong River drainage.

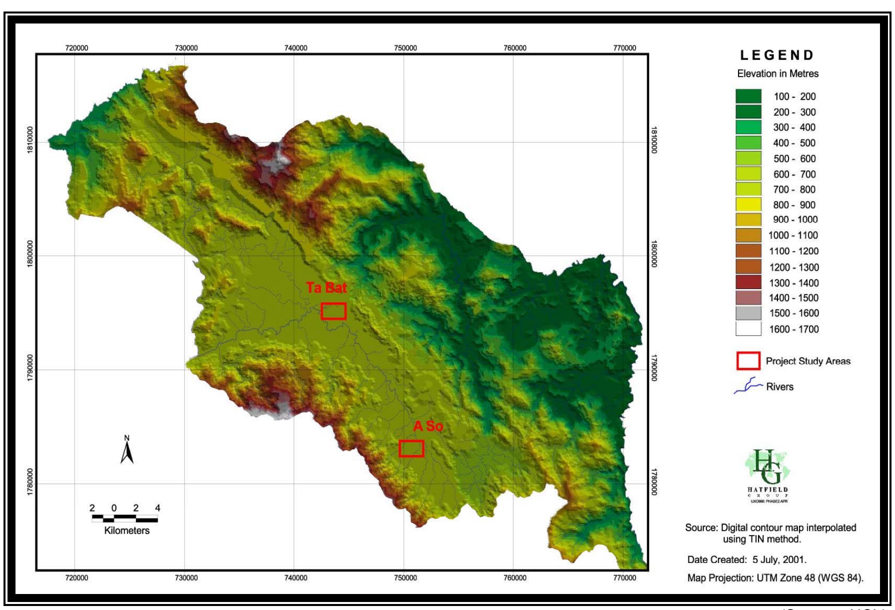
The valley is connected by valleys or roadways in four directions:

- Route 14 follows the valley bottom along its axis, connecting Aluoi District with Quang Tri province to the northwest and Lao PDR to the southeast;
- Route 49 intersects Route 14 and connects Aluoi Valley with lowland Thua Thien Hue province to the east; and
- the A Sap River valley (without a roadway) connects the valley with Lao PDR to the west.

There is no industrialisation in the Aluoi Valley; agricultural pesticides are seldom used. While portions of the valley floor are utilised for agriculture, many areas with potential for agricultural development remain unused due to the presence of UXO. However, with an increasing shortage of available land, local inhabitants are farming unsafe areas out of necessity.

Prior to the war, many areas within the Aluoi Valley contained ecologically diverse ecosystems. These ecosystems were substantially altered or destroyed as a result of military operations. Since the end of the war, Vietnamese scientists have collected a substantial quantity of information on specific environmental components throughout Viet Nam. Only recently have comprehensive long-term environmental studies been initiated in Viet Nam by western scientists familiar with the Environmental Impact Assessment process.

As with many other parts of Viet Nam, large areas of badly eroded and deforested land in the Aluoi Valley remain to



(Source: HCL)

Figure 6.1
Digital Elevation Model (DEM) of Aluoi District.

be better assessed and reforested. The present health of many rare and endangered wildlife species in war-damaged areas like the Aluoi Valley require better documentation.

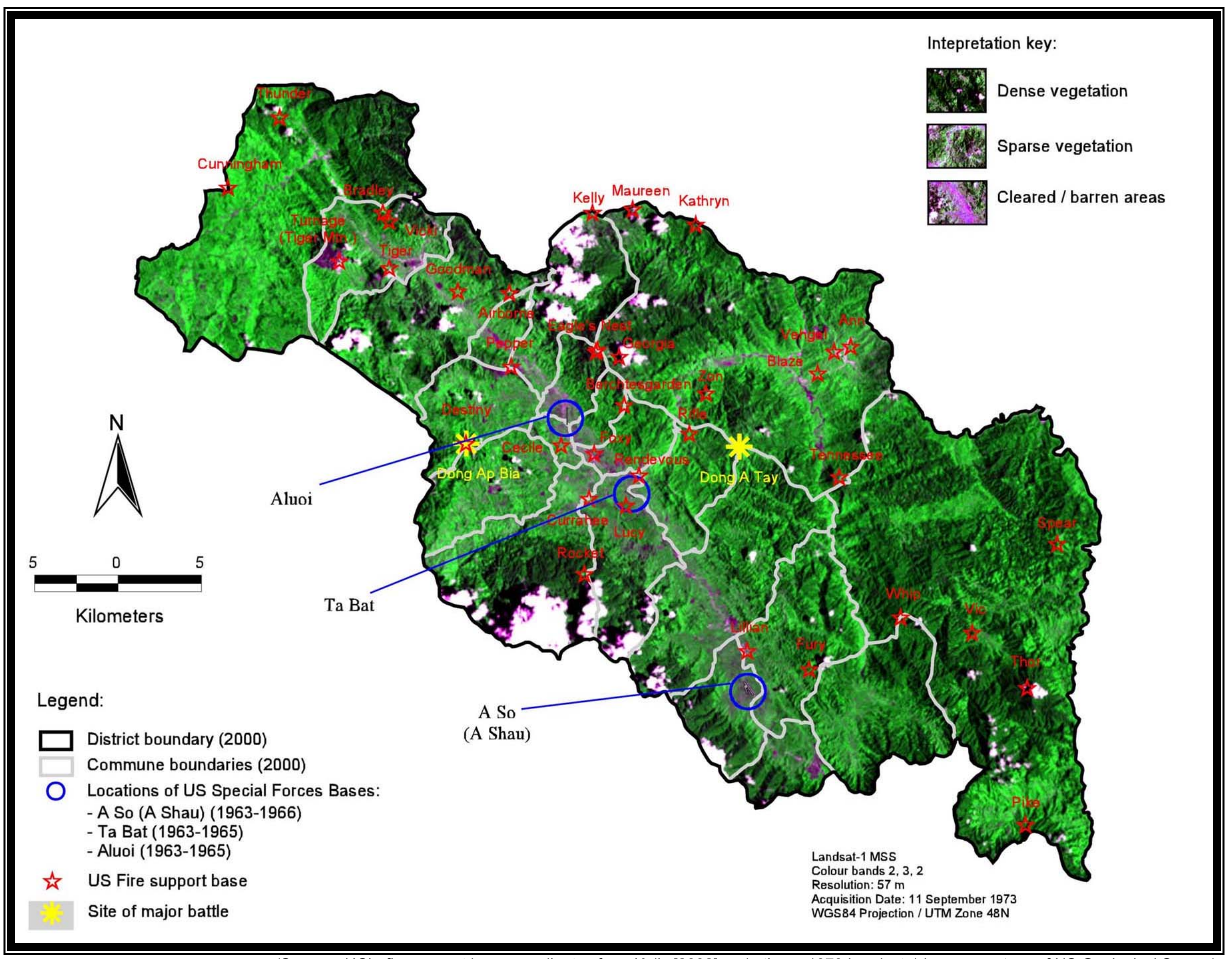
6.2 DESCRIPTION OF THE CONFLICT

6.2.1 Overview

The Aluoi Valley occupied a pivotal position during the 1965 to 1973 conflict. Called the A Shau Valley by Americans, it was a key segment along the north-south supply route of the North Vietnamese Army known as the Ho Chi Minh Trail. Contemporary US military accounts describe the valley in 1968 as "the largest enemy supply complex in South Vietnam", with two major NVA base areas immediately across the border in Laos: Base Area 611, connecting to Aluoi District along its northwestern boundary; and Base Area 607, connecting along the southern border of Aluoi Valley (USAF 1970).

Initial control of the Aluoi Valley by American and USVN troops centered around three Special Forces (SF) camps and airfields: Aluoi (established May 1965, near the modern Aluoi town centre); Ta Bat (established March 1963, near modern Hong Thuong Commune); and A Shau (hereafter referred to as A So, established April 1963 and near modern Dong Son Commune) (Figure 6.2).

Aluoi and Ta Bat supported air strips with small detachments of Vietnamese and American troops; A So (A Shau) was larger, with a fortified triangle-shaped compound and a supporting compliment of



(Source: HCL; fire support base coordinates from Kelly [2002] and others; 1973 Landsat-1 image courtesy of US Geological Survey)

Figure 6.2
Aluoi District showing former US Special Forces bases, fire support bases, and major ground battles.

US Special Forces and Vietnamese Civilian Irregulars. Aluoi and Ta Bat were abandoned in December 1965; A So (A Shau) was overrun in an intense battle in March 1966 (US Army 1989, Kelley 2002).

Following loss of these bases, the North Vietnamese Army (NVA) never completely relinquished control of the valley. However, starting in May 1968 and continuing until March 1971, US forces (1st Calvary and 101st Airborne Divisions) began a number of local operations directed at stemming the flow of soldiers and supplies along the Ho Chi Minh Trail (USAF 1970, Kelley 2002). These operations included:

- *Operation Delaware* (April-May 1968), which focused on exposing and disrupting NVA supply lines along the Ho Chi Minh Trail, and established US fire support bases in the area;
- *Operation Somerset Plain* (August 1968), a helicopter-based assault operation in the valley near Ta Bat and Aluoi town;
- *Operation Dewey Canyon* (January to March 1969), which attempted to establish control of the northern route between Aluoi and Khe Sanh, and did not involve action in the Aluoi Valley itself but did involve the northern portion of modern Aluoi District;
- *Operation Massachusetts Striker* (March to May 1969), which involved missions in the southern Aluoi Valley, including the former A Shau SF base; and
- *Operation Apache Snow* (May to June 1969), which established temporary control of the western Aluoi Valley adjacent to the Laotian border.

Notable battles in these operations include Bloody Ridge (Dong A Tay), during Massachusetts Striker in March 1969, and Hamburger Hill (Dong Ap Bia), during Apache Snow in August 1969 (Kelley 2002).

None of these operations reestablished full South Vietnamese control of the Aluoi Valley, although they did result in the establishment of several artillery fire support bases and landing zones, shown in Figure 6.2. A contemporary US Air Force (1970) report indicates that "any potential helicopter landing zones and artillery fire support bases [in Aluoi Valley] were mined and watched" by NVA troops, suggesting that many points of high ground or flat, open land in the valley may still contain mines.

No additional major ground combat actions followed these 1968-69 operations, partly due to negative US public reaction to American troop losses at battles such as Hamburger Hill (Summers 1995). For the remainder of the conflict, South Vietnamese and American activities in the Aluoi Valley focused on increasingly massive aerial bombardment.

6.2.2 Aerial Bombardment

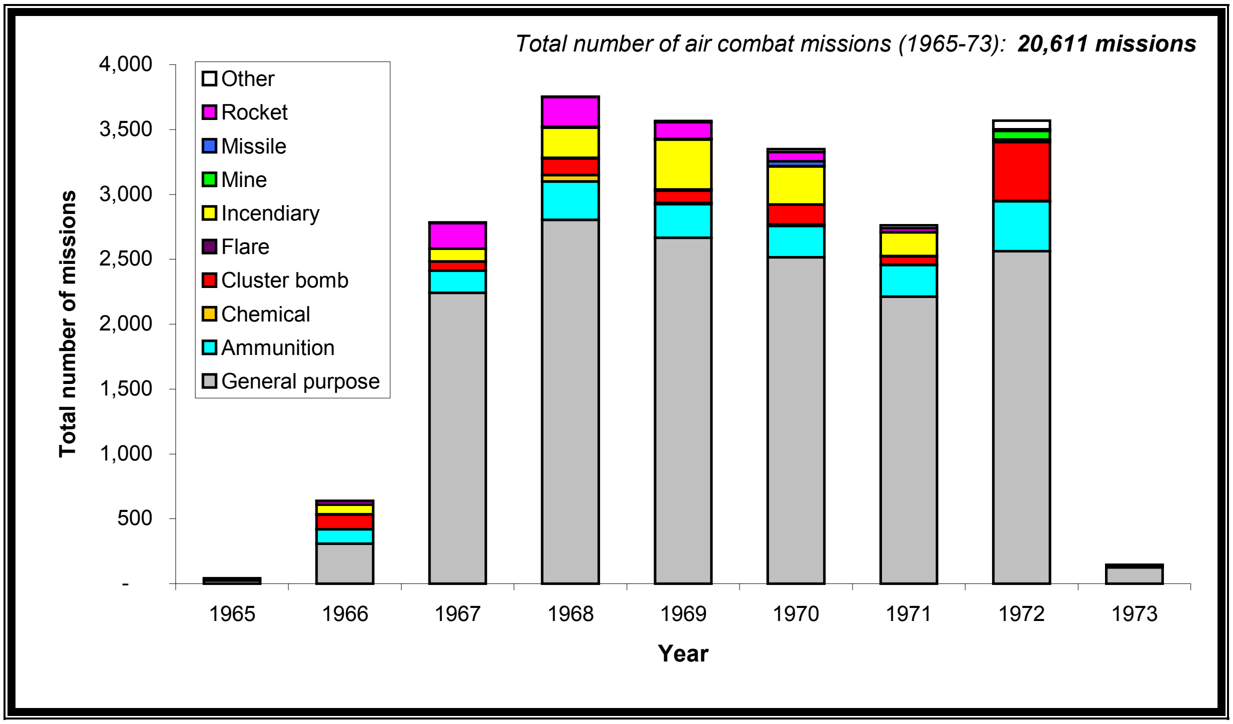
The Air Combat Database, recently declassified and released by the US government shows records of a total of 20,611 air combat missions over Aluoi District, for the years of 1965 to 1973. In total, these 20,611 missions involved 38,258 aircraft flights, which utilized a total of 302,091 pieces of ordnance, weighing a total of 611 million pounds (Appendix A4).

Figure 6.3 illustrates missions flown over Aluoi District by category of ordnance. These data illustrate the significant escalation of air combat missions from 1965 to 1968, corresponding with greater American involvement in the Viet Nam conflict generally, with most missions involving general purpose ordnance (e.g., 250-lb, 500-lb and other types of heavy bombs), followed by cluster bombs, incendiaries, and ammunition (Figure 6.3A). Number of missions flown remains high but declines from 1968 to 1971, but then rises considerably again in 1972, the final full year of major American military intervention in Viet Nam.

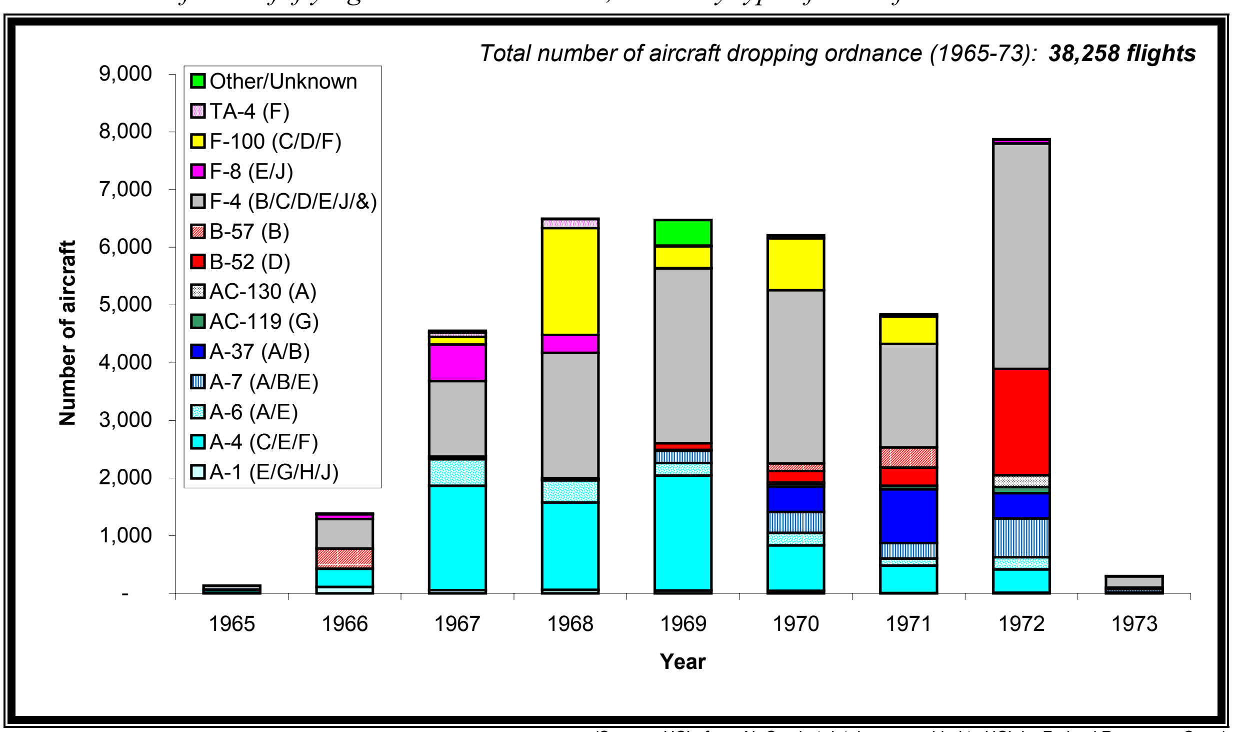
These missions included primarily small tactical fighters or fighter-bombers, such as A-4s, F-4, and F-100s, particularly from 1966 to 1969. The use of B-52 high-altitude strategic bombers to strike targets in Aluoi District began in 1969, and increased significantly in 1972 (Figure 6.3B).

When these air combat database records are examined with respect to amount of ordnance utilized instead of number of missions flown, different trends are immediately evident (Figure 6.4).

A. Number of recorded air combat missions per year, sorted by type of ordnance dropped.



B. Number of aircraft flying air combat missions, sorted by type of aircraft.



(Source: HCL, from Air Combat database, provided to HCL by Federal Resources Corp.)

Figure 6.3
Summary of air combat missions in Aluoi District, 1965 to 1973
(US Military Air Combat Database records).

Figure 6.4A clearly illustrates a regular increase in the number of pieces of ordnance targeted at Aluoi District from 1965 to 1971, then a very large increase in 1972. When the total weight of targeted ordnance is examined, an even more striking trend of increasing targeting of ordnance in Aluoi District over time is evident (Figure 6.4B): from 1969 to 1972, the total weight of ordnance targeted at Aluoi District increased from 1.9 million to 378.6 million pounds.

While most categories of ordnance targeted at Aluoi District increased in total pieces and weight from 1969 to 1972, use of cluster bombs and, in particular, large general purpose bombs, increased greatly over this time, consistent with increased use of B-52 strategic bombers carrying larger, heavier loads. Likely targets of these large bombs and cluster munitions were North Vietnamese Army (NVA) troops and materials traveling through Aluoi Valley along its portion of the Ho Chi Minh Trail.

Detailed spatial distribution of air combat targets in Aluoi District from 1965 to 1973 has previously been presented in Chapter 3 (Figure 3.2).

Figure 6.5 illustrates the total number of pieces (6.5A) and total weight (6.5B) of ordnance targeted at specific communes of Aluoi District, organized from smallest to largest value to highlight communes which likely contain the greatest potential UXO contamination from air combat ordnance. Incendiary ordnance (e.g., napalm) has been excluded from these charts.

Communes that received the largest amount of air combat ordnance, and which therefore are likely to contain largest amounts of UXO from air ordnance, include Hong Van, Hong Ha, Huong Nguyen, Hong Trung, and Hong Thuy. However, while these communes likely received the greatest number and weight of air ordnance, they generally are large communes relative to others in the district, and therefore would be expected to exhibit generally greater numbers of ordnance targets, other factors being equal. Therefore, Figure 6.5 also reports total pieces and weight of ordnance per square kilometer, to provide a comparative measure of the density of air combat ordnance targeted at each commune. These data appear as a diamond shape at the top of a vertical line.

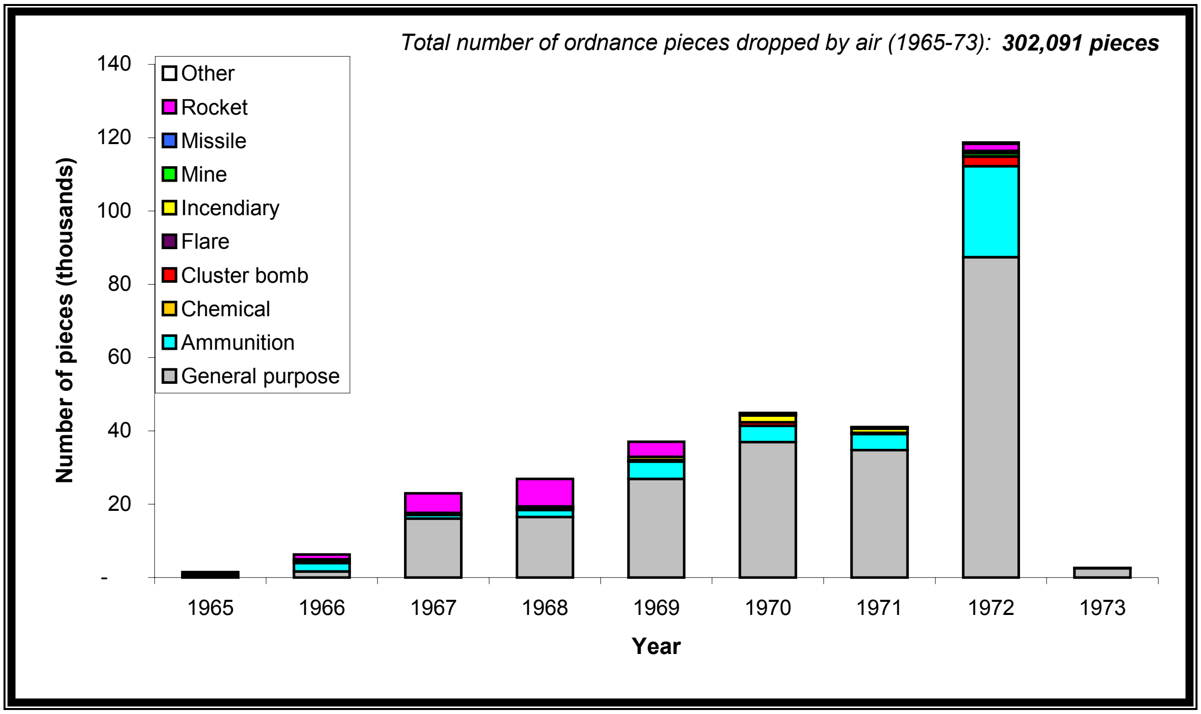
When density of air combat ordnance is examined by total number (Figure 6.5A) or total weight (6.5B), it is apparent that some small communes received many more air ordnance per square kilometer than many larger communes. Hong Van commune exhibits the highest density of ordnance by number or by weight, in addition to receiving the largest number of pieces of ordnance in absolute terms. Given the expected relationship between number of targeted ordnance per commune and amount of residual UXO contamination, Hong Van likely is the commune most heavily contaminated by UXO in Aluoi District.

Following Hong Van, other communes exhibiting high densities of targeted ordnance by number or weight include several small, relatively densely-populated communes located in the central Aluoi Valley: A Ngo, T.P. Aluoi, Bac Son, Phu Vinh, Son Thuy, and Hong Quang. Based on GIS analysis of the air combat database alone, these records suggest that the central and northern Aluoi Valley, and Hong Van commune in particular, likely contain the largest number of unexploded bombs, cluster bomblets, and other air ordnance in Aluoi District.

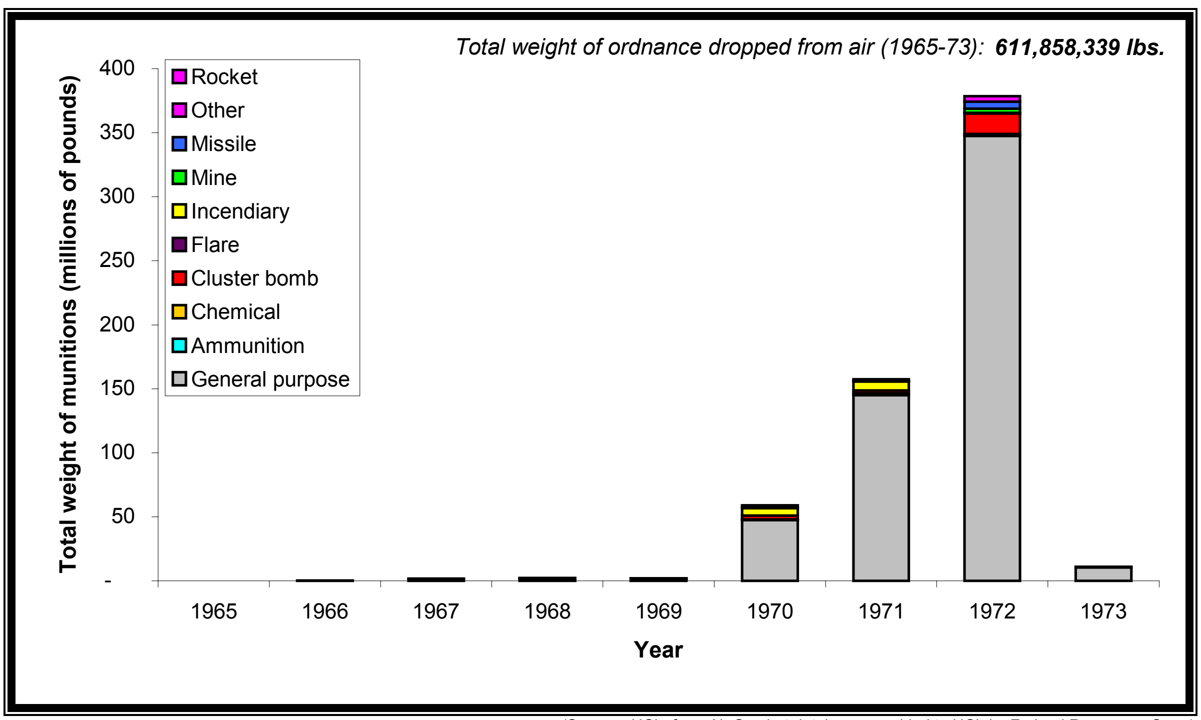
Of all categories of air combat ordnance listed in the air combat database, cluster bombs and air-dropped mines likely pose the greatest threat of creating hazardous, accidental encounters between local people and UXO. Figure 6.6 presents air targets of cluster bomb and air-dropped mine ordnance only. These data generally agree with data describing overall air ordnance contamination, with Hong Van commune exhibiting highest numbers, weight and density of targeted cluster bombs. Central valley communes, particularly Bac Son, also receiving relatively higher numbers of cluster bombs and mines by surface area than other communes in the valley.

Figure 6.7 is a map showing density of air ordnance (by load weight) in each commune of Aluoi, including all ordnance categories (6.7A) and only cluster bombs (6.7B). The concentration of aerial bombardment targets in central and northern Aluoi Valley, and along key roadways, is apparent.

A. Quantity of ordnance dropped (pieces), sorted by type of ordnance.



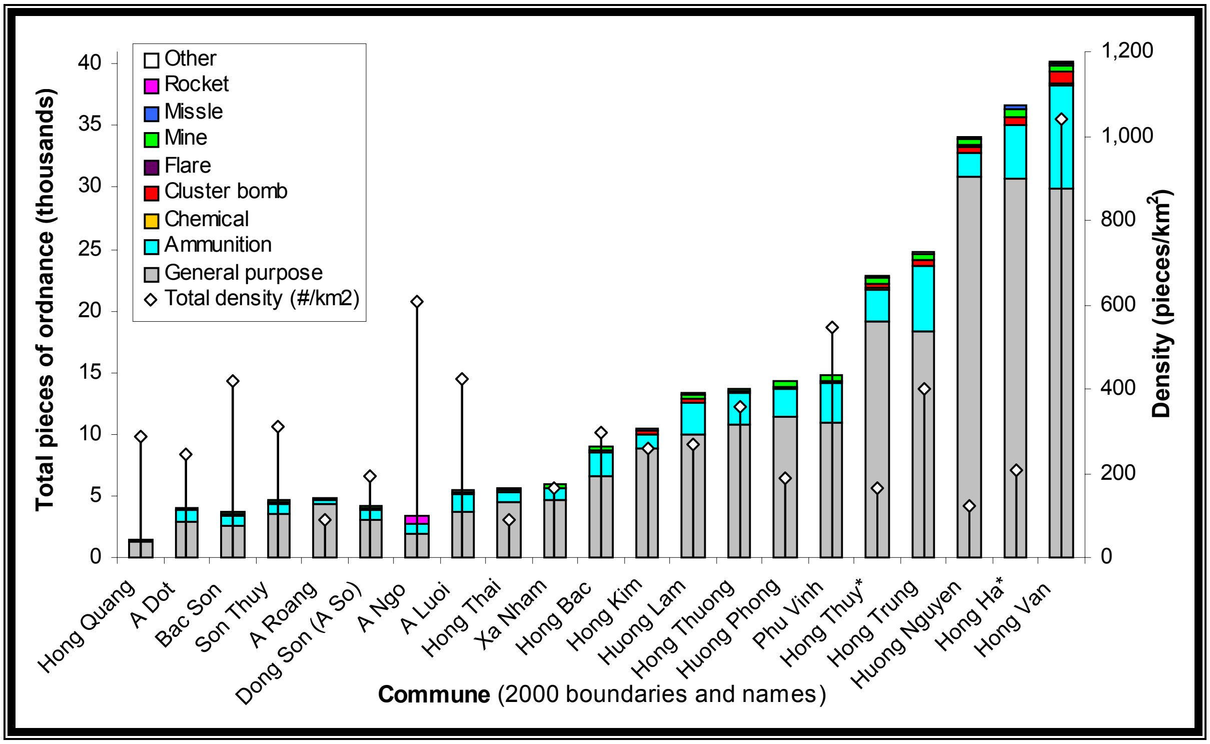
B. Quantity of ordnance dropped (pounds), sorted by type of ordnance.



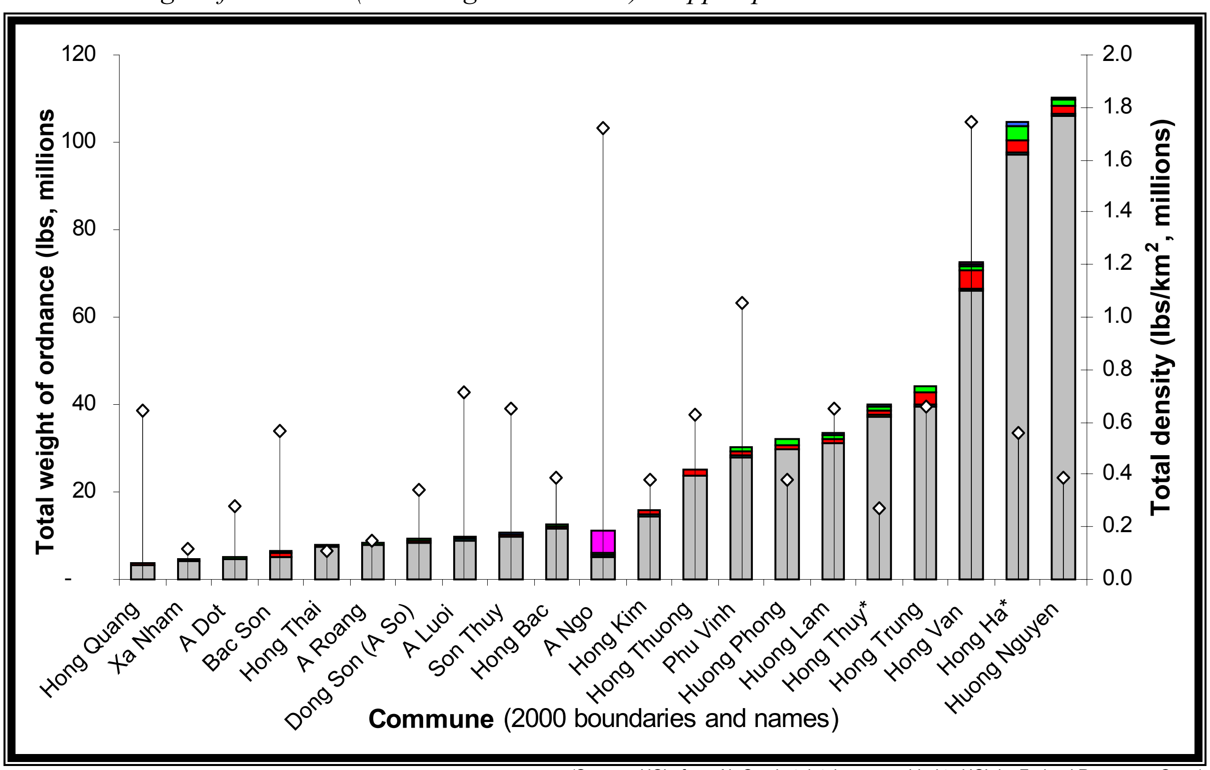
(Source: HCL, from Air Combat database, provided to HCL by Federal Resources Corp.)

Figure 6.4
Summary of targeted air combat ordnance in Aluoi District, 1965 to 1973
(US Military Air Combat Database records).

A. Number of pieces of ordnance (excluding incendiaries) dropped per commune.



B. Total weight of ordnance (excluding incendiaries) dropped per commune.

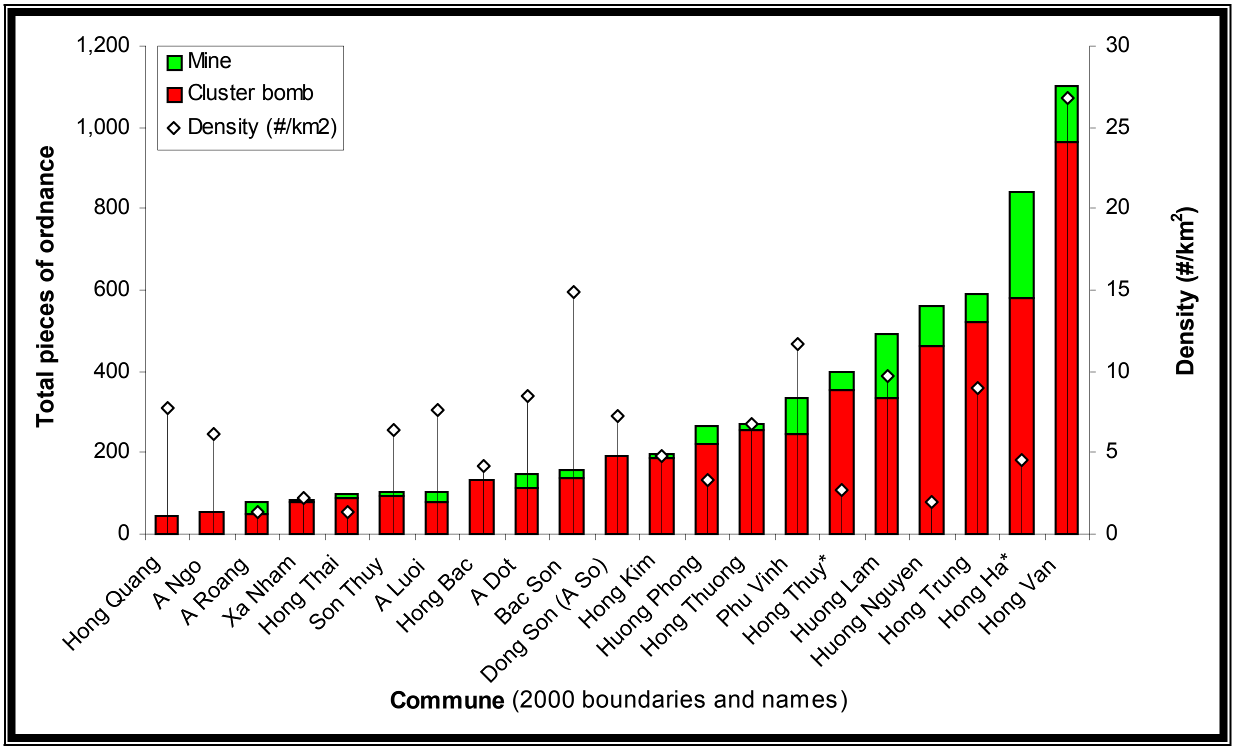


(Source: HCL, from Air Combat database, provided to HCL by Federal Resources Corp.)

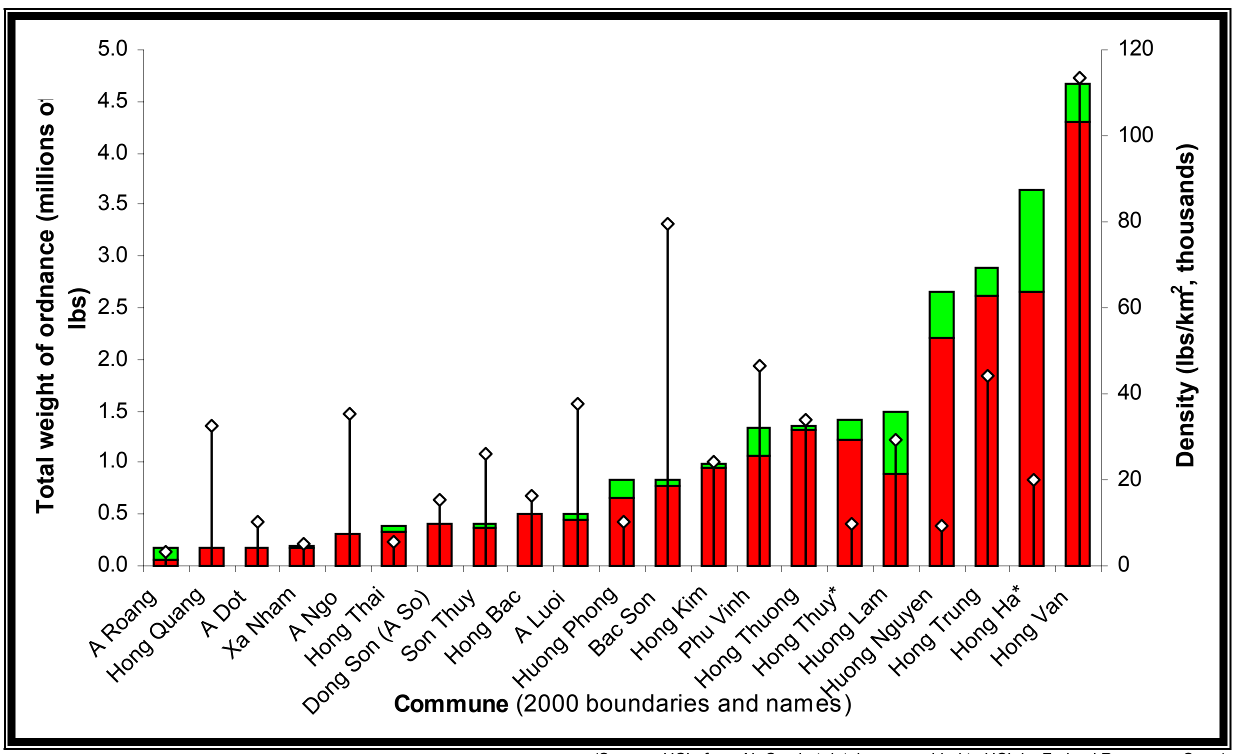
Figure 6.5

Air combat ordnance targets, 1965 to 1973 by commune, in Aluoi District (US Military Air Combat Database records).

A. Cluster bombs and mines (number of pieces) dropped per commune.



B. Total weight of cluster bombs dropped per commune.

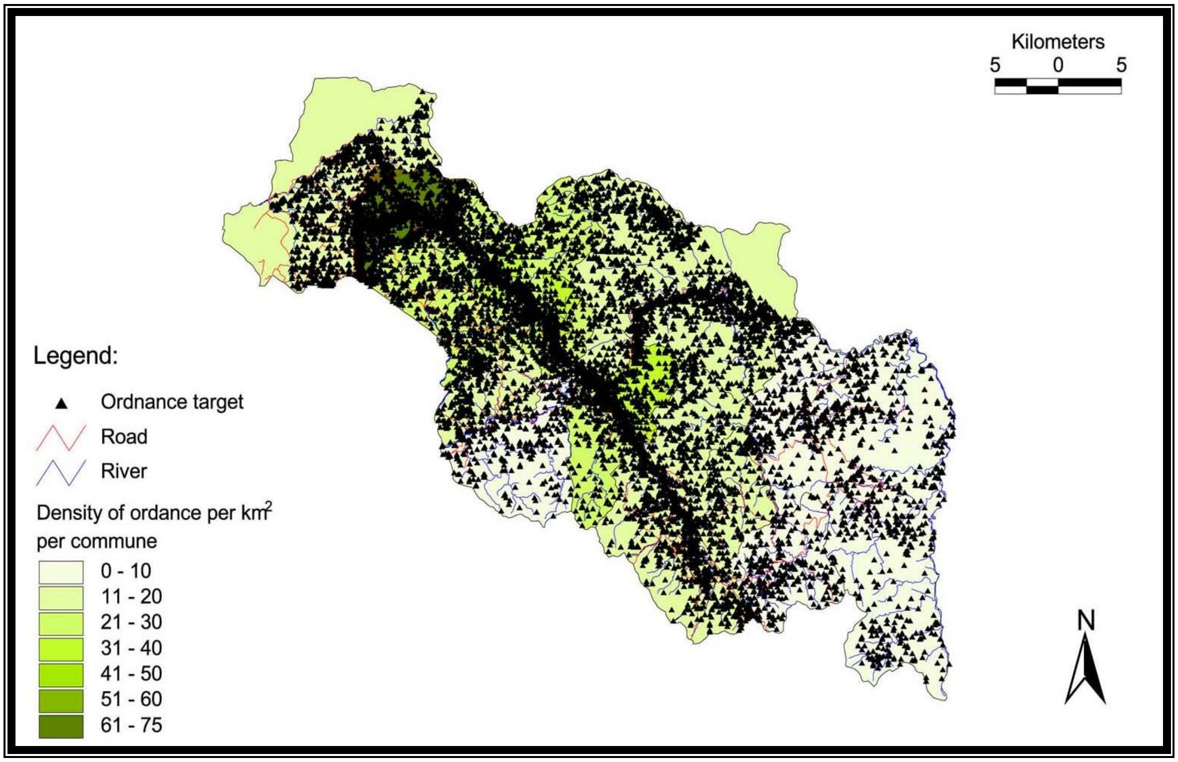


(Source: HCL, from Air Combat database, provided to HCL by Federal Resources Corp.)

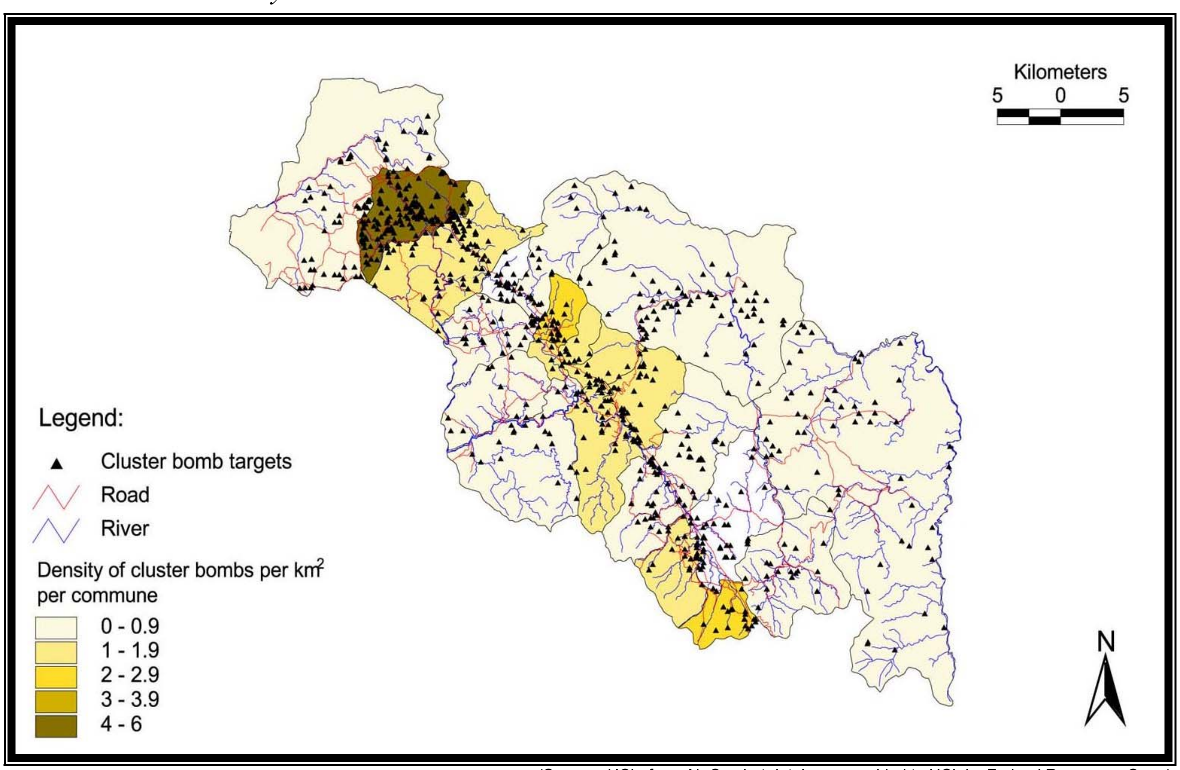
Figure 6.6

Air combat ordnance targets (cluster bombs and mines only), 1965 to 1973 by commune in Aluoi District (US Military Air Combat Database records).

A. All ordnance.



B. Cluster bombs only.



(Source: HCL, from Air Combat database, provided to HCL by Federal Resources Corp.)

Figure 6.7

Density of air combat targets by commune.

This air combat dataset does not include information related to naval and ground artillery, ground combat, or air ordnance that may have been dropped by North Vietnamese aircraft in the area. Due to the nature of the combat in Aluoi Valley (i.e., defense of air and fire bases, and interdiction of ground forces), UXO contamination resulting from ground artillery and combat likely are also important contributors to accidents and land abandonment in Aluoi District.

6.2.3 Herbicide Applications

Ten provinces in southern Viet Nam received an estimated 47% of all Agent Orange herbicide applications, with Song Be, Thua Thien Hue (which includes the Aluoi Valley) and Binh Dinh being the most targeted provinces, with 704, 606 and 558 application missions, respectively (Black 1994). Aluoi Valley received 224 of the 606 missions in Thua Thien Hue province (Dai *et al.* 1994a), which resulted in a change of dominant land cover from dense forest to open grass and shrubland in much of Aluoi District.

Maps of herbicide application intensity appear in Chapter 2 (Figure 2.2) for southern Viet Nam generally, and in Chapter 3 (Figure 3.1) for Aluoi District specifically.

6.2.4 Military Installations

The former base area at Aluoi is now within the town of Aluoi; the location of the fomer airstrip is now a school playground.

Areas around former US Special Forces bases at Ta Bat and A So (A Shau) remain abandoned and uncultivated, due to a perceived high UXO risk in these areas. Detailed investigations of these bases during this project revealed widespread and recent evidence of UXO removal by local people, likely for dismantling and sale (i.e., scrap metal). The number and extent of dug holes from this dangerous occupation suggest that UXO remains a major problem around these bases.

Historical information describing these bases has been presented and discussed in Chapter 3. Figure 6.8 presents historical information describing the former base area at A So, overlaid on a recent (2000) high-resolution satellite image of the area.

Through this comparison, it is apparent that local villagers in Dong Son commune are living in close proximity to areas of the former base that may have been mined or contain heavy UXO contamination from aerial and/or artillery bombardment.

Potential definition of the base area in future UXO surveys and remove activities at A So should consider apparent changes in the course of the A Sap River and its tributary. Comparison of historical information with modern satellite imagery indicates that during the war era, this tributary stream did not demarcate the bottom of the runway and trenches and other military objects such as mines, mortar or artillery positions, etc., may exist on the other side of the present course of the river.

6.3 SOCIO-ECONOMIC CHARACTERISTICS

The Aluoi Valley is very remote from the rest of Viet Nam, and inhabited mainly by ethnic minorities which differ in culture and language from lowland Vietnamese. Even by Vietnamese standards, the residents of this area are poor. They subsist on slash-and-burn agriculture, some rice cultivation, and modest fish farming and animal husbandry.

6.3.1 Social Structure

A 1992 census estimated that the population of 31,012 persons was comprised mainly of four ethnic minorities Ca Tu, Kinh, Pa Co and Ta Oi.

Local people tend to be conservative and follow traditional practices; for example, the marriage of a daughter involves provision of a large dowry of food, clothing and means of agricultural production to the son-in-law.

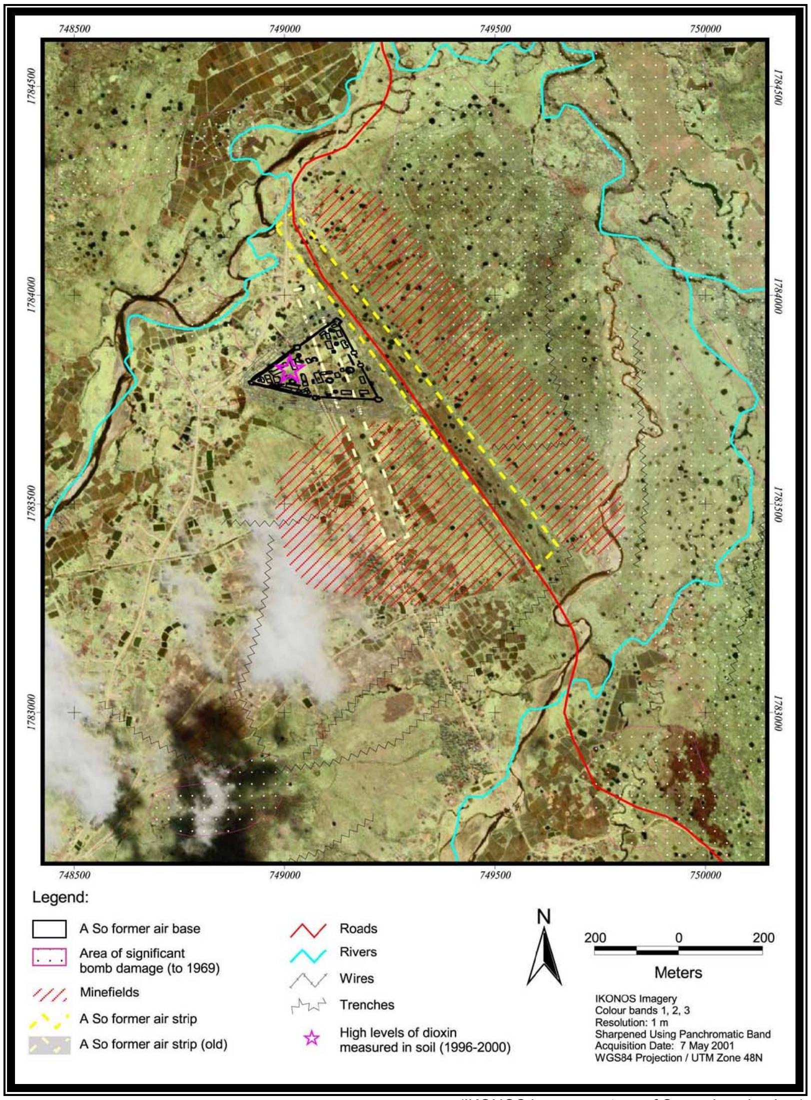
Education levels are very low and over 90% of the population is atheist/animist, with small numbers of Catholics and Buddhists. Intermarriage is permitted by various ethnic minority groups in Aluoi Valley. The husband is the final arbiter of disputes and paramount leader within the family unit. Until recently, the wife was responsible for most physical work including agriculture. The husband hunted and cut trees. Now there is a division of tasks with the husband taking on the more heavy work. If a family member becomes ill, a magician/shaman may be called.

6.3.2 Infrastructure

Transportation

Transportation to the area is limited to two main roads; Highway 14 (north/south) and Highway 49 (road from Hue City to Aluoi District. Both routes are subject to flooding and land slides, and consequently are not always passable during the wet season.

Highway 14 is currently experiencing a major upgrade and will become integrated into Highway 2 (the Ho Chi Minh Highway) network linking Hanoi and Ho Chi Minh City through the interior of the country. It is estimated that Highway 2 will be completed in 2004. The upgrade of Highway 49 is a continuing process, addressing hydraulic and geo-technical deficiencies as they arise.



(IKONOS image courtesy of Space Imaging Inc.)

Figure 6.8
Compilation map and image describing war-era conditions in the vicinity of A So Special Forces base.

Water

Water resources of Aluoi are virtually unmanaged. The main source of potable water is streams; people often use unclean water. The Health Service promotes well digging, but only a limited number of wells have been dug thus far. There are virtually no hydrological data for Aluoi. The September to December wet season includes a flooding period from October to November, particularly when annual rains exceed 3,000 mm. Only 50 ha of cropland are actively irrigated (from a diversion dam).

Public Health

There is one district hospital (A Ngo) and 21 village health clinics in Aluoi Valley. All health clinics have medical staff; however, 11 do not have their own buildings and use rooms of their village committee buildings. Medical equipment in the A Ngo hospital includes an X-ray machine, a dental drill, a microscope, a freezer, and an autoclave. Available medicines in Aluoi include iodized salt, leprosy medicine, and vaccines for whooping cough, tetanus, diphtheria, measles, tuberculosis and poliomyelitis.

DDT spraying was discontinued in 1993; people now soak their mosquito nets with permethrin (also preferred over DDT for killing bed bugs). Mosquito density is determined by the number of mosquitoes a person can catch per hour (mosquitoes/per hour/per person). In 1994, mean local mosquito density in cowsheds and pigsties was 3.6 (for *Anopheles*) and 33.4 (for other mosquitoes). The incidence of malaria is high: in 1994, the malaria fever rate was 5.03%; 15 people died from the disease.

6.3.3 Economic Activities

Agriculture

The chief occupation of people living in Aluoi Valley is farming of cassava (manioc), rice and livestock. The deforestation of hills for dry rice and cassava culture is a serious local land-use problem. Cassava also is problematic given its high soil nutrient demands; farmers like to break new ground after only one or two crops.

Both manure and some chemical fertilizers are used. Limited amounts of pesticides are used because of their high cost. Surveys conducted by HCL in 1999 suggest that Vibam 5H (Fenobucarb) is the pesticide most commonly used in recent years (approx. 100 kg/year); however Sofit 300 ND (Pretilachlor) and Dipterex (Trichlorfon) are also used. Roundup (glyphosate) is also likely used to a limited extend in the valley.

Local people also forage in forests for bamboo shoots, mushrooms, banana flowers and medicinal plants. Hunting is common and many different animal species are taken.

Most farmers' families subsist on cassava as their staple and rice is eaten less frequently. Fish is eaten more than meat (which is rarely eaten). Only relatively wealthy families have surplus food. The average household experiences food shortages for up to three months a year and "poor" households may lack food for up to six months annually.

Cows are the District's most abundant livestock. According to the JIVC (Japan International Volunteer Center, Hue), pig farming has not contributed significantly to improving local income levels. There is, however, a side benefit to raising pigs as their dung is good fertilizer. Cow rearing contributes 450,000 Dong (approximately $45 US) per head every three years. Families sell livestock rather than use them for food.

Aquaculture

Fish culture is well established in Aluoi Valley; most households have fishponds. There are approximately 100 ha of ponds in use. Ponds are relatively productive (approximately 4,800 kg/ha), and are the primary source of protein for the area. An average size pond in Aluoi Valley yields approximately 200 fish per household per year.

Grass carp is the most important species. In 1990, the Hong Thuong hatchery supplied 50,000 juveniles to local farmers; since 1991 distribution has increased to 1,000,000 annually. The district hatchery has 130 ha of ponds; 60% of their production is directed at supplying grass carp fingerlings to stock local farmer's ponds. Fifteen to twenty million fry are produced per year, as well as three to four tonnes of grown-out fish. Fish are sold when they reach 3.5 to 4.0 cm (80 to 100 Dong per fish) or from 7 to 10 cm (400 to 500 Dong per fish). Juveniles take six to eight months to reach market size. The hatchery organizes workshops to help villagers build fish ponds and grow fish.

Aquaculture production is now greater than wild-caught fish from streams. Some sea fish, from Hue, are also marketed in the region.

6.4 UXO/LANDMINE SURVEYS

UXO/landmine surveys were implemented by the chiefs of each commune medical centre under the supervision of the District medical centre staff, the provincial medical centre staff and the 10-80 Division.

The purpose of these surveys was the collection of information on not only UXO, but also impacts of UXO contamination on human health and socio-economic development in Aluoi District. Results of the surveys included a combination of qualitative and quantitative data on presence of UXO and UXO/landmine accidents.

Qualitative data were collected by interviewing individual stakeholders and organizations who could provide insight into the UXO situation in the

Aluoi Valley. Key sources of information included the Ministry of Defense, Army Engineers, Technology Centre for Bomb and Mines Demining, local Peoples' Committees, Veteran Associations, the Department of Agricultural and Rural Development, and local inhabitants.

Quantitative data were obtained through a direct interview and questionnaire program for inhabitants of the 20 communes and main town in Aluoi District. Questionnaires designed for the survey were based on a similar program carried out in Lao PDR in 1997 by Handicap International (Handicap International and Ministry of Labour & Social Welfare, Lao National UXO Program 1997).

The first questionnaire (UXO Presence Survey), asked questions on:

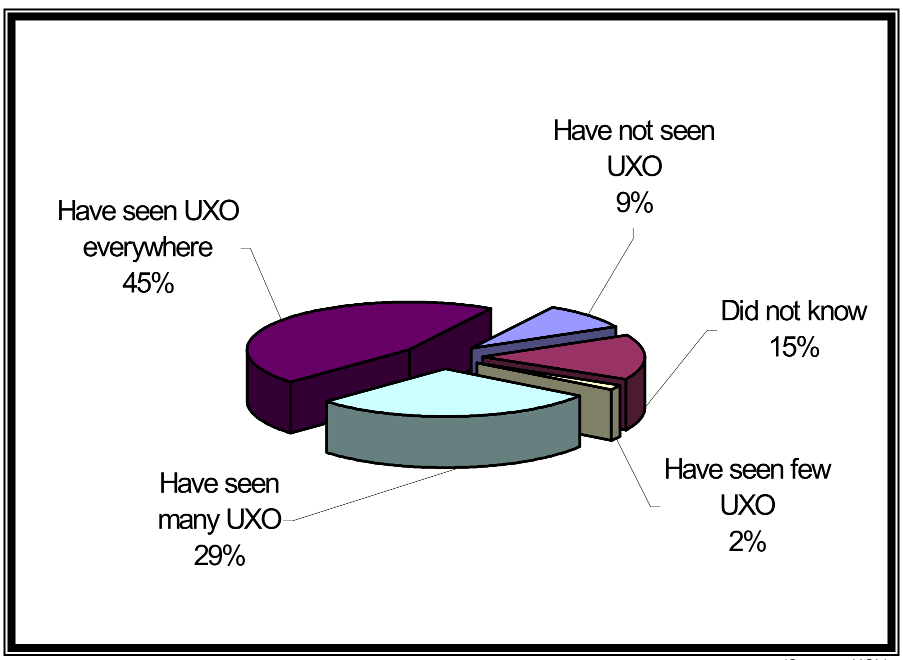
- UXO locations;
- UXO types seen;
- UXO and UXO impact attitudes; and
- feelings on impact to health and socio-economic development.

The second questionnaire (UXO Accident Survey), asked questions on specific UXO accidents and how they have affected the socio-economic status of the individual and their family.

A translated English version of the final survey report including the UXO Presence and UXO Accident questionnaires and results of the surveys are provided in Appendix A6 and A7, respectively. The results of the surveys in Aluoi District are summarized below.

6.4.1 UXO/Landmine Presence Survey

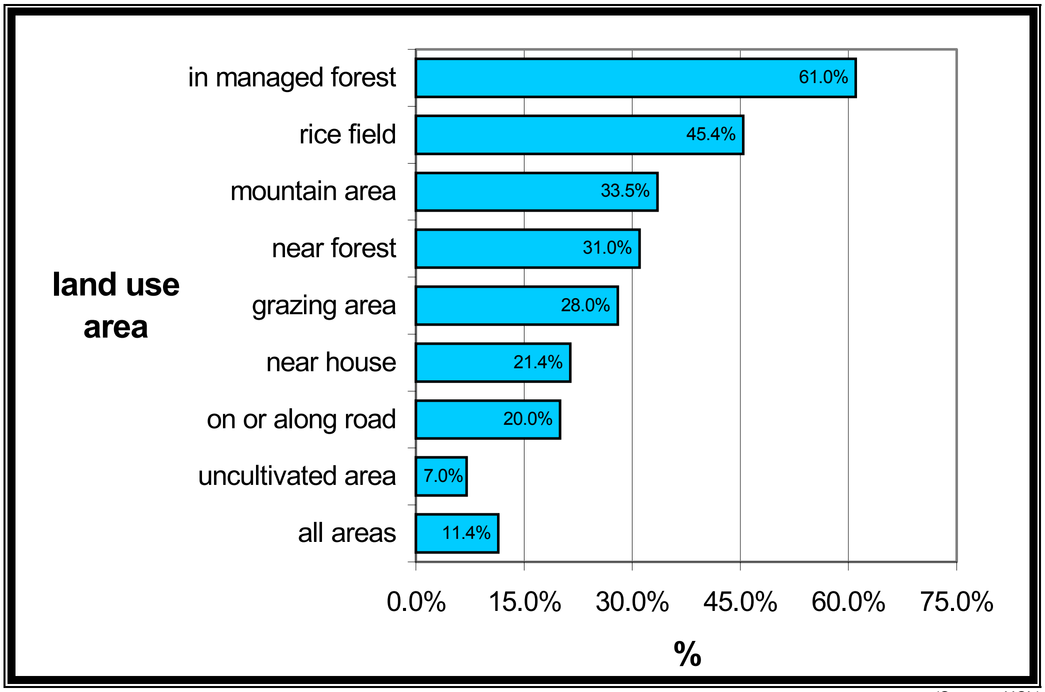
All individuals interviewed for the UXO Survey were living in Aluoi District during the US-Viet Nam Conflict (i.e., >26 years). A total of 1,951 individuals and their families were interviewed for the UXO Presence Survey. With the exception of Xa Nham Commune, all 20 communes and towns were represented. Of the 1,951 survey participants, 629 (32%) indicated that they lived in Aluoi District during the American conflict, while 1,322 (68%) moved in after the end of US military involvement in the area (1973).



(Source: HCL)

Figure 6.9
Percentage of surveyed residents that have seen UXO during daily activities.

The demographic composition of the interview group was a key variable in assessing results of the survey. Males composed approximately 80% (1,578) of the survey group. Approximately 80.5% of the males indicated they were farmers. The high percentage of farmers is typical of rural communities in Viet Nam and results in a much greater potential for exposure to UXO contamination than urban populations. Individuals were asked if they had seen UXO during their everyday activities including work, home and recreation areas (Figure 6.9).



(Source: HCL)

Figure 6.10
Where survey participants have seen UXO (% by land use).

Approximately 75% of interviewees in the District have reported seeing UXO during their everyday activities confirming a UXO/landmine problem in Aluoi District.

The impact of UXO land use activities in Aluoi District is illustrated in Figure 6.10. Although UXO was reported throughout all categories of land use, the highest incidence of encounter was reported in areas that require the most labour intensive activities: forestry and agriculture.

Another issue is the presence of UXO near homes and household farm plots (including gardens, fish ponds and domestic animal pens). In rural communities, the primary and sometimes only source of food for a family is the household garden plot. UXO contamination in and around houses can serious affect the ability of a family to produce food. The UXO survey indicated that 88% of the 1,951 families interviewed lived in a fixed residence with a small farm plot raising crops, animals, birds and fish for their own consumption. Each participant was also asked if they knew families in their commune with visible UXO or landmines in their fields. Approximately 50% of the interviewees indicated that they knew of at least one family, and 5% indicated that they knew of at least 100 families that reported visible UXO in their fields.

With respect to the non-use of land because of UXO/landmine threat, 35% of interviewees indicated that they do not use parcels of land due to contamination or perceived contamination.

Information on when and how the UXO or landmines were deployed can give mine action analysts a sense of the type of UXO or landmines that would be expected during a clearing operation. It is well documented that both battlefields and permanent bases existed in the Aluoi Valley during the war, as well as many aerial bombing missions. The main source of this information is US military records.

When interviewed, one of the victims' wives cried and said "...before the accident, he worked very hard. But now our family has not enough food. Now what should we do..."

Table 6.1

Number (%) of UXO accident cases (males, females and children) that respondents stated they were aware of, in Aluoi District.

Number of Cases	Males	Females	Children
0	430 (22%)	1,220 (63%)	1,303 (67%)
1-10	1,253 (64%)	719 (37%)	629 (32%)
> 10	268 (14%)	12 (0.5%)	19 (1%)

Part of the UXO survey asked questions relating to the type of military activity that occurred in the valley during the war. This question was only asked of participants that were living in Aluoi District during the conflict. Results indicate that all participants witnessed aerial bombing of various intensities; all but one commune saw some degree of ground battles.

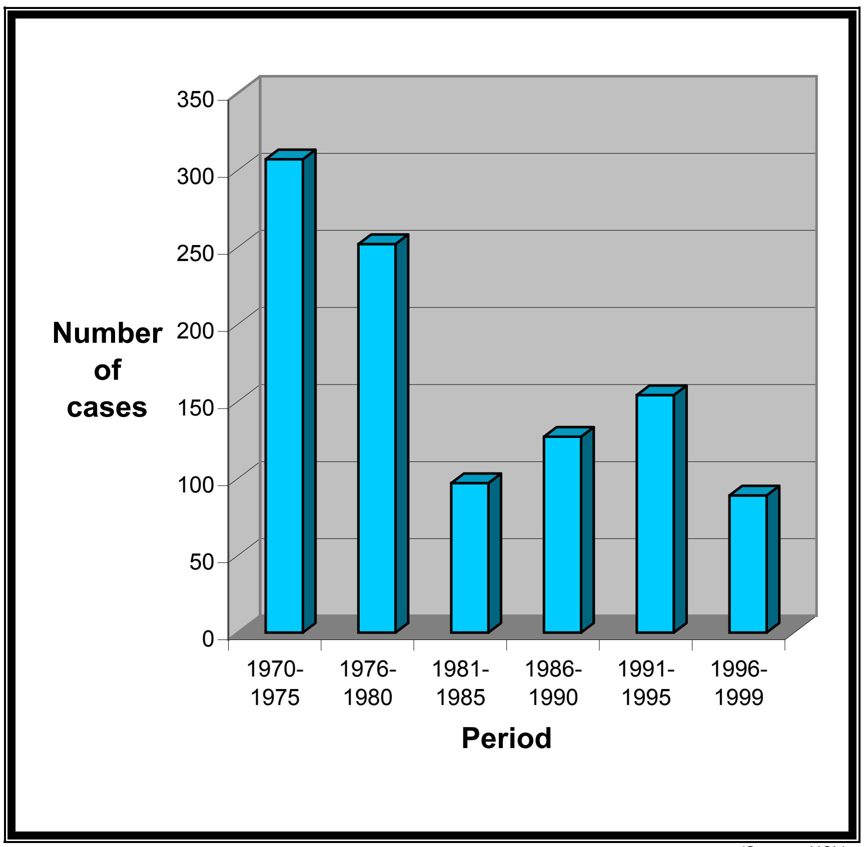
The same 1,951 survey participants were also asked questions regarding UXO accident incidence and attitudes towards UXO. 28% of the 1,951 interviewees stated that they had UXO accident victims in their family. The breakdown of the number of accident victims per family is as follows:

- 386 have one victim;
- 118 have two victims;
- 22 have three victims;
- 12 have four victims;
- five have five victims; and
- one family member had 12 victims.

The distribution of UXO accident cases between adults and children (and between sexes) is presented in Table 6.1.

Approximately twice as many males have either been injured or killed by UXO or landmines than have females and children. This statistic is not surprising, given that most of the UXO encounters were shown to be in areas (forest and fields) where males traditionally work.

A series of questions were asked with regard to attitudes toward UXO. This may have a significant bearing on the number of accidents within a commune. For example, the participants were asked what do they normally do when they see a UXO or landmine. Approximately half (52%) stated they picked up the UXO and threw it out of the way. Other options included informing authorities (36%), recycling (36%), do nothing (27%) and other (including destroying or marking the location) (0.1%). These answers overlap due to



(Source: HCL)

Figure 6.11
Number of UXO accident cases over time (1970-1999) in Aluoi District.

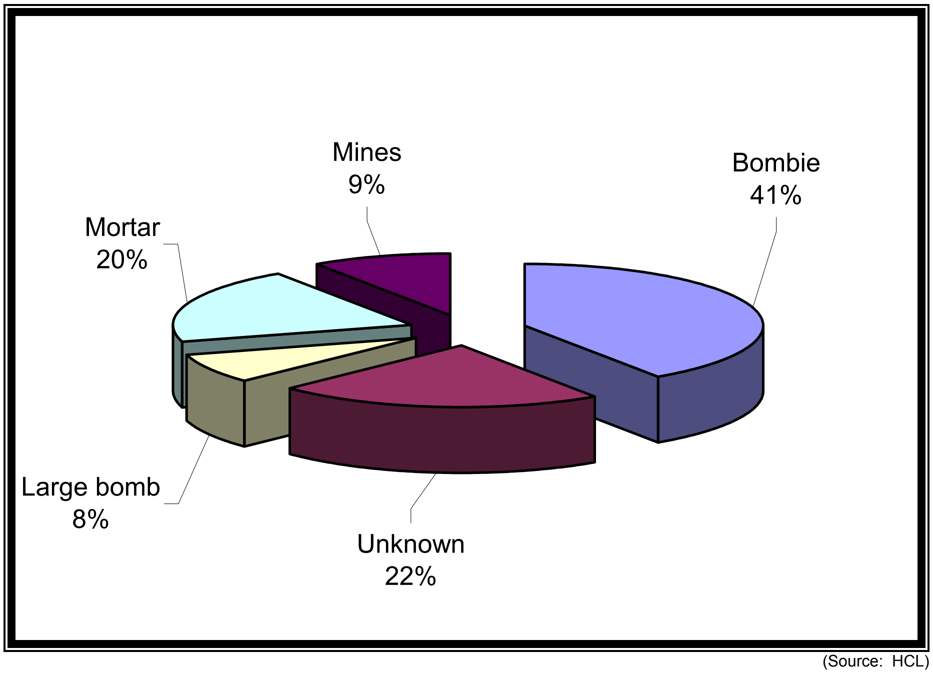


Figure 6.12
Type of war-related munitions (%) that have caused injury in Aluoi District.

An intensive forestry program was also initiated at this time involving the planting of eucalyptus (spp) and pine (spp) stands in more mountainous areas. Only 11% of accident cases were reported to have occurred at or near place of residence. The two primary locations for accidents were in rice fields (34%) and in the forest (15%).

Digging resulted in the greatest number of accidents (47%). Touching UXO (including moving, throwing, opening, defusing and playing) resulted in 26% of the accidents.

Anti-personnel bombs or "bombies" have caused the most accidents. The breakdown of type of munitions causing accidents in Aluoi District is presented in Figure 6.12.

The socio-economic impacts of UXO accidents are magnified when one considers that 40% of the victims were primary providers (married with children).

Survey results demonstrated that unemployment among accident victims increased two and one half times after injury.

Figure 6.13 presents a graphical summary of results of the UXO incidence/accident survey, shown over a map of Aluoi District.

Appendix A6 provides the methodology and process employed by the 10-80 Division and Hue Health Department to conduct the accident survey; detailed results are provided in Appendix A7.

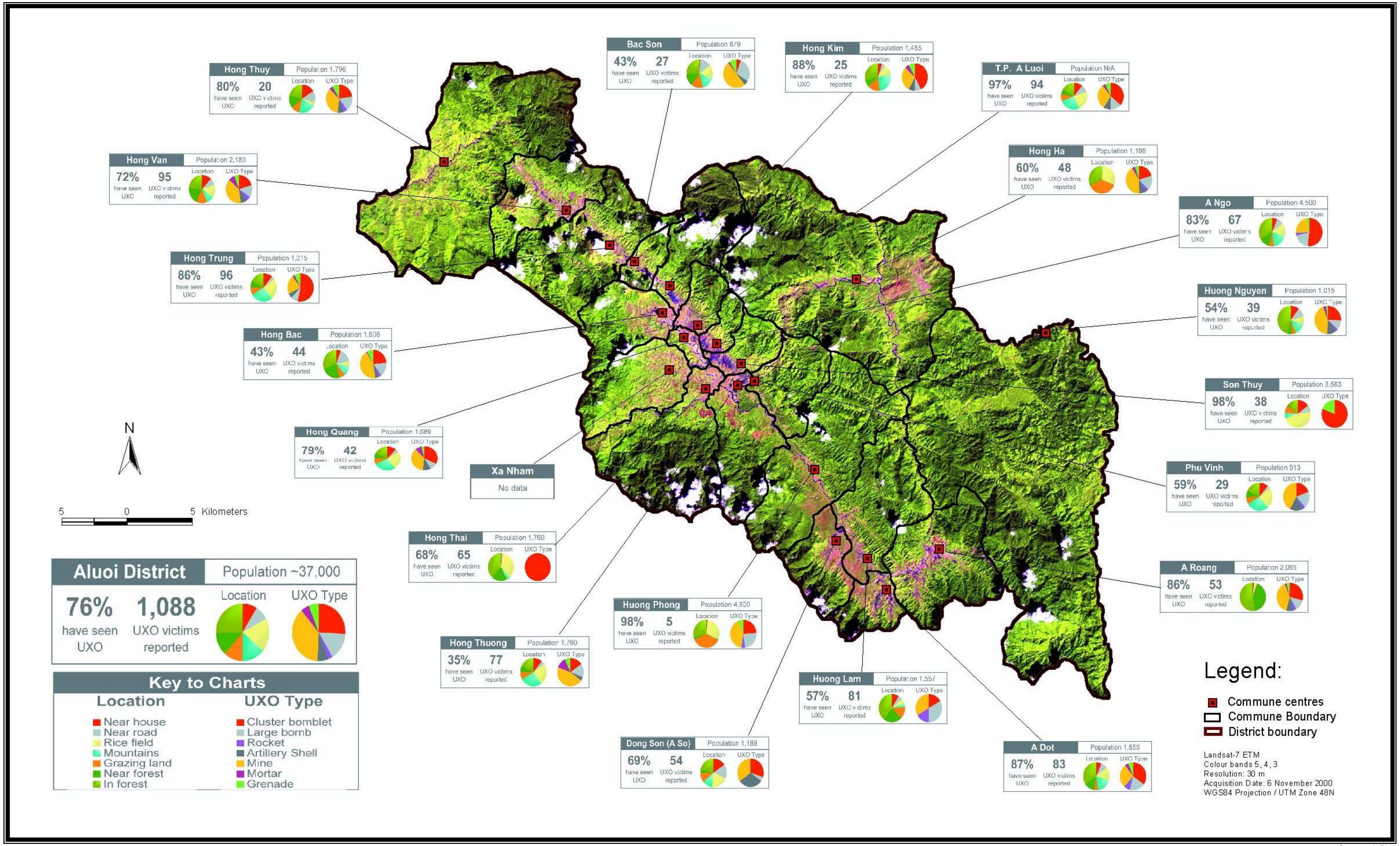
the interviewees indicating that it depends on their activity at the time, the type of UXO and the location of UXO. Nevertheless, many of the interviewees felt free to handle, throw, recycle or even destroy UXO or landmines themselves.

6.4.2 UXO/Landmine Accident Survey

The UXO/landmine accident survey targeted UXO victims and the victims' families who had been injured by UXO or landmines since 1973.

Since the end of 1973, UXO encounters have resulted in 1088 casualties in the Aluoi Valley. Of this total, 29% resulted in fatalities. The breakdown of number of cases by a number of year periods is provided in Figure 6.11.

The majority of cases occurred in the initial two-year period after the US/Viet Nam War (early 1970's). The number of cases declined thereafter until the mid 1980s, when a strong institutional push for agricultural development occurred, and the inhabitants started working larger agricultural areas that had not been cultivated since the war.



(Source: HCL)

Figure 6.13

Summary of UXO Incidence and Accident Surveys, Aluoi District, central Viet Nam.

6.5 HERBICIDE CHEMICAL CONTAMINATION

6.5.1 Historical Studies

Since 1994, Hatfield Consultants Ltd. and the government of Viet Nam 10-80 Division have cooperated in several studies involving assessment and mitigation of impacts related to spraying of Agent Orange herbicide during the Viet Nam war. The majority of our work has been undertaken in Aluoi District, Thua Thien Hue Province. Findings of this work are summarized below.

Assessment

A 1996 sampling expedition consisted of wide-spectrum sampling throughout the valley. The commune of Dong Son (formally named A So), situated in the southern sector of Aluoi Valley, was found to have soils and fish tissues contaminated with a congener of the dioxin family specific to Agent Orange. Data from 1996 formed the basis for a more focused expedition in 1997 in Dong Son, and a former US Special Forces base in the area. The study was designed to follow the pattern of dioxin movement through the food chain in this relatively restricted area. Farmer's soil, former Special Forces base soils, fishpond sediment, cultured fish and duck tissues and human blood were collected. As in the 1996 survey, former US Special Forces base soils were found to contain the highest levels of dioxin. Fish and pond sediment also had elevated levels of dioxin in this area (HCL/10-80 1998).

The project was completed in April 2000. A summary of the general conclusions is provided below.

1. The presence of elevated concentrations of Agent Orange dioxin (TCDD) in the blood and breast milk of certain residents of Aluoi District, including contemporary animal food products (e.g., duck fat and fish fat), confirms that dioxin contamination and uptake is a present-day and not an historical phenomenon.
2. Mitigation measures (short, medium and long-term) are required to manage dioxin contamination to reduce human exposure and public health risks of residents in A So commune.
3. New, cost-effective technologies are needed to decontaminate large volumes of dioxin-contaminated soils in Viet Nam.
4. Most Aluoi District soil samples contained measurable traces of dioxin which can be attributed to Agent Orange spraying, (1965-1970). However, with the exception of samples adjacent to former US Special Forces bases, most soil samples were below 10 parts per trillion (ppt), the dioxin concentration in British Columbia, Canada that serves as the remediation standard to define safe agricultural soils. Based on this observation, residual dioxins in non-military base areas of southern Viet Nam that were sprayed with military herbicides, are probably safe for human habitation and growing food crops. However, confirmatory investigations are recommended.
5. There are hundreds of former US and South Vietnamese military installations and base sites in southern Viet Nam where herbicides were spilled, handled, stored, sprayed around base perimeters, and possibly buried. In order to protect present-day public health adjacent to these areas, a systematic dioxin survey of all former military installations where Agent Orange and other herbicides were utilized is recommended, including areas where residual contamination may be present.
6. There is an opportunity to build on the comprehensive environmental work that has been carried out in Aluoi District since 1994, and to further develop environmental assessment and mitigation approaches that can be widely applied in other war-affected areas of Viet Nam, Lao PDR, and Cambodia (HCL/10-80 2000).

Findings of the project resulted in the re-location of twelve families from the area of highest dioxin contamination (i.e., near the old A So base) to a safer, low risk area within the same commune.

The key recommendation was to carry out further assessments and mitigation plans for dioxin contamination in the vicinity of former US and South Vietnamese military facilities where use/storage of Agent Orange during the war likely occurred.

6.5.2 Trend Monitoring of Herbicide Chemicals in Aluoi District

In conjunction with studies performed by HCL and 10–80 Division addressing Agent Orange and UXO, a program was implemented to monitor chemical contamination trends in the local population of Aluoi Valley. The design of the programs included determination of dioxin contamination in soils, fishpond sediments, locally produced foods, whole human blood, and human breast milk. Results of studies undertaken in 1994-1999 are presented in HCL/10-80 Committee (1998 and 2000) and Dwernychuk *et al.* (2002); an overview is provided in Appendix A10. Earlier HCL/10-80 studies revealed that former US military installations in the Aluoi Valley were "hot spots" where dioxins (principally TCDD) were in highest concentration in both the environment and human population (Figure 6.14).

Human blood was collected from the A So commune (situated on a former US military base) in 1997, 1999, and 2001. Three other communes were sampled in conjunction with the A So commune in 1999 and 2001. One of these three communes constituted an in-valley reference where very little Agent Orange was used and/or sprayed. Sample collection, handling, and laboratory analyses are outlined in detail in HCL/10-80 Committee (1998 and 2000) and Dwernychuk *et al.* (2002); please refer to these publications for more detailed descriptions of sampling protocols.

Table 6.2 summarizes levels of TCDD, the dioxin congener specific to Agent Orange, in human blood from Aluoi District. Two age categories were selected which encompassed age periods where individuals were born before/during the war and after the American war. Given restrictions of blood volume that our project team could obtain from individuals (due to health and cultural issues), pooling of blood samples necessary to ensure adequate sample volumes for analysis in the High Resolution GC/MS. Samples were analyzed at the Health Canada Laboratory in Ottawa, Canada. Dioxin and furan laboratory analysis sheets are presented in Appendix A11.

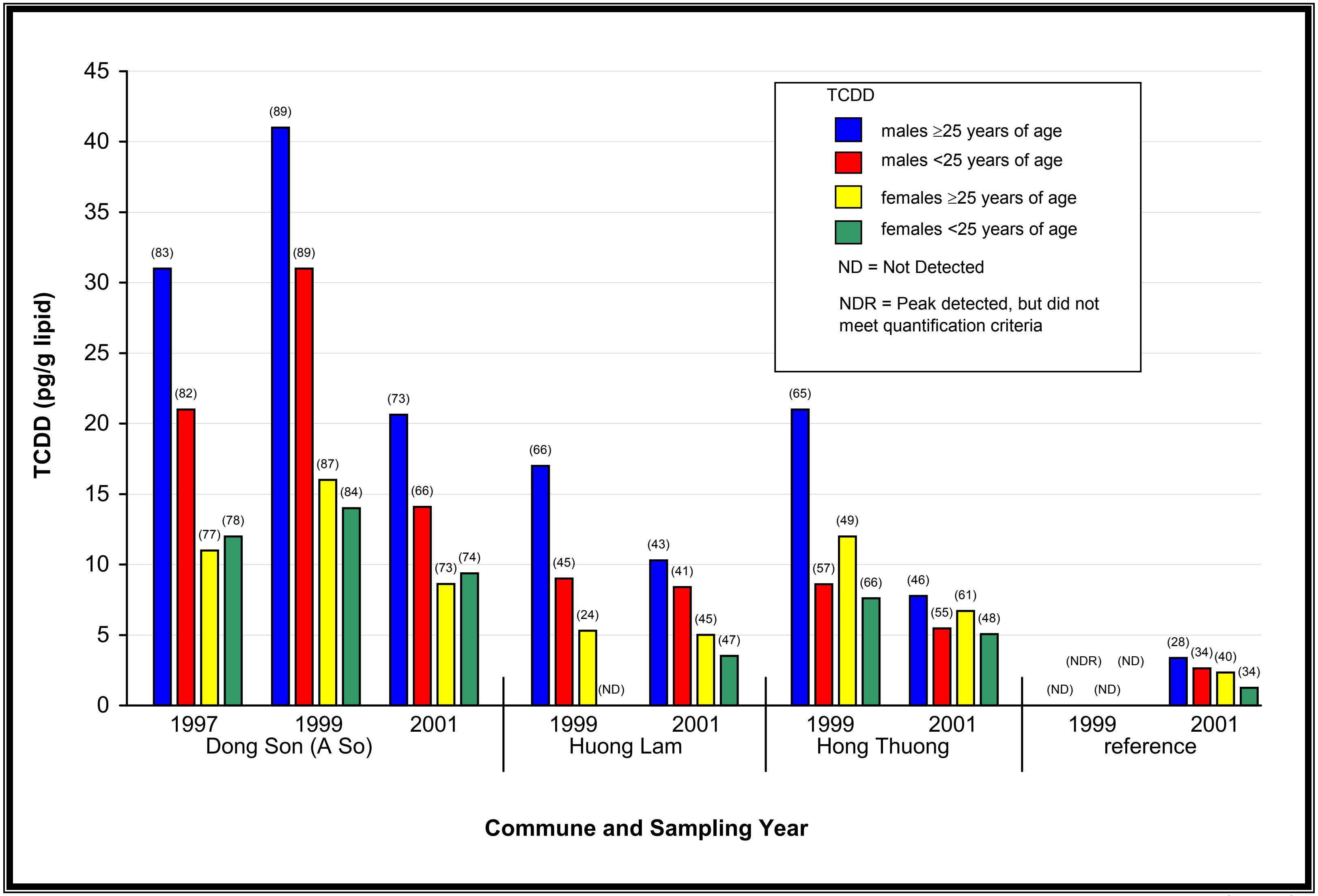
The highest level of dioxin (TCDD) contamination in human blood collected in the valley in 2001 was, as in 1999, recorded in A So residents (Figure 6.14). The pattern of contamination observed in 1999 was similar to that observed in 2001. Studies indicated that as one moves from A So to other communes in the valley onto the in-valley reference at the northern end of the valley, a gradual decline in blood level of TCDD is noted. The in-valley reference commune had the lowest concentration of TCDD for both sexes and age categories. The pattern of contamination found in 1999 was confirmed by the 2001 TCDD levels recorded in human blood. TCDD values throughout the valley in 2001 (A So, Huong Lam, and Hong Thuong) were lower than concentrations in 1999 (Table 6.2, Figure 6.14). In A So, the 2001 TCDD values were lower than those recorded in 1999 and 1997.

The apparent fluctuation of values between years may be due to variability of TCDD levels that undoubtedly occur in the valley population. It was not logistically possible to re-sample all the same individuals over the three sampling periods.

The greatest difference in TCDD levels between the two age categories (i.e., born before/during and after the war) was noted in the males from A So (all sampling years). Females of the two age categories did not display major differences in concentrations. Females born after the war had slightly higher TCDD levels than older females (this trend was also noted in 1997). The difference between male and female (and within female) categories results from the fact that females have the ability to "off load" their TCDD to offspring through breast milk, thus reducing their own body burden (Dwernychuk *et al.* 2002).

Blood data collected during this monitoring program emphasize the importance of former military installations and human proximity to such installations as a significant factor in the transfer of TCDD molecules, originating from Agent Orange, through the food chain, and into local inhabitants. Any method of releasing TCDD trapped/buried in soils, through UXO/mine detonation and agricultural activities and into the food chain, is a potential health risk to local inhabitants.

A similar pattern of dioxin contamination was obtained in 2001 with respect to human milk. The highest levels of contamination by TCDD in females occurred in mothers living in the A So commune (Table 6.3, Figure 6.15).



(Source: HCL)

Figure 6.14

TCDD (pg/g lipid) for whole human blood, Aluoi Valley, 1997, 1999 and 2001.
Data in parenthesis describe contribution of TCDD to Total I-TEQ.

Table 6.2

2,3,7,8-TCDD in pooled whole human blood, Aluoi Valley, 1997, 1999 and 2001.

Commune, Blood Donor Age Group and Sampling Year		Number in Pool	TCDD (pg/g)	Total I-TEQ	TCDD % of Total I-TEQ
A So					
Males (≥25)	1997	50	31	37.2	83.4
	1999	48	41	45.9	89.3
	2001	50	21	28.3	72.8
Males (<25)	1997	50	21	25.5	82.4
	1999	30	31	35.0	88.6
	2001	35	14	21.3	66.1
Females (≥25)	1997	50	11	14.3	76.9
	1999	44	16	18.3	87.4
	2001	44	8.6	11.9	72.5
Females (<25)	1997	50	12	15.4	78.0
	1999	41	14	16.6	84.3
	2001	45	9.4	12.7	74.1
Huong Lam					
Males (≥25)	1999	31	17	25.6	66.4
	2001	52	10	23.7	43.5
Males (<25)	1999	33	9.0	19.8	45.5
	2001	53	8.4	20.4	41.2
Females (≥25)	1999	29	5.3	22.0	24.1
	2001	39	5.0	11.2	44.8
Females (<25)	1999	27	ND (9.2)	10.0	-
	2001	35	3.5	7.48	47.0
Hong Thuong					
Males (≥25)	1999	43	21	32.3	65.0
	2001	34	7.8	17.0	45.8
Males (<25)	1999	27	8.6	15.1	57.0
	2001	34	5.5	10.0	54.9
Females (≥25)	1999	37	12	24.6	48.8
	2001	26	6.7	11.0	60.9
Females (<25)	1999	25	7.6	11.5	66.1
	2001	23	5.1	10.5	48.2
In-valley reference[1]					
Males (≥25)	1999	37	ND (4.0)	5.41	-
	2001	65	3.4	12.1	28.0
Males (<25)	1999	40	NDR (3.5)	7.67	-
	2001	44	2.6	7.66	34.3
Females (≥25)	1999	27	ND (4.3)	5.95	-
	2001	33	2.3	5.76	40.5
Females (<25)	1999	37	ND (1.9)	3.53	-
	2001	24	1.2	3.67	33.9

[1]In-valley reference commune: 1999 - Hong Van; 2001 – Hong Thuy (Source: HCL)
ND: Sample was less than detection limits.
NDR: Peak was detected but did not meet qualification criteria.

Table 6.3

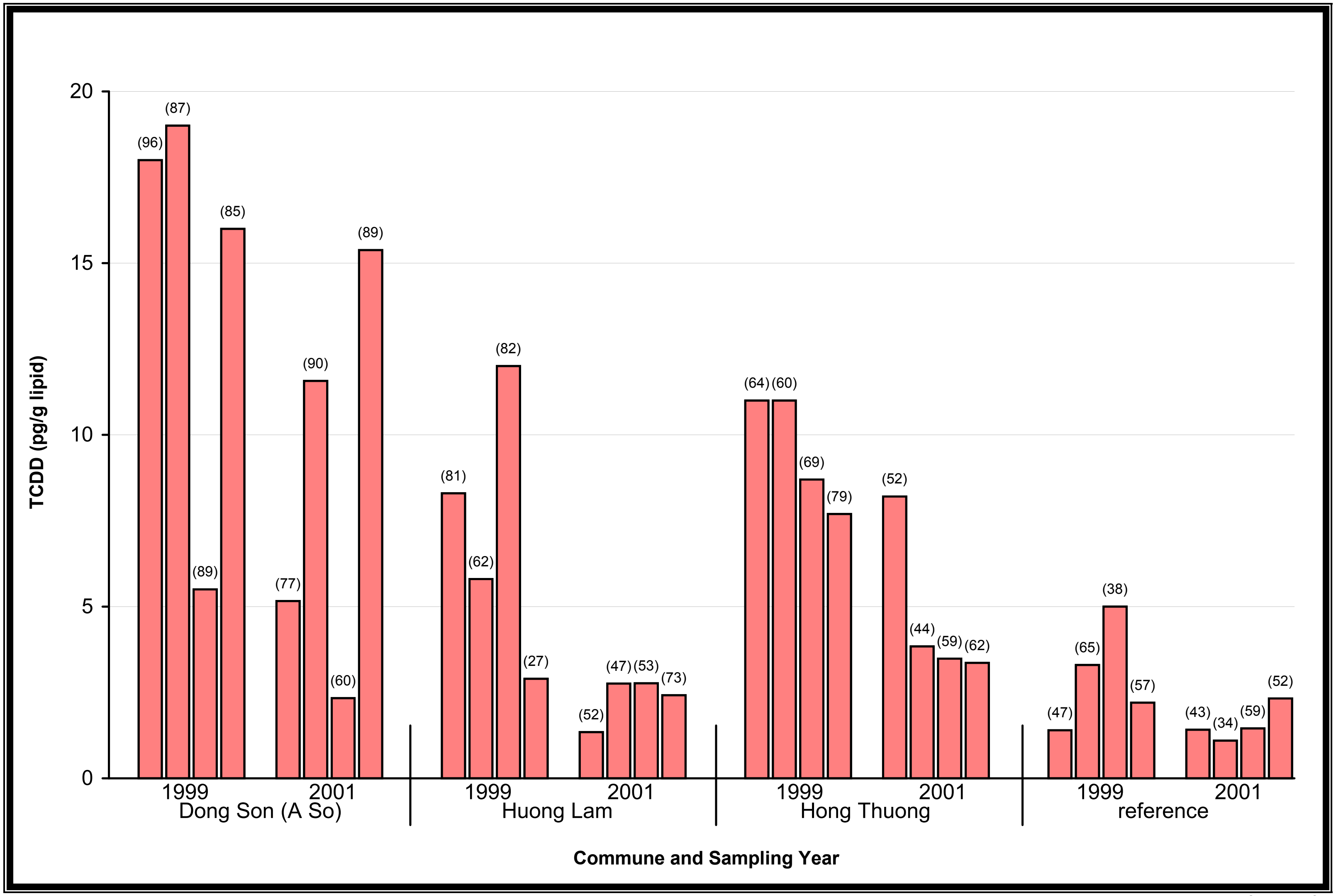
2,3,7,8-TCDD (pg/g lipid) in human breast milk from lactating primaparous females, Aluoi Valley, 1999 and 2001.

Commune and Sampling Year		Donor Age (yrs)	% lipid	TCDD (pg/g lipid)	Total I-TEQ	TCDD % of Total I-TEQ
A So	1999	22	5.6	5.5	6.15	89.4
		20	4.5	19	21.9	86.8
		18	4.0	18	18.7	96.3
		23	3.3	16	18.8	85.1
	2001	25	2.6	5.2	6.71	76.9
		20	3.3	12	12.8	90.4
		19	1.9	2.3	3.90	59.8
		17	1.6	15	17.2	89.4
Huong Lam	1999	23	1.3	12	14.6	82.2
		19	3.7	8.3	10.2	81.4
		28	3.6	2.9	10.6	27.4
		21	1.7	5.8	9.33	62.2
	2001	23	2.8	1.3	2.57	52.2
		22	3.0	2.8	5.90	46.7
		22	1.7	2.8	5.18	53.4
		27	3.0	2.4	3.31	73.0
Hong Thuong	1999	17	1.6	11	17.2	64.0
		21	1.4	8.7	12.6	69.0
		22	2.7	7.7	9.73	79.1
		19	2.1	11	18.5	59.5
	2001	22	4.3	8.2	15.7	52.3
		18	2.0	3.8	8.78	43.8
		23	4.0	3.5	5.89	59.1
		19	3.0	3.4	5.41	62.2
In-valley reference	1999	20	2.7	3.3	5.07	65.1
		23	2.1	2.2	3.85	57.1
		20	3.2	5.0	13.2	37.9
		19	1.8	1.4	2.99	46.8
	2001	18	5.0	1.4	3.31	42.7
		26	4.7	1.1	3.20	34.2
		19	3.3	1.5	2.47	58.9
		21	6.8	2.3	4.48	51.9

[1] In-valley reference commune: 1999 - Hong Van; 2001 – Hong Thuy (Source: HCL)

ND: Sample was less than detection limits.

NDR: Peak was detected but did not meet qualification criteria.

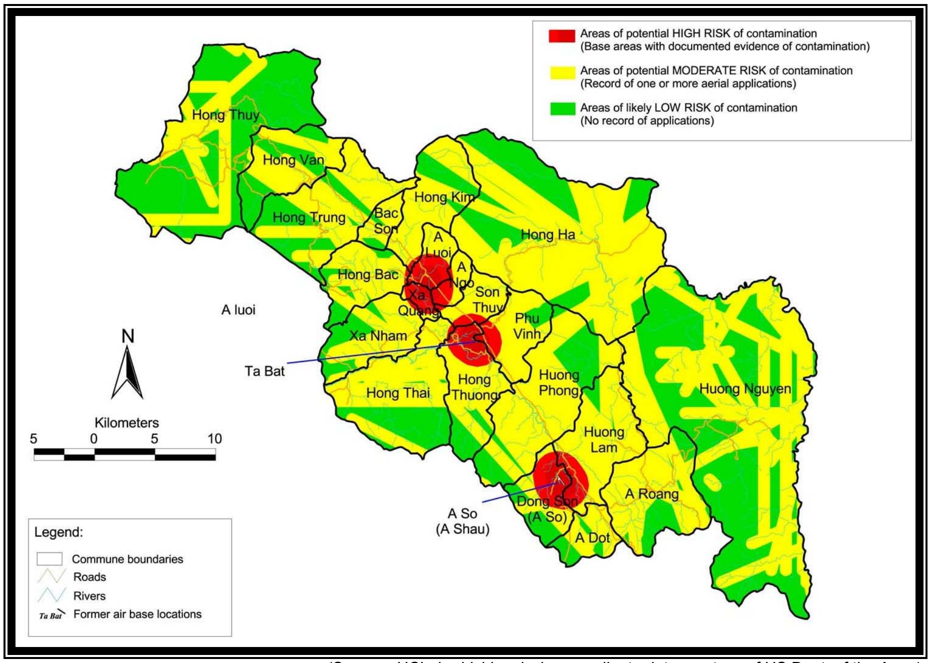


(Source: HCL)

Figure 6.15

TCDD (pg/g lipid) for human breast milk (primaparous mothers), Aluoi Valley, 1999 and 2001. Data in parenthesis describe contribution of TCDD to Total I-TEQ.

The highest percentages of TCDD responsibility (numbers of parentheses in figures) in overall toxicity indicates that Agent Orange was the principal source of the TCDD molecule, particularly on the A So base.



(Source: HCL; herbicide mission coordinate data courtesy of US Dept. of the Army)

Figure 6.16
Potential risks of residual chemical contamination from military herbicide applications, Aluoi District.

Therefore, based on the finding of these studies and according to chemical contamination assessment procedures outlined in Chapter 5, in order to minimize exposure of demining crews and local populations to chemical contaminants in Aluoi District:

- a soil sampling 'screening' program should be included in any UXO clearance project; and
- depending upon the findings of the screening program, appropriate mitigative strategies should be considered during the planning stages of any UXO/landmine clearance and land rehabilitation program.

6.5.3 Assessing Risk of Herbicide Chemicals to Deminers, Local People and the Environment

When considering undertaking demining in Aluoi District and other areas of southern Viet Nam, it is important to consider potential residual dioxin contamination, in order to minimize potential exposure of deminers and local people to dioxins. Furthermore, demining activities also may remobilize dioxins currently trapped in soil into the food chain and the environment if precautions are not taken.

Our previous studies suggest that there are two major types of dioxin contamination due to herbicide application in Aluoi District: first, low-level contamination in areas that received aerial applications of herbicides during the war; and second, potentially high contamination in areas surrounding war-era Special Forces bases, where ground application and storage of herbicides may have occurred.

Figure 6.16 presents a risk hazard map of areas of Aluoi District that may pose a potential hazard due to residual dioxin contamination from herbicide applications. Following a precautionary principle, this hazard map presents three types of assessed risks: first, areas of likely low risk, which are not near bases and where no aerial herbicide applications were recorded; second, areas of potential moderate risk, where aerial herbicide applications may have occurred (due to uncertainty as to the precise flight path of spray missions, a buffer of 500 m on either side of the mission flight line has been used to define these risk areas); and areas of potentially high risk in the vicinity of bases, which have been defined using a 2 km buffer around each base in the valley (i.e., A Shau, Ta Bat, and Aluoi).

Deminers should use caution and protective clothing when working in contact with soils in these areas, particularly in areas near the former American Special Forces bases.

6.6 PILOT PROGRAMS

6.6.1 Site Selection

The areas chosen for the pilot studies in Aluoi District were located in Hong Thuong commune (near the former base at Ta Bat) and Dong Son commune (near the former base at A So). The pilot sites are named for the former special forces bases that were so located (Figure 6.2).

Ta Bat and A So were selected for pilot sites for this project because:

- there was a perceived threat of UXO/landmine and chemical contamination by local inhabitants. Subsequent investigations during the impact/risk assessment showed that there was a real threat of UXO/landmine and chemical contamination; and
- The land was not being used for domestic purposes (agricultural or residential) due to the above threats.

6.6.2 Soil Screening Program

Soil samples from the locations of the two pilot sites were analyzed for dioxin contamination. One soil sample was collected for analysis from each of the two pilot site locations. Each soil sample analyzed was a composite of ten individual cores. Due to the high risk of UXO and landmine contamination, soil sample cores were taken from the edge of well-traveled sections within the 1 ha boundary for each pilot site.

Soil samples were analyzed at AXYS Laboratories in Sidney, BC, Canada. The analytical methodology followed those described by PTI Environmental Services for USEPA in: *Recommended guidelines for measuring organic compounds in Puget Sound sediment and tissue samples* (PSEP 1989).

Soil composites from the Ta Bat pilot site were found to have a 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) (most toxic congener) concentration of 2.34 pg/g and a Total TEQ level of 3.17 pg/g. Soil composites from the A So pilot site had TCDD and Total TEQ concentrations of 6.55 pg/g and 6.84 pg/g, respectively. The Total TEQ levels for soil samples from both the pilot sites did not exceed either the Canadian residential/agricultural land use standards (350 pg/g Total TEQ based on protection of human health) or the Canadian agriculture rehabilitation standards (10 pg/g Total TEQ) based on environmental protection criteria. Raw data sheets for both soil sample laboratory analyses are presented in Appendix A11.

Based on these criteria and following the decision tree developed for contaminated soils and UXO clearance (described in Chapter 5), it was determined that toxic contaminants did not exceed risk thresholds for the protections of human health and standard UXO clearance/demining protocols were implemented at the two pilot site locations.

6.6.3 UXO/Landmine Clearance

General Clearance Procedures

The Hue Defense Department (HDD) was responsible for the UXO clearance/demining work undertaken for the project. The demining crew consisted of 13 deminers and two supervisors. The unit had two metal detectors at their disposal during the clearance operations. These detectors were of different types, one of US manufacture (bomb locator) and one of Chinese manufacture (presumed mine detector). Plate 6.1 shows one of the HDD deminers demonstrating the use of one of the metal detectors.

Before initiating clearance activities, the HDD demining group established an awareness program for the local communities. This program included:

- briefing of local people on the planned conduct of the operation;
- informing local people of danger areas and safety distances required around the clearance sites; and
- erecting warning signs on paths, roads and access to the clearance area.

The general methodology used by the HDD

(Source: HCL)

Plate 6.1
HDD deminer demonstrating the use of a metal detector.

deminers is presented below.

1. Set down a bench mark location for one corner of the 1 ha plot;
2. Deploy the detecting team along the perimeter ahead of the brush clearers;
3. From the benchmark, slash-cut the brush along the perimeter of the 1 ha plot;
4. Mark the perimeter of the pilot site with tall stakes;
5. Slash cut the remainder of the brush and grass within the plot;
6. Burn the site from the outside towards the middle;
7. With a crew of five or six personnel, a four to five metre wide lane is be "swept" the length of the plot with one detector following behind the other; and
8. Dig up UXO, scrap metal and landmines, and place in one central location.

HDD staff not directly involved with the demining operation were assigned other duties such as supervision, fire tending or brush cutting. This procedure was followed until the HDD commander felt that the area was cleared of all UXO and landmines. At this point, the 1 ha site was officially declared "clean of all UXO and landmines" and handed over to the Aluoi District Peoples' Committee for land reclamation work.

All scrap metal found on the two sites was sold to a local scrap metal dealer. UXO and landmines collected from both sites were transported to a remote location in Dong Son Commune for detonation.

A photograph of some of the UXO and AP mines found by the HDD demining crew is provided in Plate 6.2.

Ta Bat Pilot Site

Demining of the Ta Bat site (Plate 6.3) was completed in six days. UXO and landmines cleared and collected by the HDD demining crew included:

- two M18 directional fragmentation anti-

(Source: HCL)

Plate 6.2
An example of ordnance found by the HDD demining crews.

personnel (AP) mines (claymore);

- five M16 bounding fragmentation AP mines;
- three unused M79 (rifle grenades) still in plastic casing;
- one US military issue hand grenade;
- unidentified cluster munitions; and
- various scrap metal and larger bomb fragments.

An assessment by HCL's demining expert determined that the two sites were potentially contaminated with M14 anti-personnel (AP) mines. M14 mines are particularly dangerous, given their low metal content and associated 'non-detectability' by conventional means. However, no M14 mines were discovered during clearance operations.

M14 mines are often found in conjunction with M16 mines (found at both the Ta Bat and A So pilot sites). However, the inability of the demining crews to located M14 mines may have been due to:

- M14 mines not present at this site;
- the inability of HDD detectors to locate the low metal content of the M14 mines; or
- M14 mines may have migrated deeper into the soil over the last twenty-five years and are now beyond their functional depth.

(Source: HCL)

Plate 6.3

HDD demining crew clearing UXO and landmines from the Ta Bat pilot site.

A So Pilot Site

UXO clearance and demining for the A So pilot site also took six days. During the period of observation, clearance procedures employed at the A So site were the same as those used at the Ta Bat pilot site.

UXO and landmines found during the A So pilot site clearance operation included:

- one M18 directional fragmentation AP mine (claymore);
- two M16 bounding fragmentation AP mines;
- four unused M79 (rifle grenades);
- two US Military issue mortar shells;
- miscellaneous rifle bullet rounds; and
- various scrap metal and larger bomb fragments.

Despite the perceived threat of M14 pressure AP mines (similar to the Ta Bat site), none were found during clearance operations at the A So pilot site.

Plate 6.4 shows the HDD demining crew clearing brush in preparation for UXO clearance at the A So pilot site.

6.6.4 Land Rehabilitation

General Procedures

Hue Agriculture University (HAU) personnel were responsible for the land rehabilitation portion of the project. Prior to the UXO project, the HAU had sponsored land reclamation projects using the same site designs proposed for the UXO clearance sites. The reclamation of these sites were part of an overall agricultural infrastructure re-building program instituted after the floods that decimated large areas of central Viet Nam in the fall of 2000. Both shallow and steep slope sites contoured and planted one year ago showed a successful transition to arable land with effective erosion control measures.

The Vietnamese agriculture specialists refer to the land reclamation/erosion program used in the Aluoi Valley as the Sloping Agricultural Land Techniques (SALT) system. An English translation of SALT system theory, procedures and technology is provided in Appendix A12. Although designed somewhat differently, many of the erosion control features outlined in the SALT system are functionally similar to those suggested by HCL specialists for these sites.

The SALT program is designed to enhance development of the agricultural land base while preserving and improving the environmental conditions as described in the caption below.

The basic theory of using interceptor ditches (or drainage ditches) along contour lines as the key feature to control and direct overland water flow is same for both HCL's and the HAU's programs (Plate 6.4). Other similarities between the two plans include the use of rock check dams and sediment traps to slow water velocity in the ditches and settle out suspended sediments.

The HCL plan suggested the use of native grass and shrubs as ground cover after initial erosion control procedures were undertaken. The SALT system goes one step further, specifying agricultural plant types, plant locations and planting/harvesting timing. Due to the rural nature of the project area, local inhabitants benefit most from agricultural crop planting and increased land productivity. The use of nitrogen-fixing legumes (referred to as “green-manure plants” in the Vietnamese SALT summary) improve the productivity of the soil while pineapple, cassava, corn and peanuts in the initial stages of land reclamation provide erosion control with their extensive root systems. Once reclaimed areas have been established as productive agricultural land, short-term crops can be gradually replaced with longer term, sustainable plant species (i.e., fruit, forestry and pharmaceutical trees).

"This (SALT) is expected to diversify products, increase income for farmers, improve soil conditions, prevent land erosion, limit slash-and-burn practice and increase ecological environment protection particularly in areas affected by UXO and toxic chemicals."

An excerpt from the Vietnamese SALT Guidebook.

(Source: D. McCracken)

Plate 6.4
Hong Thuong Youth Corps digging interceptor ditches at the Ta Bat site.

Given reclaimed land will be incorporated into the agricultural land base and maintenance of plots is tied directly to potential productivity, it was in the best interests of local farmers to monitor and maintain erosion control on the sites. These activities should, to a large extent, preclude the requirement for a structured post-reclamation monitoring and maintenance schedule.

Ta Bat Pilot Site

Land reclamation work on the Ta Bat pilot site overlapped by two days with the UXO clearance/demining work. As the HDD deminers were completing work at the site at the south end, erosion control crews surveyed the contours and started the interceptor ditching network at the north end. The land reclamation phase for the Ta Bat pilot site lasted five days.

(Source: HCL)

Plate 6.5
Hong Thuong Youth Corps fertilizing and planting the Ta Bat pilot area.

The SALT program was supervised by two experts from the HAU. These same specialists designed a site specific erosion control and planting plan for the Ta Bat site taking into consideration the UXO/landmine contamination, possible chemical contamination, quality of soil and slope of the site.

A workshop was held at Hong Thuong Commune introducing approximately 18 young men and women from the Hong Thuong Youth Corps to the SALT pattern of development. Training included the use of survey equipment to determine slope, erosion control techniques, fertilizing methods and planting procedures. These 18 individuals became the work force for all erosion control, reclamation and planting work at the Ta Bat site.

(Source: HCL)

Plate 6.6
Peanut plant from the Ta Bat site four months after planting.

Over a period of five days, the one hectare site was cleared of all remaining brush, ditched, planted and fertilized (Plate 6.5). Four days after planting, HCL staff returned to the Ta Bat site and observed that the peanuts and nitrogen-fixing plants were starting to emerge from the soil. Four months after the initial planting, the peanuts and nitrogen-fixing plants were approaching a height of 0.5 m and the peanuts were starting to bear fruit. Plate 6.6 is a photograph of one of the peanut plants after this four month period.

Plates 6.7A, 6.7B and 6.7C show a progression of the pilot site area at Ta Bat from pre-UXO/landmine clearing through to revegetation.

(Source: HCL)

Plate 6.7A

Ta Bat pilot site before mine action - January 11, 2002

(Source: HCL)

Plate 6.7B

Ta Bat pilot site after completion of land remediation program - January 20, 2002.

(Source: HCL)

Plate 6.7C

Ta Bat pilot site four months after land remediation program – May 4, 2002.

(Source: HCL)

Plate 6.8
The A So pilot site four months after the planting of agricultural crops.

A So Pilot Site

The site chosen for rehabilitation near Dong Son (A So) was less steep than the Ta Bat site. Land reclamation procedures for the site at A So required a less frequent ditching network than Ta Bat. After demining was complete, the site was to be mechanically tilled prior to fertilizing and planting.

A workshop on the SALT program, similar to that held in Hong Thuong Commune, was held for Dong Son inhabitants on the SALT program. The same numbers of local residents were required for the land rehabilitation/erosion control work at the A So pilot site (which lasted ten days). Due to the lower slope of the Dong Son site, corn was also planted long with peanuts and nitrogen plants. Plate 6.8 shows the corn, peanuts and nitrogen – fixing plants at the Dong Son site. Plates 6.9A, 6.9B and 6.9C show a similar 'start to finish' progression of the rehabilitation work as was shown for the Ta Bat site.

6.6.5 Prospectus

After a four-month period of observation, it was evident that the program had been successful in returning non-productive, UXO contaminated parcels back into economically viable agricultural land base.

According to objectives set out by the local Peoples' Committees, long-term goals for the two plots include continued agricultural crops and/or plantings of trees for the pharmaceutical and forestry industries.

(Source: HCL)

Plate 6.9A
A So pilot site before mine action - January 17, 2002.

(Source: HCL)

Plate 6.9B
A So pilot site after UXO/landmine clearance - January 22, 2002.

(Source: HCL)

Plate 6.9C
A So pilot site four months after planting – May 4, 2002.

6.7 UXO/LANDMINE AWARENESS PROGRAM

A key component of an integrated mine action program is UXO/landmine awareness and risk education for local inhabitants. The United Nations has found that, although a mass media approach is appropriate in some situations, it is the grass roots education at the local level that is most successful (UNICEF 1999). Involvement at the local level in program design and implementation encourages sustainability by building a proactive capacity in local communities.

Our project used the International Guidelines for Landmine and Unexploded Ordnance Awareness Education as a guiding document (UNICEF 1999). The UXO awareness program for Aluoi District was designed to target community members most at risk, while identifying the social and economic situations that may be the source of high risk behavior.

A district wide UXO awareness and education program (UAEP) was run in conjunction with the UXO presence and accident surveys (Figure 6.10). The program was designed and implemented by Vietnamese authorities in the Aluoi District Peoples' Committee, 10-80 Division, and Hue Health Department. An outline of the UAEP program implemented in the Aluoi District is provided in Appendix A6

Conducting the UXO survey and awareness programs in concert for Aluoi Valley residents, enhanced the educational and analytical experience by offering a 'two-way' flow of information that encouraged dialogue on the UXO/landmine problem.

The Aluoi District UAEP project provided educational information and emphasized effective dissemination of knowledge to all communes.

The media products produced for the Aluoi UAEP included pictorial booklets, posters, billboards and video/cassette tapes. All school children in the District received a cartoon pictorial book, which they were asked to discuss among themselves and with their families. A reproduction of the book is provided with English sub-titles in Appendix A13.

(Source: 10-80 Division)

Plate 6.10
Aluoi Valley resident participating in the UXO Awareness and Education Program (May 2001).

7.1 DEVELOPING AN INTEGRATED APPROACH TO MINE ACTION

7.1.1 Overview

The perceived hostility and fear of residents towards lands contaminated with UXO and chemicals is well founded, given the number of people killed and maimed as a result of UXO encounters. The cordoning off and avoidance of suspected UXO/chemically contaminated sites is a potential mitigative strategy; however, land pressure and poverty often dim the suitability of this option. In areas where such knowledge and technology are not available, local inhabitants run the risk of death, dismemberment, and ingestion of chemically contaminated foods

Projects comparable to this one need to be undertaken at other former US military installations in southern Viet Nam. These projects would require significantly greater resources than were utilized in Aluoi Valley, given the extent of potential chemical contamination and UXO presence throughout southern Viet Nam.

Our information reveals that former bases (e.g., Da Nang and Bien Hoa) may be significant reservoirs of chemical contamination with the interspersion of UXO. These bases could form a focus of projects comparable to the Aluoi Valley exercise, but on a much larger scale. Preliminary studies indicate that these bases should be priority targets; however, further research may uncover other contaminated sites, given the hundreds of US and South Vietnamese military installations in southern Viet Nam and the extensive use of landmines, bombs and herbicides during the US-Viet Nam conflict.

In Indochina the pressures of population growth are forcing local authorities to actively remediate unused lands – lands contaminated with chemicals and UXO. The resettlement of people into areas that once sustained vibrant communities displaced by the actions of war is a priority in many regions of southern Viet Nam, Cambodia, and Lao PDR.

HCL is confident that the pilot project undertaken in the Aluoi Valley has wide applicability throughout Indochina. Protocols presented in this report can be applied by numerous UXO clearing operations throughout the region, many of which are oblivious to the dangers of chemical contamination in the soils encountered when clearing UXO. Rehabilitation of lands through the application of clean-up protocols for hazardous materials developed in the west is needed by the countries of Indochina.

Technology transfer and services related to the identification and remediation of contaminated lands is a vital component of UXO clearance, particularly in post-conflict areas where historical chemical use is suspected.

The field application of methods and technologies outlined in this report facilitated the development of an integrated approach to UXO/landmine clearance activities, which included the following key elements for each clearance area:

- an inventory of the biophysical environment;
- identification of socio-economic impacts and constraints;
- risk characterization of UXO and landmine contamination;
- risk characterization of chemical contamination; and
- identification of future land use and land rehabilitation goals.

This project implemented a systematic assessment, clearing and remediation process involving two UXO/landmine contaminated and potentially chemically contaminated plots of land. All aspects of the project involved in-country institutional training and grass roots strengthening from the federal agency level down to local inhabitants.

Given the site specific biophysical, socio-economic, and technical nature of each mine action activity, the assessment and procedural methods presented in this report are not intended to provide a stringent approach to mine action. They are intended to provide a systematic, step-by-step planning approach which will allow mine action planners to realize and act upon land rehabilitation and chemical contamination issues within the framework of a specific UXO and landmine clearance program.

7.1.2 Utilizing Historical Data and New Mapping Technologies

This project drew upon a wide variety of primarily spatial data sources to develop analytical tools and approaches to support UXO assessment and removal. A geographic information system (GIS) was used to organize and compare historical remote sensing imagery (both film and digital), modern digital imagery, historical aerial photography and sketch maps, baseline topographic and land cover information, project field surveys, local community information and responses, anecdotal information, etc. Most of the data comparison maps presented in this report were outputs from a GIS.

GIS provides a natural environment for quantitative assessment of data pertaining to UXO presence and risks, and opportunities for removal. Using GIS to combine and analyze remote sensing information, historical spatial data, and other map data, a wide variety of novel and powerful approaches may be developed for supporting UXO assessment and removal activities. These approaches assist removal programs to be better informed, safer, more efficient, and more cost-effective.

Procedures developed in this project provide a better understanding of the spatial, temporal, and behavioural dimensions of UXO contamination and related/confounding issues in Aluoi District than is achieved using current survey methods. Project maps, data bases, and other outputs directly benefit all residents of Aluoi District, particularly those living in areas where more detailed study was undertaken (i.e., A So and Hong Thuong communes). It is expected that protocols and tools developed will also be applicable to other areas that are striving to address their own, unique UXO problems.

7.1.3 Managing Risk in Chemically Contaminated Areas

In many area of southern Viet Nam, and for the Aluoi Valley project in particular, UXO clearance activities can be confounded by the potential for chemically contaminated soils occurring within the boundaries of the clearance area. Aside from chronic exposure problems for local inhabitants, the existence of chemical contaminants can result in acute exposure risks to UXO/landmine clearance personnel.

During the course of UXO clearing activities in soils potentially contaminated with chemicals, the following activities should be implemented in consideration of protecting human health:

- identification of the potential for soils to be chemically contaminated in the area to be cleared of UXO;
- determination of extent and type of chemical contamination in the area;
- development of site specific protocols and mitigation measures for clearance crews;
- develop disposal plans for point source chemical contaminants; and
- post-UXO clearance monitoring for chemical contamination in the area.

7.1.4 Implementing Effective Land Management and Rehabilitation

The primary goals of land management and rehabilitation procedures are to ensure the ability of land to support productive agriculture and foster the development of sustainable and diverse ecosystems subsequent to UXO/landmine clearance.

The key guidance document for any comprehensive land rehabilitation project is the land rehabilitation plan. This plan should include all information on pre-clearance conditions, predicted impacts and timetables for land rehabilitation, monitoring, and maintenance activities. Major considerations for a land rehabilitation project include:

- the collection of pre-clearance data on locations and topography, watercourses and drainage, climate, soils and vegetation, current and future land uses;

- project assessment and implementation involving the review of pre-clearance data the development of an impact assessment;
- monitoring and maintenance during and after land rehabilitation activities.

7.2 RECOMMENDATIONS

The goals of this project were to develop methods and technologies to support unexploded ordnance (UXO) clearance activities in Viet Nam. The following recommendations are made based on field experience and information gained during Impact/Risk Assessment, UXO/landmine Clearance and Land Rehabilitation components of this project.

1) In order to better understand the degree to which these remnants of war are burdening the people of Viet Nam, a nation-wide Impact/Risk Assessment is needed that addresses both the UXO/landmine and chemical contamination issues. International funding agencies and Vietnamese authorities can use the information gained to direct resources to areas and populations most in need.
2) Areas to be cleared of UXO and landmines should be assessed regarding the potential for chemical presence. UXO/landmine and chemical contamination mitigation should proceed as integrated objectives, not as stand-alone activities.
3) Use of GIS and remote sensing data for UXO/landmine and threat assessment of chemical contamination should be developed further to include other data sources and areas of Viet Nam. In particular, data sets in the US military archives that are becoming de-classified should be examined for relevant information. Information gained from a previous data gathering exercise/project was invaluable for assessing risks and developing risk management for this project.
4) The Vietnamese SALT system appears to be an appropriate model for agricultural and infrastructure development in Aluoi District. Continued bi-annual monitoring of the program at the two pilot site locations should be conducted to ensure long-term environmental and socio-economic goals are met.
5) It would be beneficial to design a set of 'SALT' type systems for use in agricultural areas throughout Viet Nam. These systems would have to be designed for a variety of social, agricultural, climatic and geomorphological conditions.
6) The UXO and chemical risk assessment and site reclamation methods and technologies introduced in this document should be developed further for use in infrastructure and industrial development projects. The threat of UXO or chemical contamination is present throughout Viet Nam for all proposed future land use.
7) Work in support of Vietnamese demining capabilities should be expanded. Future efforts include the supplying of Vietnamese demining teams with personal protection equipment, training in hazardous chemical handling, general first aid training, and modern UXO/landmine detection capabilities.

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TABLES

FIGURES

PLATES