PRIORITY AREA
ENVIRONMENTAL SECURITY

ASSESSMENT METHODOLOGIES FOR SOIL/GROUNDWATER CONTAMINATION AT FORMER MILITARY BASES IN LITHUANIA,
PART ONE: CHEMICAL INVESTIGATION

GEOLOGICAL SURVEY OF LITHUANIA
GEOLOGICAL SURVEY OF NORWAY
CANADIAN DEPARTMENT OF NATIONAL DEFENCE
NORWEGIAN DEFENCE RESEARCH ESTABLISHMENT

FINAL REPORT

NORTH ATLANTIC TREATY ORGANIZATION
SCIENTIFIC AFFAIRS DIVISION

NGU Report 96.146

Assessment Methodologies for
Soil/Groundwater Contamination at Former
Military Bases in Lithuania.
Part one: Chemical Investigation

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REPORT

Report no.: 96.146
ISSN 0800-3416
Grading: Open

Title:

Assessment Methodologies for Soil/Groundwater Contamination at Former Military Bases in Lithuania. Part one: Chemical Investigation

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Client:
NATO, Geological Survey of Norway, Geological Survey of Lithuania, Canadian Department of National Defence, Norwegian Defence Research Establishment and Norwegian Ministry of Foreign Affairs

County:
Lithuania

Commune:

Map-sheet name (M=1:250.000)

Map-sheet no. and -name (M=1:50.000)

Deposit name and grid-reference:

Number of pages: 142 Price (NOK): 242
Map enclosures:

Fieldwork carried out:
September 1994

Date of report:
February 1997

Project no.: 2642.00
NATO:
ENVIR.LG.940341

Person responsible:

Summary:

A total of 421 military units were built at 275 sites in Lithuania during the years of Soviet occupation. These units had an important influence on the environment of the country as many of the sites were contaminated by oil products, organic materials and chemicals. After the withdrawal of the Russian army it was necessary to urgently evaluate the extent of military pollution in order to assess possible future use of the sites for defence and/or non-military purposes. An appropriate methodology was consequently required for such an assessment.

An international team consisting of scientists from the Geological Survey of Lithuania, the Geological Survey of Norway, the Canadian Department of National Defence and the Norwegian Defence Research Establishment were awarded a NATO Scientific Affairs Division Grant for the development of a methodology for investigation of soil/groundwater contamination at former military sites in Lithuania. The results of this co-operative work are presented in this report.

Keywords:

Hydrogeology	Military bases	Landfill
Contamination	Groundwater	Chemical analysis
Oil	Methodologies	

ASSESSMENT METHODOLOGIES FOR SOIL/GROUNDWATER CONTAMINATION AT FORMER MILITARY BASES IN LITHUANIA, PART ONE; CHEMICAL INVESTIGATIONS

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1 INTRODUCTION

Dr. B. Paukstys (Lithuania) and Dr. C. Tucker (Canada)

1.1 Background

During the 50 years of the Soviet occupation of Lithuania, the military presence in the country was significant. Military units and bases of varying size and type covered an area of 67,762 hectares, or more than 1% of the territory of Lithuania. In total, 421 military units were built at 275 different sites in the country. Airfields and airbases, rocket bases, military forests, training fields, fuel storage centres, tank regiments, military towns - along with associated military activities - have caused wide-ranging damage to the environment.

Inventory studies carried out by Lithuanian and foreign environmental institutions have shown that the Soviet army destroyed or damaged 3,293 hectares of forests and 11,400 hectares of arable land. A further 12,000 hectares of recreational area and agricultural land was occupied by the military and unavailable for civilian use.

Many of these sites are contaminated: 160 military sites are polluted with oil products; hydrocarbons have been found in surface water at 35 sites and organic or bacteriological contamination has been found at 88 sites. In addition, at 164 military bases there are 478 registered landfills and waste sites and at 34 sites there are 56 registered cases of soil contamination by chemical wastes. At 10 bases soil pollution by rocket fuel has been detected. Soil cover has been damaged at 234 military sites and at 156 bases the landscape has been severely altered. The list of environmental damage is considerable.

Lithuania' s drinking water supply depends completely on groundwater. For this reason, and also for general environmental considerations, it was of great urgency to evaluate, and where possible mitigate, the effects from pollution in and around the areas of former military sites and bases.

The inventory studies revealed that very little attention had been paid to the pollution vulnerability of the environment when establishing the military sites. Of all the military bases, 39 per cent were located on sandy soils, while 119 bases are within 200 m of surface streams and lakes (Figure 1). According to available data, leakage from oil tanks has polluted groundwater over large areas at some of the military fuel storage bases. Since all types of pollution can influence surface water quality, this situation gives cause for immediate concern. Polluted groundwater is discharging into the local river network. In addition, frequent accidents at fuel storage sites, for example the Kedainiai aerodrome of

Marijampole near Vilnius, have caused severe pollution of rivers.

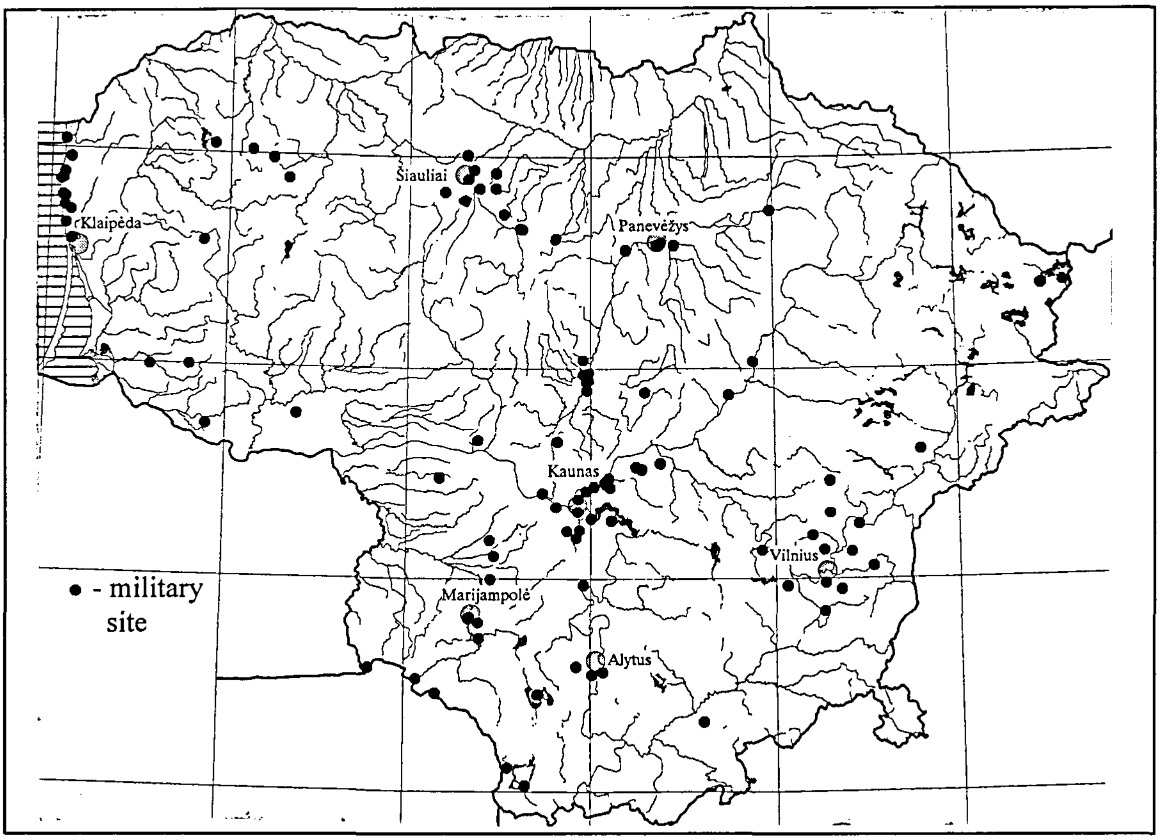


Figure 1. The river network and military bases in Lithuania.

Lithuania's river network reaches a density of 0.5-1.25 km/km^2. Smaller rivers drain either to the River Nemunas, which flows along the Russian (Kaliningrad oblast) border to the Baltic, or to the River Daugava, which drains through Latvia to the Baltic Sea. The potential for cross- border contamination from the military bases was therefore also included in this study.

In order to assess the impact of former military activities on the environment in Lithuania it was necessary to develop an appropriate methodology for the field investigations and desk studies. The development of this methodology is discussed in this report.

1.2 Aims

Representatives of the Geological Survey of Lithuania who were participating at the NATO/NACC meetings on "Cross-border Environmental Problems Emanating From Defence Related Installations and Activities", established contacts with western institutions and subsequently invited representatives from the Canadian Department of National Defence, the Norwegian Defence Research Establishment and the Geological Survey of Norway to co-operate in an assessment of military impact on the environment of Lithuania. The named institutions prepared an application and submitted it at the end of 1993 to the NATO Scientific Affairs Division for Linkage Grant Support. The proposed co-operation project was entitled "Assessment Methodologies for Soil/groundwater Contamination At Lithuanian Military Bases".

The purpose of the study was to carry out:

- a hydrogeological survey of the bases based on existing information;
- a detailed assessment of one site, where appropriate methodologies and technologies were tested and taught to Lithuanian colleagues;
- an overall assessment of the role played by military sites in internal (Lithuanian) and cross-border contamination.

In March 1994 a letter of award, signed by Mr. Luis Veiga da Cunha, Director of Priority area "Environmental Security", NATO Scientific Affairs Division, confirmed that half the required application sum (1,100,000 Belgian franks) had been granted to the co-operating institutions. Additional funding to enable the project to go ahead was generously provided by the governments of the respective participating countries.

The Department of National Defence arranged for the project participants from Lithuania and Norway (four scientists) to visit various Canadian federal and university research institutes in August-September 1994 to enable them to discuss the decommissioning of military sites with Canadian specialists. In September 1994, a field study was carried out at the military airport of Pajuoste by the Lithuanian, Canadian and Norwegian project participants. The joint investigations served to initiate a transfer of technology and practical knowledge from Norwegian and Canadian scientists to members of the Lithuanian environmental institutions. This field study was undertaken to assess the contamination at the site and its impact on the surrounding ecosystem.

The study demonstrated an approach for assessing environmental contamination and risk. Five monitoring wells were established, 38 water and 59 soil samples were collected and 8 samples of materials in storage locations were taken. Samples were subsequently analyzed in laboratories in Canada, Norway and Lithuania. In addition, a ground penetrating radar survey was conducted and several areas were examined for the presence of hydrocarbons using a portable meter. A separate survey was conducted for surface and near-surface radioactivity.

The results of this cooperative work are described in the two companion volumes of this report. Part I presented here, is largely concerned with chemical contamination while Part II investigates possible sources of radionuclide contamination. This work was carried out on behalf of Capt(N) R. Starchuk (DND's Director General Nuclear Safety (DGNS)), and Bob Novitsky and Stephen Burns (Radiological Surveyor, NOTRA Environmental Services Inc.). The two volumes of the final report have been prepared in English with summary reports in Lithuanian and Russian. The project participants hope that environmental and other interested institutions of countries speaking these languages will benefit from the results of the project.

The participants consider that the project is important for two reasons:

- it provides a significant quantity of scientific data which will hopefully be applicable to other similar problems within NATO and Cooperation Partner countries, and
- it will help to strengthen the Trans-Atlantic ties between governmental and non-governmental research communities.

The scientists who were involved in the project all contributed to the final report. They are acknowledged under the chapter headings.

1.3 Risk Assessment Approach

Risk assessment is based on a detailed evaluation of hazard and exposure potential at a particular site.

Risk assessment is an important tool in setting objectives for site remediation where, for example,

- national criteria do not exist for maximum acceptable contaminant concentrations,
- where clean-up to criteria-based levels is not feasible for the targeted land use,
- where criteria-based objectives do not seem appropriate given the site-specific exposure conditions,
- where significant or sensitive receptors of concern have been identified, or
- where there is significant public concern.

The methods used in the assessment of the air base at Pajuoste were in essence semi-quantitative, since although discrete values were generated, no criteria have been established on which to judge them. To enable the reader to place our study in context, a brief discussion of risk is presented below and an extensive bibliography may be found at the end of this report.

Ecological risk assessment has various definitions given by different researchers and jurisdictions. A number of these definitions, taken from Gaudet (1994), are presented below.

1. The process of assigning magnitudes and probabilities to adverse effects of human activities (or natural catastrophes) (Barnthouse and Suter, 1986).
2. A formal set of scientific methods for estimating the probabilities and magnitudes of undesired effects on plants, animals, and ecosystems resulting from events in the environment, including the release of pollutants, physical modification of the environment, and natural disasters (Fava et al., 1987).
3. A subcategory of ecological impact assessment that (1) predicts the probability of adverse effects occurring in an ecosystem or any part of an ecosystem as a result of perturbation and (2) relates the magnitude of the impact to the perturbation (Norton et al ., 1988) .
4. Pastorok and Sampson (1990) found that there were common features in all such definitions: (1) prediction of the probability of adverse effects and (2) the concept of exposure-response relationships. No consensus definition of ecological risk assessment exists, and a whole set of terminology has sprung up for describing ecological risk assessment and its components. In this report, terms and definitions are generally consistent with those used by the US Environmental Protection Agency (EPA) (Norton et al., 1988).

Historically, potential adverse effects were evaluated by considering impacts only (for example toxicity testing). Acute toxicity tests were generally used. Safety factors or application factors were then developed to estimate chronically safe chemical concentrations which were assumed to protect ecosystems adequately (Parkhurst et al., 1990). Environmental evaluation using only toxicity data does not consider probability of exposure. The process of hazard assessment includes this consideration and has been the principle approach used to assess the safety of single chemicals (for example, Urban and Cook, 1986). Hazard refers to the type and magnitude of effect caused by a stressor and is usually evaluated by identifying the biological effects associated with concentrations of the stressor in laboratory or field studies.

Barnthouse and Suter (1986) developed one of the first ecological risk assessment approaches during the mid-1980s for the Office of Research and Development, EPA.

According to Parkhurst et al.(1990), a need for risk assessment arose with the realization that hazard assessments were generally associated with high degrees of uncertainty concerning the extent, magnitude and probability of effects. Risk is a function of hazard and exposure. Exposure is the co-occurrence of a stressor with an ecological receptor such as an individual, a population, a community, or an ecosystem. It is usually determined by understanding the fate of the stressor and then measuring or estimating the amount of the stressor in an environmental phase - for example, soil, air or water. Risk is the evaluation of whether an adverse effect will occur; an adverse effect is likely to occur in the natural environment only if exposure approaches or exceeds the levels associated with the adverse effects identified in the hazard assessment.

Early ecological risk assessments depended largely on concepts borrowed from the human health sciences and from engineering structure failure assessments. A fundamental difference between human health risk assessments and ecological risk assessments is that the former is concerned with estimating effects on individuals (one species -humans), while the latter is concerned with estimating effects on populations, communities, and ecosystems (multi-species). As a result, ecological risk assessment is a much more complex process (Parkhurst et al., 1990).

2 RELEVANT PREVIOUS STUDIES BY THE PARTICIPANTS

Dr. B. Paukstys (Lithuania), Arve Misund and John Tørnes (Norway), Dr. K. Reimer (Canada)

2.1 Introduction

The purpose of this chapter is to give a brief outline of the previous experiences of the participating countries in the investigation and remediation of contamination at former and existing military sites. While the application of science to this field is relatively new, experience and expertise is growing at a considerable rate. This has occurred to some extent by building on the case histories of investigations carried out previously. Given that the three countries involved in this study share a northern latitude, there is much to be learned from an understanding of each country's approach to site investigation.

2.2 Investigations at Military Sites in Lithuania

The Russian army was withdrawn from Lithuania in August 1993. Before that, military territories were shown as blank spots on all maps of the country. It was not possible to carry out a detailed evaluation of the extent of environmental deterioration while the Russian army remained in Lithuania. Nevertheless, even when the troops were present, environmental specialists obtained some information about the damage that was being done to the environment. The consequences of military activities could not be hidden entirely from the public, especially when they could hear the forests being cut, artillery shells exploding and tanks roaring. There are instances where groundwater polluted by hydrocarbons has been observed discharging into surface streams, betraying the indifference of the military to the environment. At Siauliai military airport, for example, soil and shallow groundwater in and around the airport are so polluted with oil products that inhabitants of the neighbouring village are able to extract oil outside the territory of the base for heating purposes by digging pits in sandy soil.

The first selective ecological investigations of military areas were started in 1991 after the re-establishment of the independence of Lithuania. These investigations were carried out illegally, despite the presence of Soviet troops, and could not therefore be sufficiently exhaustive. The main purpose of these investigations was:

- to evaluate the status of the military areas and make preliminary conclusions regarding the harm inflicted on the environment;
- to gain methological and organizational experience.

A group of experts from the Lithuanian Institutes of Geography, Botany, Physics and others have examined four military sites: a former rocket base, an airport and two general military areas. Maps from different periods were examined, an inventory review was compiled, and samples of water, soil, air, flora and fauna were collected and analyzed.

The concept that ecologic and economic aspects are closely connected in the assessment of damage inflicted to the environment was adopted. Therefore the programme of investigations was wide and embraced such data groups as:

- mechanical destruction of the landscape and soils, artificial pavements, soil and surface water pollution and potential influence on the quality of groundwater, sources of atmospheric pollution, state of water reservoirs, radiation levels, sanitary-hygienic conditions;
- damage to forests, timber, food and pharmaceutical production losses, state of game stocks;
- utilization and loss of other natural resources, recreation and agricultural areas, water, raw materials;
- changes of natural regime and ecological potential of the land, landscape structure, ecological and social functions, influence on protected land;
- potential for reclamation of damaged areas.

This approach has remained as a core idea in the evaluation of environmental damage of different types in other projects.

After the withdrawal of the Russian troops, the ownership of these former bases was transferred to different organizations within Lithuania such as the Ministry of National Defence, local authorities and private enterprises. Today they are responsible along with others, for solving the environmental problems of the sites, which are now being used for a variety of defence and civil purposes. Schools and kindergartens could be constructed on the sites of some of the military bases in the near future - another reason for the importance of assessing the damage inflicted as precisely as possible.

In 1993, on the initiative of the Lithuanian Ministry of Environment, a special commission of experts represented by the main environmental institutions of Lithuania was established. This commission consisted of scientists from the Geological Survey, and from the Institutes of Geography, Ecology, Botany, Physics, Forestry, Land and Water Design.

Over a period of several months these scientists inspected 58 of the largest military bases, which contained 88 individual sites. These sites included three large fuel bases, nine missile and air defence units, 13 training grounds and six airbases. All military bases have been catalogued in a general manner and more detailed hydrogeological investigations have been carried out at 10 of them. More than 260 soil and 40 water samples have been collected and analyzed for oil products and heavy metals.

The Lithuanian government approached the European Union “PHARE” programme in 1993 for financial assistance to continue with the evaluation of damage and cost assessment for remediation of the environment at former military bases. An international tender in which 4 foreign consulting companies participated was won by I. Kruger Consult AS (Denmark) in late 1993. The project "Inventory of Damage and Cost Estimate of Remediation of Former Military Sites in Lithuania" was conducted by Danish and Lithuanian specialists. Four hydrogeologists from the Geological Survey of Lithuania participated in field investigations and others were involved in data on geology and hydrogeology of the military sites processing and presentation. The main task of the project was to develop a methodology according to which all types of environmental damages and losses should be assessed. The project was finished in February 1995 (I. Kruger, 1995 a).

In 1994 an investigation of soil and groundwater contamination at Siauliai aerodrome, one of the most polluted military sites in Lithuania, was initiated by the Danish consulting company I. Kruger Consult AS and the joint Lithuanian, Finish, Danish and Swedish company "Baltic Consulting Group". Siauliai military aerodrome is situated within the boundaries of the fourth largest town in the country, a town of 160 000 inhabitants. Fuel leakages of two large fuel bases have caused severe pollution of soil and groundwater at the site. On the surface of shallow groundwater, a 0.79 m thick free oil layer has been determined. The volume of contaminated groundwater is close to 1 million m^3. The area has been investigated in detail. Hydrogeologists from the Geological Survey of Lithuania also participated in this work.

The Geological Survey of Lithuania has been involved in all the projects carried out at the former military bases by different companies and institutions as it is responsible for the overall assessment of groundwater resources and environmental quality of the country. This continuity is important because environmental impacts on groundwater are among the most expensive to remediate.

2.3 Investigations of Military Sites in Norway by NGU

2.3.1 Hazardous waste mapping

In 1991, the Geological Survey of Norway (NGU) completed a 3-year reconnaissance mapping of hazardous waste pollution sources in Norway for the State Pollution Prevention Agency (SFT). The assessment of sites was based on:

- the type and quantity of hazardous waste present
- the conflict of the locality with the surrounding environment

On the basis of this the sites were prioritised as follows on a scale from 1 to 4 (Table 1).

In this Norwegian study, information was largely collected by interviews with management and employees of local authorities and waste generating businesses. Data were stored in a user-friendly PC-based database, initially based on Dbase III/Clipper.

Table 1. Prioritization of contaminated military sites in Norway

Priority	Criterion	Recommendation
Priority 1	Evidence for significant content of hazardous waste and clear conflict with surrounding environment	Immediate need for further investigation or remedial action
Priority 2*	Locality is already under investigation by SFT	Results of existing investigations/-remedial actions awaited
Priority 2	Evidence for content of hazardous waste and possible conflict with surrounding environment or clear conflict with surrounding environment, but uncertainty on quantity of hazardous waste.	Requires further investigation
Priority 3	Suspected content of hazardous waste but no existing conflict with the surrounding environment	Requires further investigation only when a change of use of the area is planned
Priority 4	No content of hazardous waste (over and above that normally found in domestic waste)	No need for further investigations

Results from this project have been published nationally (Misund et al. 1991a) and internationally (Misund et al. 1991b, Banks 1991) and have formed the basis for a subsequent reconnaissance mapping of military facilities using the same methodology (Omejer et al. 1992). Although the NGU database was designed for civil rather than military localities, the methodology developed in 1989-91, and the database developed to store the data have easily been adapted to the Lithuanian situation (with necessary upgrades to take into account the differing geology, hydrology etc.). The database has been upgraded to Oracle database-structure and has also been translated into Polish for the Gdansk District Authorities, and into English to be used in a joint project with the Ministry of Environment in Latvia.

2.3.2 Case studies at Trandum and Sessvollmoen military bases

NGU has also been involved in concrete, detailed investigations of pollution sources at Norwegian military bases. They have investigated two separate oil leakages from underground storage tanks at Trandum and Sessvollmoen military bases, and a landfill site containing hazardous waste at Trandum. The results of these investigations have been presented at a NATO/CCMS Conference (Misund et al. 1992) and a summary is given below:

Trandum military base

Trandum military base lies on the central part of the Øvre-Romerike aquifer, ca. 60 km north of Oslo. On October 12th, 1990, an acute leakage of light fuel-oil (consisting mainly of C_{10}-C_{20} hydrocarbons and with a density of 845 kg/m^3 at 15°C) was discovered at an underground storage tank at Trandum. The entire contents of the tank (20,000 l) had drained rapidly out into the ground. On excavation of the tank, the leakage was found to have occured through a discrete hole of c. 2 cm diameter. It is believed that the hole was caused by a sharp stone puncturing the (possibly corrosion-weakened) tank under loading. The incident was reported immediately and NGU were requested to undertake further investigations and immediate remedial action. The results of these investigations are reported in detail by Storrø (1991) and Storrø & Banks (1992).

Sessvollmoen military base

As a result of the Trandum leakage, awareness of potential leakage problems was undoubtedly increased within the military authorities. Indeed, it was not long before a second suspected leak was reported, at Sessvollmoen base, which lies a little to the NW of Trandum and the central part of the aquifer. On November 2nd, 1990, an underground fuel tank were routinely inspected, without any indication of leakage. Re-inspection took place on December 13th, 1990, and calculations revealed that a volume of up to 10,000 l of light fuel oil appeared to have been lost through leakage. It is assumed that the leakage occurred near the entry pipe to the return tank and was due to excavation work in the vicinity. The leakage was reported to the pollution authorities and the Geological Survey of Norway (NGU) was again invited to investigate the leakage. This well was sunk to 24 m, about 6 m from the assumed point of leakage. The scavenger well was continuously pumped at 1800 l/hr, such that the pump sat "in" the pumping water level at a depth of 19.65 m in order to recover any oil phase floating on the water table.

The oil-leakage incident was investigated by means of:
(a) drilling, sampling and test-pumping boreholes and piezometers to investigate stratigraphy and hydrogeology
(b) sampling the sediments in these boreholes and analysing them for hydrocarbon content.
(c) taking regular water samples from the scavenger well for THC (Total HydroCarbon), TOC (Total Organic Carbon) and inorganic analyses

Conclusions and recommendations

Neither oil leakage produced consequences remotely approaching the "doomsday scenarios" predicted by the media. In both cases, groundwater contamination appears to be localised and controllable by appropriately sited scavenger wells. In the case of Sessvollmoen, the degree of groundwater contamination was minor. The contrast between the two case studies illustrates the importance of the type of sediment in the unsaturated zone, and thus its retention capacity, when assessing the impact of oil spills on aquifers.

When oil leaks into the ground it will seep downwards towards the water table. All geological materials have, however, a certain capacity to retain oil (retention capacity - Testa & Paczkowski 1989). If the retention capacity of the unsaturated zone (the zone above the water table) is large enough, significant oil contamination may be prevented from reaching the water table. Fine sediments generally have higher retention capacities than coarse.

If the unsaturated zone is thick and contains fine-grained sediments, much of the oil will be retained and the danger of oil-phase contamination reaching the water table is reduced. A thin, coarse grained unsaturated zone carries a much higher risk. The Norwegian Military acted very promptly in boring scavenger wells to prevent the migration of oil contaminated groundwater and undoubtedly saved considerable expense and adverse publicity by their quick response. However, the investigations and remediation they were obliged to carry out were expensive; at least $ 300,000. The incidents could have been prevented by:

a) placing storage tanks above ground, within a bund of c. 1½ times the volume of the tank. Thus the tanks could have been easily monitored, and any leak contained. Such a solution may, however, be inappropriate for military areas for other reasons.
b) installing vapour monitoring systems on all Underground Storage Tanks (USTs), which release an alarm if a leakage is detected (Pollution Engineering 1989).
c) regular monitoring of tanks' oil content and, if possible, physical condition.

Trandum landfill

The investigation was undertaken as a result of a national survey of hazardous waste in landfills within Norway (Misund et al., 1991). The primary data on which this paper is based are reported in detail in Misund and Sæther (1991), and Sæther et al. (1992).

The Trandum military base covers about 0.5 km^2 and lies to the west of the lake of Transjøen. Drinking water for the base is pumped from two wells northeast of the base at the perimeter of Transjøen. The landfill is an "undesigned" landfill of "dilute and disperse" type, which is located in a dead ice hollow west of the base. The landfill was started in 1954 and is now c. 15 m thick. The base of the landfill lies just below the water table and has no basal liner. Until 1978 it was used as a sanitary landfill for both military and civilian purposes. Since 1978 it has been used for the disposal of solid domestic waste. In addition to domestic waste, there are good reasons to suspect that the landfill contains a wide variety of batteries containing various amounts of heavy metals (e.g. Pb, Ni, Fe, Hg, Cd, Zn), paints, solvents, used lubricating oil from vehicles etc. Combustible material was incinerated on site.

Conclusions and recommendations

The landfill at Trandum has led to detectable groundwater contamination up to 500 m away from the site. It does not appear to present a major threat to the groundwater resources of the Øvre Romerike aquifer, partly because it is rather small compared with many continental landfills.

For remedial action it may be worth considering scavenging groundwater from beneath the landfill. In addition to hindering the further spread of leachate contamination, the elevated temperature of the contaminated water may render it suitable for energy extraction for the military base via heat pumps. It is recommended that both inorganic and organic components of the groundwater are monitored in the future until contamination from the landfill is significantly reduced or has ceased.

The investigatory work insisted upon by the State Pollution Authority (SFT) has cost the military approximately $ 130 000. This could have been avoided had the landfill been more sensibly located and constructed rather than using the nearest hole in the ground. When considering a landfill as a means of waste disposal at a military base the following guidelines should be followed:

a) always obtain advice from a competent hydrogeologist and engineer
b) avoid areas which are current or potential major aquifers
c) avoid areas where the unsaturated zone is thin or non-existent, or highly permeable,

d) consider the use of a basal liner of suitable fine-grained sediment (fine sand/silt) with a high attenuation capacity, or

e) if the geological conditions are such that conditions b)-d) cannot be satisfied, or if the waste is particularly hazardous, consider a concentrate & contain site.

2.4 Previous studies in Norway by the Norwegian National Defence Research Establishment (NDRE)

2.4.1 Mapping of special wastes and contaminated ground at Norwegian Military Bases

Since 1990, NDRE has been involved in the mapping and investigation of chemical pollution at military bases and installations throughout Norway. Polychlorinated biphenyls (PCBs) in sediments, oil spills from fuel tanks, heavy metals and white phosphorus from firing ranges and sea-dumped chemical weapons have been investigated using advanced instrumentation such as gas chromatography, mass spectrometry and atomic absorption spectroscopy. The investigations have also included an evaluation of the risk such contaminants pose to the environment. Much of the experience gained from the development of procedures for sampling, sample handling and analysis of chemical warfare agents could be applied to other situations involving chemical pollution.

In 1990 and 1991, the Norwegian Ministry of Defence carried out a mapping of special wastes and contaminated ground at their installations based on the methodology used during the national mapping of hazardous waste sites (Section 2.3.1 and Misund et al. 1991a). Initially, all departments in the defence forces were asked to fill out a questionaire providing a description of possible contaminants and landfills within the department, the location of each possible dump site or contaminant and a description of possible conflicts with water resources, settlements, recreation or other land use. It was considered important that the registration of potential wastes was carried out by personnel familiar with each site, and who possessed information about the activities carried out within their department. Former employees were also asked to supply information. Using this technique, much information was obtained which would not have been available if a central mapping team had been brought in to carry out the registration. It was, however, important to inform the personnel in advance that it was in the interest of everyone to map and investigate possible environmental problems within the military installations. No sampling were carried out during this phase of the investigation. The reported localities were ranked into four groups (as listed in the previous chapter) according to the need for further investigation and remedial action.

The mapping described above is the first of four phases in the investigation of soil and groundwater contamination at defence installations. The work is carried out in accordance with the directions given in the "Guide for environmental ground investigations" (SFT, 1991) from the State Pollution Control Authority (SFT).

These phases are described below:

Phase 1	Preliminary investigation, involving the collection and evaluation of all background information on the present and past activities at the site, including the physical and chemical properties of the possible contaminants.
Phase 2	Investigation to clarify the existence of contamination at the site and whether it has spread to the environment. If no contamination is detected, the investigation is concluded.
Phase 3	Extended investigation of source and propagation of the contamination to see if there is a need for remedial action. At locations where remedial action is found to be unnecessary, the investigation is concluded.
Phase 4	Investigation to test and evaluate possible remediation techniques including assessment of efficiency and cost.

After the remedial action has been carried out, a monitoring phase is needed, to determine whether the requirements have been met and whether a permanent solution has been obtained.

The investigation was started at prioritized localities in Group 1, selected after consultations with SFT. The localities have been registered in a WinMap SQL Geographical Information System (GIS) where the status of each locality is continuously updated. Phase 2 investigations have been carried out at all localities in Group 1, and at some of the localities in Group 2. Phase 3 and 4 investigations have also been started at prioritized localities. An example of investigation of oil pollution at a naval base is shown in the case study.

2.4.2 Case Study: Oil Pollution At Haakonsvern Naval Base

The mapping of special waste and contaminated ground at defence installations in Norway discovered oil pollution in the ground at a fire-fighting training area at Haakonsvern naval base. The pollution was caused by oil-polluted waste water from the training area, an oil spill from training activities and from an incinerator used to burn spill oil. Three landfill sites and nine areas with suspected contaminated ground were identified during the mapping. Phase 2 and 3 investigations have been carried out at some of the localities and will be finished during 1995. The positions of the localities together with the results from all sampling points is recorded in a WinMap SQL Geographical Information System. This system is being used in the planning of further investigation and remedial action at the naval base. Fourteen sampling wells have been drilled in the area around the training field. The investigation showed that the soil was heavily contaminated with oil products and that some of the pollution is leaking into the sea. The leakage to the sea, however, has been substantially reduced after the closure of the training area in 1993.

It has been estimated that about 5,000 m^3 of soil is so contaminated that treatment is necessary. In-situ biological treatment is being considered, and a research project has been started that will test the treatment on contaminated soil from the area. The objective of the treatment is to clean the contaminated ground to a level below 1,000 mg oil/kg. Any residual oil should not restrict the use of the area as a parking area or storage area in the future, and the leakage of oil to the harbour should be reduced so as not to exceed 0.5 mg/kg in the monitoring wells. This level would mean a total leakage of 0.10-0.15 kg/year.

Investigation has also been started to evaluate the level of contamination in sea sediments outside the fire-fighting training area. It has been found that the sediments contain high levels of oil-products, PCBs, polyaromatic hydrocarbons (PAHs) and heavy metals. The sea-traffic and diving activities in the area have been restricted to prevent further transport of the sediments. Permanent remedial action on the contaminated sediments has been postponed until the land investigation has been finished and further leakages from land have been prevented.

2.5 Investigations at Military Sites in Canada

2.5.1 The National Contaminated Sites Refediation Program

In 1989, the Canadian federal government, together with the Canadian Council of Ministers of the Environment (CCME), announced a five year cooperative federal/provincial program designed to clean up contaminated sites across Canada. The National Contaminated Sites Remediation Program (NCSRP) is a 250 million U.S. dollar (USD) program based on a 50/50 federal/provincial cost-sharing formula. NCSRP will provide 200 million USD to clean up high priority contaminated sites, and 50 million USD for cleanup technology development and demonstration. Each of the provinces and territories will have access to the federal portion of the cost-shared program.

The federal government is responsible for the assessment and remediation of contaminated sites under its jurisdiction, as part of the national commitment to NCSRP. The Canadian Department of National Defence (DND) has signed a Memorandum of Intent with

Environment Canada, and is in the process of developing a hierarchy of preferred remediation options based on previous experience and cost effectiveness in an effort to reduce the cost of remediation. This usually means that if there is contaminated groundwater, the contaminated soil above the groundwater has to be cleaned up before the groundwater itself. The decommissioning policy of military sites in Canada is as follows:

- Contamination is usually checked by a consulting company;
- Contamination is cleaned up to federal CCME criteria or site specific risk based analysis;
- If any infrastructure remains for new users, fix environmental concerns without replacement, or environmental liability is transferred to new users;
- If there are no new users, the infrastructure is removed to 1 m below ground, graded and vegetation is planted;
- Place residual concerns on land titles, e.g. landfills; and
- A full environmental disclosure of contamination found and actions taken is provided.

Remediation of soil polluted by oil products in Canada is being conducted using the following methods:

- Natural attenuation;
- On - site land farming;
- Biopile;
- Soil treatment facility;
- Bioventing;
- Soil vapour extraction;
- Low temperature thermal desorption;
- Land filling of excavated material.

For water remediation and free product recovery the following methods, listed according to hierarchy are used based on previous success rates and cost effectivness:

- Natural attenuation;
- Bioslurping;
- Air sparging;
- Pump and treat

2.5.2 A Protocol for the Cleanup of DEW Line Sites

The Distant Early Warning (DEW) Line initially consisted of 42 radar sites constructed across Canada at approximately 65-70°N. A two-year environmental study was conducted at eight of the sites, two of which were identified as prototypes and subjected to particularly intensive investigation.

- Soil and water samples were taken from obvious spill areas, and possible migration pathways.
- Initially, samples were analyzed for a broad screen of chemicals. Once the key contaminants had been identified it was possible to target subsequent analytical programs - an approach that led to considerable cost-savings.

It soon became apparent that:

- the main contaminants were copper, lead, zinc and PCBs (polychlorinated biphenyls);
- that there were clear waste disposal patterns at the sites - out the window, down the drain, or out the back door;
- Dumps were poorly maintained.

It was also determined that contaminants could migrate by means of surface runoff (since groundwater is not significant in a permafrost environment) and, in the case of lead and PCBs, by aerial transport. Little was known, however, about the impact of chemicals in the Arctic, so samples of key receptors - plants on land, sedentary organisms in the marine environment (clams, urchins, bottom-dwelling fish) were obtained and analyzed. The measurements indicated the concentrations at which chemicals entered the terrestrial food chain, and that even low levels of leachate entering the sea resulted in unusually high uptake by marine organisms.

A general approach, or Protocol, was developed which focused on preventing the migration of contaminants into the food chain rather than cleaning up all stained soils or attempting to return the sites to a pristine state. Only persistent chemical contaminants were targeted - fuel spills, unless they contained lead or PAHs (polyaromatic hydrocarbons) - were left to undergo natural degradation. This Protocol formed the baseline for the evaluation of individual sites and for the development of specific cleanup specifications.

In many parts of Canada, hydrocarbon remediation is essential to prevent the contamination of groundwater and direct contact with human or animal populations. The remoteness of the DEW Line sites and the virtual absence of conventional groundwater has permitted a more economic approach without compromising environmental health.

2.5.3 Case Stucy: Remediation at CFB Cold Lake

Canadian Forces Base Cold Lake is a fighter training base that has been in use for a number of years. A landfill adjacent to the runway system had previously been used as a repository for municipal and industrial waste; typically, there were few records of waste disposal. Waste oil and lubricating fluids were discarded in a pit and the area used as a fire training area. This was verified from interviews with former base personnel as well as from aerial photographs. Unfortunately, the pit was filled in without regard for residual contaminants.

Recently, an oily sheen was observed in a boggy area on the side of a hill adjacent to the landfill. There was additional concern that this contamination, which was due to surfacing groundwater, would reach the creek below the bog and impact on the fisheries resource.

The investigation included:

- the installation of groundwater wells to delineate the extent of the contamination;
- the sampling of surface runoff and of soil and plants within the bog itself;
- extensive sampling of the shoreline of the creek and of water/sediments from the creek.

It became apparent that:

- the groundwater contained benzene, toluene, ethylbenzene and/or xylenes (BTEX), chlorinated solvents, and phenols;
- the concentrations of the resident chemicals exceeded all known groundwater criteria;
- no contamination was evident in the creek, as the bog was providing a natural mechanism of remediation.

As the pathways to higher receptors were minimal and the impact low, remediation was restricted to monitoring rather than cleanup.

3 METHODOLOGIES FOR ASSESSMENT OF SOIL AND GROUNDWATER CONTAMINATION

Dr. B. Paukstys (Lithuania), Dr. Chris Tucker and Dr. John Poland (Canada), Jan Steinar Rønning , Einar Morland and John Tørnes (Norway)

3.1 The Military Site Database (WASTE)

All information collected from the desk study and field work has been computerized and processed using various software and database management systems. The Geological Survey of Lithuania owns a database "Well" in DBMS "Oracle", where all information on the wells drilled in Lithuania is maintained. During the investigations at the military sites the database was supplemented with information from the site survey. ARCInfo software has been implemented for the preparation of a groundwater run-off map by the Geological Survey of Lithuania. The Baltic Consulting Group has their own database for the military sites. It consists of two major software packages: a program of FoxPro for Windows and the geographical information system CRISP. These packages are linked, allowing information to be exported from one database to another. Following discussion, it was agreed to create a special database for the project. The database was named "WASTE", and was linked with the existing database "Well" by the Lithuanian and Norwegian hydrogeologists and computer specialists.

The database WASTE has been developed with Oracle* “CASE” technology under the MS-Windows 3.1 environment. The database and surrounding applications are based on state of the art tools from Oracle: Oracle Server 7.0/7.1 and Oracle*Forms 4.0/4.5, and is in production as a client/server configuration. The database runs on a Motorola UNIX box, and the client runs on a PC connected to the server via local area network, TPC/IP and Oracle's SQL*Net version 1.0/2.0.

WASTE is a multi-user database; several users can simultaneously insert, update, delete and query the database without the fear of destroying each others work. It is also open in the sense that other tools such as MS-Excel or MS-Word, may retrieve information directly from the database. Other third-party reporting or database tools may also be used if they are ODBC compliant.

Each database user has a unique username and a password by which access to the database is authorized. This prevents abuse and unintentional change and deletion of database information.

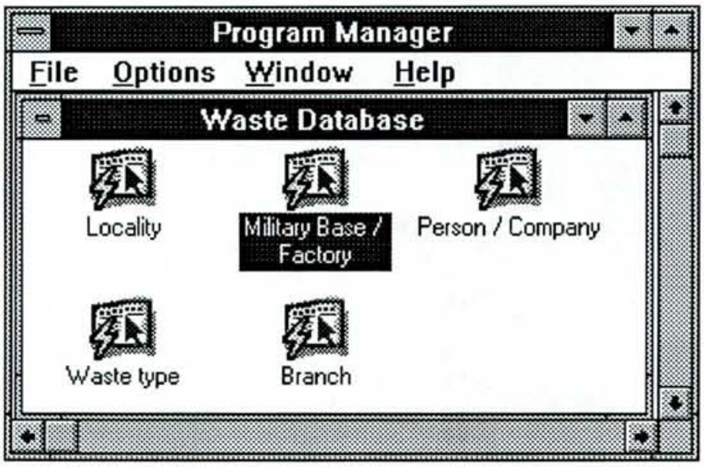


Figure 2. Database "Waste" applications

As shown above, the applications are a set of modules, each focusing on a different part of the database. Thus, changing the user interface and tailoring the screen prompts towards the needs of the users is a straight forward and simple process.

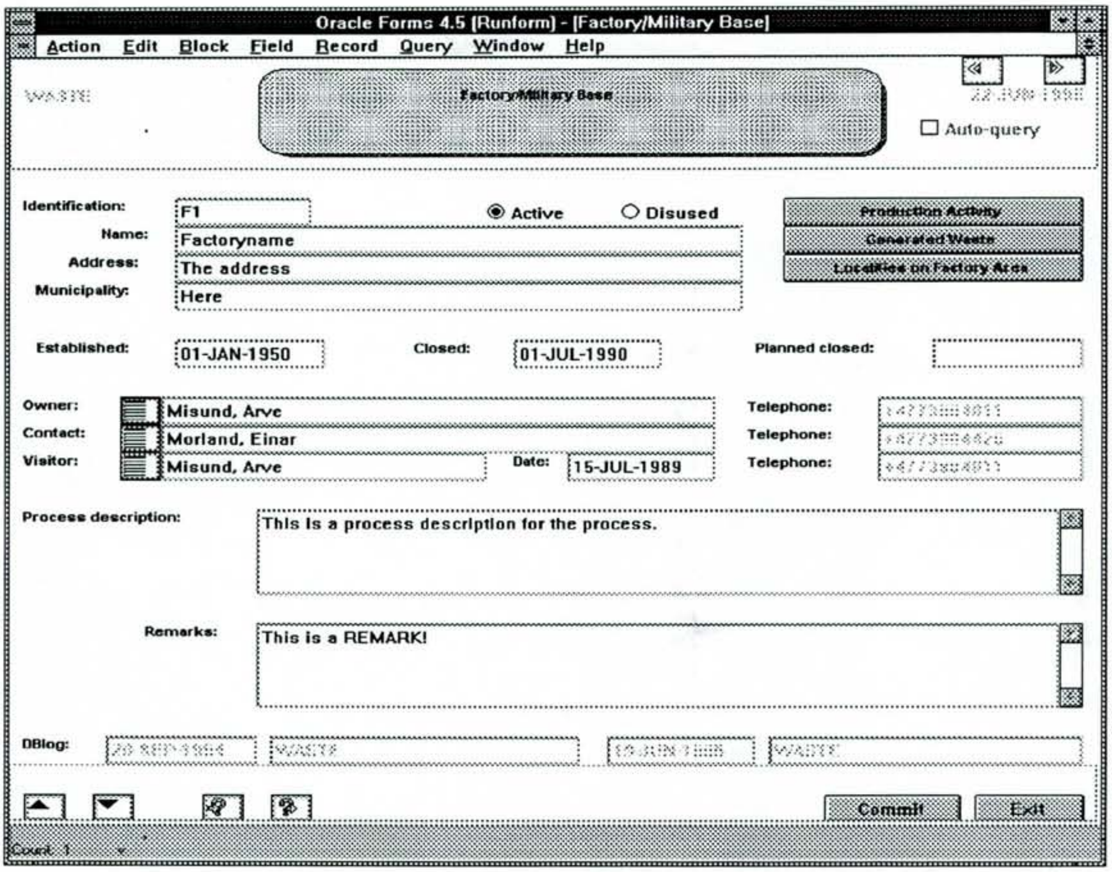
Currently, five applications are available as icons in the Program Manager of MS-Windows. The first and second are the main applications. The last three are applications for maintaining necessary lookup information:

- Locality
- Military Base or Factory
- Person or Company
- Waste types
- Branches

Through these applications, users are able to insert, update, delete and query information from the database. The user can also follow links to other application modules by pressing the appropriate buttons on the screens. Thus, navigating a path through the large amounts of information is easy and can be accomplished simply by using the mouse.

The user interface is based on the look and feel of MS-Windows, with graphical items like radio boxes, popup lists, and images, and uses mouse navigation. This is a significant improvement over traditional alphanumeric interfaces known from previous releases of the Oracle tools.

Below is an example of the main application screen obtained by activating the Military Base/Factory icon in the Program Manager.



Identification: F1
● Active ○ Disused
Name: Factoryname
Address: The address
Municipality: Here
Established: 01-JAN-1950
Closed: 01-JUL-1990
Planned closed:
Owner: Misund, Arve
Telephone:
Contact: Morland, Einar
Telephone:
Visitor: Misund, Arve
Date: 15-JUL-1989
Telephone:
Process description: This Is a process description for the process.
Remarks: This is a REMARK!
DBlog: WASTE WASTE

Figure 3. Main screen of the database "Waste"

There are several fields, buttons and other graphical objects in this screen, as described above. The screen also illustrates a useful feature of the database system. In the lower part of the picture there are four fields called DBlog. These show when and by whom this piece of information (the database row) was originally inserted into the database, and when and by whom it was last updated. Every row in all the tables of the database is supplied with this information, allowing a certain security enforcement and making it possible to generate accurate statistics on the growth and change of the database.

The database is user friendly and when connected with the central database of the Geological Survey of Lithuania "Well" it becomes an important tool for subsurface information collection, maintenance and processing.

3.2 Description of Soil and Groundwater Assessment Techniques

3.2.1 Methodology

A wide range of methods has been utilized for the evaluation of soil and groundwater contamination at former military sites in Lithuania. A description of the methods is presented in the following chapter. Some methods were implemented solely by Lithuanian environmental scientists; others were worked out in co-operation with western institutions (I. Kruger Consult, Canadian Department of National Defence, Norwegian Defence Research Establishment, Geological Survey of Norway). The Geological Survey of Lithuania participated in most of the projects and consequently gained a great deal of experience from the co-operative effort.

The following methods have been used for the assessment of soil and groundwater contamination at former military bases (Paukstys and Belickas, 1996):

1) Desk methods:

- evaluation of available geological and hydrogeological information from archives and databanks;
- computerized data processing and presentation;
- satellite data acquisition and processing;
- map compilation and reporting;

2) Field methods:

- inventory survey;
- drilling;
- soil and groundwater sampling;
- aquifer tests;
- geophysical investigations;
- laboratory analyses (in field and office conditions);
- soil contamination investigations with photo-ionization no hypher detector (PID)
- topographical surveys;
- radiological survey (See Part II of this report).

The application of the most important of these methods is described briefly below.

Some new methods (for example satellite data acquisition and processing, radiological survey) have been utilized during the co-operative NATO/NACC project described in this report.

3.2.2 Previous studies at Military Sites in Lithuania (PHARE and NATO-projects)

The Geological Survey of Lithuania is responsible for the collection and maintenance of all data related to subsurface investigations in the country. Most of the overall information on geology and hydrogeology in document and computerized forms is stored in the archives and databanks of the Survey. The "Well" database comprises records on more than 25,000 boreholes and wells drilled to different depths and crossing various geological formations. Information on lithological features of the area, hydrogeological parameters of the aquifers and impermeable layers as well as chemical composition of groundwater are also included in the database.

Before the start of field investigations, all available data on military sites were collected from various organizations including the Ministry of the Environment, the Geological Survey of Lithuania, the Ministries of Agriculture, Forestry and the Institutes of Geography and Physics, etc.

All municipalities of Lithuania have been requested to provide administrative data on each site and to obtain information on former, present and future land use at former military sites. Special forms have been prepared by the Baltic Consulting Group, approved by the main environmental institutions (the Geological Survey of Lithuania and the Ministry of Environment) and completed (Annex A). The types of soil and groundwater contamination has been registered on the forms as shown below:

- Pollution by oil products;
- Chemical contamination;
- Rocket fuel spills;
- Bacteriological and organic contamination;
- Contamination from waste deposits;
- Presence of radioactive material, etc.

In addition, all data on the geological and hydrogeological conditions of each site have been collated and the number, depth and location of existing production wells at each site have been put on the maps. This was important in order to know how contaminants can affect aquifers and spread outside the former military areas.

All information collected from office and field work has been computerized and processed using various software and database management systems. As mentioned in the previous chapters, the Geological Survey of Lithuania supplemented its database "Well" with information from the site survey in DBMS "Oracle". A special databank for the evaluation of soil/groundwater contamination has been developed and linked with the existing database "Well" by Lithuanian and Norwegian hydrogeologists. ARCinfo software has been implemented for GIS application and the compilation of a groundwater run-off map by the specialists of Geological Survey.

Remote sensing techniques were used to obtain specific environmental information on the Lithuanian military base at Pajuoste. A satellite image was obtained, processed and utilized prior to field investigations at Pajuoste airbase and this proved to be a very efficient method for this type of work. Representatives of the Canadian Department of National Defence, within the framework of a joint Lithuanian, Canadian and Norwegian project, analyzed the satellite image in order to gain a better appreciation of the past and present operations on the base. A detailed description of the method is provided in Part II of this study.

Available geological and hydrogeological maps at a scale of 1:200,000 and 1:50,000 were used for the regional evaluation of the area in and around the former military bases. Geological cross-sections of important sites were prepared where lithological composition of soils and groundwater levels were available. The Landuse Department of the Ministry of Agriculture compiled maps and cross-sections at different scales for the bases not covered by existing maps. The Ministry of Forestry prepared maps of the areas covered by forests. For the sites where detailed investigations have been carried out, maps at a scale of 1: 10,000 have been compiled. This was necessary to facilitate inventory work at the site, to plan environmental research and to present the data. Previously secret military maps of the sites, found for some of the bases after the withdrawal of Russian troops, proved to be an important source of information.

A total of more than 2,300 site reports with information on pollution sources at the military sites have been prepared by different research institutions and companies, including the Baltic Consulting Group, I. Kruger Consult AS, the Geological Survey of Lithuania and the Institute of Geography. Final reports in which overall research work of the military sites were also compiled by these organizations in Lithuanian and English.

3.2.3 Inventory Survey

After the data collection and the inventory of military sites were completed several field teams were established. These field teams generally consisted of three specialists: one or two hydrogeologists, one chemist/military expert and one geographer or biologist. A two day seminar was organized to familiarize the field groups with the requirements of completing forms, to discuss common survey methodology and the use of equipment, and to provide instruction on health and safety measures during the field work. Field groups were equipped with protective clothing, safety equipment, first aid kits, global positioning devices (GPS), soil and water sampling equipment, water level and free phase oil meters, dosimeters and photo cameras. Each group was also equipped with a car. The country was divided into four geographical areas: Vilnius, Kaunas, Klaipeda and Siauliai-Panevezys districts (Figure 4.). These areas were divided among the field groups. The site surveys were carried out from early April 1994 until the 10th of June 1994.

3.2.4 Drill Sampling Methodology

For the detailed evaluation of soil and groundwater contamination, drilling and sampling proved to be the most effective investigation methods. The boreholes and monitoring wells were drilled in such a way that the soil and groundwater pollution could be mapped as precisely as possible and that the groundwater flow direction could be determined .

Groundwater level detection wells were drilled using hand augers. Drilling was conducted by folding hand augers with removable drill bits, produced by a Dutch company "Eijkelkamp". Depending on the soil conditions, 70 mm or 100 mm diameter augers were used. At intervals of 0.3 m the augers were removed from the borehole. The appearance and smell of the sample were used as indicators of soil contamination. Soil samples were collected from the intervals where pollution was suspected. The maximum depth of hand-drilled wells was 6 m. In the areas investigated the shallow groundwater table is usually shallower than this.

For deeper subsurface investigations hollow stem auger and rotary mud drilling rigs were used. Four types of wells and boreholes were established during the site investigations:

- test boreholes;
- probe-test wells;
- monitoring wells and
- recovery wells

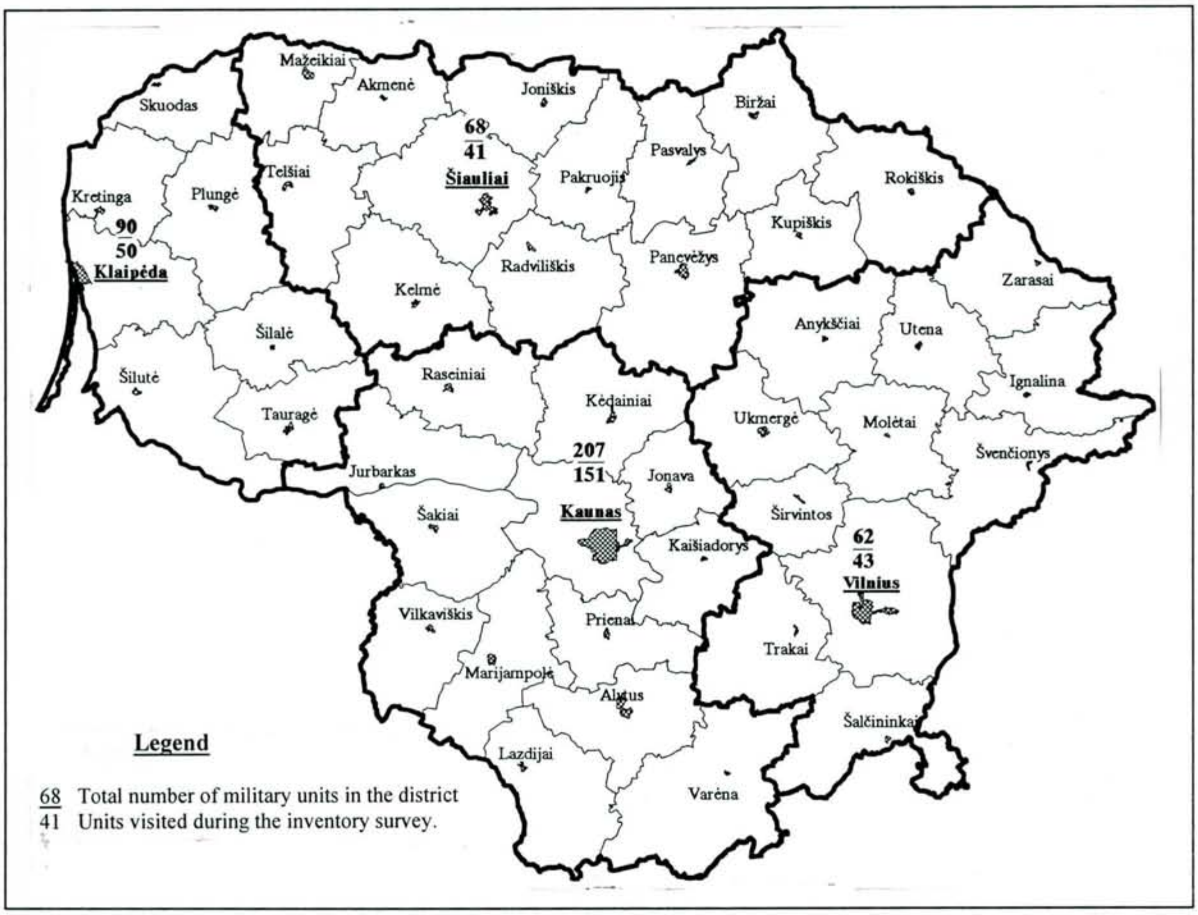


Figure 4. The main former military districts of Lithuania

Test boreholes were used for the general assessment of geological and hydrogeological conditions of the site. The maximum depth of these boreholes was 25 m. At intervals of 1.5 m to a depth of 3 m and 1 m thereafter, soil characteristics were described and soil samples taken. After each well had been sampled, all casing and screens were extracted and the remaining hole then filled with a drilling mud.

Probe-test wells were drilled for the determination of groundwater quality, depth to groundwater level and the assessment of free phase oil thickness. Wells sunk to shallow groundwater were drilled by hand auger; the deeper aquifers were reached by using a drilling rig.

Monitoring wells were drilled for groundwater sampling, level evaluation and continuous observations. Monitoring wells of various diameters were installed following the delineation of a pollution plume by test boreholes. After the drilling of boreholes, stainless steel and PVC casing was installed together with appropriate screens. For hand-drilled wells, screens of 0.25 - 0.5 m long slotted PVC pipes and perforated pipe wrapped with stainless steel net and were used. The wells were purged with special bailers or pneumatic hand pumps. From 2 to 10 volumes of water were purged before sampling.

Deeper aquifers were reached using rotary drilling machines. Metal casing and screens of 89 or 108 mm diameter were used. Screens were made of perforated metal pipe wrapped in bronze netting. The length of the filters was 2 m and the length of silt traps was 1 m. After the well screen had been positioned, a filter pack consisting of sand or gravel was installed around the screen. The filter pack was placed from the bottom of the borehole to 1 m above the top of the screen. The annulus space of deeper wells was grouted by a clay and bentonite mixture in order to protect aquifers from interconnection and contamination.

Before the wells were sampled, they were purged using "Honda" type petrol pumps. Wells with low yield were cleaned up using bailers. Up to 10 casing volumes were purged before a sample was collected.

At the military sites selected for detailed investigations, recovery wells were drilled where severe groundwater pollution was detected. The wells were drilled using rotary drilling machines to depths dependent on the depths of polluted groundwater. Casing 219 mm diameter was installed and PVC screens up to 8-10 m length were placed so that they were open across the thickness of soil polluted by oil. The length of the screen was selected to take into account potential fluctuations of groundwater level and thickness of free phase oil.

3.2.5 Aquifer Tests

Aquifer tests provide necessary information on hydraulic properties of water-bearing formations and impermeable layers, such as permeability, transmissivity, storage capacity. This information is essential for the evaluation of the transport of contaminants in subsurface media. Aquifer tests employed included pumping tests and slug tests. The duration of the pumping tests depended on the depth and amount of groundwater in the water-bearing formation and varied from 96 to 48 hours. Groundwater levels were measured in production and observation wells during the pumping tests and the subsequent recovery phases, at intervals from 5 to 30 minutes. For water abstraction from the test wells submersible electric pumps and compressors were used.

The permeability of the aquifers was also determined by slug tests. For this purpose the well casing was filled with water and the recovery of groundwater to its original level was recorded. Soil permeability was calculated based on this data.

3.2.6 Groundwater sampling

Groundwater samples were collected with Waterterra hand pumps, 12 V Eijkelkamp pumps of 8 l/min capacity, special bailers and Grunfos MP-1 pumps. Prior to sampling the wells were purged using clean Teflon bailers and pipes. The bailers and pumps were cleaned and rinsed in clean water before using them in the wells.

Groundwater samples were analysed in the field and in static laboratories. For the field analyses portable HACH field kits were used. Groundwater temperature, specific conductivity, pH, Eh, dissolved oxygen, and some cations and anions (including NO_3^- NO_2^-, NH_4^+, SO_4^{2-}), and a number of heavy metals were analysed for in the field. For more precise evaluation of the groundwater quality, samples were shipped to static laboratories where they were analysed.

3.2.7 Soil investigations by photo-ionization-detector (PID)

For the preliminary determination of soil contamination and detection of the areas for soil sampling, the PID SI 11 or HNU-101 was used. The PID was utilized for the assessment of volatile organic compounds in the soil. Soil samples were collected in plastic bags and the PID probe was placed in the bag and VOC (volatile organic carbons) concentrations were measured. Soil samples with high PID readings were taken for laboratory analysis.
PID was also used during the field work at Pajuoste airport.

3.2.8 Geophysical Investigations

a) Ground-penetrating radar

Ground-penetrating radar is an electromagnetic method which can be used to delineate features in the ground such as the groundwater table, sedimentary structures and bedrock topography. The method involves the transmission of pulses of energy into the ground. Measurements are conducted by moving the transmitting and receiving antennae with constant separation stepwise along a line. A recording is performed at each station. Reflected signals are registered digitally and plotted as traces in a distance-time section. The distance-time section is further transformed to a distance-depth section by using estimated, calculated or measured electromagnetic (EM) wave velocity.

The EM wave velocity can be found by conducting CMP measurements (CMP = common mid-point). The measurements are carried out by moving the transmitting and receiving antennae in small steps away from a mid-point while recording at each station. The EM pulse will then be reflected from the same points on reflectors which are parallel with the terrain surface. The travel time for reflections increases as the antennae separation increases. To eliminate this effect, one has to perform NMO corrections (NMO = normal move-out). The correction decreases with increasing velocity. The correction is performed using different velocities. After performing NMO correction, the individual traces are stacked to give one trace. The velocity which defines a reflector best in terms of high amplitude, is the stacking velocity for this reflector.

The velocity is related to relative permittivity, following the expression;

$$\varepsilon_r = (\frac{c}{v})^2$$

ε_r = relative permittivity of the medium
c = 2.998 10^8 m/s, velocity in free space
v = velocity in medium

The EM pulse is reflected from interfaces separating layers with different relative permittivities. Relative permittivities for dry sand and water are 5-10 and 80 respectively. Thus, the groundwater table is normally a strong reflector. In geological materials, differences in water content give rise to reflections. The penetration depth of EM waves is strongly dependent on electrical conductivity and antenna frequency. Increasing electrical conductivity and antenna frequency will both increase absorption of energy, and the penetration depth decreases. In good electrical conductors such as silt, clay and saline water, penetration depths are sometimes negligible. In poor conductors (e.g. dry sand and gravel), the penetration depths can be in the order of 10 to 40 m when using relatively low frequency antennae. For higher vertical resolution of the shallow subsurface, a higher antennae frequency is used.

b) Geomagnetic Surveys

The method is primarily used in the mapping of magnetic properties of crystalline rocks. Magnetic anomalies are normally caused by the mineral magnetite, and these anomalies reveal the content of magnetite in the rock. Magnetic measurements are also used in the mapping of waste deposits, where buried iron objects (e.g. drums, steel rods) give rise to magnetic anomalies.

Iron objects placed in the earth's magnetic field (a primary field) will produce a secondary field. The strength of this secondary field depends on the strength of the primary field and on the volume, magnetic susceptibility and geometry of the object. Normally, the secondary field gives rise to positive anomalies. Due to geometry and the eventuality of remnant magnetism, the anomalies can sometimes be negative.

To reduce or eliminate the effect of diurnal variations in the earth's magnetic field, magnetic data are usually corrected using data recorded from a stationary magnetometer. When measuring the vertical magnetic gradient with the gradiometer, it is not necessary to perform diurnal corrections, since output from the gradiometer is the difference in total field strength between two vertically separated sensors.

c) Borehole and surface geophysics

Cone penetrometer tests were conducted in some deep boreholes to obtain additional information on the lithology and availability of groundwater in sediments. The tests, which consisted of gamma and standard electrical tests, were performed using standard geophysical probes with continuous registration.

For the determination of groundwater flow direction and velocity a tracer test using NaCl as a tracer was applied. The salt was diluted in water and poured into the well. The velocity and direction of groundwater flow was determined on the surface by electric probes at a radius of 4 m around each well, from the differences in electric field.

3.2.9 Analytical Methods for Groundwater and Soil Samples

Samples were sent to laboratories in Canada and Norway by commercial airline and taken to Lithuanian laboratories. Upon receipt of the samples, they were stored at 4° C for water and -20° C for soil prior to analysis. Water samples were analysed for petroleum products, phenols, total organic carbon, metals and anions. Soil samples were analysed for petroleum products, PCBs and metals. Four soil samples and two water samples were analysed for a suite of priority pollutants.

All soil and water samples were analysed for petroleum products in Norway and selected samples were analysed in Canada. Water samples were analysed in both laboratories by gas chromatography with flame ionization detectors (GC/FID) after dichloromethane extraction. Slightly different extraction methodologies were used for soil determinations, though both used GC/FID analysis as the final step. The Norwegian method involved a double extraction with an acetone/heptane mixture while the Canadian laboratory employed a single hexane extraction after addition of sand and sodium sulphate. This method, though quicker and cheaper, was less efficient at extracting the petroleum products.

Capillary columns (DB5 or equivalent) and computer driven data collection systems were used by both groups. The results for petroleum products obtained were similar except for one sample (LT2W, see Tables 18 and 19, Annex B) for which results of 63 mg/l and 3.4 mg/l were found. This difference may well be due to aeration of one of the samples during collection with the Waterterra system. The procedure requires the oscillation of the plastic tube and unless this is done in a carefully controlled manner, aeration of the water samples can occur resulting in loss of volatile components; the contaminant in this case was the more volatile light fuel fraction.

Phenols were determined using an automated colourimetric system (Technicon) with on-line distillation. Total organic carbon was determined using an Astro 2001 instrument with autosampler attachment. PCBs were determined in all soil samples using immunoassay test kits supplied by Millipore (Enviroguard). Six selected samples (four soil and two groundwater) were submitted to a commercial laboratory in Canada for analysis of 78 priority pollutants. These were chlorinated hydrocarbons, PAHs, phthalates, pesticides and PCBs. Standard EPA 624 methods were employed.

The content of the heavy metals copper, zinc, lead, nickel, chromium and cadmium in soil and water were analyzed at the Norwegian Defence Research Establishment using graphite furnace atomic absorption spectrometry (GFAAS). Norwegian standard methods (NS 4780 and NS 4781) were used. In addition, mercury was determined in the samples using a cold vapour technique (Norwegian standard NS 4768). Before analysis, the water samples were filtered through 0.45 µm filter and acidified by nitric acid. The soil samples were decomposed by concentrated nitric acid in an autoclave. The content of 30 metals in the water samples was also determined by use of inductively coupled plasma atomic emission spectroscopy (ICP) at NGU. This made it possible to compare the results from two different laboratories for some metals.

Seven anions were analysed for on the untreated aliquot by HPIC using an ion chromatograph model 2010i from DIONEX. Laboratory measurements at NGU were performed according to NGU-SD 0.1: Quality Manual for NGU-Lab (NGU-SD 3.1 and 3.4). Standard NGU procedures are also reported in Ødegård & Andreassen (1987). Water samples obtained from the four wells were analyzed in the field with an YSI 3560 Water Quality Monitoring System for pH, conductivity, redox potential and temperature.

The unknown samples collected from the storage areas were analyzed using several different instruments. The identification of unknown compounds is not straight-forward, especially when no previous information is available. After initial examination to determine the melting points, solubilities in different solvents and the weight loss at 550°C, the solid samples were screened for their main elements using electron microscopy with an X-ray fluorescence (XRF) probe and X-ray crystallography. For some of the samples, the elemental composition was also determined using ICP analysis. Preliminary examination showed that the samples Lit II-1, Lit II-2 and Lit IV-2 (see Table 2) contained organic compounds and were further analyzed using gas chromatography-mass spectrometry (GC-MS), MS with direct inlet probe and ^1H and ^{13}C nuclear magnetic resonance spectroscopy (NMR).

4 SITE INVESTIGATIONS

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4.1 Background Information

4.1.1 Geographical and Historical Description

A preliminary site investigation was conducted at the former Soviet air base at Pajuoste. The site was selected for study as it is typical of the sites of military activity which have caused extensive environmental problems in Lithuania. Furthermore, the geological and hydrogeological conditions at Pajuoste are typical of Lithuania in that the soil is composed of moraine till, sandy loam and sand. These sediments contain shallow groundwater.

The Pajuoste airport is situated on the eastern side of the town of Panevezys, at the confluence of Juosta and Nevezis rivers, 2 km to the east of the town (Figure 5). Panevezys has approximately 130 000 inhabitants. The River Nevezis forms the western border of the airport and the River Juosta represents the northern boundary of the area. The base is situated on a flat moraine plain, which is cut by shallow valleys (3-6 m) deep containing small streams. Surface run-off is directed towards the streams.

The airport covers a total area of 816 hectares. Military activities at Pajuoste started in the 1930s, and after 1945 was used by the Soviet Union as an airbase for transport aircraft. In 1950 the airport was reconstructed and enlarged to provide for about 54 aircraft, 300 transport vehicles and more than 140 buildings, in addition to providing an infrastructure that supported up to 1,200 soldiers.

After the withdrawal of the Russian army in 1993, Pajuoste airport came under the control of the Ministry of Defence of Lithuania. It is planned to use the airport for military and civil transport aircraft.

Special bunkers with 7 m high soil walls were built at the base for the protection of military installations. Thirty-two such installations were constructed, using 17 000 m^3 of soil (Figures 5 and 6). After the withdrawal of Russian troops the airport was left in very poor condition. Many buildings were ruined, much rubbish was left behind, and unidentified chemicals in open containers were abandoned.

The airport area was divided into four areas according to potential impact on the environment:

1. The military village located near the mouth of the River Juosta.
2. Garages for cars and trucks.
3. Oil storage areas.
4. Runways and aircraft parking ramps, with workshops and storage areas.

The vicinity of the airport is heavily urbanised. Neighbouring villages use groundwater from dug wells for their drinking water supply. At a distance of 1.5 - 2.0 km to the southwest is the main waterworks for Panevezys, with an estimated groundwater abstraction of 65 000 m^3/day.

Very little was previously known about the status of the environment and soil/ groundwater contamination at Papuste airport. Therefore, in 1993, representatives of the Ministry of the Environment conducted an inventory of contamination sources at the base. Several water and soil samples were collected and analyzed, 6 boreholes were drilled near the oil storage areas and garages and groundwater contamination from the boreholes evaluated.

The site was visited for the purpose of this study on the 20th and 21st September 1994. On-site sampling was limited to one and a half days. Although this study was very preliminary in nature, the field work allowed the exchange of experiences and ideas between the project participants. This study was limited to identifying contaminants present and areas of concern. In the time available, it was not possible to assess the impact that these contaminants might have on the environment or the extent of the contamination.

Five monitoring wells were established, and a total of 38 water and 59 soil samples were collected in addition to eight samples of materials in storage locations were taken during the site survey and the following monitoring programme. Samples were subsequently analysed in laboratories in Canada, Norway and Lithuania. In addition, a ground-penetrating radar survey was conducted and several areas were examined for the presence of hydrocarbons using a portable meter. A separate survey of soil contamination by radioactive materials was also carried out.

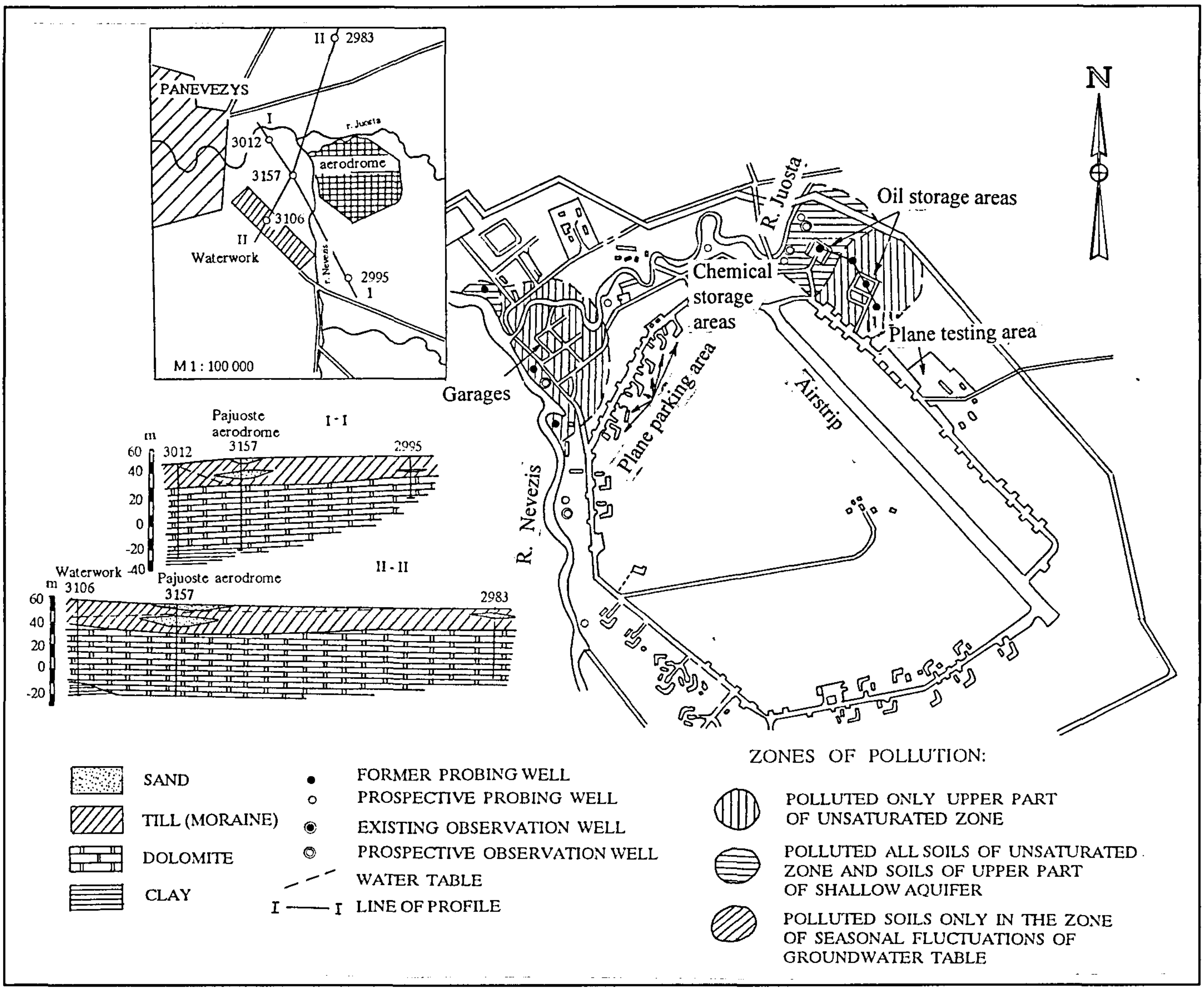

Figure 5. Site map of Pajuoste airbase.

4.1.2. Hydrogeological Conditions

Underlying the site are rocks of Devonian age overlain by Quaternary sediments.

The Quaternary sediments are represented by glacial tills with a thickness ranging from 10 to 24 m. Sand lenses of 1-3 m thick are often present in these glacial tills. The elevation of the land surface in the area varies between 51 - 59 m above sea level. Much of the shallow groundwater flow under the site occurs as unconfined flow in the scattered sand lenses and underlying layers. The water table was detected at a depth of 0.4-2.6 m.

In the south-southwestern part of the airbase, shallow groundwater discharges into the River Juosta, whilst in the western part of the site groundwater flow is directed towards the River Nevezis (Figure 6).

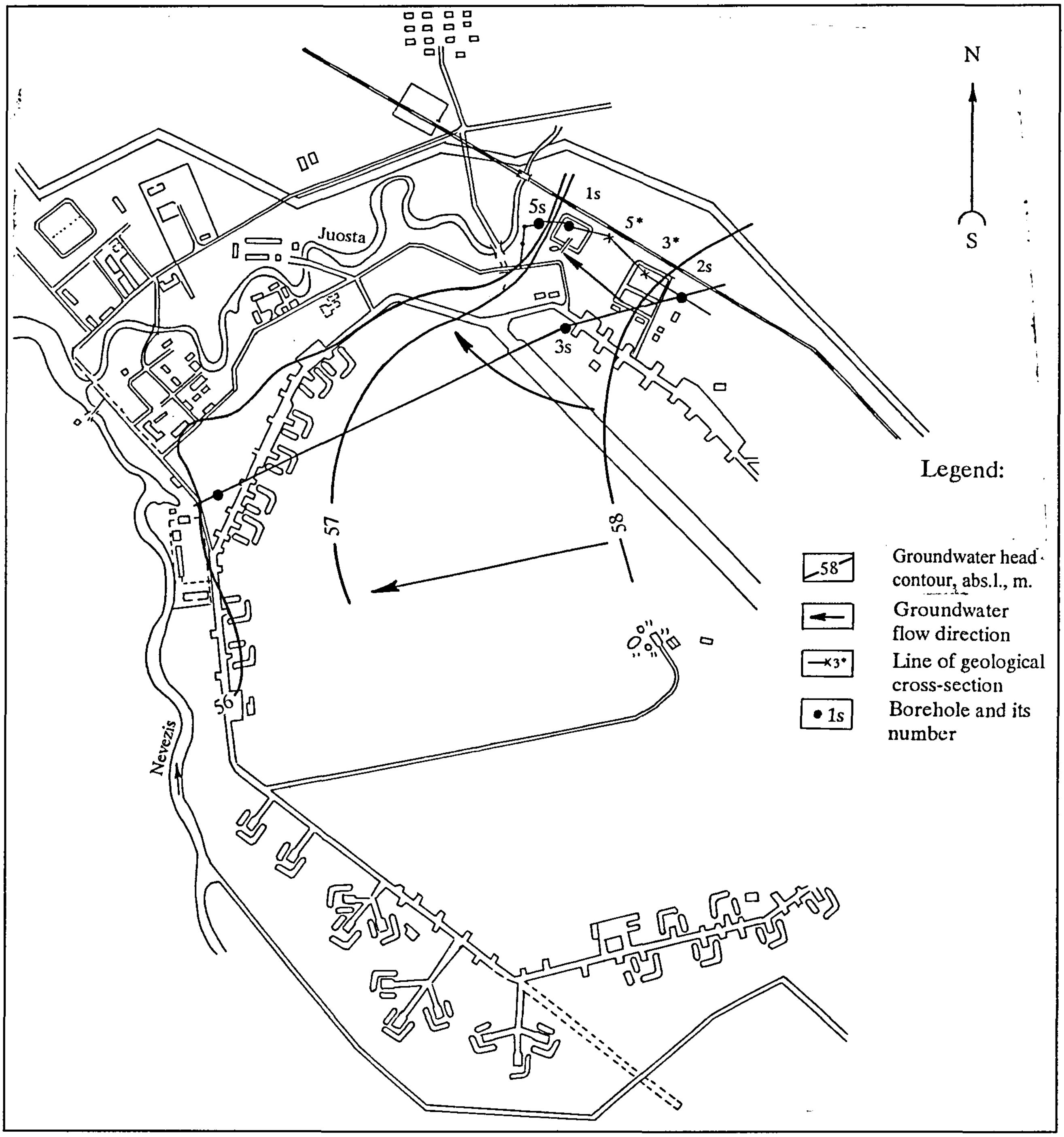

Figure 6. Groundwater flow direction at Pajuoste airbase

Quaternary tills are underlain by the Upper Devonian dolomites of the Suosa- Kupiskis beds (D_3 ss-kp) with a thickness of 23-24 m. (Figure 7). Groundwater is contained in hard, unevenly cavernous dolomites. The groundwater piezometric level occurs at a depth of 25 m. The aquifer is underlain by the Upper Devonian Jera marls and dolomites which act as a local aquitard in the area.

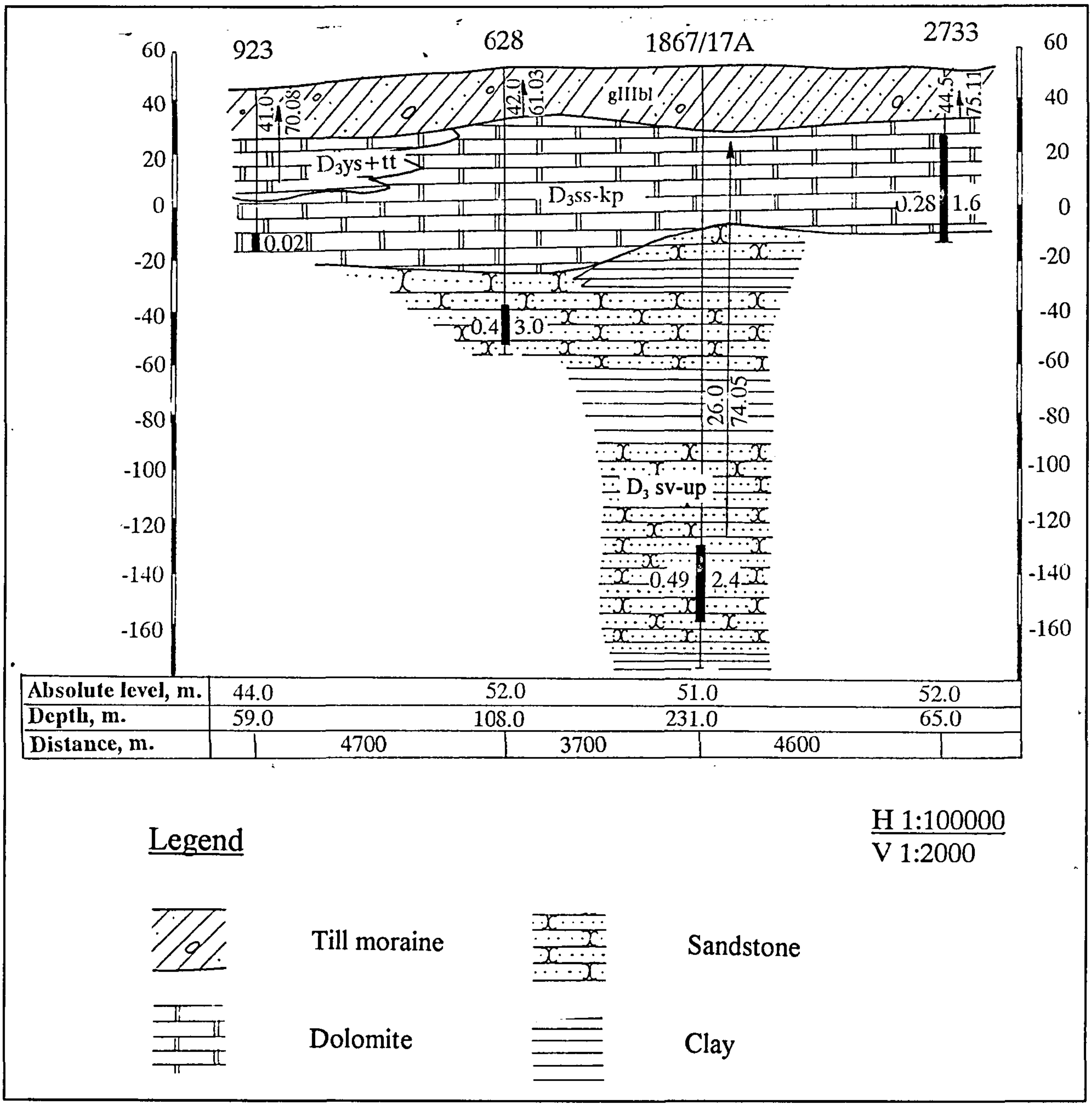

Figure 7. Geological composition of the subsurface at the Pajuoste airbase.

The Sventoji - Upninkai aquifer (D_3 sv-up) underlying the Jera marls is the main aquifer utilized by the centralized drinking water supply not only for the Panevezys area but also for all of eastern Lithuania. In the area of Pajuoste airport, the aquifer occurs at a depth of

53-66 m. The thickness of water bearing sands, sandstones, and clay sands reaches 220 m. The upper part of the sediments contains more clay minerals, and therefore the effective thickness of aquifer is halved and reaches 110 m.

The most productive part of the aquifer occurs at a depth of 170-187 m. Natural groundwater head reached ground level in the past but has declined to 50 m below ground level due to groundwater abstraction. Part of the Pajuoste airport is built on the third protection zone of the Panevezys water intake area. Garages, a former heating plant and storage facilities are located in the area where chemical contamination is prohibited. The Sventoji-Upninkai aquifer is underlain by the Middle Devonian Narva aquiclude (D_2 nr), composed mainly of marls with a thickness of 80 m.

From the description of the geology of Pajuoste airport area it can be seen that the productive aquifers in the area are quite well protected. However due to groundwater extraction and the development of a depression cone, favourable conditions for downward infiltration of polluted surface and unconfined water are created.

4.2 Site Survey

4.2.1 Investigation Strategy

On arrival at the site, the sampling team, consisting of Dr. John Poland (DND, Canada) and four members of the Lithuanian Geological Survey, familiarized themselves with the area by means of a reconnaissance. Sampling locations were selected and samples collected; numbered tags were placed at each location to mark the sampling position. Areas likely to be contaminated were chosen and sampled near the sources of such contamination and in drainage pathways leading from it. The overall approach was designed to obtain samples that would:

- be representative of the status of the site - samples were obtained from all of the major areas of the site;
- determine the nature and distribution of major chemical contaminants - samples were collected from both stained and non-stained soils; and
- indicate the presence of any contaminant migration within the ecosystem

In addition, background samples remote from the sites and free of any local inputs were collected.

Two types of samples were collected at most locations. Soil samples designated for inorganic analyses were obtained using a plastic scoop and stored in plastic bags while those for organic components were collected in 50 mL jars fitted with a top covered with aluminum foil. Some additional soil samples were taken in 1 L wide-mouthed amber bottles. Soil samples were generally restricted to the upper 50 cm and care was taken to obtain representative material. Water samples for inorganic analyses were collected in 250 mL plastic bottles. Acid preservative was added to samples from the wells in Lithuania and to the remainder on receipt at the laboratory. Water samples for organic analyses were collected in 250 mL amber bottles fitted with Teflon lined lids and in 1 L glass jars. Four soil samples (two bags and two jars) and five water samples (two 250 plastic and amber glass bottles and one 1 L glass bottle) were taken at each location where water and soil were sampled.

All sampling supplies were shipped by air freight from Canada and Norway and samples sent by the same means. Considerable delay was experienced in getting both through the customs formalities in Vilnius.

4.2.2 Sampling Locations

Figure 8 shows a map of the airfield including the main features of the site and the sampling locations. The River Nevezis flows along the western perimeter of the site and is fed by two tributaries which drain the site. The tributary to the north, the River Juosta, flows through the site itself and receives drainage from the fuel storage area and landfill. The tributary to the south drains the southern area of the site. Many drainage ditches cover the area but there was not time during the site visit to ascertain the flow directions and linkages between these various channels. Photograph-1, an aerial photograph of the site, clearly shows some of these drainage courses but others are hidden. This photograph also shows the wooded areas surrounding the site and in the central region as well as large areas covered mainly by grasses adjacent to the runway and taxiing areas.

In order to facilitate discussion, the site was divided into geographic areas and these are discussed separately below. Descriptions of the surface soil and water samples are given in Table 15, Annex B. Descriptions of the samples obtained from the monitoring wells are given in Table 16, Annex B. A total of 18 water samples, 39 soil samples and 8 samples of materials were collected and split into 264 separate samples to be analysed at laboratories in Lithuania, Canada and Norway.

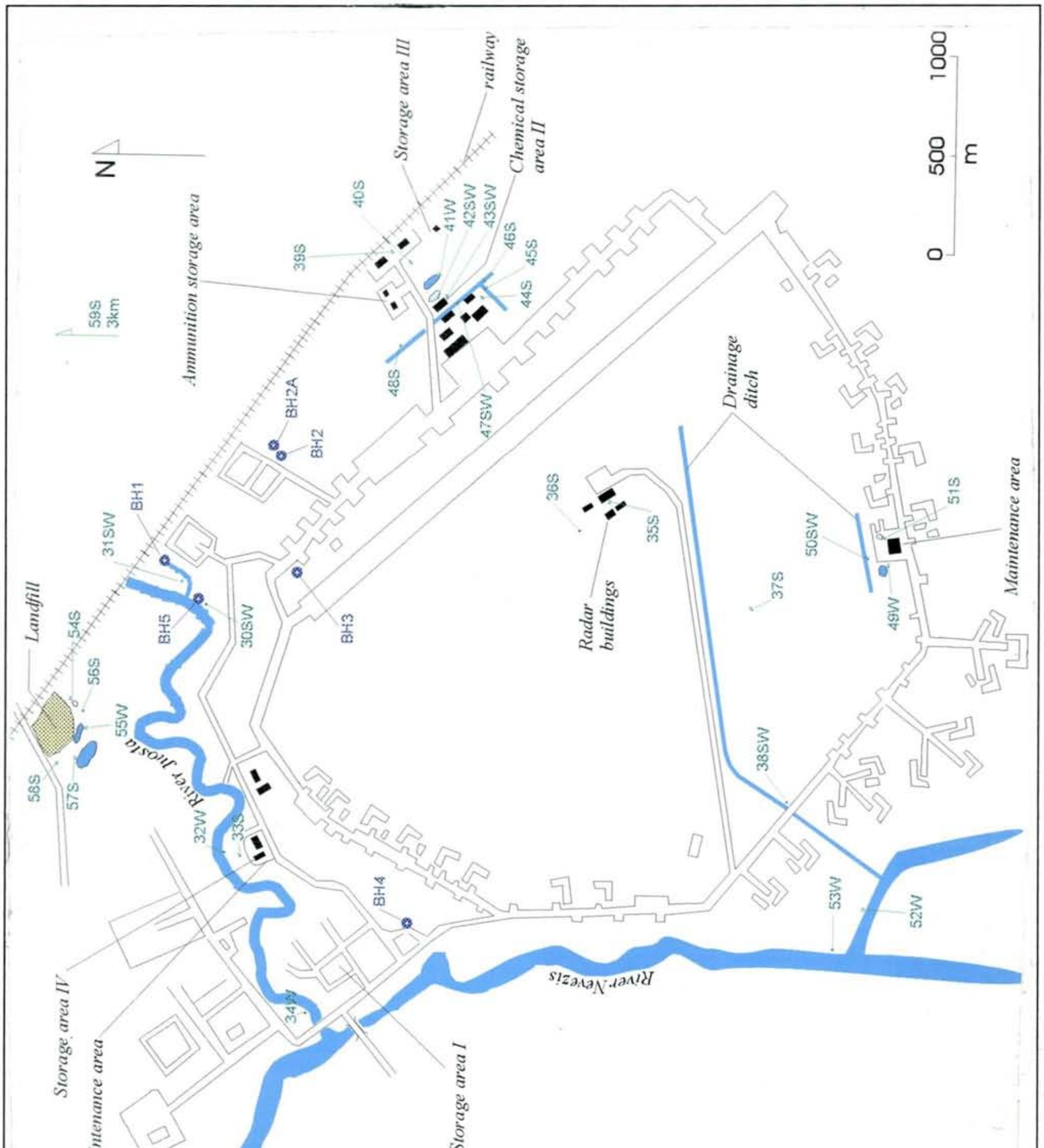

Figure 8. Sample locations at Pajuoste airfield, Lithuania.

4.2.3 Monitoring Wells

Five monitoring wells were established. Their locations are shown in Figure 5. An auger drilling rig was used to establish the wells. The wells were pre-manufactured, 5 m long, with 1.15 m slotted filter over a 60 cm length of wood. Soil samples were collected from the auger every meter; four samples from Wells 1, 2 and 4, and three samples from Well 3. Caution was taken to remove the outermost soil to avoid contamination by upper strata when the auger was pulled up. After well installation, the wells were purged two to three times. The next day each well was sampled for water analysis, one sample per well. For Wells 1, 2 and 4 a Waterterra foot valve pump was used and for Well 3 an electrical Eikjelkamp 12.12 Dip-pump system was used. With a maximum capacity of 8 L/minute this was much better for purging the wells than the Waterterra foot valve pumps.

A description of the samples taken at the monitoring wells is shown in Table 16, Annex B.

4.3 Geophysics

4.3.1 Ground-Penetrating Radar

Measurements were carried out using a 'Pulse EKKO IV' radar system (Sensors & Software INC., Canada) with 50 Mhz antennae. Signals were stacked 32 times at each station. Time sample intervals were 1.6 ns and the antennae separation was 1 m.

Ground Penetrating Radar (GPR) profiling in Lithuania as in other parts of the world has shown that the method is very sensitive to subsurface electrical properties. In areas of high electrical resistivity (> 1000 ohm) the method can give valuable information. In areas with subsurface resistivities of less than 100 ohm, the depth of penetration is very limited.

4.3.2 Magnetic Gradiometer

Measurements were carried out using the Scintrex ENVI-MAG magnetic gradiometer. Two sensors are used with a vertical spacing of 0.5 m. The lowermost sensor was placed 2 m above ground level. The measured value is the difference in total magnetic field strength between the two sensors and is expressed as nano Teslas per metre (nT/m).

4.3.3 Results

At Pajuoste airport, GPR and magnetic gradient measurements indicated the position of a landfill giving rise to large gradient anomalies. In the three other areas of Pajuoste airport, only magnetic gradient measurements were conducted. Metal objects such as buried oil tanks, could be easily detected. In one area, the search for underground pipelines was unsuccessful due to severe noise from surface objects, masking the weaker anomalies from the pipelines.

4.4. Photoionization Detector Survey

A photoionization detector (an HNU Canada Ltd. meter) was used to detect volatile organic vapours which may have resulted from contamination by petroleum products and other volatile organics. The HNU meter samples were analyzed using the "jar head - space" method. The HNU meter demonstrated was a HW - 101 using a 10.2 eV ionization lamp. This lamp was chosen because most petroleum reacts at 10.2 eV. Field screening for organic vapors (total petroleum hydrocarbon) was carried out in several areas to demonstrate the use of this equipment in indicating areas which do not require further study. Surface runoff ditches were sampled in seven aircraft parking areas, in addition to the area around the control tower and its auxiliary generator building.

4.4.1 Results

From the results of the photoionization detector survey, of the seven aircraft parking areas, two showed moderate levels of petroleum vapors (150 and 60ppm) in the ditch immediately adjacent to the concrete aprons. However, these levels rapidly diminished within a few meters, indicating that the spills are probably insignificant and do not warrant further study. The other parking areas were saturated with water with no observable, or only trace levels recorded and therefore do not warrant further study. There was considerable petroleum spillage around the rear of the control tower building. This area should be investigated in more detail and the disused fuel tank should be removed. A number of transformer kiosks and the radar site were inspected for indications of the dumping of PCB oils. This cursory check did not reveal any indications of the dumping of transformer oil. A preliminary investigation was conducted for the remnants of chemical warfare agents and decontamination agents. Some unidentified chemicals were found when samples were taken. There were numerous ventilation unit air decontamination canisters on site. No burn pits were found at the ammunition storage compound. Two waste pits were found in the aircraft maintenance workshop area. Soil samples were taken.

4.5. Sampling and Analysis Results

All results obtained are given in Tables 17 to 25 in annex B. Samples were analysed for a total of over 1,800 individual analytes.

4.5.1 Background sample

Sampling

Two background soil samples were obtained. One (LT37S) was obtained about 20 m from the road linking the taxi area to the radar control tower in an undisturbed wooded area at the centre of the site. The other (LT59S) was taken in a wooded area approximately 3 km north of the airfield.

Results

The two background soil samples were not found to contain any of the organic contaminants that were analyzed. Metal levels were all low except cadmium which was present at 0.4 and 1.7 mg/kg, somewhat higher than the Canadian CCME assessment criteria of 0.5 mg/kg. Chromium (2.5 and 7.0 mg/kg), nickel (5.3 and 9.2 mg/kg) and zinc (24 and 32 mg/kg) were also found in both samples but mercury (<0.05 mg/kg) was not detected in either. These values are all below the assessment criteria.

4.5.2 Fuel Storage Areas

Sampling

Fuel storage took place in two separate areas. The fuel was transported to the site by train and the railway tracks are consequently adjacent to both of these fuel tank areas. The tank area furthest from the River Juosta and landfill still contained a number of underground tanks; these were thought to still contain fuel. This area is generally flat and partially wooded.

In the second area, all the fuel tanks had been removed. Drainage from the area was towards the River Juosta in a northwesterly direction. Drainage initially occurred to a surface tank located in a wooded area close to the former position of the fuel storage tanks (Photograph-2, Annex C) and was probably there as a catchment facility. A small stream is present in this area and flows into the nearby River Juosta.

Four wells, two surface water samples and two surface soil samples were taken in this area. Well 1 was located near the railway tracks in the fuel storage area nearest to the landfill site. Four soil samples (LT1S-LT4S) were taken at various depths from the well; the piezometer was installed to a depth of 3.6 m and a water sample (LT1W) obtained from the well. Well 3 was positioned near to the runway and to the south west of Well 1. Three soil samples (LT9S-LT11S) were collected during drilling of the well and a water sample (LT3W) was obtained from the piezometer which was placed at a maximum depth of 3.6 m. Well 5 was placed near to the river to the northwest of the fuel storage area. A surface water sample (LT31W) and a sediment sample (LT31S) were taken from the small stream that originates close to the fuel storage area. The sediment in this area was black and smelt of petroleum products; the water was clear but developed an oily film when the sediment below was disturbed. A water sample (LT30W) and a sediment sample (LT30S) were taken from the river bank downstream of the previous samples; neither gave any indication that they were contaminated with petroleum products.

Well 2 was located at the site of the fuel storage area furthest from the landfill site. A first attempt at constructing this well was abandoned as it was discovered that the well was dry. Three soil samples (LT5S-LT7S) were taken from this original well (Photograph-3). A second well (Well 2A) was developed next to the first and one soil sample (LT8S) taken along with a water sample (LT2S). The monitoring well was installed at a depth of 4.3 m and water smelling of petroleum products encountered below 1.5 m.

Results

Water samples from Wells 1 and 2 were both found to contain light hydrocarbons (< C_{15}) which was also found in four of the seven soil samples analyzed. A high level was also found in sample LT31S from the drainage area toward the river but was not detected in samples LT31W, LT30W or LT30S. Water and soil samples from Well 3 were not contaminated indicating that the contamination has not migrated in that direction. Results are not available for Well 5. Phenols were also found in the water from Wells 1 and 2 but not in LT31W. TOC (total organic carbon) levels were elevated in both wells (35 and 43 mg/L) and in LT31W (20 mg/L) but not LT30W (8.6 mg/L). Metal levels were not elevated in any of the soil samples and pH and conductivity levels were normal in the water sampled from the wells. Nickel levels were found to be elevated in water samples LT31W (<2.0 µg/L) and LT30W (7.9 µg/L) analyzed by AAS. These values are, however, low in comparison to the remediation criteria.

The petroleum product levels indicate that there is potential for contaminated groundwater from this location to migrate to other areas and to resurface and contaminate surface water. Further monitoring wells need to be established in order to fully investigate the extent of the problem and to define the plume of contamination. Remediation of the area will be required if the plume of contamination is migrating into the river or threatens the town's drinking water. However, if this is not the case then other steps such as natural bioremediation possibly assisted by nutrients may be the appropriate remediation method. An oil absorbent boom could be placed across the stream leading from this area to contain surface runoff.

4.5.3 Chemical Storage Area

Sampling

This area is situated between the railway tracks and the paved area where the planes were parked. Several buildings were present in the area which was generally covered with trees and grassland. A small road led from the terminal area to the railway lines. On the north-west side of the road was a former ammunition storage compound. No samples were taken at this location. At the end of the road were two large buildings which were previously used as warehouses. One soil sample (LT39S) was taken between these two buildings. The area in front of the building to the east contained the foundations of former buildings and miscellaneous wooden and metal debris (Photograph-4). A small partially demolished building still remained at the edge of this area. A soil sample (LT40S) was taken from among the building foundations and a white flour-like powder (Lit III-1, Table 2) was collected from the partially demolished building.

Two ponds were found in the open area on the opposite side of the road to the ammunition dump. A water sample (LT41W) was taken from the edge of the pond and a water sample (LT42W) and sediment sample (LT42S) taken from the other. The second pond was covered with duckweed and the water was brown with humic material. It was adjacent to a large building with a chimney. Between this building and the terminal area were several buildings and drainage ditches. Four soil samples (LT45S-LT48S) were taken from these drainage ditches as shown on Figure 8. A soil sample (LT43S) and a water sample (LT43W) were taken from a pit to the south of the large building which was obviously part of a landfill area. Soil sample LT44S was taken from another pit in the area which contained broken fluorescent light fixtures. Two samples of unknown materials were taken from this general chemical storage area. One sample (Lit II-1), taken in duplicate, was from a barrel lying outside one of the buildings (Photograph-5). The barrel was severely corroded and had a hole in it. It contained a yellow liquid with a strong irritating smell. Several barrels were also present inside one of the buildings (Photograph-6) but no attempt was made to sample these because it was not foreseen that this type of sampling would be required and therefore the necessary protective equipment and sampling tools were not available. A second sample (Lit II-2) of yellow flakes was collected in this area from another open drum inside the building.

Results

Low level contamination by lubricating oil (C_{18} - C_{29}) was found in three of the four water samples from this area and at high levels in two of the soil samples (LT47S and LT48S) from the drainage channels near the storage areas. Low level contamination was found in another sample (LT46S) further south-east in the same area. The direction of flow of the water in the drainage ditch perpendicular to the road is not known as no significant flow was present at the time of the visit. However, the high level of contamination in LT48S indicated that migration has taken place. Phenols were found in LT42W and LT43W but this may be due to the naturally occurring high humic levels; TOC levels were also high in these samples. Contamination was absent in the sample from between the two warehouses and from behind the buildings furthest from the road.

Very high levels of cadmium (26, 39 and 31 mg/kg) were found in samples LT46S, LT47S and LT48S respectively, taken from the drainage ditch perpendicular to the road. Elevated levels of zinc (399, 1123 and 1122 mg/kg) were found in all of these samples and high levels of mercury (1.7 mg/kg) and chromium (141 mg/kg) were found in sample LT47S. The corresponding water sample LT47W also contained elevated levels of nickel (15 µg/L) but not cadmium (<0.2 µg/L) and chromium (<0.2 µg/L).

These results show that the drainage area that flows between the buildings is highly contaminated with hydrocarbons and cadmium. The cadmium level is greater than the Canadian guidelines for commercial/industrial sites and the Dutch C criteria (both 20 mg/kg). The direction of flow in the channel is not known. Further sampling of this channel is required to establish the source of the contamination. This could be in the region of LT47S but could also be beyond LT48S or from a landfill site adjacent to the ditch. Vegetation samples from the ditch should be taken to establish if the cadmium is being taken up by plants.

4.5.4 Landfill areas

Sampling

A large landfill was situated adjacent to the railway lines to the northwest of the airfield. The location was originally a quarry and contained a large pond in addition to several smaller ones. The area was open though several plants were growing around the landfill. A distinct edge or toe of the landfill was evident which was several metres in height (Photograph-7). Four soil samples (LT54S and LT56S-LT58S) were taken below the toe of the landfill and one water sample (LT55W) from a small pond immediately adjacent to the toe of the landfill.

Results

Petroleum products were found in three of the four soil samples but not in the water sample from below the landfill. The level was particularly high at the eastern end of the landfill. Phenols were not detected in the water sample but the TOC level of 154 mg/L was high, indicating the presence of organic compounds; priority pollutants were not, however, found in samples LT54S and LT55W. This latter sample, which to some extent represented landfill leachate, contained elevated levels of the metals nickel (24 µg/L) and chromium (19 µg/L) and also various anions particularly fluoride (12.6 mg/L) and chloride (352 mg/L). Metals were not found at elevated concentrations in the soil samples from the landfill.

The elevated chloride level is not particularly high but chloride is generally a good tracer for landfill leachate. Other ponds in the area and drainage ditches and pits could be sampled and analyzed for chloride as a simple procedure for establishing the extent of migration of leachate from the landfill. One or two monitoring wells are also required. The fluoride level is particularly high; Canadian water guidelines range from 1 to 2 mg/L and the Dutch B criteria is 1.2 mg/L for total fluoride. The presence of nickel and chromium in the water from the pond indicates some leaching of these elements and again the extent of this should be checked in nearby water. Leachate containment may be necessary if it threatens to impact the River Juosta or the source of the town's water supply.

4.5.5 Other Areas

Sampling

Several other samples were taken from various locations around the remainder of the site. A small maintenance area was present on the northwest side of the airfield. It contained two buildings and a pile of debris containing gas masks and filters. One of the buildings contained large quantities of two chemicals. A sample of a grey powder (Lit IV-1) of which there was approximately 10 tonnes, was taken. This powder was suspected of being de-icing reagent and bags of it were marked in Russian with "Granulate reagent ANC, produced 1991 by Dneprodzerzinsk AO Azot". The second material, which was thought to be sulphur, consisted of approximately 12 tonnes and was sampled as Lit IV-2. A soil sample (LT33S) was taken approximately 10 m from the river which flowed to the northwest of this area. The sample was about 60 m from the buildings in an area that collected drainage from the buildings and smelt of gasoline. A water sample (LT32W) was collected from the River Juosta. An additional water sample (LT34W) was collected downstream from this sample, 50 m from where it joined the River Nevezis.

The buildings associated with the Pajuoste airfield were located to the northwest of the airfield. Three samples of materials were collected from a small room in a building near the staff headquarters. This room contained several bottles and boxes of chemicals. Some transparent pellets were collected from a wooden box and labeled Lit I-1. Samples of red granular material and a white powder were also collected from the same room and named Lit I-2 and Lit I-W respectively. A well was constructed adjacent to what was thought to be the laundry facility. Four soil samples (LT14S-LT17S) were collected from various depths during the drilling operation and a water sample LT4W taken from the monitoring well. A sample of waste material mixed with soil (LT12S) was taken from near to Well 4 and a samples of black ash labelled LT13S was taken near the chimney of the laundry building.

The radar facilities of the base were situated near the centre and southwest of the main runway. They were reached by a road from the west side of the airfield parking areas. The radar facilities area contained several buildings which were bounded on the west side by a wooded area and a grassy area to the east. Two soil samples were taken from this location. One sample (LT35S) was taken adjacent to the west side of the main building (Photograph-8) outside of the back door. The second sample (LT36S) was taken beside a pile of discarded electronic components at the edge of the woods to the northwest of the radar facilities.

A second maintenance area, near the apron to the south of the site, consisted of a main building and a large paved area. To the rear of the building was a densely wooded area. Immediately in front of this wood was a drainage ditch. A soil sample (LT50S) and a water sample (LT50W) were taken from the ditch. The relationship of this ditch to the rest of the drainage system of the area was not known. A soil sample (LT51S) and a water sample (LT49W) were also taken from the edge of two ponds situated between the drainage ditch and the main maintenance building.

Three further water samples were taken from the southwest area of the site. LT38W and an associated soil sample, LT38S, were taken from a drainage ditch that passed beneath the taxiway. Samples LT52W and LT53W were taken from the river to the south of the main airfield and from the River Nevezis respectively.

Results

Petroleum products were found in the soil sample LT33S but not in the water from the River Juosta (LT32W) near the northern maintenance area. Metal levels were normal. The petroleum products found in the surface drainage of this maintenance area was probably the result of spillage from the fuel supply for vehicles but could represent a much larger problem. A monitoring well is needed in this area to verify the vertical extent of the contamination; water from this well should also be analyzed for volatile organic compounds.

Water from Well 4 (situated near the laundry building), contained a low level of petroleum products (0.2 mg/L) but the four soil samples taken were not contaminated. Phenols were also detected in the well water sample (63 µg/L) but were not detected in any water samples from the rivers. A re-sampling and analysis of this well for phenols will be neccessary if phenols are again detected. An additional well positioned nearer to the River Nevezis would ascertain if the phenols found were likely to impact the nearby environment. Elevated metal levels (cadmium, chromium, copper, and nickel) were found in the black ash sample LT13S indicating that this type of sample observed at several other locations at the site should be removed from contact with the environment; some of these levels exceeded the guidelines.

Sample LT35S also contained some black ash-like material. This sample contained elevated levels of some metals (zinc and arsenic) and petroleum products, indicating that it should also be removed. Sample LT36S taken adjacent to some electronic components contained elevated levels of mercury, cadmium and zinc. Again the electronic debris and underlying soil should be removed. Confirmation testing should be conducted following the removal of all of these contaminated materials. As these are small volumes containing high levels of contaminants, point source removal is the most cost effective solution.

The drainage ditch behind the maintenance building to the south of the airfield was found to be severely contaminated with petroleum products (LT50S). Elevated levels of copper, nickel and zinc were also found in water from this location (LT50W). The samples taken from near the ponds between the maintenance building and the ditch were not found to be contaminated. The source of contamination in the ditch is unknown. It is possible that waste materials were dumped into the ditch at this point, or they could be migrating from a source further to the northeast. Further reconnaissance is required to see how this drainage ditch is connected to the rest of the drainage system in the area. Further sampling is also required to establish the extent and source of the contamination found at this point.

The three water samples and soil sample taken from the southwest corner of the site were not found to be contaminated.

4.6 Summary of field investigations

The limited time available in Lithuania for the field work restricted the amount of work that could be achieved. This report is, therefore, very preliminary in nature. The discussions above have indicated future investigations which should be carried out.

As expected, many samples contained petroleum products. They were found in 7 of the 18 water samples and 15 of the 39 soil samples. Phenols were detected in 5 of the 18 water samples which give TOC levels ranging from 4.0 to 154 mg/L though the second highest concentration was only 43 mg/L. No priority organic pollutants were found in any of the six samples analysed; some phthalates were found but these were attributed to the sampling containers. PCBs were not detected in any of the soil samples.

Elevated levels of metals were found in some samples, but generally contamination in the samples collected was limited. Elements that were found at elevated levels were cadmium, chromium, mercury, nickel and zinc. None of the seven anions were found in particularly high levels except in the landfill water sample. Only those parameters that were elevated above background levels or assessment criteria are discussed in detail below.

Analysis of soil and groundwater samples shows that the most polluted area is the oil storage area. Concentrations of oil products in soil vary from 1000 mg/kg (according to analyses conducted at Lithuanian laboratories) to 368 mg/kg (results obtained from Canadian laboratory) and 40 mg/kg (Norwegian laboratory). The total area of polluted soil reaches about 30,000 m^2. In some oil storage areas concentrations of oil products of up to 17,261 mg/kg have been detected at a depth of 0.5m.

The eight materials analysed from storage areas at the site were found to contain substances as given in Table 2. The main constituents of environmental concern are the chlorinated organic compounds. The dichloroethane was probably used as a degreaser and might prompt analysis for volatile pollutants (for example, USEPA 625 analysis or equivalent) in future water samples from the chemical storage area and maintenance areas. Lit-II-2 was probably used as a pesticide; its environmental toxicity is not known. Urea was used as a runway deicer but the use of the large quantity of sulphur is not known. Urea decomposes rapidly in the environment to give nitrates whereas the ultimate fate of the sulphur would depend on its use.

Table 2. Identification of unknown materials from the storage areas.

Sample	Description	Identity of Major Components
Lit I-1	transparent pellets	silicagel
Lit I-2	red granular material	zeolite
Lit I-W	white powder	sodium carbonate
Lit II-1	yellow liquid	mostly 1,2 dichloroethane
Lit II-2	yellow flakes	4-chlorobenzenesulphonamide and 1,1'-sulphonylbis(4-chlorobenzene)
Lit III-1	white powder	sodium carbonate
Lit IV-1	yellow powder	sulphur
Lit IV-2	gray-white powder	urea and a calcium salt

Analyses of shallow groundwater included detection of main cations and anions, trace elements and oil products. According to general groundwater composition (main anions and cations) in the oil storage area, a concentration of permanganate oxidation (indirect index showing concentration of organic compounds) of 22-60 mgO_2/L has been detected, with total hardness of groundwater ranging from 10 to 37 mg-ekv/L. The Lithuanian drinking water standard limits are 2.0 mg/L and 7 mg-ekv/l respectively. Investigations of trace elements indicate that groundwater in some places is polluted by iron (3.4-7.5 mg/l). The maximum permitted concentration (MPC) for iron in drinking water is 0.3 mg/l. Elevated levels of lead (0.039 mg/l, MPC 0.03 mg/l) and chromium (0.096 mg/l, MPC 0.05 mg/l) were also detected. The highest concentrations of oil products in shallow groundwater were detected in the oil storage area, and reached 886 mg/l (according to the data from Lithuanian laboratories).

The main findings from the field work are as follows:

- Analysis of a sample obtained from a drum at the chemical storage area showed that the dominant chemicals was 1,2 dichloroethane. There were several other drums present in this storage area which should be sampled and analysed. Volatile hydrocarbons, and 1,2 dichloroethane in particular, should be analysed in future water samples from the site; the two maintenance areas and the chemical storage area should be targeted.

- Cadmium was found at high concentrations in a drainage ditch in the chemical storage area along with petroleum products. The source and extent of the cadmium contamination should be ascertained and its impact assessed.
- Groundwater contamination by petroleum compounds was found near the fuel storage areas. The extent of this contamination should be investigated and its impact assessed.
- Other areas where contamination has been found include the two maintenance areas, and the landfill and require further investigation to ascertain if there is significant environmental impact.

5 EVALUATION OF THE REGIONAL IMPACT OF MILITARY POLLUTION

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5.1 Introduction

A large number of contaminated military bases can have a substantial regional impact on the environment. Investigations of soil and groundwater contamination at former military bases in Lithuania have been carried out by a number of national and international teams. However, due to the large number of military bases and limited financial resources, almost all previous contaminant studies were of a local character. Although the regional context is also of great importance, few references exist from such studies. This chapter describes a regional evaluation of pollution from military activity.

As an initial assessment, data from all previous studies carried out by private consultancies and government institutions were collated and summarised. Particularly useful information was obtained from the report by I. Kruger Consult in partnership with the Baltic Consulting Group (1995a) entitled: «Inventory of Damage and Cost Estimate of Remediation of Former Military Sites in Lithuania». Existing geological and hydrogeological information was also examined. The following procedure was adopted for the evaluation of regional contamination from military bases in Lithuania:

- all military bases were classified according to their perceived potential environmental impact;
- the natural geological-hydrogeological conditions existing at each of the bases were categorised according to their vulnerability and inherent potential for contamination;
- a groundwater-monitoring network was established at three selected military bases and water-level measurements and sampling were carried out at these bases; contaminant transport modelling was carried out at a number of selected military bases;
- a groundwater run-off map for the region was compiled;
- a limited number of military bases were identified, which were assumed to be representative on a regional basis;
- the contaminant discharge from each of these selected bases was estimated and used as a basis for extrapolation to estimate the total contaminant flux from all bases.

A description of the methods used and the results obtained are presented in this chapter.

Note: In the following text, a ***report*** (or ***case***) describes a case of environmental damage (e.g. damaged forest) or source of pollution (e.g. leaking oil tank) which has been documented during the inventory survey of military sites. There may be several ***reports*** (or ***cases***) of environmental damage at a single military ***base*** (or ***site***). At each **base**, there may have been one or more military **units** (tank regiments, paratroop regiments, military hospitals etc.) stationed. In fact, 275 ***bases*** were examined, stationing 421 military **units**, resulting in 2743 ***reports*** of environmental damage.

5.2 Classification of military bases according to their perceived potential environmental impact

The following principal types of military bases were identified:

- military forests
- training areas (polygons)
- air-bases
- rocket bases
- border defence units
- communication centres
- fuel storage areas
- tank regiment bases
- infrastructure and service facilities
- military barracks

Each type of military activity and installation is associated with particular pollutants which have a specific behaviour and cause a specific type of environmental damage. Military forests and training areas, for example, are associated mostly with landscape deterioration, timber damage and the devastation of arable lands. The most common sources of contamination from military areas are landfill and waste sites. A large number of military bases including air-bases, rocket bases and fuel storage areas discharge predominantly oil pollutants into the soil and groundwater. The size of the military bases varies significantly, from the size of a single building to large military forests. The extent of environmental damage caused by a base is usually directly related to its size. The range in size of the military bases investigated is presented in Table 3.

Table 3. Variation in size of military bases investigated (I. Kruger, 1995 a).

Size of the sites, ha	Number of sites	Total area occupied, ha
< 1	59	17
from 1 to 10	77	309
from 10 to 100	80	2,718
from 100 to 1000	45	13,594
from 1000 to 10.000	13	37,261
> 10.000	1	13,862
Total	**275**	**67,762**

Table 4 shows the types of observed damage recorded at the bases investigated. This table indicates that in at least 1266 cases (46% of the 2743 total cases), a possibility or real threat of groundwater contamination exists. Of these 1266 cases, oil contamination constitutes 45% and waste contamination constitutes 38%. A total of 566 cases of oil contamination have been registered at 160 bases.

Table 4. Types of damage recorded at the bases investigated (I. Kruger, 1995 a)

Environmental damage	Number of reports
Oil contamination	566
Bacteriological/biological pollution	137
Contamination by chemicals	56
Soil disturbance	778
Damaged forest	249
Radioactive pollution	9
Spill/leakage of rocket propellant	20
Landscape disturbance	438
Explosives	12
Waste sites	478
Total number	**2743**

All 566 reports describing oil contamination were categorised according to contamination source. The results are shown below in Table 5.

Table 5. Oil contamination sources in cases where oil contamination is observed (I. Kruger, 1995 a)

Type of source	Number of cases
Oil/fuel storage	115
Oil/fuel transfer facility	7
Garages	185
Filling station	92
Railway ramp	1
Washing station	58
Other	108
Total	**566**

A total of 214 of the 566 reports describe oil storage activities, while the remaining 352 reports relate to sites where the handling of oil products has taken place (I. Kruger, 1995 a). In 142 cases, fuel was stored in tanks, or groups of tanks, which were either fully or partially covered by soil - i.e. subsurface tanks. In 21 cases, groups of more than 10 tanks were registered. In 210 reports, data on the construction material of the tanks were available: 177 tanks were made of steel and 5 of concrete while the remaining 28 were made of composite concrete and steel. The physical condition of the tanks was classified as "good" at only 15% of the storage sites. Approximately 80% were classified as "unsafe". At 38 bases the lining below the storage was made of clay or concrete. In 132 cases no lining under the tanks was defined.

5.2.1 Soil contamination by oil products

The areal coverage of the 566 cases where oil-contaminated soil was registered is shown in table 6. During the site investigation, hand-drilled boreholes were constructed to a depth of 1 m to estimate the depth of soil contamination. The depth of soil contamination at the 566 oil-contaminated cases was divided into 3 distinct groups:

- 176 cases of shallow contamination at a depth of 0.2 m;
- 212 cases with a contamination depth of 0.2 - 1.0 m;
- 178 cases with a contamination depth of greater than 1.0 m.

Table 6. The size of the oil-contaminated areas.

Size of area, ha	Contaminated area, ha
< 0.1	12
0.1 - 0.5	32
0.5 - 1.0 .	40
1.0 - 2.0	33
> 2.0	282
Total	**399 ha**

5.2.2 Groundwater contamination by oil products

Due to the high cost of borehole drilling, groundwater contamination was investigated at only 15 military bases. Summarised data on the groundwater pollution detected at these bases is presented in Table 7. Groundwater contamination was detected at all investigated military bases built on sandy and sandy loam soils.

Table 7. Military bases where groundwater contamination has been investigated.

Military territory	Area of polluted groundwater, km^2	Max concentration of oil products, mg/l
Kedainiai airfield	0.4	26.0
Pagegiai fuel storage	0.14	13.0
Pajuoste airfield	0.13	6.4-4.2*
Karmelava rocket base	0.008	3.1
Fuel base of Pilainiai engineering regiment	0.03	0.22
Alytus paratroop unit	0.001	51.47
Pabrade fuel base	0.021	15.0
Kazlu Rudos fuel base	0.03	22.5**
Valciunai fuel base	0.1	38.0**
Raudondvaris rocket base	0.01	0.64
Fuel storage of Kairiai tank regiment	0.03	3.15
Zokniai aerodrome	1.0	10.5
Taurage military unit	0.007	600.0 (1.2 dichloroethane); 20.0 (1.1.2.trichloroethane)
Nemenchine civil defence centre	0.03	35.0
Vilnius "Siaures miestelis"	0.014	1.3

* concentration recorded during the joint Lithuanian - Canadian - Norwegian investigations;

** -concentration recorded during a groundwater monitoring course.

5.2.3 Surface water pollution by oil products

In 119 cases the oil-contamination source is located within 200 m of a surface water body (river or lake). In 35 of these cases direct influence of oil contamination on surface streams was observed. The relationship of oil contaminated bases to surface water bodies is shown in Figure 9.

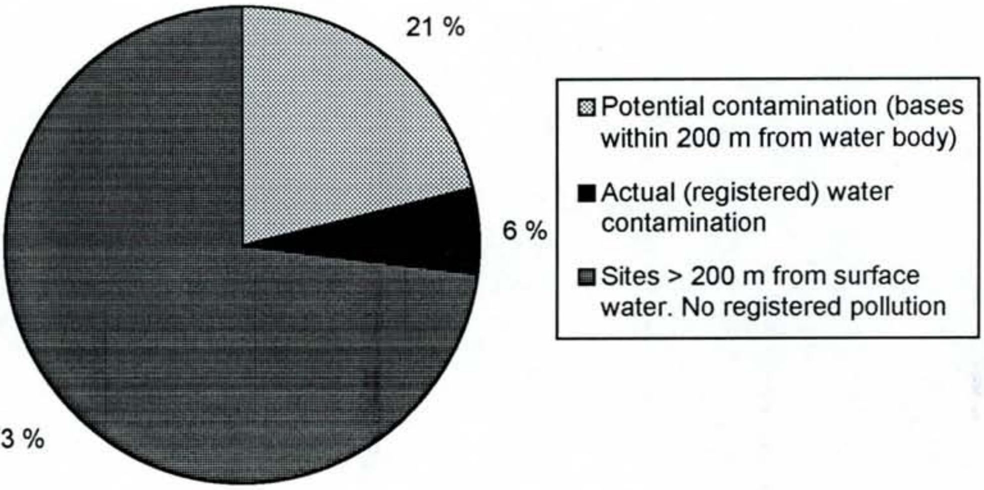


Figure 9. The relationship of oil contaminated sites to surface water bodies.

A study of the site inventory indicates that in most cases environmental contamination from the military bases is related to surface run-off. However, subsurface infiltration is also an important factor in contaminant transport on a regional scale, as polluted groundwater discharges into surface streams. This issue will be considered in greater detail below.

5.3 Classification of the geological and hydrogeological conditions at military bases

Shallow unconfined groundwater is found throughout much of Lithuania. It is used for drinking purposes with 1 million inhabitants taking water from 350 000 dug wells, mostly in rural areas. Groundwater depth is closely related to landscape and drainage conditions. The groundwater level normally lies between 0.5-5.0 m below ground level (b.g.l.), in upland areas reaching 10 m below ground level (b.g.l.). The vulnerability of shallow groundwater depends on both the lithology and thickness of the vadose (unsaturated) zone.

The amplitude of groundwater level fluctuation depends on the lithology of the water-bearing strata, which is often the same as that of the vadose zone. The average annual water-level fluctuation in sandy soils is 0.2-0.7 m whilst in tills and clays the fluctuation amplitude reaches 1.5-2.0 m and more. Large areas of Lithuania are composed of sandy soils. Shallow groundwater is therefore poorly protected from contamination at both a local and regional scale. A shallow aquifer acts as an initial barrier protecting deeper confined aquifers from pollution. Contaminants penetrating the vadose zone of a shallow aquifer can be transported by groundwater flow to surface streams. Figure 10 demonstrates that in over 80 % of cases, military bases are located on very vulnerable geological formations - sand, gravel or sandy loam.

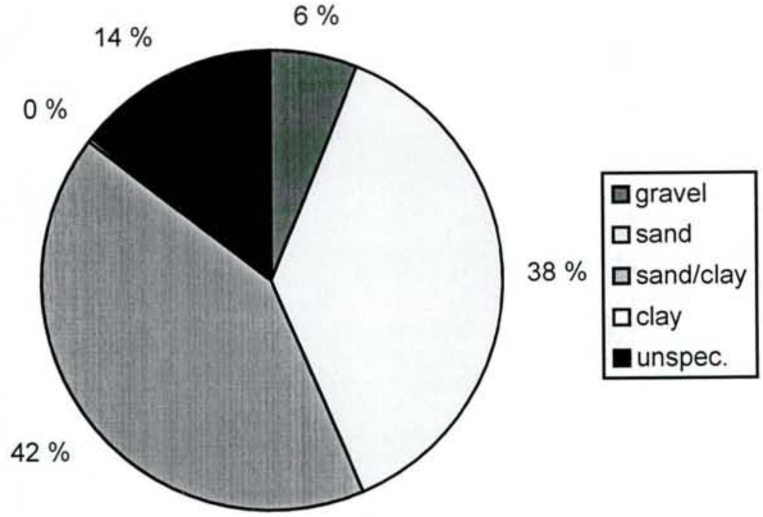


Figure 10. Soil types at contaminated sites

The military bases assessed have been categorised according to their groundwater run-off characteristics. Groundwater run-off has been quantified as an integrated index representing the rate of groundwater discharge into surface streams per unit area. This index reflects the surface geology of the area: the lithology and thickness of vadose zone, the lithology of water-bearing sediments and groundwater recharge conditions. Given the groundwater run-off and contaminant concentration, the flux of contaminants transported to surface streams by the groundwater flow can be estimated. This amount is used as the main index for the regional assessment of military pollution. Shallow groundwater resources and run-off in Lithuania have previously been evaluated in detail (D. Sakalauskiene 1982). The groundwater run-off index for different regions of Lithuania is presented in Table 8.

68 military bases are located on sandy soils where the groundwater run-off index is typically 1-5 l/s.km^2 (100-400 m^3/day.km^2). In this case the flux of contaminants discharged into surface streams depends on the contaminant concentration, the distance to the stream, and the rates of attenuation or degradation of contaminants in the aquifer. For the assessment of the regional impact of military pollution on the environment, only the 160 bases on which oil contamination was detected were considered. These bases were

superimposed on a digitised version of the topography/groundwater run-off map linked to global co-ordinates (Figure 11).

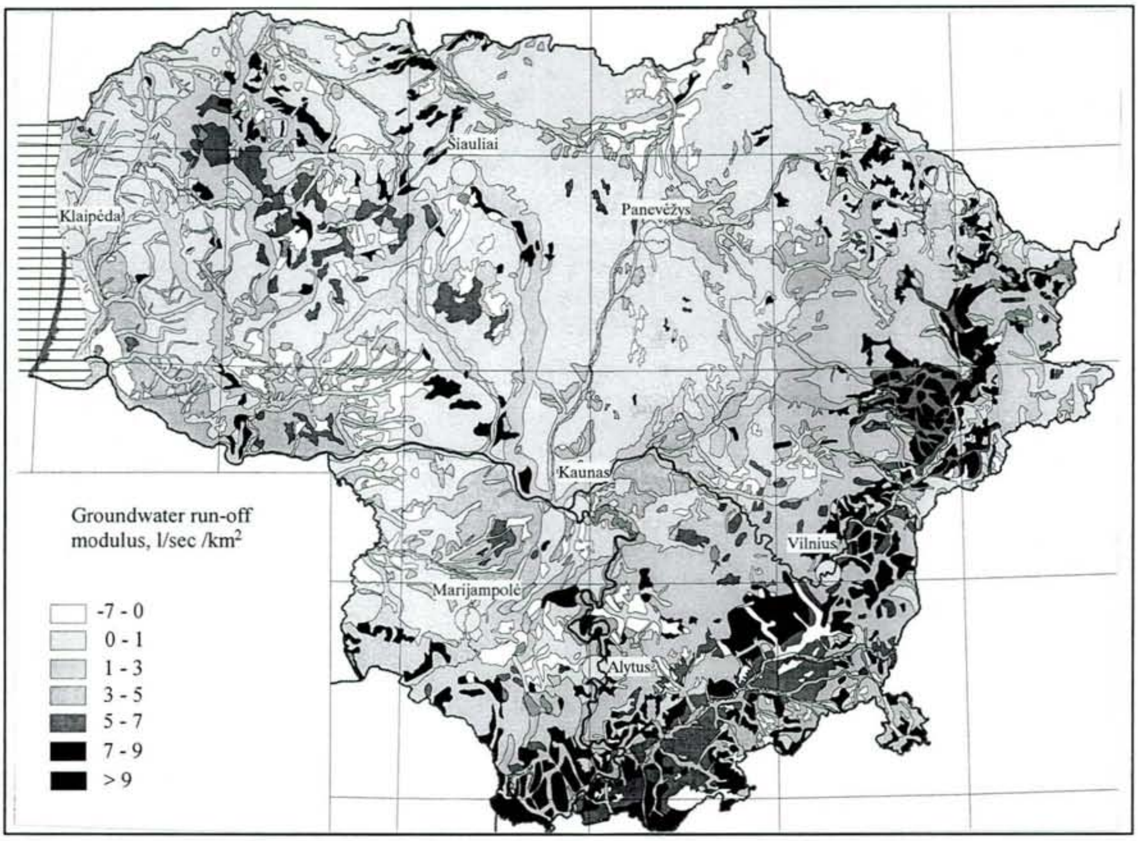


Figure 11. Groundwater run-off map of Lithuania

ARCINFO software was used for the conversion of global co-ordinates into the Lithuanian co-ordinate system used in the project. All relevant information was then transferred to the MAPINFO programme and a final groundwater map with a legend and captions compiled and printed.

Table 8. Groundwater run-off distribution in Lithuania (Sakalauskiene, 1982).

Region	Lithology	Area,	Storage Coeffi-cient	Dynamic resources	Groundwater runoff Total	per km^2
		km^2		m^3 /km^2/d	m^3/d	l/s km^2
1	2	3	4	5	6	7
Maritime lowland	Peat,	103	0.001	0.2	89	0.01
	Moraine till, loam,	2984	0.004	8.0	77500	0.30
	Sand, poorly sorted	2922	0.009	135.0	1420000	5.64
	Clayey and fine-grained sand	518	0.140	70.0	131000	2.95
Zemaitijos highland	Peat,	355	0.001	0.2	378	0.01
	Loam,	173	0.003	0.9	497	0.03
	Moraine till	4916	0.004	8.0	134000	0.31
	Sand fine-grained, clayey,	763	0.090	135.0	386000	5.85
	Sand middle-grained	169	0.190	57.0	29900	2.05
	Sand poorly sorted, gravely.	1196	0.200	180.0	732000	7.08
	-"-	555	0.210	126.0	232000	4.84
	Sand coarse-grained	435	0.230	161.0	262000	6.98
Middle Lithuanian lowland	Peat,	157	0.001	0.2	171	0.01
	Sandy loam, loam,	3022	0.004	7.2	80300	0.31
	-"-	12904	0.004	8.0	381000	0.34
	Sand fine-grained,	1031	0.140	84.0	320000	3.59
	Sand fine-grained, gravely,	5507	0.160	160.0	3250000	6.83
	Sand middle-grained,	58	0.180	126.0	27000	5.38
	Sand coarse-grained, gravely	1418	0.230	161.0	842000	6.88
	Sandy gravel deposits	282	0.260	182.0	180000	8.39
1	2	3	4	5	6	7
South-Eastern sandy plain	Peat,	57	0.001	0.2	31	0.01
	Sand fine-grained,	1080	0.110	22.0	745000	0.80
	Sand coarse-grained,	1619	0.210	126.0	236000	1.69
	Sand coarse- grained, gravely,	2078	0.230	161.0	1100000	6.15
	Sandy gravel deposits	292	0.260	52.0	47900	1.90
	Total:	61070	-	57.9	1190000	2.26

Note: ***Dynamic resources*** = integrated groundwater recharge from natural and anthropogenic sources (infiltration of precipitation, recharge from rivers, water basins, reservoirs, irrigation etc.).

Given the concentration of pollutants at typical military bases and the groundwater run-off index, it is possible to estimate contaminant transport to the surface water bodies, and consequently assess the regional impact of military pollution on groundwater and the environment in general. In these estimates, attenuation of pollutants, e.g. by biodegradation, is not taken into account. These estimates therefore represent an upper limit to the pollution potential. For the regional assessment of military pollution cases were selected where identified oil contamination was located less than 200 m from surface streams. These included the 15 bases where more detailed hydrogeological investigations were undertaken. The distance of 200 m was selected, as mathematical modelling of the Kazlu Ruda oil storage site indicates that in sandy soils oil products will typically not migrate more than 200 m from the pollution source in 10 years. Site selection was based on two considerations:

(i) that the dominant part of groundwater run-off discharges into surface waters (rivers and lakes);

(ii) that the site lies less than 200 m from the surface water. As stated above previous research has indicated that hydrocarbons dissolved in shallow groundwater can be transported up to 200m by groundwater flow within a period of c. 10 years. (However, exceptions from this rule-of-thumb exist and these are described below. One such case is the Siauliai (Zokniai) military base.)

Groundwater run-off figures for the 15 military bases where hydrogeological investigations were undertaken bases are presented in Table 9. Difficulties were encountered as contaminant concentrations are only known for these 15 bases. At other bases, contaminant concentrations could only be estimated by analogy with other sites with similar military activity and geological and hydrogeological conditions. Furthermore, additional data have recently become available and updating of the estimations presented in this report may be necessary.

Table 9. Groundwater run-off at the investigated military bases

Military territory	Groundwater runoff, l/s.km^2	Groundwater runoff, thus m^3/day.km^2
Kedainiai airfield	3-5	0.2 -0.4
Pagegiai fuel base	3 -5	0.2 - 0.4
Pajuoste airfield	0 - 1	0 - 0.1
Karmelava rocket base	3 - 5	0.2 - 0.4
Fuel base of Pilainiai engineering regiment	3 -5	0.2 - 0.4
Alytus paratroop unit	3 - 5	0.2 - 0.4
Pabrade fuel base	1 - 3	0.1 - 0.2
Kazlu Rudos fuel base	3 - 5	0.2 - 0.4
Valciunai fuel base	7 - 9	0.6 - 0.8
Raudondvaris rocket base	1 - 3	0.1 - 0.2
Fuel base of Kairiai tank regiment	0 -1	0.0 - 0.1
Zokniai airfield	1 - 3	0.1 - 0.2
Taurage military unit	1 - 3	0.1 - 0.2
Nemenchine civil defence centre	1 - 3	0.1 - 0.2
Vilnius "Siaures miestelis"	1 - 3	0.1 - 0.2

5. 4 Modelling of pollution transport from representative military sites with typical geological conditions

Oil contaminants are the main pollutants originating from Lithuanian military bases. It was mentioned above that oil contamination can be transported up to 200 m /decade in sandy soils by groundwater flow. However, in some hydrodynamic situations such as occur near groundwater abstractions, contamination can migrate greater distances both horizontally and vertically. Siauliai (Zokniai) air-base is the best example of this and is described below.

5.4.1 Siauliai (Zokniai) airbase

According to Kadunas and Domasevicius (1997), Siauliai and its surroundings (Figure 12) are situated on a complex sequence of aquifer and aquitard horizons, the aquifer units having varying potential value as groundwater resources. Groundwater from the deepest utilised aquifer, The Devonian Stipinai (D3st) aquifer (Figure 13), is abstracted by all the main city wellfields, at Lepsiai, Birute and Bubiai.

The Devonian Stipinai aquifer is separated from the next overlaying aquifer horizon, of Permian (P2) age, by a thick layer of Devonian dolomites, limestone and marls. This aquitard is regarded as 'leaky', permitting vertical filtration of water from one aquifer to the other. The Permian aquifer is overlain by Quaternary deposits over the major part of the area. Only in the western part of city do Triassic (T) red clays intervene between the Permian aquifer and Quaternary deposits.

The Quaternary materials are dominated by loamy glacial till which reaches 50-60 m thickness in Siauliai city. Within the till sequence is one so-called intermorainic aquifer, whose full extent has not, as yet, been adequately defined. It tends to occur between the depths of 10-15 m and 30-40 m. Water is abstracted from this aquifer by a limited number of private wells. Shallow groundwater is also find in surficial deposits of varying composition, mainly weathered glacial till. Shallow groundwater in such shallow deposits is widely abstracted by numerous dug wells, particularly in areas were a centralised water supply system does not exist.

Mathematical modelling of the Siauliai air-base (Figure 12) was undertaken with the principle objective of evaluating the threat posed to the main aquifer (upper Devonian Stipinai) by oil-contaminated groundwater. A secondary objective of the modelling was to determine how far dissolved hydrocarbons migrate with groundwater flow. The 3 km profile from Siauliai airport to the Lepsiai well field was modelled including 1 km in the air-base area and 2 km towards the Lepsiai well field north of the air-base.

The participants of the project described in this report were involved in the mathematical modelling of pollution transport at the site. The base was also investigated in detail by the I. Kruger Consult & Baltic Consulting Group (1995b) conducting the project "Investigations and Clean Up of Oil Contamination on the Former Military Air-base in Siauliai, Lithuania". The upper (Quaternary) aquifer at the base is locally contaminated by dissolved oil products. Free phase oil is also present in a few localised areas. The

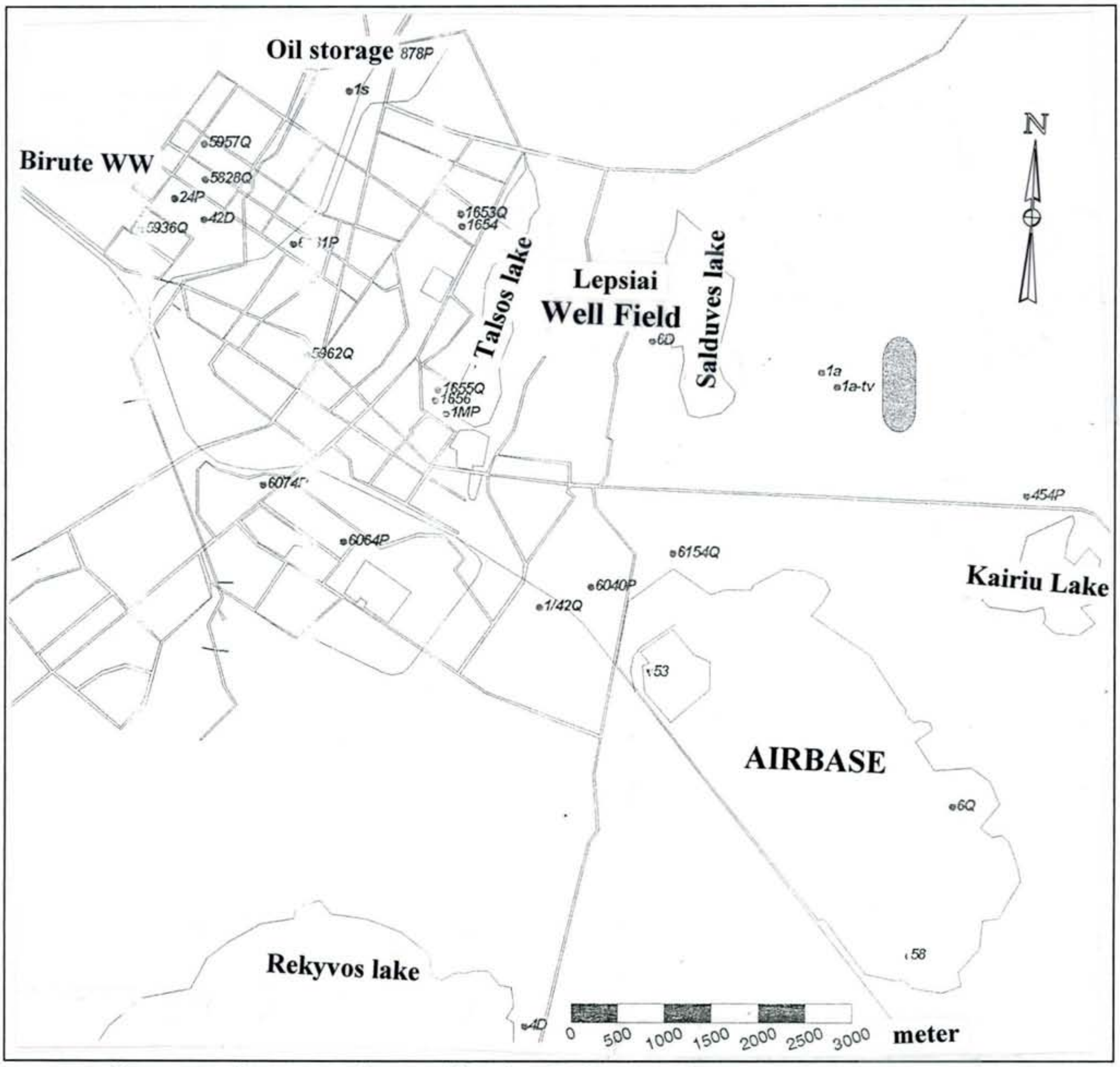
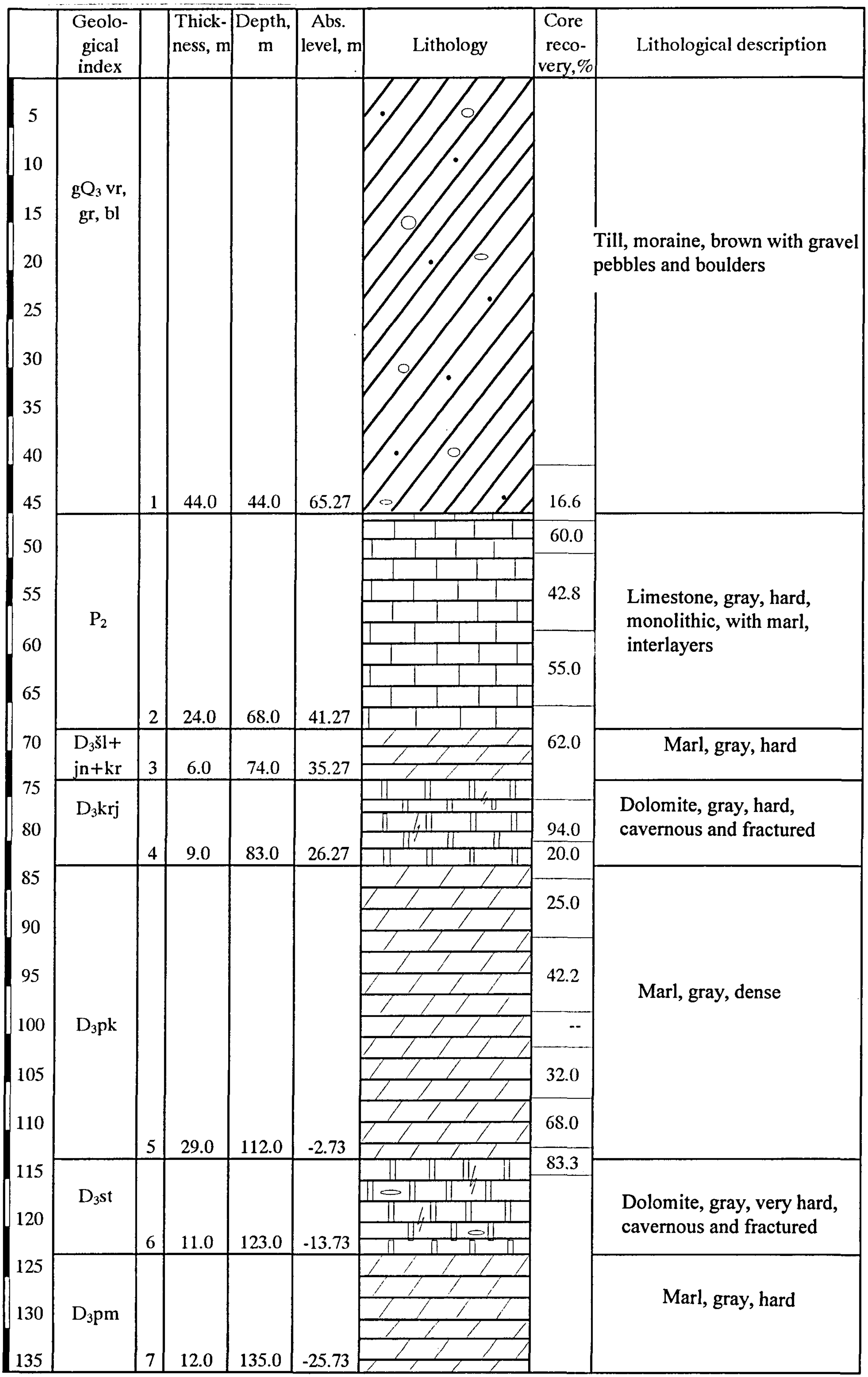


Figure 12. Location scheme of Siauliai (Zokniai) airbase

contaminated groundwater may in time spread to the areas surrounding the air-base and reach private wells, surface water bodies, etc. Two lakes lying to the NE and SE of the air-base and the streams running from the air-base to the lakes have already been contaminated by oil products.



	Geological index		Thickness, m	Depth, m	Abs. level, m	Lithology	Core recovery,%	Lithological description
5 10 15 20 25 30 35 40 45	gQ_3 vr, gr, bl	1	44.0	44.0	65.27		16.6	Till, moraine, brown with gravel pebbles and boulders
50 55 60 65	P_2	2	24.0	68.0	41.27		60.0 42.8 55.0	Limestone, gray, hard, monolithic, with marl, interlayers
70	D_3šl+jn+kr	3	6.0	74.0	35.27		62.0	Marl, gray, hard
75 80	D_3krj	4	9.0	83.0	26.27		94.0 20.0	Dolomite, gray, hard, cavernous and fractured
85 90 95 100 105 110	D_3pk	5	29.0	112.0	-2.73		25.0 42.2 -- 32.0 68.0	Marl, gray, dense
115 120	D_3st	6	11.0	123.0	-13.73		83.3	Dolomite, gray, very hard, cavernous and fractured
125 130 135	D_3pm	7	12.0	135.0	-25.73			Marl, gray, hard

Figure 13. Geological column of Lepsiai well field

Based on the results of the site investigation, an assessment can be made of the risks associated with the contamination and its impact on the upper groundwater aquifer and nearby surface water bodies. Important factors to be considered in such an assessment are the nature of the soil contamination (extent, depth, type, degree, etc.), soil characteristics, aquifer characteristics, groundwater flow direction, distance to surface water bodies and the degree of hydraulic contact between the upper Quaternary groundwater aquifer and the surface water bodies.

The Quaternary deposits in the Siauliai area are represented by a terminal moraine consisting predominantly of a silty till with sand and gravel-pebble-sand lenses. Such fluvio-glacial sand or sand and gravel deposits are found in the immediate subsurface across a large part of the Siauliai military air-base and the area to the SE. The thickness of the moraine deposits (till, including sand and gravel) varies from 42-44 m in the area NE of the airport to 80-90 m in depressions in the pre-Quaternary surface and in the area SW of the air-base. The thickness of the sand and gravel deposits is up to 30 m. The chemical composition of groundwater sampled from the area is shown in Table 10.

Contamination by oil products in the soil and upper groundwater aquifer is infiltrating deeper into the ground and could threaten groundwater quality in the main Devonian aquifers used for potable water supply. In this case, the aquifer is a limestone/dolomite lithology. The vulnerable well fields are those supplying the city of Siauliai, particularly the Lepsiai well field located approximately 2 km NE of the air-base (Figure 12).

Data from the site investigation were used as input for the model. Formation permeability in Quaternary deposits was estimated from grain-size analyses using the equations of Kozeni, Kruger and Slichter. Porosity (n) was determined using laboratory methods. The groundwater flow velocity was estimated using Darcy's Law.

Table 10. Chemical composition of shallow groundwater at the Siauliai air-base.

Parameter	Min. concentration mg/l	Max.concentration mg/l	Average concentration mg/l	Maximum permissible concentration mg/l
Total Dissolved Solids	422	1182	701	1000
Total hardness (Mg + Ca meq/l)	3.5	14.99	10.2	7
Permanganate oxidation (mgO_2/l)	0.64	25.13	3.24	5
Ca^{2+}	30	300	147	-
Mg^{2+}	0	85.4	35.4	30
Na^+	13.3	111	44.6	200
NH_4^+	0	4.22	0.19	0.5
Cl^-	7	211	75.1	350
SO_4^{2-}	9.1	215.8	85	250
NO_2^-	0	4.5	0.18	3.3
NO_3^-	1.5	141.2	48.9	45

The Russian/Swedish solute transport groundwater model FLOW3 (simulating two-dimensional contaminant migration) was used together with MTS (Mass Transport Simulation) software designed for multi-layer modelling of solute transport in aquifers. The transport problem was solved under steady-state groundwater flow conditions using the Russian GWFS (Ground Water Flow Simulation) software system.

The mathematical models are able to take into consideration changes in concentration of the chemical component caused by convective transport, hydrodynamic dispersion and diffusion, sorption (under equilibrium conditions assuming a linear isotherm), contaminant sources, recharge and leakage and sources and sinks (e.g. wells and drains, surface reservoirs and streams). The transport calculation is based on the method of characteristics (MOC) using the "particles-in-cells" scheme. Transport is simulated by the use of particle tracking. For this study, attenuative factors such as adsorption, dispersion and biodegradation were not taken into consideration. The results of the modelling exercise therefore represent a 'worst-case' scenario.

In the modelling procedure, the time period is broken down into a number of time intervals. Within each time interval, the number of time steps is defined by the size of the time step which, in turn, is defined automatically from the stability criteria of the calculation algorithm. Simulation tests for the classical doublet scheme in homogeneous media demonstrated that numerical dispersion in the method is negligible compared with that of finite-difference methods when applied to similar problems.

The theoretical and modelled concentration values in the abstraction well were in good agreement, even where particle numbers per cell were small (i.e. 13 - 19). The spatial distribution of the particles shows a high sensitivity to the number and spatial arrangement of the particles being traced. Heterogeneous media drastically complicate the temporal and spatial behaviour of the tracer so that no simple scheme (such as dispersion) produces a good match. Two-dimensional transient groundwater flow through intermediate layers in an anisotropic saturated system, consisting of intercalated aquifers and aquicludes, can be described by the equation (Mironenko, 1983):

$$\frac{\partial}{\partial X}(T^{k}\frac{\partial H^{k}}{\partial X})+\frac{\partial}{\partial Y}(T^{k}\frac{\partial H^{k}}{\partial Y})+G(H^{k-1}-H^{k})+R(H^{k+1}-H^{k})+q^{k}=\mu^{k}\frac{\partial H^{k}}{\partial t} \quad (1)$$

,

where

T	transmissivity of the water-bearing sediments, $[L^2/T]$
H	groundwater head, [L]
G, R	vertical permeability coefficients (ratio of conductivity to thickness of low-permeability layer), $[T^{-1}]$
q	source or sink disturbing natural infiltration (e.g. pumping well), $[L^3/T]$
μ	storage coefficient, [].
t	time, [T]
k, k+1, k-1	aquifer indices, [ ].

Four aquifers and their confining layers were defined for the modelling (Fig. 14).The input data for the model were chosen in order to simulate the conditions most favourable for the spreading of contamination. This produces ‘a worst case scenario’ where conditions produce the highest rate of infiltration and migration of contaminants. The input data were collated from the field investigation of this site and data collected during previous geological and hydrogeological investigations in similar lithologies.

The results of the site investigation indicated that the upper part of the Quaternary sediments is contaminated by oil products. In the investigated area, contamination is migrating heterogeneously vertically and horizontally. The maximum concentration of oil products measured in the soil is 46,750 mg/kg whilst the maximum concentration of dissolved oil in the upper aquifer is 10.5 mg/l. The maximum concentration of dissolved oil in the inter-moraine aquifer (aquifer II-I zm-dn) overlain by silty till (17.5 m thick) is 0.15 mg/l.

The natural direction of groundwater flow in the Quaternary deposits is towards the SW, away from the Lepsiai well field (the nearest well field), located only about 2 km NNE of the air-base. The only possibility for the migration of contaminants to the well-field is therefore by infiltration to the lower aquifers at, or further downstream from, the contaminated sites. Groundwater abstraction from the lower aquifers will facilitate the migration of contaminated groundwater once it enters the lower aquifers. The Lepsiai well field exploits the Stipinai aquifer (D_3st) at an average yield of 20,000 m^3/day

The site investigation indicated that the upper Quaternary aquifer has a limited extent. In the upper part of the Quaternary deposits, towards the Lepsiai well field, a silty till with localised sand lenses is dominant. This till was assumed to represent a low permeability layer in the model. (Fig. 14).

The model also delines the Zemaitija-Dainava inter-moraine aquifer (aquifer II-I zm-dn), which is found at a substantial thickness only at the air-base. In the direction of the Lepsiai well field, silty till is predominant although thin sandy layers are also present. In the model, this inter-moraine aquifer was assumed to extend the entire length of the profile (i.e. "a worst case scenario"), thus creating the theoretical possibility of the continuous migration of contaminants to the Lepsiai well field (see Figure 14).

Finally, the Upper Permian (P_2) and the Upper Devonian Stipinai aquifers were defined in the model. The 90 m thick layer separating the Stipinai and Permian aquifers was defined as a low permeability layer, although thin aquifers (such as the 9 m thick Kruoja (D_3krj) aquifer) are present within this layer (Figure13). However, this assumption appears valid given the difference between the piezometric heads of the Permian and Stipinai aquifers which can be over 30 m. The lower boundary of the model is the Pamusio bed (D_3pm) which has a thickness of 50-60 m and is modelled as a no-flow boundary (i.e. impermeable). The upper boundary condition used in the model is a constant recharge across the airfield area to the upper aquifer and zero infiltration (due to low-permeability tills) in the area between the airport and the well field. The end boundaries are constant head boundaries in accordance with the piezometric heads created by the well field.

According to the Siauliai Hydrogeological Company, the piezometric head within the Permian aquifer (P_2) at the air-base is 97.0-97.7 m a.s.l. and 65.0 m a.s.l at the Lepsiai well field. The piezometric head of the Stipinai aquifer at the air-base is 62.4 m a.s.l and 40.65 m a.s.l. at the Lepsiai well field. If the Stipinai well field is exploited at its full capacity, the piezometric head in the aquifer will decrease.

The permeability values used in the model were taken from the results of the modelling assessment of the Lepsiai well field and a number of on-going water resources investigations. These results indicate that the permeability of the upper part of the Quaternary water-bearing sediments varies from 0.7 to 7.4 m/d. At the air-base, it was found that the prevailing permeability is 1-3 m/d. A permeability value of the upper aquifer of 3 m/d was used in the model, i.e. the value giving the highest groundwater flow velocity and maximum contaminant migration. Pumping test data from tests carried out indicate that the permeability of the inter-moraine Zemaitija-Dainava aquifer is approximately 1 m/d. This value is used in the model.

The permeability values for the Permian and Stipinai aquifers, the confining layers and the Quaternary silty till were all derived directly from regional modelling results. The modelling assessment of the Lepsiai well field indicated that the transmissivities of the Permian and Stipinai aquifers are approximately 100 m^2/d and 370 m^2/d respectively. In the model profile, the average thickness of both the Permian and Stipinai formations is 15 m, giving permeability values for the Permian and Stipinai aquifers of 7 m/d and 25 m/d respectively. The thickness of the Quaternary silty till is modelled as 60 m and the permeability of the low permeability formations is approximately 0.001 m/d. This value is in agreement with the results of the regional modelling and laboratory analyses. The average permeability of the low permeability layer separating the Permian and Stipinai aquifers is 0.009 m/d. The average thickness of this layer is approximately 90 m (Figure 14.)

Definition of the effective porosity of the waterbearing and low permeability formations was more complicated. Data on the effective porosities of the aquifers were available from geophysical well logs, laboratory analyses of borehole cores and from the results of calculations using empirical equations. However, data on the effective porosity of the lower permeability formations are not abundant. Determination of these values (especially those of the clay formations) from laboratory analysis of the borehole core obtained during the site investigations was not practical. Data from neutron cone penetrometer tests conducted on the Lithuanian coast and laboratory analyses conducted during detailed investigations of the Mazeikiai well field and from the solution of inverse problems of mass transfer in the N. Akmene region (Miksiene 1994) were therefore used.

The effective porosity values determined from the results of the neutron cone penetrometer tests conducted on core samples from the Lithuanian coast (where permeability values are similar to those of the Siauliai region).

An effective porosity of 0.05 and permeability of 7 m/d were used in the model of Zokniai air-base for the Permian aquifer horizon. A permeability of 25 m/d and a porosity of 0.20 are assumed for the Stipinai dolomite. The effective porosity values for the low permeability formations were taken from the solution of the inverse problem of mass transference in the N. Akmene region (Miksiene 1994). Effective porosity values of 0.007 and 0.0085 are assumed for the Quaternary loam and the low permeability layer between the Permian and Stipinai aquifers respectively. The effective porosity values for the inter-moraine aquifer and the upper aquifer are assumed to be 0.02 and 0.04 respectively (Figure 14).

The modelled area was divided into grids with a horizontal discretisation of 50 m and a vertical discretisation of 15 to 25 m. During the initial stages of the modelling, analytical calculations were undertaken to assess the possibility of contaminated groundwater reaching the Lepsiai well field by infiltration into lower aquifers. The results of this assessment are presented in Table 11 below.

Table 11 shows that the total travel time of vertical flow between the Upper Quaternary and Stipinai aquifers at the Siauliai military air-base is approximately 446 days. Contaminants in the Stipinai aquifer would then take c. 2222 days to travel in the Stipinai aquifer to the Lepsiai well field from the air-base.

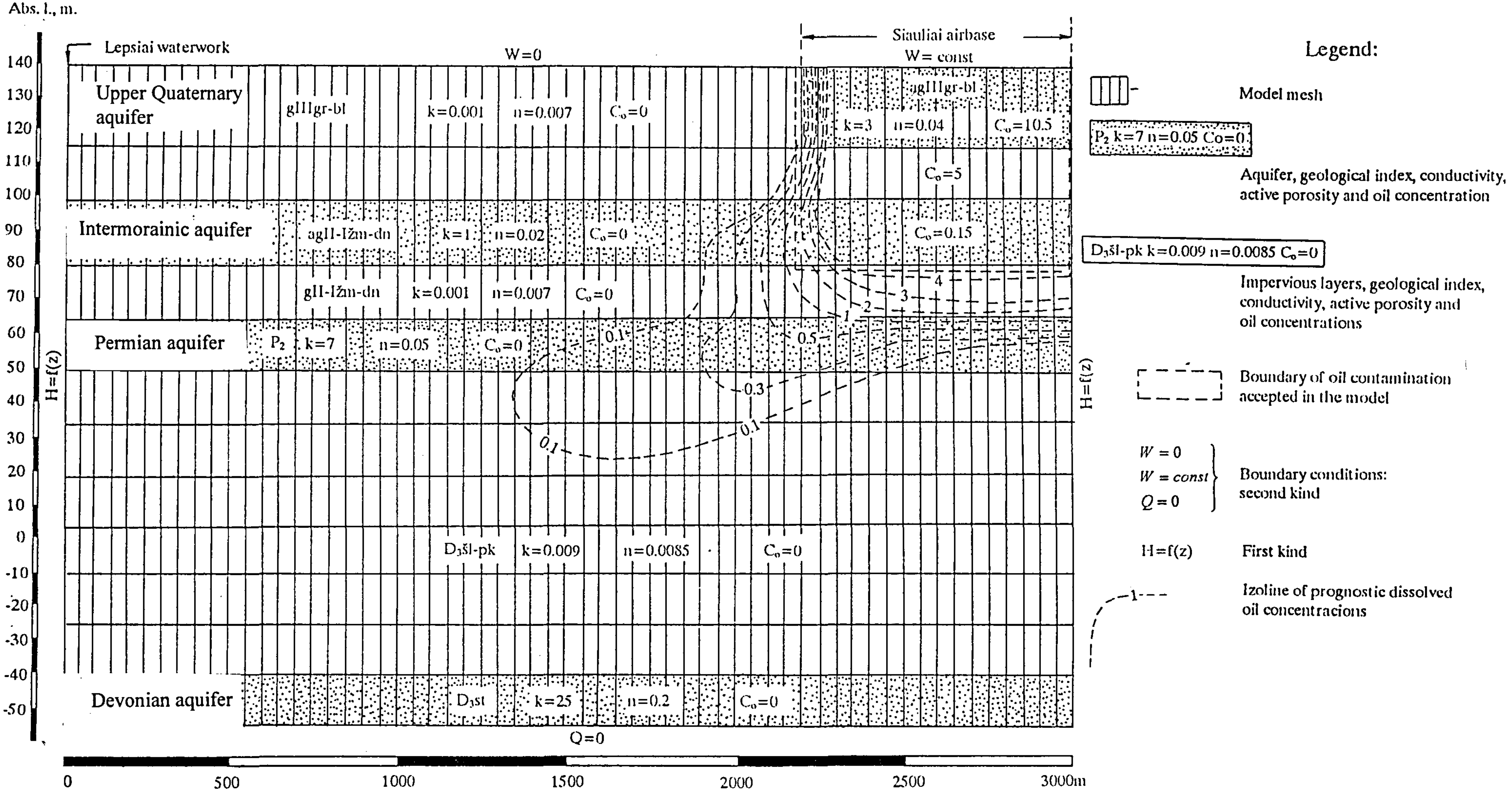


Figure 14. Model filtration scheme of Siauliai airbase.

Table 11. Theoretical travel times for vertical flow between aquifers at the Siauliai military air-base, and approximate representative piezometric levels and thicknesses.

Aquifer	Piezometric level, m	Thickness of low K layer, m	Flow duration, days
Unconfined (shallow)	130		
		17.5	119
Intermoraine	112.04		
		15	110
Permian	97.7		
		90	217
Productive Stipinai	62.4		
Total	-	-	446

The total travel time for contaminants transported vertically into the Stipinai aquifer and then horizontally to the Lepsiai wells is approximately 2700 days or 7.5 years (Figure 14). Again it is emphasised that these estimates take no account of attenuative processes such as sorption or biodegradation.

The migration model was constructed to determine the distribution of dissolved oil products in the ground when contaminants migrate through aquifers and mix with fresh groundwater. Values representing a "worst case scenario" were selected for input to the model. Concentrations of the dissolved oil products in the upper and inter-moraine aquifers at the air-base were chosen as 10.5 and 0.15 mg/l respectively. The concentration of oil products in the layer separating the upper and inter-moraine aquifers used in the model was assumed to be 5.0 mg/l. In all other model layers (in both water bearing and low permeability formations) the initial concentration of oil products is assumed to be zero.

The natural degradation of oil products and sorption, which will of course also decrease contaminant concentrations, has not been taken into consideration. At the upper boundary of the model near the border of the air-base, an infiltration value (W) of 180 mm with a concentration of dissolved oil products of 0 mg/l was used, i.e. it is assumed that the surficial source of contamination has been removed at model time t=0.

The modelled period was set to 25 years, i.e. a time period where continued abstraction at the well field is likely. Results of the modelling indicate that after 25 years, significant concentrations of dissolved oil will only be present in groundwater in the Quaternary layers. The concentration of dissolved oil in the upper aquifer will decrease to 4.2-4.4 mg/l due to the infiltration of fresh rain water. The concentration of dissolved oil in the inter-moraine aquifer will increase to 3 mg/l due to the vertical migration of contaminated water. There are large stable resources of fresh groundwater in the Permian aquifer and there is a large inflow of fresh water (due to a significant hydraulic gradient of 0.011) from the model boundaries. When contaminated water penetrates the aquifer, the processes of mixing and dilution reduce the concentration of oil products by a factor of 5-8, to a value below the drinking water limit for potable water in Lithuania (0.3 mg/l). Despite the fact that groundwater reaches the Stipinai aquifer relatively quickly, the model did not indicate the future occurrence of high concentrations of oil products in this aquifer, due to dilution during vertical infiltration.

The results of the modelling using "the worst-case hydrogeological and contamination scenario" indicated that, within 25 years, the contaminants might reach a depth of 115 m and migrate 1650 m from the border of the air-base towards the Lepsiai well field. The concentration of dissolved oil would, at that time, be 0.1 mg/l at the well field, i.e. one-third of the maximum allowable level (0.3 mg/l). It should be remembered, however, that the migration is enhanced by human activity, i.e. groundwater abstraction. As will be shown later, dissolved hydrocarbons migrate much shorter distances under non-stressed conditions (i.e. no artificial abstraction), although in such a situation less dilution might be available.

The modelling results indicate that in specific conditions of groundwater withdrawal, oil contamination may migrate more than 200 m horizontally within periods of a few decades. It is emphasised that this is a worst case scenario not taking degradation into account.

5.5 Regional assessment of groundwater contamination

An assessment of the regional contaminant discharge into the environment was undertaken at three levels of detail:

Level 1 Detailed calculations (numerical modelling) for the 3 selected military bases where groundwater monitoring was carried out. For each base both contaminant concentrations and hydraulic parameters of the soils were known;

Level 2 Calculations for further 12 military bases with known pollutant concentrations, but unknown hydraulic soil properties. Hydraulic parameters were estimated by analogy to other similar sites (the 15 bases, level 1 and 2 are shown in table 9);

Level 3 Other military bases (c. 100) where few data were available. Concentrations of oil products and hydraulic properties of the soils were estimated by analogy and extrapolation from known values.

A groundwater run-off map at the scale of 1:500 000 was used for the assessment of potential contaminant discharge. Given the groundwater discharge index and the area of contamination, the quantity of affected groundwater can be estimated from the following equation:

$$Q = M \times F,$$

where

$M =$ the groundwater run-off index (m^3/day.m^2);
$F =$ the size of the contaminated area (m^2).
$Q =$ quantity of affected groundwater (m^3/day)

Investigations at the first and second accuracy levels indicated that significant discharge of polluted groundwater only occurs into surface water bodies (i.e. rivers and lakes) and could be observed in groundwater discharge zones in sandy soils.

The following assumptions were made for the assessment:

- if a military base is located within 200 m of a river or lake, contaminants seeping into the groundwater will reach the river or lake;
- if the soil is polluted, contaminants will affect shallow groundwater (especially if the soil is sandy);
- oil contaminants do not significantly degrade biochemically during migration over a distance of 200 m.

Given these assumptions, the amount of oil contaminants reaching the shallow groundwater was calculated using the equation:

$$L = C \times Q,$$

where:
C = background oil product concentration (mg/l).
L = contaminant flux (mg/day)
Q = water flux through base (l/day)

5.6 Evaluation of contaminant transport at typical military sites

Three bases were selected for the detailed (level 1) evaluation of pollution transport: the Pajuoste airfield, the Kazlu Ruda oil storage base and the Valciunai rocket fuel storage base. These bases were selected as their geology and hydrogeology were known from previous research studies and monitoring wells had already been installed at the sites. The sites also represent different, but typical geological conditions within Lithuania.

The main objective of the groundwater monitoring was to obtain data on changes in water level and chemistry at these 3 representative military bases. These data could then be used to evaluate the environmental status of other similar military sites located with similar geological conditions. Groundwater level monitoring, sampling and analysis were undertaken at the selected sites. Water levels were measured 3 times per month and samples for the analysis of major cations and anions, trace elements and hydrocarbon concentrations were collected twice a year over a period of 2 years.

The hydraulic parameters for the shallow groundwater aquifer required for groundwater flow balance calculations, such as hydraulic conductivity (K), aquifer thickness (m), hydraulic gradient (i) and contaminant retardation factor (a), were evaluated for each of the selected sites. Groundwater flow balance calculations were performed to ensure that the perceived groundwater flow system at the site was compatible with regional data from Sakalauskiene (1982).

A procedure described by Sakalauskiene (1982) was used for the groundwater-balance calculations. The results obtained from groundwater flow balance calculations of the Pajuoste and Kazlu Ruda military bases corresponded well with the regional assessment presented in Sakalauskiene (1982). This enables the use of regional groundwater run-off data for contaminant transport calculations as, on a regional scale, natural groundwater resources are equal to groundwater run-off values.

The contaminant discharge, L (volume per unit time) from a military base can be calculated by the equation:

$$L = C \times Q,$$

where

L = contaminant flux [M/T]

C = the background oil product concentration [M/L^3]

Q = the amount of groundwater discharging from the area during the time period [L^3/T]

5.6.1 Pajuoste air-base

At the Pajuoste air-base the superficial sediments are composed of a 10-24 m thick moraine till with 1-3 m thick sandy lenses and interlayers containing perched groundwater tables. The shallow groundwater table within sandy interlayers and till fluctuates from 0.4 to 2.6 m b.g.l. In the southern and south-western parts of the base, groundwater discharges into the Juosta river and in the western part of the base into the Nevezis river (See Figure 8).

The accurate determination of the hydraulic properties of the soil and water-bearing lenses is limited by the highly inhomogeneous distribution of the sandy lenses. As can be seen from the chemical analysis reported in Annex 2, the highest soil contamination by oil products was observed in the oil storage areas, where hydrocarbon concentrations exceeding 1000 mg/kg were typically detected. Oil product concentrations of up to 17261 mg/kg at a depth of 0.5 m were discovered. The total contaminated area is approximately 30 000 m^2.

The groundwater was also shown to be contaminated with heavy metals: concentrations of up to 7.5 mg/l Fe (maximum permitted concentration, MPC for drinking water is 0.3 mg/l), 0.039 mg /l Pb (MPC 0.03 mg/l) and 0.096 mg/l Cr (MPC 0.05 mg/l) were detected (Annex 2). However, the main groundwater contaminants here are hydrocarbons. A concentration of dissolved oil products of 886 mg/l was found in one sample although further sampling did not reveal concentrations greater than 35 mg/l.

5.6.2 Kazlu Ruda fuel storage site

A map of the base is shown in Fig. 15 The dominant groundwater flow direction is towards the Jure river which lies 1.7 km to the NW of the base. The concentration of dissolved oil products in the shallow groundwater in 1993 reached 22.5 mg/l and the free phase oil layer was 3 cm thick. Contaminated water has not yet spread outside the perimeter of the base.

The vadose zone and shallow aquifer at the site are composed of medium-grained sand. The groundwater table lies at 1.5-2.5 m b.g.l. The thickness of the shallow aquifer is approximately 8 m. The hydraulic conductivity of the aquifer is 3.0 m/d. The hydraulic parameters used for the groundwater flow calculations are presented in Table 12.

Table 12. Calculations of lateral groundwater run-off at the Kazlu Ruda oil storage (see Figure 15)

Well No.	Thickness of the aquifer (D), m	Absolute gw. Level (H), m above sea level	Distance of the well to the central well (l), m	Distance, m	Length of the side of element A	Length in meters	Area of separated element F, m^2	K, m/day
1s	7.9	61.9	-	-	-	-	48075	3.0
2s	7.1	61.1	l_2	240	A_2	212		
3s	8.3	62.3	l_3	135	A_3	245		
4s	8.0	62.0	l_4	235	A_4	215		
5s	7.0	61.0	l_5	255	A_5	201		

The volume of groundwater inflow (and outflow) into each groundwater flow element can be calculated by the equation:

$$q = A\,k\,\frac{D_n + D_i}{2} \times \frac{H_n - H_i}{1}$$

Symbols are explained in table 12.

It can be assumed that this groundwater flux flows in to the element from the direction 3s - 5s (side A_3, Figure15):

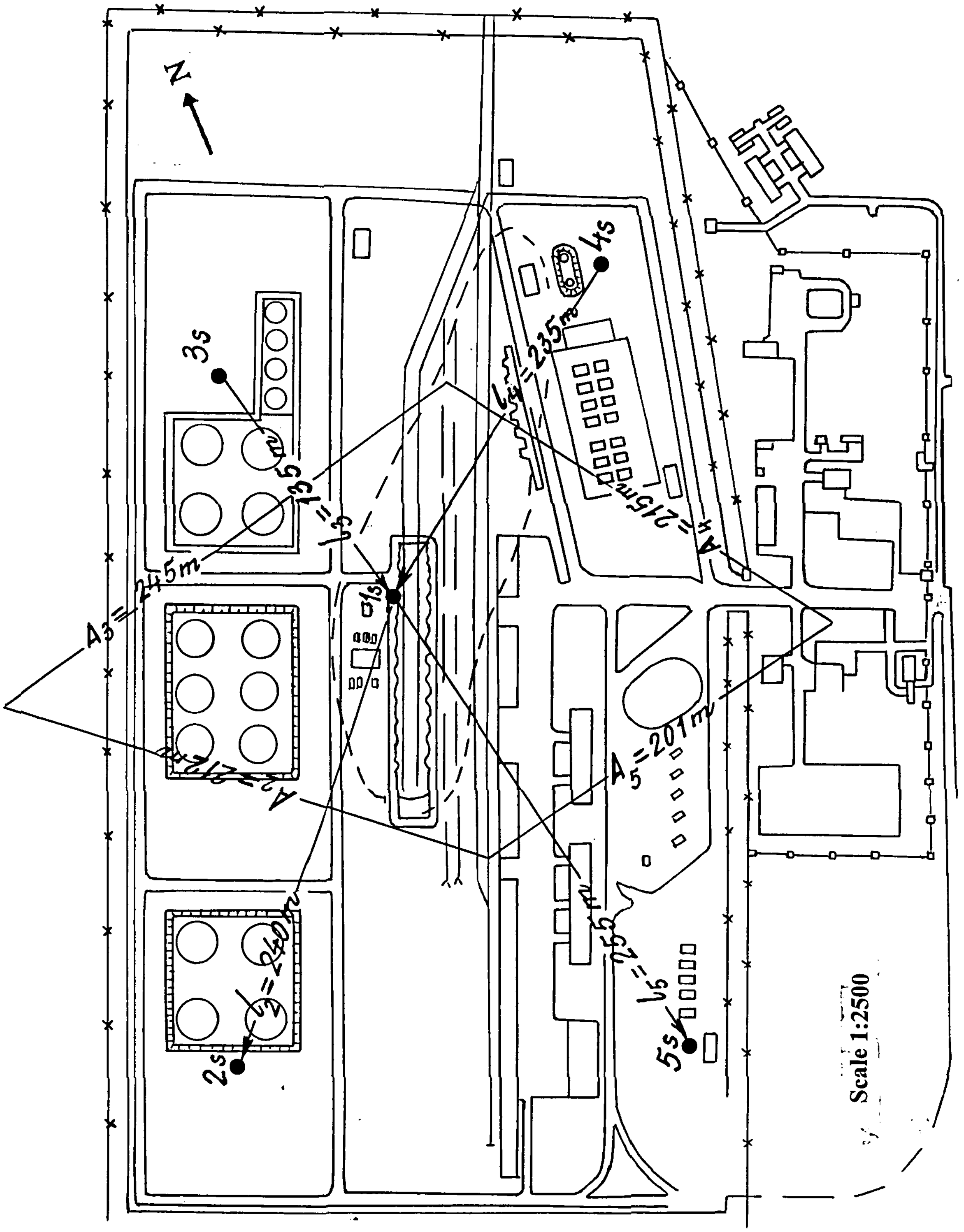


Figure 15. Location of the wells used for water balance calculations in Kazlu Ruda Oil storage.

$$q_{3,1}=A_3\,k\frac{D_3+D_1}{2}\times\frac{H_3-H_1}{l_3}=245\times3\frac{8.3+7.9}{2}\times\frac{62.3-61.9}{135}=17.64m^3\,/\,day;$$

Groundwater outflow from the element to the direction 3s-5s (through side A_5) is:

$$q_{1,5}=A_5\,k\frac{D_1+D_5}{2}\times\frac{H_1-H_5}{l_5}=201\times3\frac{7.9+7.0}{2}\times\frac{61.9-61.0}{255}=15.855\,m^3\,/\,day;$$

$$\Delta q=q_{3,1}-q_{1,5}=17.64-15.85=1.79m^3\,/\,day\,/\,1m^2).;$$

From the direction 4s (side A_4) groundwater inflow can be calculated by the same equation:

$$q_{4,1}=A_4\,k\frac{D_4+D_1}{2}\times\frac{H_4-H_1}{l_4}=215\times3\frac{8.0+7.9}{2}\times\frac{62.0-61.9}{235}=2.18m^3\,/\,day;$$

Groundwater outflow to the direction 2s (side A_2) is:

$$q_{1,2}=A_2\,k\frac{D_1+D_2}{2}\times\frac{H_1-H_2}{l_2}=212\times3\frac{7.9+7.1}{2}\times\frac{61.9-61.1}{240}=15.90\,m^3\,/\,day;$$

$$\Delta q'=q_{4,1}-q_{1,2}=2.182-15.90=-13.7\,m^3\,/\,day\,/\,1\,m^2.$$

Assuming that in such small area a vertical groundwater flow between the aquifers E≈0, we can calculate that infiltration recharge on the territory of the base is:

$$M=\frac{W}{F}=-\frac{\Delta q+\Delta q'}{F}=-\frac{1.79-13.72}{48075}=0.00025m^3\,/\,day\,/\,m^2=0.00025m\,/\,day=91mm\,/\,year$$

F = area of the element

Quantity of contaminants discharging with groundwater flux from the base to the surface stream (in the direction 2s) per time unit can be calculated by the equation:

$L=q_{1,2}\times C=15.9\times5=79.5g\,/\,day$

where $q_{1,2}$ = 15.9 m^3/d

C = 5 mg/l = 5 g/m^3

This rate represents the current rate of discharge of oil products into surface waters. Mathematical modelling indicates that after 10 years, hydrocarbons dissolved in a shallow aquifer will travel a distance of 200 m from the pollution source. The concentration of oil products will be reduced to 0.1 mg/l by this distance (Figure 16). This conclusion was based only on hydrodynamic calculations. If biological degradation or adsorption were also to be considered, the migration distance would be even lower. At present, however, data on oil product degradation in the subsurface are unavailable.

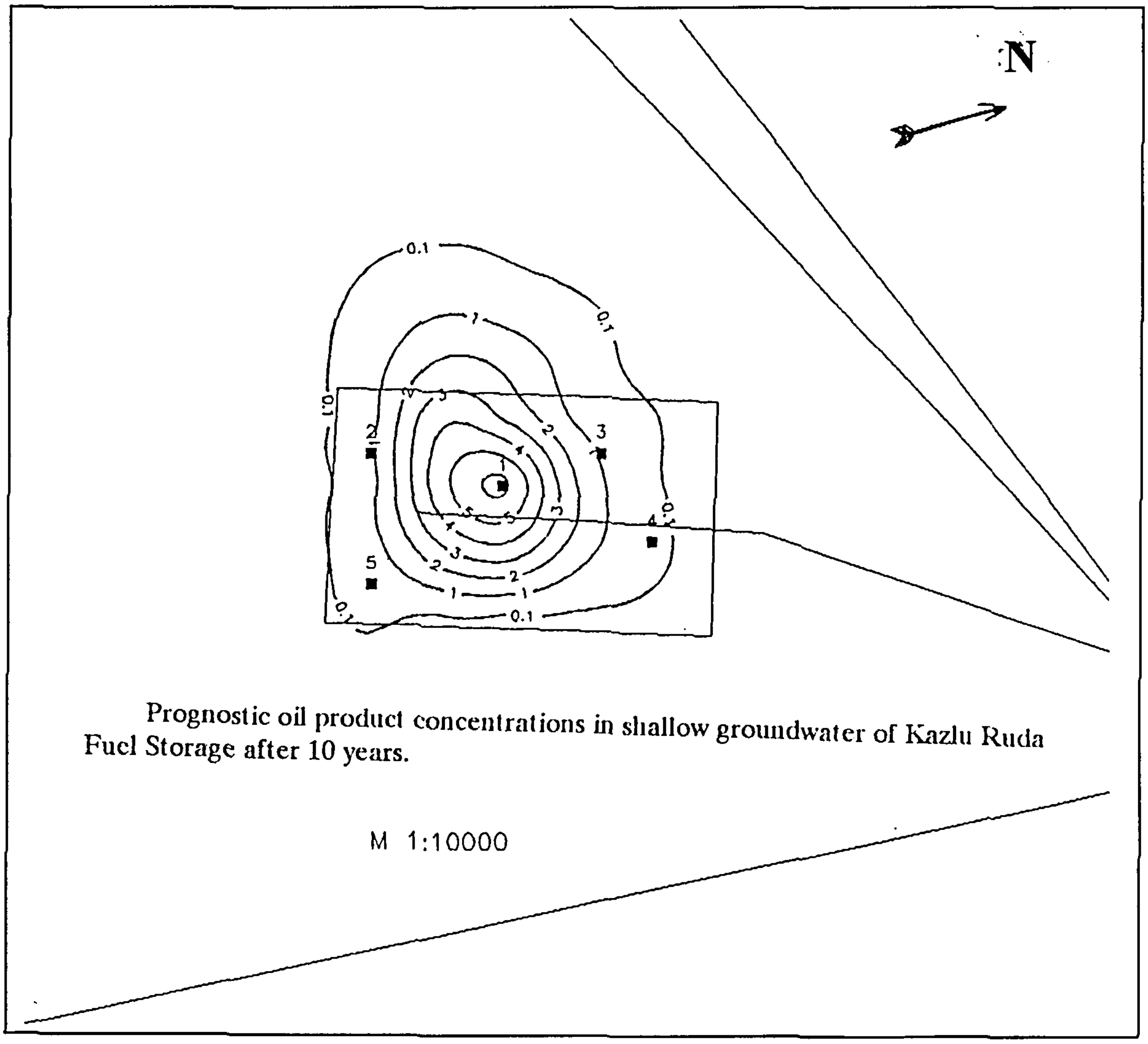


Figure 16. Modelling results at Kazlu Ruda military base. Concentrations in mg/l)

5.6.3 Valciunai oil storage site

The geological composition of the subsurface at this site (shown in Figure 17) is rather complex. Such a complex geological cross-section is typical for marginal glacial deposits. In the western part of the site, clay sediments are uppermost. In the central and eastern parts of the site, these sediments are covered by sand and gravel deposits. The clay sediments are locally weathered and the superficial sands are in hydraulic connection with the lower sandy sediments. The shallow groundwater table varies from 2.6 - 14.0 m b.g.l.. In the eastern part of the site, the shallow aquifer is hydraulically connected with the inter-moraine aquifer. Groundwater flow is directed to the SE towards the Rudamina river, about 800 m from the base.

There are two areas within the base where groundwater is contaminated by rocket fuel (Figure 18). One of these is in the western and central parts of the base and occupies an area of 380 000 m^2. In this area, concentrations of dissolved oil products in the shallow groundwater fluctuate from 0.12-33.6 mg/l. Approximate concentrations of other detected pollutants are as follows: 0.01 mg/l phenols, 0.2 mg/l SSAM (suspended surficial active materials), 0.2- 2.9 mg/l Zn, 0.9-2.5 mg/l Mn and 12.4-335.0 mg/l Al. The free phase oil layer probably occupies an area of about 5 000 m^2. The second contaminated area occurs in the southern, eastern and south-eastern parts of the base and extends over 31 200 m^2. The concentration of dissolved oil products in the groundwater reaches 0.61-2.41 mg/l. Contaminant migration was estimated along a profile between Wells 15s and 38s in the main direction of groundwater flow.

Estimates of the dissolved hydrocarbon discharge into surface streams from groundwater are presented in Table 13.

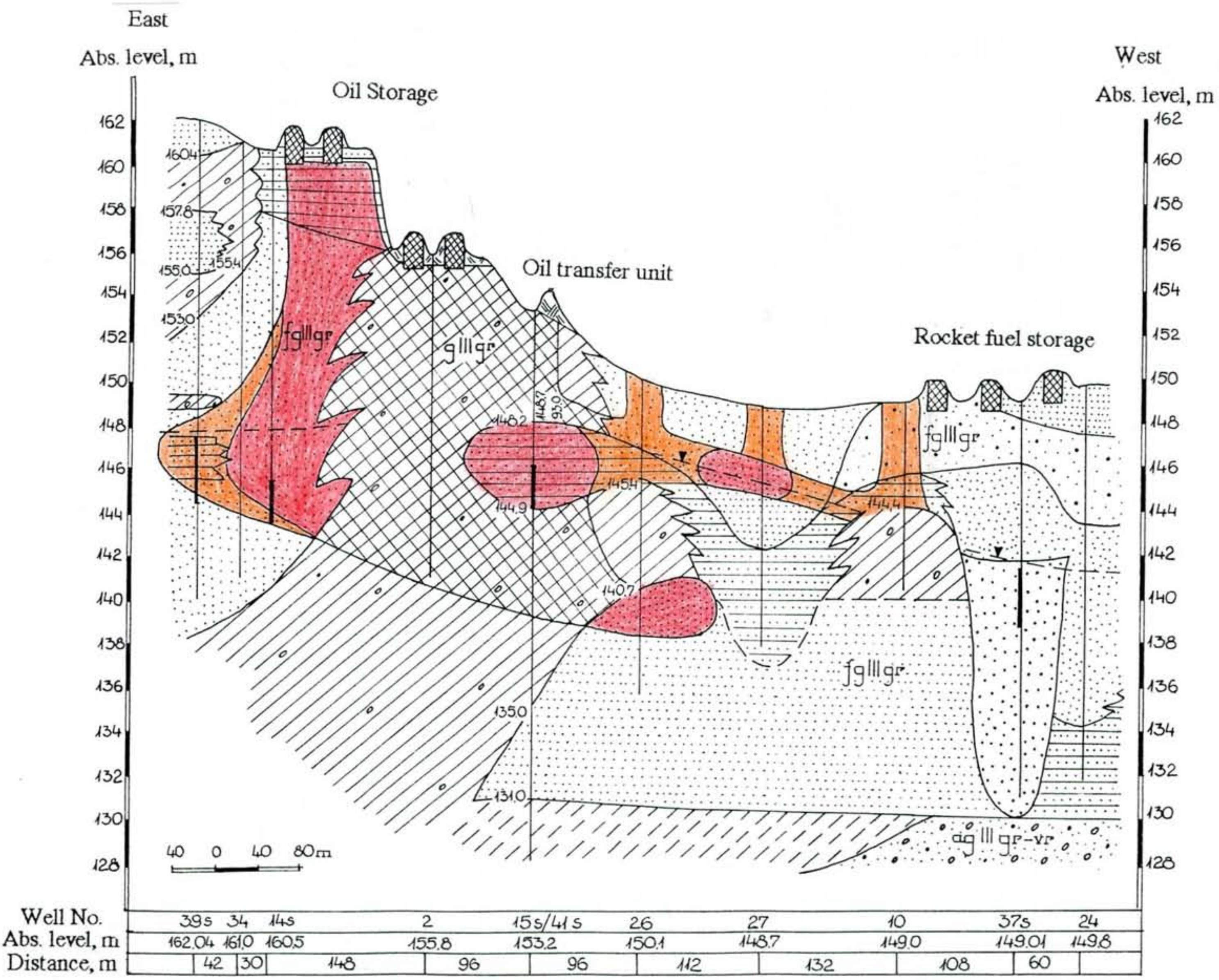


Figure 17. Geological cross section of Valciunai military Oil Storage
Legend in Figure 17a.

░	Sand fine grained
░	Sand medium grained, homogenous
░	Sand with different grain size
░	Sand different grained, mixed with gravel and pebbles (fine grained gravel)
░	Sand different grained, mixed with gravel and pebbles (coarse grained gravel)
▤	Sand clayey
☰	Silt
▥	Loam
▧	Till
▤	Clay
▩	Man made ground
🟧	Soil slightly polluted by oil products
🟥	Soil medium and heavily polluted by oil products
▦	Contaminants sporadically spread in moraine till
▼	Shallow groundwater level
(1)— 5.7— (2)—12.0—	Lithological (1) and stratigraphical (2) boundary and its absolute level, m
2.0 22.0 95.08 0.17	Well, filter interval and groundwater head (absolute level, m; measuring date);on the left-specific yield; on the right-total dissolved solids, g/l
fgIIIgr, gIIIgr	Fliuvioglacial (fg) and glacial (moraine, g) sediments of Gruda glaciation

Figure 17 a. Legend to Figure 17

Figure 18. Shallow groundwater contamination at the Valciunai military Oil Storage

Table 13. Results of groundwater flow and assessment of oil product discharge

No. No.	Base No. According to I.Kruger 1995a	Name of the base (region, military district)	Lithology of aeration zone and aquifer	Thickness of vadose zone, *m*	Distance from the base to sur-/face stream, *m*	Area of polluted soil *F, ha*	Infiltration recharge modulus *M, thous* $m^3/d/km^2$	Gw run-off from the base *(Q=M×F)*, m^3/d	Factual data (for 15 bases) Thickness of shallow gw aquifer, *h, m*	 Groundwater level gradient *I*	 Conductivity coeficient *k, m/d*	 Yield of gw flow *q*, m^3/d	Average oil product concentra tion - *C, mg/l*	Oil product discharge *g/d*
Typical military bases														
1.	290	Kazlu Rudos Oil Storage	f/g sand	~2	1800	1.1	0.25	2.75	~8	0.003	3	15.9	5	79.5
2.	304	Oil Storage of Pajuoste airbase	till	0.5-2	100	30	0.1	30	0.5-2.5	0.045	0.7	5.3	15	80
		Rest territory		0.5-2	close		0.1		2	0.02	0.7	28	7	196
3.	332	Valciunai Fuel Storage	clayey sand	3-8	800	38	0.1-0.2	76	4-15	0.02	6.6	1337.6	0.6	800
Other bases with known oil concentration in groundwater														
4.	168	Fuel base of Kedainiai airfield	Till, loam, sand	0.5-3.0	90	22.34	0-0.1	22.34	5-7	0.01	~1.0	40.8	14	571
5.		Pagegiai fuel base	sand	1.8-2.2	>1500	5.7	0.2-0.4	17.1	~4-7	0.003	~10	72	13	936
6.	138	Karmelava rocket base	loam, sand	0.05-3.5	250	0.5	0.1-0.2	1.0	~2	0.014	~8	22.4	~2	45
7.		Fuel base of Pilainiai engineering regiment	gravel, pebbles	0.5-6.0	30	1.2	0.1-0.2	2.4	~7	0.03	~50	2100	0.22	462
8.	5	Alytus paratroop unit	sand	4.2-10.5	1200	0.01	0.2-0.4	0.04	~4	0.01	~10	12	17.16	206
9.	372	Fuel base of Pabrade tank regiment	sand	2.2-4.3	>200	20	0.6-0.8	60	~1	0.02	~10	14	8.0	112
10.	339	Raudondvaris rocket base	sand	2-7	~1500	0.003	0-0.1	0.003	4-8	0.04	~12	29	0.5	14
11.		Fuel base of Kairiai tank regiment	sand	1-1.2	~500	~1	0-0.1	~1	2-3	0.001	~6	~3	1.6	~5
12.	418	Zokniai airbase	till, sand, gravel	4-10	>1000	~100	0.1-0.2	200	10	0.02	~7	~2100	10	21000
13.	265	Taurage military unit	till, sand	1.8-2.5	30	0.27	0.1-0.2	0.54	~7	0.01	~5	73.5	12	882
14.	330	Nemencine center of civil defence	sand, gravel	0.5-1.0	200	2.4	0.1-0.2	4.8	>5	0.015	~20	45	17.6	792
15.		Vilnius “Siaures miestelis”	sand, gravel	0.5-2.0	~1500	5.4	0.1-0.2	10.8	0.3	0.02	~10	15	1.3	19.5
		TOTAL:												**26200**

5.7 SUMMARY

Table 13 shows that from the three bases (level 1, see Section 5.5) where the most reliable results were obtained (Kazlu Ruda, Pajuoste and Valciunai), 1155 g/day of dissolved oil products are modelled as entering surface streams. This is equivalent to 0.42 tonnes/yr.

From the 12 level 2 bases (see 5.5), up to 25045 g/day of hydrocarbons are polluting rivers and/or lakes, or 9.14 tonnes/yr.

The total contaminant emission from these 15 bases is 26200 g/d or 9.6 tonnes per year. The biggest source of hydrocarbon pollutants (21 000 g/day) is the Siauliai (Zokniai) air-base.

For the 35 other bases where the dissolved oil concentration was known, it was estimated that 6056 g/day or 2.21 tonnes/year of oil products reach surface water bodies.

It was also calculated that at the remaining bases located on sandy soils less than 200 m from a surface water body and where oil concentration is unknown, groundwater run-off is rather low at 22.45 m^3/day (Table 14). Assuming that up to 1 mg/l of hydrocarbons is dissolved in the groundwater and that all this groundwater flows into surface streams, a total of 22 g/day or 0.008 tonnes/year is discharging into rivers.

Thus, given the available data it can be concluded that as a 'worst-case' scenario approximately 11.8 tonnes/year of dissolved oil products are discharging from groundwater into surface water bodies. This total is very sensitive to the figure for Zokniai airbase which accounts for 65 % of the total.

Table 14. Calculations of groundwater run-off at the bases located within the distance of 200 m from the surface streams

No	Base Number according to I. Kruger 1995a	Name of the base (region, military district)	Lithology of vadose zone and aquifer	Groundwater run-off from the base (Q=MxF), m^3/d	Area of contaminated soil F, ha	Modulus of infiltration recharge M, thous $m^3/d/km^2$
1.	11(30)	Kapciamiestis radiolocation unit	sand	0.7	0.10	0.6-0.8
2.	58(148)	Paratroop supply unit Kaunas district	sandy loam	2.7	1.36	0.1-0.2
3.	71(156)	Material supply unit Kaunas district	gravel	0.16	0.04	0.2-0.4
4.	84(164)	Floating bridge unit	sandy loam	0.42	0.21	0.1-0.2
5.	85(164)	744 rocket division Kaunas district	sandy loam	1.28	0.64	0.1-0.2
6.	160(191)	Radiolocation survey division Kaunas district	sandy loam	2.18	1.09	0.1-0.2
7.	215(65)	Artilery-rocket regiment Klaipeda military district	sand	4	2.00	0.1-0.2
8.	217(65)	Klaipeda military town	sand	0.02	0.01	0.1-0.2
9.	235(75)	Klaipeda training center	sand	0.02	0.01	0.1-0.2
10.	236(75)	Klaipeda frontier defence unit	sand	0.01	0.01	0.0-0.1
11.	215(75)	Klaipeda radiolocation regiment	sand	0.01	0.01	0.0-0.1
12.	287(219)	Marijampole artilery rocket division	sandy loam	1.68	0.84	0.1-0.2
13.	298(1)	Panevèzys airfield construction regiment	till	9	4.50	0.1-0.2
14.	328(236)	Vilnius rocket unit	till	0.26	0.13	0.1-0.2
		Total:		**22.45**		

6 CONCLUSIONS AND RECOMMENDATIONS

The collaborative project between Lithuania, Canada and Norway has been useful for all involved. Friendly contacts were established between the scientists from the two NATO and one Co-operation partner countries. These links are not only inter-continental but also inter-institutional, as geophysicists and hydrogeologists from Geological Surveys and consultants worked together with scientists from Defence Departments and Universities.

During the field work, the participants have become very aware that contamination sampling and evaluation methodologies differ significantly from country to country. It is thus important to develop procedures which are more universally accessible and understandable, although flexible enough to accommodate the widely differing geographical, climatic and geological conditions in each country. The co-operation between Lithuanian, Canadian and Norwegian experts has provided valuable experience in dealing with chemical contamination at complex military sites and in the preliminary evaluation of risk associated with this pollution. Canada, in particular, has worked with the investigation of groundwater pollution, risk assessment and remediation of contaminated ground for some considerable time. The contacts established with experts in Canada during the early phase of our project are therefore of great importance for the remediation of polluted military sites in both Norway and Lithuania.

Groundwater samples analysed in the nationally accredited laboratories of Norway and Canada and the non-accredited laboratories of Lithuania yielded rather variable results, although they were collected at the same time by the same people using the same procedures. It cannot, however, be concluded that this variation is necessarily connected with accreditation or the lack of it, but, more likely, with differing transport, storage and analytical techniques. This leads to the conclusion that it is advisable to base comparative sampling of contaminated areas on the data received from a single laboratory, although the absolute values returned by this laboratory should be checked by careful inter laboratory comparison. It is regarded as an essential part of laboratory accreditation that a comprehensive program of international cross-laboratory calibration is regularly undertaken.

Lithuanian environmental specialists were able to observe soil/groundwater sampling and handling techniques used by «western» nations and to make an objective assessment of whether such procedures would be suited to use in Lithuania. It is recommended that a standard sampling methodology should be created in Lithuania and approved by the appropriate governmental institutions.

A wide variety of field methods have been used, albeit somewhat superficially, during the field work at the Pajuoste airbase. It is concluded that no universal methodology for assessment of environmental contamination can be recommended which is specific to military bases, over and above that which tends to be adopted at most contaminated sites (including civilian), viz.:

(i) Initial desk study incorporating collation of existing data on geology, hydrology, hydrogeology, site use and history. Environmental audit of past and present contaminant use, storage and disposal, working practices. Audits of chemical and fuel consumption and loss. Assessment of reliability of information sources.

(ii) Reconnaissance investigation with coverage of large areas using rapid and relatively cheap techniques such as trial pitting, soil gas surveying (PID), geophysics and augering. This, together with information from the desk study, should allow provisional identification of contaminant «hot-spots».

(iii) Preliminary semi-quantitative risk-assessment of the existing contaminant situation. Identification and provisional ranking of contaminant sources, pathways and receptors. Assessment of whether further investigation in required.

(iv) Detailed site investigations of contaminant hot-spots, usually using intrusive techniques such as drilling and borehole installation.

(v) Quantitative risk assessment, often involving contaminant transport modelling, to identify areas and/or contaminants (if any) which should be prioritised for remediation

(vi) Remediation-targeted site investigation, to establish the parameters necessary to design remedial options.

(vii) Risk assessment and cost/benefit analysis of remedial options. The risk assessment will identify risks to humans and the environment during remediation, and will quantify the risk reduction effected by the remediation. The cost-benefit analysis will assess the benefits (in terms of risk reduction and alleviation of legal liabilities) in the light of financial, and possible environmental, costs incurred during remediation.

Some problems will be specific to the investigation of military bases, however. The most important of these is the secrecy and lack of information surrounding some military installations. It is probably true that environmental information from military bases is easier to access in many former «Warsaw pact» countries than in many NATO countries today. Whether the comparatively free flow of environmental information in eastern Europe will continue into the future is difficult to assess. Chemicals and fuels are often known in military circles by (from the civilian point of view) somewhat obscure codes or abbreviations. This situation was encountered at Valciuniai rocket fuel storage area where a Soviet propellant was identified only by a code name and its exact composition could not readily be determined by Lithuanian scientists. The situation was eventually clarified through contacts with military agencies in the UK with knowledge of the names used by Soviet forces for propellants.

Pajuoste Airfield

Investigation at Pajuoste during the NATO project has reached stage (ii), above. From the reconnaissance investigation and chemical sampling carried out at Pajuoste, the following conclusions can be drawn:

(i) The petroleum product levels observed indicate that there is a potential for contaminated groundwater from this location to migrate to other areas and to resurface and contaminate surface water. Further monitoring wells need to be established in order to fully understand the problem and define the plume of contamination. Remediation of the area may be required if the plume of contamination is migrating into the river or threatens the town's drinking water. However, if this is not the case, other processes such as natural bioremediation, possibly assisted by nutrient addition, may suffice to decrease contamination to acceptable levels. An oil-absorbent boom could be placed across the stream leading from the area to contain surface-runoff of hydrocarbons, although protocols for the maintenance of this facility and the disposal of collected product would have to be made.

(ii) Results also indicate that sediments associated with drainage flowing between the buildings in chemical storage area II are highly contaminated with hydrocarbons and cadmium. The cadmium level is greater than the guidelines for Canadian commercial/industrial sites and the Dutch C criterion (both 20 mg/kg). The direction of flow in the drainage channel is not known. Further sampling of this channel is required to establish the source of the contamination. The source may lie in the region of sample LT47S but may also lie beyond LT48S or from a landfill site adjacent to the ditch. Cadmium derived from aircraft tyres could also be regarded as a potential source. Vegetation samples from the ditch should be taken to establish if the cadmium is being taken up by plants.

(iii) Elevated chloride levels associated with the landfill are not particularly high, but chloride is regarded as a good tracer for other components of landfill leachate. Other ponds in the area, drainage ditches and pits could be sampled and analysed for chloride as a relatively simple indicator of the extent of migration of leachate from the landfill (although the possibility that other sources, such as de-icing salt, may exist should be borne in mind). Monitoring wells are also recommended for leachate migration monitoring in groundwater.

(iv) Fluoride levels are particularly high in the landfill area where one sample showed 12.56 mg/l. Canadian water guidelines range from 1 to 2 mg/l and the Dutch B criterion is 1.2 mg/l for total fluoride. The presence of nickel and chromium in the water from the pond in the landfill area, chemical storage area (sample 47) and sample 50, indicates some contamination by these elements and again the extent of this should be checked in other nearby water bodies. Leachate containment may be necessary if it threatens to impact on the Rivers Juosta and Nevetzis or the groundwater source of the town's water supply.

Regional Situation - Contamination from Military Bases

A regional·assessment of soil/groundwater contamination at military bases has not been an easy task, as few similar regional studies have been published and environmental data were not sufficiently dense, requiring an undesirably high level of both extra- and interpolation. The figure of 11.8 tonnes/yr for dissolved hydrocarbon contaminant migration from military sites is thus highly provisional and should probably be regarded as a «worst case» upper limit. The estimate does, however, indicate the potential for a significant pollution load derived from military sites, but also that much more intensive environmental assessment is needed for precise calculations of the environmental cost of military activity. With the anticipated future availability of more detailed information, the figures for potential contaminant load will be corrected. Nevertheless, it is believed that the methodology for the evaluation of military pollution load could be applied in other NATO and Co-operative countries.

A database, "Waste", of contaminated sites, was created in Oracle by the Lithuanian and Norwegian scientists as a result of this project. Further data collection on military and civil contamination will be continued by the Geological Survey of Lithuania. The database can be modified and transferred to other countries dealing with similar environmental problems.

Finally....

The Lithuanian team hope that their NATO counterparts have also gained some new experience of international co-operation and that this project will improve human relations between the co-operating countries and create a basis for further contacts. In addition to scientific benefits, all scientists involved gained a substantial insight into the society and environmental politics of the co-operating countries, and all are agreed that this aspect of such projects should not be undervalued.

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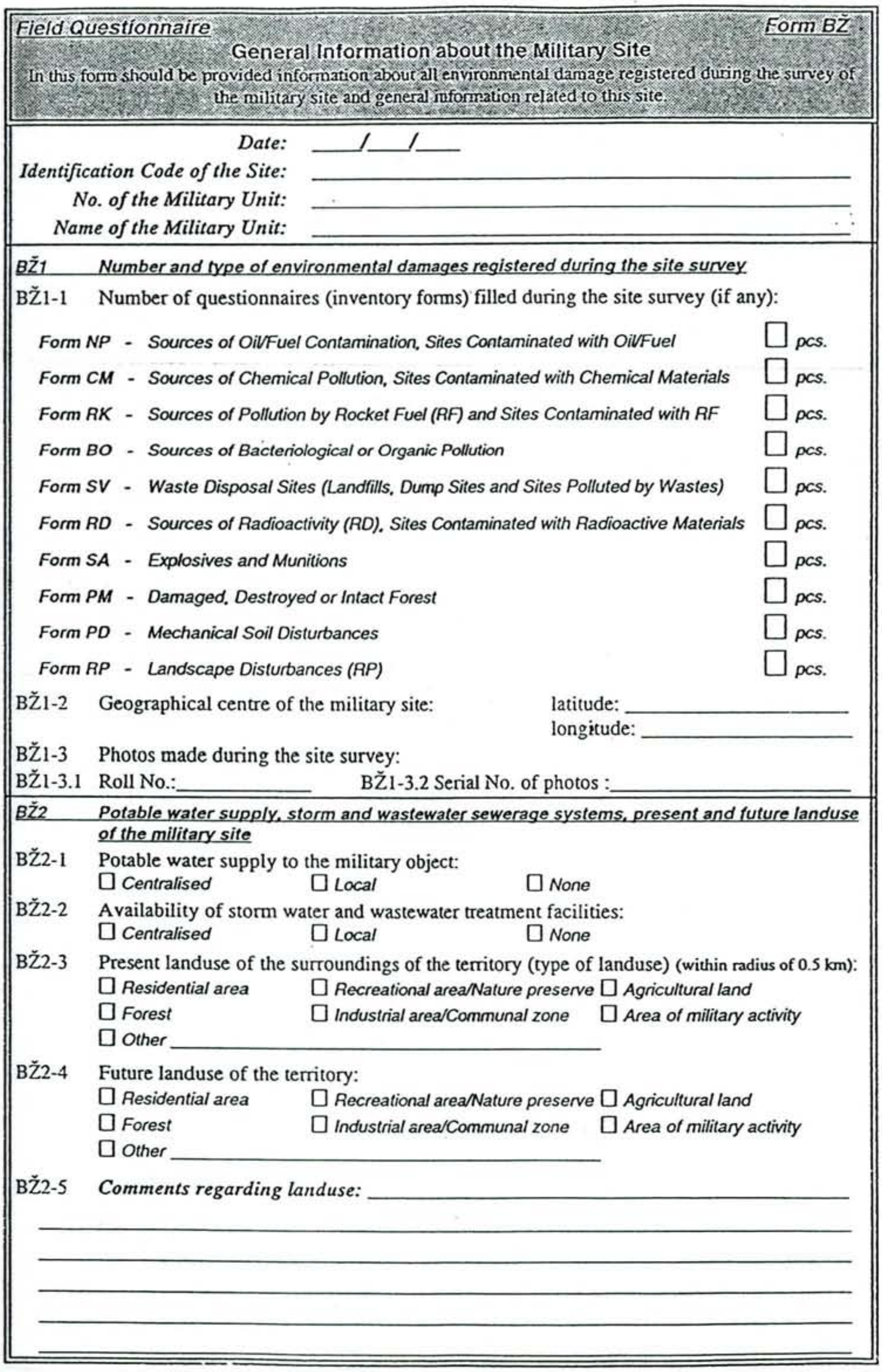
ANNEX A

Questionnaire for general field information and oil contamination,
PHARE-project.



Field Questionnaire *Form BŽ*

General Information about the Military Site

In this form should be provided information about all environmental damage registered during the survey of the military site and general information related to this site.

Date: ___/___/___

Identification Code of the Site: ____________________

No. of the Military Unit: ____________________

Name of the Military Unit: ____________________

BŽ1 Number and type of environmental damages registered during the site survey

BŽ1-1 Number of questionnaires (inventory forms) filled during the site survey (if any):

Form NP - Sources of Oil/Fuel Contamination, Sites Contaminated with Oil/Fuel ☐ *pcs.*

Form CM - Sources of Chemical Pollution, Sites Contaminated with Chemical Materials ☐ *pcs.*

Form RK - Sources of Pollution by Rocket Fuel (RF) and Sites Contaminated with RF ☐ *pcs.*

Form BO - Sources of Bacteriological or Organic Pollution ☐ *pcs.*

Form SV - Waste Disposal Sites (Landfills, Dump Sites and Sites Polluted by Wastes) ☐ *pcs.*

Form RD - Sources of Radioactivity (RD), Sites Contaminated with Radioactive Materials ☐ *pcs.*

Form SA - Explosives and Munitions ☐ *pcs.*

Form PM - Damaged, Destroyed or Intact Forest ☐ *pcs.*

Form PD - Mechanical Soil Disturbances ☐ *pcs.*

Form RP - Landscape Disturbances (RP) ☐ *pcs.*

BŽ1-2 Geographical centre of the military site: latitude: __________

longitude: __________

BŽ1-3 Photos made during the site survey:

BŽ1-3.1 Roll No.:__________ BŽ1-3.2 Serial No. of photos :__________

BŽ2 Potable water supply, storm and wastewater sewerage systems, present and future landuse of the military site

BŽ2-1 Potable water supply to the military object:

☐ *Centralised* ☐ *Local* ☐ *None*

BŽ2-2 Availability of storm water and wastewater treatment facilities:

☐ *Centralised* ☐ *Local* ☐ *None*

BŽ2-3 Present landuse of the surroundings of the territory (type of landuse) (within radius of 0.5 km):

☐ *Residential area* ☐ *Recreational area/Nature preserve* ☐ *Agricultural land*

☐ *Forest* ☐ *Industrial area/Communal zone* ☐ *Area of military activity*

☐ *Other* ____________________

BŽ2-4 Future landuse of the territory:

☐ *Residential area* ☐ *Recreational area/Nature preserve* ☐ *Agricultural land*

☐ *Forest* ☐ *Industrial area/Communal zone* ☐ *Area of military activity*

☐ *Other* ____________________

BŽ2-5 ***Comments regarding landuse:*** ____________________

General field questionnaire

Field Questionnaire *Form NP*

Sources of Oil/Fuel Contamination, Sites Contaminated with Oil/Fuel

In this form oil and fuel storage facilities, filling stations, oil and fuel transfer facilities, railway ramps, garages and maintenance workshops, car and truck washing stations, and other sites contaminated with oil/fuel are described

Date: ___/___/___

Identification Code of the Site: ____________________

No. of the Military Unit: ____________________

Name of the Military Unit: ____________________

NP1 Characteristics of oil pollution source and its location

NP1-1 No. of the object/No. of the form: ____________

NP1-2 Type of oil pollution source/contaminated site:

☐ *Oil/fuel storage facility* ☐ *Filling station* *- parts NP2, NP3, NP4, NP5, NP6 to be filled in*

☐ *Oil/fuel transfer facility* ☐ *Railway ramp* *- parts NP3, NP4, NP5, NP6 to be filled in*

☐ *Garage/mainten. workshop* ☐ *Car/truck washing st.- parts NP4, NP5, NP6 to be filled in*

☐ *Other contaminated site*

NP1-3 Geographical co-ordinates: *latitude* ____________ *longitude* ____________

NP1-4 Photos made during the site survey:

NP1-4.1 Roll No.:__________ NP1-4.2 Serial No. of photos :______________

NP2 Characteristics of oil/fuel storage facility

NP2-1 Type of oil/fuel storage tanks: ☐ *Underground* ☐ *Surface*

NP2-2 Number of oil/fuel storage tanks: ______________ *units*

NP2-3 Total capacity of the tanks: ______________ m^3

NP2-4 Construction material of the tanks:

☐ *Concrete* ☐ *Metal* ☐ *Mixed construction*

NP2-5 Present condition of oil/fuel storage tanks (tank surface condition, mechanical damage, corrosion, etc. should be considered)(*Refer to Risk Assessment Instruction*):

☐ *Good* ☐ *Fair* ☐ *Poor*

NP2-6 Present use of oil/fuel storage facilities:

☐ *In use/not empty* ☐ *Not used (empty)*

NP2-7 Lining underneath the area of oil/fuel storage facilities:

☐ *Concrete/asphalt* ☐ *Clay* ☐ *Gravel/sand* ☐*No lining*

NP2-8 Type of stored oil products:

☐ *Crude oil* ☐ *Petrol* ☐ *Diesel*

☐ *Kerosene* ☐ *Greasing oil* ☐ *Furnace fuel/heating oil*

☐ *Fuel oil* ☐ *Aviation fuel* ☐ *Other* ______________

NP2-9 Number of years in operation (age): ______________________ *years*

NP2-10 Safety of the storage facility, possibility of accidents (*Refer to Risk Assessment Instruction*):

☐ *Very safe* ☐ *Fairly safe* ☐ *Potentially unsafe*

NP3 Characteristics of oil/fuel transportation and filling system

NP3-1 Oil/fuel delivery and means of transport:

☐ *Railway* ☐ *Trucks* ☐ *Pipelines*

NP3-2 Lining underneath the oil/fuel filling area:

☐ *Concrete/asphalt* ☐ *Clay* ☐ *Gravel/sand* ☐ *No lining*

NP4 Characteristics of the site contaminated with oil/fuel products

NP4-1 Area of site with contaminated soil: __________ *hectares*

NP4-2 Average thickness of contaminated soil: __________ *m*

Questionnaire on oil contamination

NP4-3 Type of spilled or visually observed oil products on/in the soil:
☐ *Mixed oil products* ☐ *Petrol* ☐ *Diesel* ☐ *Kerosene*
☐ *Greasing oil* ☐ *Furnace fuel/fuel oil* ☐ *Aviation fuel* ☐ *Other OP*______
NP4-4 Reports of accidents in the past: ☐ *Yes* ☐ *No*
NP4-5 Date(s) of accident(s): ____________________
NP4-6 Prevailing composition of surface soil layer:
☐ *Gravel* ☐ *Sand* ☐ *Sandy loam*
☐ *Sandy clay* ☐ *.Clay* ☐ *Other type* ____________
NP4-7 Data on the contaminated soil samples (No of sample, depth of sampling, date):
____
____
NP4-8 Distance to the nearest residential area/settlements (km) : ______________ *km*

NP5 ***Characteristics of the risk of groundwater pollution:***
NP5-1 Risk of pollution by oil/fuel:
☐ *Direct* ☐ *Indirect* ☐ *None*
NP5-2 Data on the contaminated water samples (No of well, No of sample, depth of sampling, date):
____
____
____

NP6 ***Characteristics of the risk of surface water pollution:***
NP6-1 Type(s) of surface water body(bodies) (within a distance of 0.2 km):
☐ *Lake* ☐ *River/stream* ☐ *Artificial reservoir*
☐ *Lagoon* ☐ *Sea*
NP6-2 Name of the surface water body(bodies): ____________________
NP6-3 Risk of pollution by oil/fuel:
☐ *Direct* ☐ *Indirect* ☐ *None*
NP6-4 Area of surface water body(bodies) suspected to be polluted: ____________ *hectares*
NP6-5 Turnover conditions of polluted water body(bodies):
☐ *Active water turnover* ☐ *Inactive water turnover* ☐ *No water turnover*
NP6-6 Use of contaminated surface water body(bodies):
☐ *Fishery* ☐ *Nature preserve* ☐ *Leisure/recreation*
☐ *No specific use* ☐ *Other purposes*________________

ATTENTION! Remember to fill out the Form **General Information**, locate all objects and sites on the map, and produce pictures.

Form NP was filled in by: ______________________________
(name and surname, organisation)

Comments: _____________________________________
____
____
____
____
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Questionnaire on oil contamination

ANNEX B

Table 15: Sample numbers, tags and descriptions of surface soil and water samples.
Table 16: Sample numbers, and descriptions of soil and water samples from monitoring wells
Table 17: Analytical Results obtained from the well water samples in the field.
Table 18: Hydrocarbon analytical results for water samples (Norway)
Table 19: Organic analyses for water samples (Canada)
Table 20: Metal analytical results for water samples by GFAAS (Norway) in mg/L
Table 21a: Metal analytical results for water samples by ICP (Norway) in mg/L
Table 21b: Metal analytical results for water samples by ICP (Norway) in mg/L
Table 21c: Metal analytical results for water samples by ICP (Norway) in mg/L
Table 22: Anion analytical results for water samples (Norway) in mg/L
Table 23: Hydrocarbon analytical results for soil samples (Norway)
Table 24: Hydrocarbon and PCB analytical results for soil samples (Canada)
Table 25: Metal analytical results for soil samples by AAS in mg/kg
Table 26: Main cations and anions in the shallow groundwater of Pajuoste air base
Table 27: Analysis of trace elements, oil products and aromatic hydrocarbons in groundwater of Pajuoste air base.

Canadian analysis on acid and base neutral organics in soil and water

Table 15: Sample numbers, tags and descriptions of surface soil and water samples.

Sample	Tag	Location	Description
LT30S	-	80 m from Well #1 and 80 m from the Juosta river	Black soil from 40 cm below water in stream. Smell of petroleum compounds
LT30W	-	as above	water
LT31S	-	from the Juosta river, 40 m downstream from where stream joined	from the river bed, mostly stones and sediment
LT31W	-	as above	water
LT32W	-	from the Juosta river below the maintenance area	water
LT33S	651	10 m from the river and LT32W in drainage from the maintenance area	soil and stones
LT34W	-	from Juosta river, 50 m from where it joined the Nevezis river	water
LT35S	652	next to the main radar building outside the back door	sandy loam mixed with black ash
LT36S	653	by a pile of electronic components to the northeast of the main radar building	dark soil and roots
LT37S	-	background sample from 50 m from the road linking the radar buildings with the taxiway at the halfway point	sandy loam
LT38S	654	from a drainage ditch by the side of the taxiway, the ditch travelled under the paved apron.	muddy sediment
LT38W	654	as above	water
LT39S	655	from midway between the two warehouses at the chemical storage area near the railway tracks	soil, stones and sand
LT40S	656	from an open area in front of one of the warehouses in between building foundations	soil, s tones and sand
LT41W	-	from a pond opposite the ammunition area	water
LT42S	657	from a pond opposite the ammunition storage area and close to the first building in the chemical storage area which had a tall chimney adjacent to it; the pond was in a deep depression	clayey soil from beneath leaves at the bank of the pond
LT42W	657	as above	water containing duckweed
LT43S	658	from a depression behind the largest building in the chemical storage area; buried debris was evident in the banks of the depression	soil and debris
LT43W	658	as above	water
LT44S	659	from a pit behind the building (garage) furthest from the road at the chemical storage area. The pit contained broken fluorescent light fixtures	sandy loam
LT45S	660	from a ditch behind the garage and LT44S	muddy soil and roots

Table 15 (continue):

LT46S	661	from the main drainage channel perpen-dicular to the road through the chemical storage area, beyond the junction with the ditch from which LT45S was obtained	muddy soil and roots
LT47S	662	from the main drainage channel perpendicular to the road through the chemical storage area by a bridge and close to a building by the road	muddy soil from below thick moss in the ditch
LT47W	662	as above	water with a sheen on top
LT48S	663	from the main drainage channel perpendicular to the road through the chemical storage area 30 m from the opposite side of the road from the storage buildings	muddy sediment and leaves
LT49W	-	from main pond at the southern maintenance area	water
LT50S	-	from the ditch behind the maintenance complex near LT49W	muddy sediment
LT50W	-	as above	water
LT51S	-	from beside a small pond behind the southern maintenance area	sandy loam
LT52W	-	from the tributary that runs on the southern edge of the aerodrome about 70 m from where it joined the Nevezis river	water
LT53W	-	from the Nevezis river about 40 m down stream from where the tributary to the south of the airfield joins it.	water
LT54S	664	near a pond at the toe of the landfill on the eastern side	sandy soil
LT55W	665	from a pond adjacent to the toe of the landfill near the centre of the edge of the landfill	water
LT56S	666	from the opposite side of the pond from which LT54S was taken further from the landfill	sandy soil
LT57S	667	from the edge of the main pond leading away from the landfill	sandy soil
LT58S	668	from the toe of the landfill on the side nearest to the road	sandy soil, stones and debris
LT59S	-	from about 3 km north of the airfield in a wooded area	dark sandy clay

Table 16: Sample numbers, and descriptions of soil and water samples from monitoring wells

Sample	Well	Depth	Description
LT1W	1	2.5 m	piezometer base at 3.6 m [a]
LT2W	2	2 m	piezometer base at 3.2 m [a]
LT3W	3	2 m	piezometer base at 3.6 m [a]
LT4W	4	2 m	piezometer base at 4.5 m [a]
LT1S	1	top meter	sandy light medium brown loam with some blackened with petroleum compounds
LT2S	1	2 m	red-brown silty clay
LT3S	1	3 m	stony, sandy red-brown clay
LT4S	1	3.75 m	brown silty clay with stones
LT5S	2	top meter	grey-brown sand; petroleum-kerosine odour
LT6S	2	2.7 - 3 m	red-brown silty sand
LT7S	2	4.7 m	sample taken for TV demonstration
LT8S	2A	4.5 m	clay with odour of petroleum (water at 1.5 m)
LT9S	3	1.5 m	brown pebbly sandy loam
LT10S	3	2.7 m	red- brown pebbly sand (water lens at 1.8 m)
LT11S	3	4.2 m	reddish brown sandy gravel
LT12S	-	-	sample of whitish material mixed with soil near laundry building
LT13S	-	-	sample of black material from near laundry building
LT14S	4	1.3 m	black sandy material with some garbage
LT15S	4	2.7 m	wet golden coarse sand
LT16S	4	4.3 m	medium brown sand
LT17S	4	5.3 m	fluvial sand and pebbles

[a] piezometers contained a filter slotted section from 0.6 to 2.75 m from the base.

Table 17: Analytical Results obtained from the well water samples in the field.

Sample	pH	Conductivity (uS/cm)	Redox (mV)	Temperature (C)
LT1W	6.7	952	-29	14.4
LT2W	6.8	1430	-29	15.0
LT3W	7.36	886	+35	14.4
LT4W	7.09	1112	+118	13.7

Table 18: Hydrocarbon analytical results for water samples (Norway)

Sample	Total hydrocarbon (mg/L)	Comments
LT1W	6.4	light hydrocarbons $<C_{15}$
LT2W	63	light hydrocarbons $<C_{15}$
LT3W	< 0.04	-
LT4W	0.20	light hydrocarbons C_{18} -C_{28}
LT30W	< 0.04	-
LT31W	< 0.04	-
LT32W	< 0.04	-
LT34W	< 0.04	-
LT38W	< 0.04	-
LT41W	0.08	light hydrocarbons C_{13} -C_{29}
LT42W	0.49	light hydrocarbons C_{13} -C_{29}
LT43W	< 0.04	-
LT47W	1.7	light hydrocarbons clustered around C_{21}, C_{24}, and C_{28}
LT49W	< 0.04	-
LT50W	1.6	light hydrocarbons C_{12} -C_{18}
LT52W	< 0.04	-
LT53W	< 0.04	-
LT55W	< 0.04	-

Table 19: Organic analyses for water samples (Canada)

Sample	Total hydrocarbon (mg/L)	Phenols (µg/L)	Total Organic Carbon (mg/L)
LT1W	4.2 (light fraction)	50	35
LT2W	3.4 (light fraction)	6.3	43
LT3W	<0.2	<1.0	8.1
LT4W	<0.2	63	4.0
LT30W	not determined	<1.0	8.6
LT31W	<0.2	<1.0	20
LT32W	not determined	<1.0	9.1
LT34W	not determined	<1.0	6.0
LT38W	not determined	<1.0	5.7
LT41W	not determined	<1.0	16.4
LT42W	not determined	78	45
LT43W	not determined	7.5	18.5
LT47W	<0.2	<1.0	22
LT49W	not determined	<1.0	18.0
LT50W	3.8 (diesel fuel)	<1.0	17.8
LT52W	not determined	<1.0	7.2
LT53W	not determined	<1.0	6.8
LT55W	<0.2	<1.0	154

Table 20: Metal analytical results for water samples by GFAAS (Norway) in µg/L

Sample	Cu	Zn	Pb	Hg	Ni	Cr	Cd
LT1W	<2.0	na	<1.0	<0.5	na	na	1.2
LT2W	<2.0	na	<1.0	<0.5	na	na	<0.2
LT3W	<2.0	na	<1.0	<0.5	na	na	<0.2
LT4W	2.3	na	<1.0	<0.5	na	na	0.8
LT30W	<2.0	4.8	1.2	<0.5	7.9	30	0.3
LT31W	<2.0	1.7	<1.0	<0.5	<2.0	18	<0.2
LT32W	<2.0	5.1	<1.0	<0.5	<2.0	3.8	<0.2
LT34W	<2.0	3.6	<1.0	<0.5	<2.0	<2.0	<0.2
LT38W	<2.0	2.6	<1.0	<0.5	<2.0	<2.0	0.3
LT41W	<2.0	2.3	<1.0	<0.5	<2.0	<2.0	<0.2
LT42W	4.0	5.8	<1.0	<0.5	<2.0	<2.0	<0.2
LT43W	<2.0	3.9	<1.0	<0.5	<2.0	<2.0	0.4
LT47W	<2.0	6.3	1.4	<0.5	15	57	<0.2
LT49W	<2.0	4.1	1.8	<0.5	<2.0	11	<0.2
LT50W	3.3	208	1.0	<0.5	45	<2.0	<0.2
LT52W	<2.0	3.3	<1.0	<0.5	<2.0	<2.0	<0.2
LT53W	<2.0	1.5	1.1	<0.5	<2.0	10	0.3
LT55W	<2.0	3.2	<1.0	0.6	20	22	<0.2

na = not available due to small sample volume

Table 21a: Metal analytical results for water samples by ICP (Norway) in mg/L

Sample	Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P
LT1W	6.000	< 0.0200	4.920	< 0.0050	25.700	174.00	2.960	3.40	1.590	<0.100
LT2W	8.350	0.021	12.000	0.008	45.200	243.00	15.900	9.28	0.600	<0.100
LT3W	8.410	0.132	0.122	0.006	40.500	126.00	14.000	6.87	0.088	<0.100
LT4W	4.740	< 0.0200	0.058	< 0.0050	39.200	137.00	48.400	10.6	0.744	0.122
LT30W	1.930	< 0.0200	< 0.0100	< 0.0050	29.500	109.00	7.320	8.03	0.002	<0.100
LT31W	0.094	< 0.0200	< 0.0100	< 0.0050	32.200	105.00	2.490	0.607	0.001	<0.100
LT32W	1.760	< 0.0200	< 0.0100	< 0.0050	29.600	109.00	7.330	7.93	0.001	<0.100
LT34W	1.390	< 0.0200	< 0.0100	< 0.0050	21.800	69.900	9.540	3.62	0.001	<0.100
LT38W	3.850	< 0.0200	< 0.0100	< 0.0050	19.400	112.00	4.160	7.55	0.001	<0.100
LT41W	< 0.02	0.046	< 0.0100	< 0.0050	19.900	52.200	3.400	0.807	<0.001	<0.100
LT42W	7.540	< 0.0200	0.058	< 0.0050	23.200	102.00	9.630	4.18	0.017	<0.100
LT43W	1.140	< 0.0200	0.041	< 0.0050	11.800	18.500	1.840	5.23	<0.001	<0.100
LT47W	6.100	< 0.0200	0.019	< 0.0050	27.900	116.00	8.930	4.81	0.127	<0.100
LT49W	0.389	< 0.0200	< 0.0100	< 0.0050	27.500	66.300	16.400	2.50	0.001	<0.100
LT50W	5.520	< 0.0200	< 0.0100	< 0.0050	38.700	185.00	13.800	9.15	0.003	<0.100
LT52W	1.680	< 0.0200	< 0.0100	< 0.0050	22.200	70.900	12.400	4.70	<0.001	<0.100
LT53W	1.850	< 0.0200	< 0.0100	< 0.0050	22.300	70.800	11.200	3.59	0.001	<0.100
LT55W	18.700	< 0.0200	0.145	0.018	26.400	16.900	602.00	229	0.005	0.231

Table 21b: Metal analytical results for water samples by ICP (Norway) in mg/L

Sample	Cu	Zn	Pb	Ni	Co	V	Mo	Cd	Cr	Ba
LT1W	<0.0050	0.023	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.235
LT2W	<0.0050	0.014	< 0.0500	< 0.0200	< 0.0100	0.0063	<0.010	<0.005	<0.010	0.865
LT3W	<0.0050	0.010	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.450
LT4W	<0.0050	0.018	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.115
LT30W	<0.0050	<0.0020	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.124
LT31W	<0.0050	<0.0020	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.065
LT32W	<0.0050	<0.0020	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.126
LT34W	<0.0050	<0.0020	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.084
LT38W	<0.0050	<0.0020	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.120
LT41W	<0.0050	0.002	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.017
LT42W	<0.0050	0.005	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.076
LT43W	<0.0050	0.004	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.115
LT47W	<0.0050	0.045	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.103
LT49W	<0.0050	0.005	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.122
LT50W	<0.0050	0.200	< 0.0500	0.0584	< 0.0100	<0.005	0.0141	<0.005	<0.010	0.118
LT52W	<0.0050	0.019	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.085
LT53W	<0.0050	0.008	< 0.0500	< 0.0200	< 0.0100	<0.005	<0.010	<0.005	<0.010	0.085
LT55W	<0.0050	0.017	< 0.0500	0.0288	< 0.0100	0.0139	0.0154	<0.005	0.0161	0.166

Table 21c: Metal analytical results for water samples by ICP (Norway) in mg/L

Sample	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y
LT1W	0.206	<0.0050	< 0.0100	0.016	< 0.0010	0.005	<0.001	0.086	<0.010	<0.001
LT2W	0.555	0.007	< 0.0100	0.084	0.002	0.012	<0.001	0.107	<0.010	<0.001
LT3W	0.212	<0.0050	< 0.0100	0.021	< 0.0010	0.021	<0.001	0.077	<0.010	<0.001
LT4W	0.204	<0.0050	< 0.0100	0.223	< 0.0010	<0.005	<0.001	0.079	<0.010	<0.001
LT30W	0.128	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT31W	0.135	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	0.051	<0.010	<0.001
LT32W	0.128	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	0.054	<0.010	<0.001
LT34W	0.118	<0.0050	< 0.0100	0.014	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT38W	0.155	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	0.066	<0.010	<0.001
LT41W	0.064	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT42W	0.113	<0.0050	< 0.0100	< 0.0100	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT43W	0.043	<0.0050	< 0.0100	0.054	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT47W	0.175	<0.0050	< 0.0100	< 0.0100	< 0.0010	0.009	<0.001	0.050	<0.010	<0.001
LT49W	0.203	<0.0050	< 0.0100	0.048	< 0.0010	0.007	<0.001	<0.050	<0.010	<0.001
LT50W	0.297	<0.0050	< 0.0100	0.043	< 0.0010	<0.005	<0.001	0.078	<0.010	<0.001
LT52W	0.122	<0.0050	< 0.0100	0.018	< 0.0010	0.007	<0.001	<0.050	<0.010	<0.001
LT53W	0.123	<0.0050	< 0.0100	0.018	< 0.0010	<0.005	<0.001	<0.050	<0.010	<0.001
LT55W	0.563	<0.0050	< 0.0100	0.337	< 0.0010	0.253	<0.001	<0.050	<0.010	0.001

Table 22: Anion analytical results for water samples (Norway) in mg/L

Sample	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
LT1W	<0.100	5.01	<0.100	<0.100	0.099	<0.200	1.097
LT2W	0.451	12.330	<0.250	0.113	0.072	<0.200	151.333
LT3W	0.428	3.386	<0.100	0.236	1.070	<0.200	52.661
LT4W	<0.100	37.210	<0.500	<0.100	33.681	<0.200	148.84
LT30W	0.214	25.906	<0.500	<0.100	0.425	<0.200	109.44
LT31W	0.190	1.195	<0.100	<0.100	0.077	<0.200	212.103
LT32W	0.260	26.469	<0.500	<0.100	0.720	<0.200	106.04
LT34W	0.186	16.124	<0.250	<0.100	1.264	<0.200	29.742
LT38W	0.320	2.119	<0.100	<0.100	3.047	<0.200	35.957
LT41W	0.100	3.986	<0.100	<0.100	0.122	<0.200	45.814
LT42W	<0.100	16.818	<0.250	<0.100	0.197	<0.200	72.957
LT43W	0.236	2.777	<0.100	<0.100	0.377	<0.200	5.900
LT47W	<0.100	11.143	<0.250	<0.100	4.769	<0.200	303.218
LT49W	0.393	8.165	<0.250	<0.100	0.075	<0.200	62.345
LT50W	0.300	20.873	<0.500	<0.100	5.775	<0.200	300.056
LT52W	0.194	20.829	<0.500	<0.100	1.431	<0.200	31.544
LT53W	0.192	16.817	<0.100	<0.100	1.658	<0.200	27.685
LT55W	12.56	352.1	<2.50	0.278	0.052	<0.200	62.314

Table 23: Hydrocarbon analytical results for soil samples (Norway)

Sample	Total hydrocarbon (mg/kg)	Comments
LT1S	368	mainly hydrocarbons between C_8 and C_{13}
LT2S	739	-
LT3S	<45	mainly hydrocarbons between C_8 and C_{13}
LT4S	74	mainly hydrocarbons between C_8 and C_{13}
LT5S	267	mainly hydrocarbons between C_8 and C_{13}
LT6S	<45	-
LT8S	<45	-
LT9S	<45	-
LT10S	<45	-
LT11S	<45	-
LT12S	<45	-
LT13S	564	mainly hydrocarbons between C_{15} and C_{30}
LT14S	<45	-
LT15S	<45	-
LT16S	<45	-
LT17S	<45	-
LT30S	<45	-
LT31S	8852	mainly hydrocarbons between C_8 and C_{13}
LT33S	669	mainly hydrocarbons between C_{10} and C_{20}
LT35S	47	mainly hydrocarbons between C_{10} and C_{20}
LT36S	<45	-
LT37S	<45	-
LT38S	<45	-
LT39S	<45	-
LT40S	<45	-
LT42S	<45	-
LT43S	<45	-
LT44S	<45	-
LT45S	<45	-
LT46S	72	mainly hydrocarbons between C_8 and C_{30}
LT47S	889	mainly hydrocarbons between C_8 and C_{25}
LT48S	336	mainly hydrocarbons between C_8 and C_{25}
LT50S	2581	mainly hydrocarbons between C_{12} and C_{18}
LT51S	<45	-
LT54S	5352	mainly hydrocarbons between C_{11} and C_{14}
LT56S	220	mainly hydrocarbons between C_{11} and C_{14}
LT57S	102	mainly hydrocarbons between C_{11} and C_{14}
LT58S	<45	-
LT59S	<45	-

Table 24: Hydrocarbon and PCB analytical results for soil samples (Canada)

Sample	Total hydrocarbon (mg/kg)	PCBs (mg/kg)
LT1S	313	<1.0
LT2S	251	<1.0
LT3S	<40	<1.0
LT4S	<40	<1.0
LT5S	<40	<1.0
LT6S	<40	<1.0
LT8S	<40	<1.0
LT9S	<40	<1.0
LT10S	<40	<1.0
LT11S	<40	<1.0
LT12S	<40	<1.0
LT13S	<40	<1.0
LT14S	<40	<1.0
LT15S	<40	<1.0
LT16S	<40	<1.0
LT17S	<40	<1.0
LT30S	<40	<1.0
LT31S	<40	<1.0
LT33S	<40	<1.0
LT35S	<40	<1.0
LT36S	<40	<1.0
LT37S	<40	<1.0
LT38S	<40	<1.0
LT39S	<40	<1.0
LT40S	<40	<1.0
LT42S	<40	<1.0
LT43S	<40	<1.0
LT44S	<40	<1.0
LT45S	<40	<1.0
LT46S	49	-
LT47S	740	<1.0
LT48S	<40	<1.0
LT50S	3900	<1.0
LT51S	<40	<1.0
LT54S	1240	<1.0
LT56S	384	<1.0
LT57S	<40	<1.0
LT58S	<40	<1.0
LT59S	<40	<1.0

Table 25: Metal analytical results for soil samples by AAS in mg/kg

Sample	Cu	Zn	Pb	Hg	Ni	Cr	As	Cd
LT1S	0.4	42	4.8	<0.05	16	13	18	0.6
LT2S	4.8	35	11	<0.05	18	22	12	0.6
LT3S	1.3	31	9.0	<0.05	8.1	14	4.9	0.2
LT4S	1.5	21	6.4	<0.05	8.2	10	4.4	0.1
LT5S	0.6	25	8.4	<0.05	14	24	12	0.4
LT6S	0.9	33	9.0	<0.05	21	21	6.8	0.1
LT8S	1.0	47	9.0	<0.05	28	17	5.7	0.1
LT9S	1.8	27	5.0	<0.05	14	24	4.6	0.2
LT10S	8.2	36	6.0	<0.05	23	24	4.0	0.2
LT11S	8.7	48	15	<0.05	27	23	6.8	0.3
LT13S	113	244	124	0.7	261	114	32	13
LT14S	10	46	13	<0.05	30	14	8.5	0.5
LT15S	2.0	10	3.0	<0.05	17	4.0	4.1	0.3
LT16S	2.0	23	3.8	<0.05	5.3	1.3	2.3	0.1
LT17S	0.3	38	27	<0.05	8.7	12	3.8	0.1
LT30S	1.4	42	7.4	<0.05	5.8	4.0	5.1	5.3
LT31S	15	83	41	<0.05	33	36	16	2.1
LT33S	15	183	48	<0.05	14	13	9.8	1.6
LT35S	50	668	37	<0.05	31	14	28	9.5
LT36S	16	670	20	2.1	5.5	3.3	6.5	15
LT37S	3.3	24	8.0	<0.05	5.3	2.5	2.0	1.7
LT38S	12	64	22	<0.05	30	34	14	2.0
LT39S	5.2	429	28	<0.05	18	5.3	4.0	1.1
LT40S	11	58	31	<0.05	2.6	4.5	4.8	0.1
LT42S	3.9	63	6.0	<0.05	11	3.7	2.6	0.3
LT43S	14	32	15	<0.05	13	7.1	1.9	13
LT44S	7.6	37	9.8	<0.05	5.0	5.1	1.4	3.4
LT45S	14	66	23	<0.05	4.7	4.2	2.4	0.2
LT46S	39	399	118	0.1	45	15	8.6	26
LT47S	93	1123	116	1.7	42	141	7.8	39
LT48S	77	1122	111	0.1	67	24	37	31
LT50S	46	540	3.0	<0.05	53	13	3.9	0.8
LT51S	15	591	111	<0.05	15	41	5.2	0.3
LT54S	5.6	34	8.0	<0.05	11	7.4	5.4	0.4
LT56S	6.2	18	29	<0.05	9.1	8.5	5.1	0.3
LT57S	7.3	16	4.4	<0.05	21	15	3.1	<0.05
LT59S	6.6	32	18	<0.05	9.2	7.0	3.1	0.4

TABLE 26: MAIN CATIONS AND ANIONS IN THE SHALLOW GROUNDWATER OF PAJUOSTE AIR BASE

No. No.	Well No.	Date	Unit.	Cations					Anions						TDS	Permanganatic oxidation	pH	Hardness			Kurlov formula
				Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	NO_3^-	NO_2^-	Cl^-	HCO_3^-	SO_4^{2-}	CO_2				total	carbonatic	permanent	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.	1s	93 08 24	1.	5.36	5.63	164.00	31.00	15.00	trace	<	10.00	659.00	5.00		565.49	55.20		10.73	10.73	<	$M_{0.57}\frac{HCO_3 96}{Ca68\ Mg21}$
			2.	0.23	0.14	8.18	2.55	0.882	<	<	0.28	10.80	0.10								
			3.	1.94	1.20	68.24	21.26	7.36	<	<	2.52	96.51	0.93								
2.	1s	94 09 22	1.	14.50	1.00	144.00	53.50	2.50	1.00	0.02	3.50	757.00	2.75		601.00	22.40		11.60	11.60	<	$M_{0.60}\frac{HCO_3 99}{Ca58\ Mg36}$
			2.	0.63	0.03	7.19	4.40	0.15	0.02	<	0.10	12.41	0.06								
			3.	5.09	0.21	58.00	35.52	1.19	0.12	0.003	0.78	98.59	0.45								
3.	1s	94 11 25	1.	22.00	2.14	180.00	14.60	4.63	0.38	0.01	3.61	684.00	18.70		588.00	22.40		10.20	10.20	<	$M_{0.59}\frac{HCO_3 96}{Ca78}$
			2.	0.96	0.05	8.98	1.20	0.27	0.01	<	0.10	11.21	0.39								
			3.	8.34	0.48	78.33	10.47	2.37	0.05	0.002	0.87	95.72	3.32								
4.	1s*	95 05 05	1.	2.22	3.90	170.00	28.05	4.04	0.23	<	2.83	646.00	2.49	203.28	537.00	37.40	6.80	10.79	10.60	0.19	$M_{0.54}\frac{HCO_3 98}{Ca76\ Mg21}$
			2.	0.10	0.10	8.48	2.31	0.225	0.004	<	0.08	10.60	0.05								
			3.	0.86	0.89	75.67	20.58	2.00	0.034	<	0.74	98.00	0.48								
5.	1s**	95 12 14	1.	1.79	1.85	184.00	34.16	2.06	0.31	<	5.32	719.80	21.00	245.30	610.46	19.04	6.76	11.99	11.80	0.19	$M_{0.61}\frac{HCO_3 95}{Ca75\ Mg23}$
			2.	0.08	0.05	9.18	2.81	0.114	0.005	<	0.15	11.80	0.44								
			3.	0.64	0.39	75.07	22.97	0.93	0.04	<	1.21	95.20	3.53								
6.	2s	94 09 22	1.	17.20	0.50	276.00	38.90	13.30	1.63	0.004	8.80	1074.00	13.20		906.00	27.20		17.00	17.00	<	$M_{1.07}\frac{HCO_3 97}{Ca74}$
			2.	0.75	0.01	13.77	3.20	0.78	0.03	<	0.25	17.60	0.27								
			3.	4.04	0.07	74.39	17.28	4.23	0.14	<	1.37	96.94	1.51								
7.	2s	94 11 25	1.	66.70	8.75	264.00	34.00	14.50	1.63	<	10.80	1123.00	68.10		1030.00	60.80		16.00	16.00	<	$M_{1.03}\frac{HCO_3 91}{Ca66}$
			2.	2.90	0.22	13.17	2.80	0.85	0.03	<	0.30	18.41	1.42								
			3.	14.54	1.12	66.04	14.02	4.28	0.13	<	1.51	91.29	7.03								
8.	2s*	95 05 05	1.	14.70	9.96	245.00	66.20	13.20	0.23	<	16.30	1098.00	10.12	414.82	924.88	37.60	6.70	17.67	17.67	<	$M_{0.92}\frac{HCO_3 96}{Ca63\ Mg28}$
			2.	0.64	0.25	12.23	5.45	0.73	0.004	<	0.46	18.00	0.21								
			3.	3.31	1.32	63.34	28.23	3.81	0.02	<	2.46	96.37	1.13								
9.	2s**	95 12 24	1.	31.73	5.40	236.00	54.90	1.33	0.26	<	3.55	1073.00	24.00	236.18	894.14	16.32	6.94	16.29	16.29	<	$M_{0.89}\frac{HCO_3 97}{Ca66\ Mg25}$
			2.	1.38	0.14	11.78	4.51	0.07	0.004	<	0.10	17.60	0.50								
			3.	7.71	0.77	65.85	25.23	0.41	0.023	<	0.55	96.65	2.74								
10.	3s	94 09 22	1.	36.10	2.00	64.00	105.00	0.55	4.13	0.005	2.64	733.00	81.30		662.00	3.60		11.80	11.80	<	$M_{0.66}\frac{HCO_3 87}{Mg64\ Ca24}$
			2.	1.57	0.05	3.19	8.64	0.03	0.07	<	0.07	12.01	1.69								
			3.	11.64	0.38	23.69	64.05	0.24	0.48	0.001	0.54	86.73	12.22								
11.	3s	94 11 25	1.	57.50	2.86	156.00	36.50	0.45	1.63	0.004	4.52	684.00	126.00		727.00	5.00		10.80	10.80	<	$M_{0.73}\frac{HCO_3 80}{Ca58\ Mg22}$
			2.	2.50	0.07	7.78	3.00	0.03	0.03	<	0.13	11.21	2.62								
			3.	18.68	0.55	58.15	22.42	0.20	0.19	0.001	0.91	80.12	18.75								
12.	3s*	95 05 05	1.	10.09	2.57	177.00	35.01	0.24	0.11	<	3.54	640.50	106.24	54.83	655.33	7.36	7.36	11.71	10.50	1.21	$M_{0.66}\frac{HCO_3 82}{Ca72\ Mg24}$
			2.	0.44	0.07	8.83	2.88	0.01	0.002	<	0.10	10.50	2.21								
			3.	3.59	0.54	72.22	23.54	0.11	0.013	<	0.78	81.88	17.25								
13.	3s**	95 12 14	1.	11.61	5.40	164.00	47.82	0.10	0.58	<	4.61	640.50	133.50	86.80	688.06	9.60	7.16	12.12	10.50	1.62	$M_{0.69}\frac{HCO_3 78\ SO_4 21}{Ca64\ Mg31}$
			2.	0.50	0.14	8.18	3.93	0.01	0.01	<	0.13	10.50	2.78								
			3.	3.95	1.08	64.11	30.81	0.04	0.07	<	0.97	78.21	20.71								
14.	4s	94 09 22	1.	103.00	8.34	96.00	72.90	0.80	26.30	0.92	34.40	684.00	165.00		850.00	3.40		10.80	10.80	<	$M_{0.85}\frac{HCO_3 70\ SO_4 21}{Mg39\ Ca31\ Na29}$
			2.	4.48	0.21	4.79	6.00	0.05	0.40	0.02	0.97	11.21	3.44								
			3.	28.85	1.37	30.86	38.62	0.30	2.52	0.12	6.05	69.87	21.41								

Note: water samples were analysed at the labs of Institute of Geology, Institute of Geography (*) and Hydrogeological Co. “Grota” (**).

< = below detection limit

Units:
1 - mg/l;
2 - eq/l;
3 - eq-%.

Table 26 (continue):

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
15.	4s	94 11 25	1. 2. 3.	80.50 3.50 28.29	8.13 0.21 1.68	112.00 5.59 45.18	36.50 3.00 24.26	1.23 0.07 0.58	7.13 0.11 0.89	0.08 0.002 0.014	34.30 0.97 7.59	537.00 8.80 69.09	137.00 2.85 22.39		685.00	5.10		8.60	8.60	<	$M_{0.68}\frac{HCO_3 69\ SO_4 22}{Ca45\ Na28\ Mg24}$
16.	4s*	95 05 05	1. 2. 3.	34.13 1.48 13.72	5.81 0.15 1.37	120.00 5.99 55.37	38.43 3.16 29.22	0.62 0.03 0.32	0.70 0.01 0.10	< < <	18.43 0.52 4.57	466.65 7.65 67.22	153.50 3.20 28.09	84.42	605.00	4.50	7.04	9.15	7.65	1.50	$M_{0.60}\frac{HCO_3 67\ SO_4 28}{Ca55\ Mg29}$
17.	4s**	95 12 14	1. 2. 3.	40.15 1.75 14.63	6.82 0.17 1.46	130.00 6.49 54.35	42.70 3.51 29.42	0.29 0.02 0.13	0.32 0.005 0.044	0.06 0.001 0.01	26.62 0.75 6.34	506.30 8.30 70.07	133.50 2.78 23.47	42.35	633.84	3.36	7.37	10.00	8.30	1.70	$M_{0.63}\frac{HCO_3 70\ SO_4 23}{Ca54\ Mg29}$
18.	5s	94 09 22	1. 2. 3.	67.40 2.93 24.03	9.17 0.23 1.92	64.00 3.19 26.19	70.50 5.80 47.54	0.65 0.04 0.31	0.75 0.01 0.09	0.02 < 0.003	7.10 0.20 1.60	733.00 12.01 95.89	14.30 0.30 2.38		600.00	12.00		10.80	10.80	<	$M_{0.60}\frac{HCO_3 96}{Mg48\ Ca26\ Na24}$
19.	5s	94 11 25	1. 2. 3.	93.10 4.05 30.96	6.86 0.18 1.34	120.00 5.99 45.80	34.00 2.80 21.39	1.13 0.07 0.51	0.75 0.01 0.09	0.01 < 0.002	4.52 0.13 0.95	610.00 10.00 74.32	159.00 3.31 24.61		724.00	13.20		8.80	8.80	<	$M_{0.72}\frac{HCO_3 74\ SO_4 25}{Ca46\ Na31\ Mg21}$
20.	5s*	95 05 05	1. 2. 3.	4.00 0.17 2.40	3.32 0.08 1.17	93.00 4.64 64.04	28.06 2.31 31.84	0.71 0.04 0.55	0.05 0.001 0.011	< < <	3.54 0.10 1.45	390.40 6.40 92.95	18.26 0.38 5.52	45.57	346.00	12.96	7.24	6.95	6.40	0.55	$M_{0.35}\frac{HCO_3 93}{Ca64\ Mg32}$
21.	5s**	95 12 14	1. 2. 3.	4.12 0.18 1.66	3.74 0.10 0.88	150.00 7.49 69.23	36.60 3.01 27.84	0.76 0.04 0.39	0.79 0.013 0.113	0.07 0.001 0.013	3.90 0.11 0.97	573.40 9.40 83.18	85.00 1.77 15.66	61.08	571.89	11.84	7.27	10.49	9.40	1.10	$M_{0.57}\frac{HCO_3 83}{Ca69\ Mg28}$
22.	River Juosta upstream the oil storage	94 11 25	1. 2. 3.	25.30 1.10 11.90	5.00 0.13 1.38	108.00 5.39 58.30	31.60 2.60 28.11	0.47 0.03 0.30	22.50 0.36 3.75	0.11 0.002 0.02	19.80 0.56 5.83	391.00 6.41 66.58	110.00 2.29 23.79		518.00	8.80		8.00	6.40	1.60	$M_{0.52}\frac{HCO_3 67\ SO_4 24}{Ca58\ Mg28}$
23.	River Juosta downstream the storage	94 11 25	1. 2. 3.	20.70 0.90 10.17	5.63 0.14 1.63	112.00 5.59 63.13	26.80 2.20 24.89	0.28 0.02 0.19	20.00 0.32 3.48	0.08 0.002 0.02	21.70 0.61 6.63	366.00 6.00 65.02	110.00 2.29 24.82		500.00	8.80		7.80	6.00	1.80	$M_{0.50}\frac{HCO_3 65\ SO_4 25}{Ca63\ Mg25}$
24.	Small stream near the storage	95 05 05	1. 2. 3.	3.56 0.15 1.94	1.66 0.04 0.53	93.00 4.64 58.23	37.82 3.11 39.03	0.38 0.02 0.26	0.17 0.003 0.03	< < <	8.15 0.23 2.87	469.70 7.70 96.13	3.48 0.07 0.90	61.52	383.22	25.28	7.19	7.75	7.70	0.05	$M_{0.38}\frac{HCO_3 96}{Ca58\ Mg39}$
25.	River Nevezis upstream airbase	94 11 25	1. 2. 3.	11.60 0.50 6.26	5.00 0.13 1.59	104.00 5.19 64.46	26.80 2.20 27.38	0.43 0.02 0.31	15.60 0.25 2.96	0.11 0.002 0.03	3.61 0.10 1.21	391.00 6.41 76.19	79.10 1.65 19.58		442.00	3.76		7.40	6.40	1.00	$M_{0.44}\frac{HCO_3 76\ SO_4 20}{Ca64\ Mg28}$
26.	River Nevezis downstream airbase	94 11 25	1. 2. 3.	23.00 1.00 11.70	5.00 0.13 1.50	104.00 5.19 60.71	26.80 2.20 25.78	0.45 0.03 0.31	10.50 0.17 1.88	0.08 0.002 0.02	21.70 0.61 6.85	391.00 6.41 71.76	83.50 1.74 19.47		470.00	9.20		7.40	6.40	1.00	$M_{0.47}\frac{HCO_3 72}{Ca61\ Mg26}$

Note: water samples were analysed at the labs of Institute of Geology, Institute of Geography (*) and Hydrogeological Co. "Grota" (**).

< = below detection limit

Units:
1 - mg/l;
2 - eq/l;
3 - eq-%.

TABLE 27: ANALYSIS OF TRACE ELEMENTS, OIL PRODUCTS AND AROMATIC HYDROCARBONS IN GROUNDWATER OF PAJUOSTE AIRBASE

No.. No.	Well number	Date	Concentration, mg/l												
			Fe	Zn	Cu	Pb	Ni	Cd	Cr	Co	Al	Sr	Mn	Oil products	Sum of aromatic hydrocarbons
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	1s*	94 09 22	3.43	0.022	0.0014	<	0.0026	<	<	-	0.020	0.183	2.87	7.00	
2.	1s	94 11 25	1.25	0.035	0.006	0.027	0.015	0.005	0.027	0.008	-	-	0.915	36.50	
3.	1s	95 05 05	1.95	0.035	0.008	0.020	0.025	0.002	0.13	0.013	-	-	0.50	886.00	
4.	1s	95 12 15													0.07
5.	2s*	94 09 22	7.49	0.017	0.0014	<	0.0005	<0	0.001	-	0.069	0.474	0.71	7.40	
6.	2s	94 11 25	1.57	0.036	0.008	0.039	0.024	0.005	0.096	0.023	-	-	0.50	75.30	
7.	2s	95 05 05	2.18	0.046	0.009	0.023	0.045	0.003	0.29	0.022	-	-	0.465	33.40	
8.	2s	95 12 15													2.03
9.	3s*	94 09 22	0.047	0.014	0.0032	<	<	<	<	-	0.051	0.137	0.20	0.10	
10.	3s	94 11 25	0.074	0.028	0.009	0.025	<	0.004	<	0.01	-	-	0.125	0.16	
11.	3s	95 05 05	1.35	0.046	0.011	0.029	0.034	0.004	0.05	0.026	-	-	0.325		
12.	3s	95 12 15													<
13.	4s*	94 09 22	0.02	0.028	0.0038	<	0.028	<	<	-	0.030	0.150	0.70		
14.	4s	94 11 25	0.135	0.039	0.007	0.032	0.021	0.02	<	0.012	-	-	0.42	0.20	
15.	4s	95 05 05	0.27	0.022	0.008	0.017	0.013	0.004	0.021	0.005	-	-	0.315		
16.	4s	95 12 15													<
17.	5s*	94 09 22	0.02	0.004	0.0027	0.0011	0.0021	<	<	<	0.034	0.148	0.22	0.40	
18.	5s	94 11 25	0.53	0.032	0.007	0.024	0.013	0.03	0.027	0.012	-	-	0.85	0.50	
19.	5s	95 05 05	1.82	0.027	0.007	0.014	0.013	0.002	0.071	0.008	-	-	0.40		
20.	5s	95 12 15													<
21.	River Juosta upstream the oil storage	94 11 25	0.064	0.038	0.007	0.017	0.013	0.001	<	0.008	-	-	0.006	0.05	
22.	River Juosta downstream the storage	94 11 25	0.083	0.028	0.006	0.032	0.013	0.002	<	0.005	-	-	0.008	0.09	
23.	Small stream close to the storage	95 05 05	1.37	0.033	0.007	0.013	0.013	0.002	0.031	0.008	-	-	0.245	0.09	
24.	River Nevezis upstream the airbase	95 11 25	1.37	0.033	0.007	0.038	<	0.003	<	0.006< 6	-	-	0.007	0.08	
25.	River Nevezis downstream the airbase	94 11 25	0.12	0.035	0.005	0.013	0.011	0.001	<	0.008	-	-	0.014	0.07	

< = below detection limit

NOVAMANN
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Laboratoires Analytiques de Qualité
Quality Analytical Laboratories

QUEEN'S UNIVERSITY
ANALYTICAL SERVICES UNIT
DEPARTMENT OF CHEMISTRY
KINGSTON, ON
Canada K7L 3N6

Report Date: 94/10/27
Report #: NM-21804

Attention: Paula Whitley

ANALYTICAL REPORT

NOVAMANN JOB #: 9403893, Received: 94/10/14, 10:00

Sample Matrix: SOIL, # Samples Received: 4

Analyses	Quantity	Date Extracted	Date Analyzed	Analytical Method	Method Reference
ACID AND BASE NEUTRAL ORGANICS	4	94/10/18	94/10/25	GC/MS	EPA 8270

Sample Matrix: WATER, # Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Analytical Method	Method Reference
ACID AND BASE NEUTRAL ORGANICS	2	94/10/18	94/10/24	GC/MS	EPA 625

NOVAMANN (QUÉBEC) INC.

TERESA BATTISTA, B.Sc.
Technical Representative

Approved by CLAUDE R. DUPRESSOIR, Ph.D., Chemist
Director, Organics

Claude Roger
Dupressoir
90-047

TB/er
encl.

NOVAMANN
INTERNATIONAL

LES 50 SOCIÉTÉS LES MIEUX GÉRÉES

REPORT DATE: 25/10/94

NOVAMANN JOB #: 9403893

ACID AND BASE NEUTRAL ORGANICS IN SOIL
(mg/kg)

Novamann ID	78000		77999		77997	77998		
Parameter	LT 54 S	DL	LT 50 S	DL	LT 31 S	LT 47 S	BLANK	DL
% Moisture	83		65		42	33		
Phenol	ND	1	ND	0.3	ND	ND	ND	0.1
2-Chlorophenol	ND	1	ND	0.3	ND	ND	ND	0.1
2-Nitrophenol	ND	1	ND	0.3	ND	ND	ND	0.1
2,4-Dimethylphenol	ND	1	ND	0.3	ND	ND	ND	0.1
2,4-Dichlorophenol	ND	1	ND	0.3	ND	ND	ND	0.1
4-Chloro-3-Methylphenol	ND	1	ND	0.3	ND	ND	ND	0.1
2,4,6-Trichlorophenol	ND	1	ND	0.3	ND	ND	ND	0.1
2,4-Dinitrophenol	ND	1	ND	0.3	ND	ND	ND	0.1
4-Nitrophenol	ND	1	ND	0.3	ND	ND	ND	0.1
2-Methyl-4,6-dinitrophenol	ND	1	ND	0.3	ND	ND	ND	0.1
Pentachlorophenol	ND	1	ND	0.3	ND	ND	ND	0.1
Bis(2-chloroethyl)ether	ND	1	ND	0.3	ND	ND	ND	0.1
1,3-Dichlorobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
1,4-Dichlorobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
1,2-Dichlorobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
Bis(2-chloroisopropyl)ether	ND	1	ND	0.3	ND	ND	ND	0.1
N-Nitroso-di-N-propylamine	ND	1	ND	0.3	ND	ND	ND	0.1
Hexachloroethane	ND	3	ND	0.9	ND	ND	ND	0.3
Nitrobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
Isophorone	ND	1	ND	0.3	ND	ND	ND	0.1
Bis(2-chloroethoxy)methane	ND	1	ND	0.3	ND	ND	ND	0.1
1,2,4-Trichlorobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
Naphthalene	ND	1	ND	0.3	ND	ND	ND	0.1
Hexachlorobutadiene	ND	3	ND	0.9	ND	ND	ND	0.3
Hexachlorocyclopentadiene	ND	5	ND	2	ND	ND	ND	0.5
2-Chloronaphthalene	ND	1	ND	0.3	ND	ND	ND	0.1
Dimethyl phthalate	ND	1	ND	0.3	ND	ND	ND	0.1
Acenaphthylene	ND	1	ND	0.3	ND	ND	ND	0.1
2,6-Dinitrotoluene	ND	3	ND	0.9	ND	ND	ND	0.3
Acenaphthene	ND	1	ND	0.3	ND	ND	ND	0.1
2,4-Dinitrotoluene	ND	3	ND	0.9	ND	ND	ND	0.3
Fluorene	ND	1	ND	0.3	ND	ND	ND	0.1
Diethyl phthalate	ND	1	ND	0.3	ND	ND	ND	0.1
4-Chlorophenyl phenyl ether	ND	1	ND	0.3	ND	ND	ND	0.1
N-Nitrosodiphenylamine	ND	2	ND	0.6	ND	ND	ND	0.2
4-Bromophenyl phenyl ether	ND	1	ND	0.3	ND	ND	ND	0.1
Hexachlorobenzene	ND	1	ND	0.3	ND	ND	ND	0.1
Phenanthrene	ND	1	ND	0.3	ND	ND	ND	0.1

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REPORT DATE: 25/10/94

NOVAMANN JOB #: 9403893

ACID AND BASE NEUTRAL ORGANICS IN SOIL
(mg/kg)

Novamann ID	78000		77999		77997	77998		
Parameter	LT 54 S	DL	LT 50 S	DL	LT 31 S	LT 47 S	BLANK	DL
Anthracene	ND	1	ND	0.3	ND	ND	ND	0.1
Di-N-butyl phthalate	37	1	19	0.3	1.3	6.7	0.5	0.1
Fluoranthene	ND	1	ND	0.3	ND	ND	ND	0.1
Benzidine	ND	20	ND	6	ND	ND	ND	2
Pyrene	ND	1	ND	0.3	ND	ND	ND	0.1
Benzyl butyl phthalate	ND	1	ND	0.3	ND	ND	ND	0.1
Benz(a)anthracene	ND	1	ND	0.3	ND	ND	ND	0.1
3,3'-Dichlorobenzidine	ND	2	ND	0.6	ND	ND	ND	0.2
Chrysene	ND	1	ND	0.3	ND	ND	ND	0.1
Bis(2-ethylhexyl)phthalate	ND	1	1.4	0.3	0.4	25	0.2	0.1
Di-N-octyl phthalate	ND	1	ND	0.3	ND	29	ND	0.1
Benzo(b+j+k)fluoranthene	ND	1	ND	0.3	ND	ND	ND	0.1
Benzo(a)pyrene	ND	1	ND	0.3	ND	ND	ND	0.1
Indeno(1,2,3-cd)pyrene	ND	4	ND	1	ND	ND	ND	0.4
Dibenz(a,h)anthracene	ND	4	ND	1	ND	ND	ND	0.4
Benzo(ghi)perylene	ND	4	ND	1	ND	ND	ND	0.4
a-BHC	ND	3	ND	0.9	ND	ND	ND	0.3
Lindane	ND	3	ND	0.9	ND	ND	ND	0.3
b-BHC	ND	3	ND	0.9	ND	ND	ND	0.3
Heptachlor	ND	3	ND	0.9	ND	ND	ND	0.3
Aldrin	ND	2	ND	0.6	ND	ND	ND	0.2
Heptachlor epoxide	ND	5	ND	2	ND	ND	ND	0.5
a-Endosulfan	ND	5	ND	2	ND	ND	ND	0.5
p,p'-DDE	ND	2	ND	0.6	ND	ND	ND	0.2
Dieldrin	ND	3	ND	0.9	ND	ND	ND	0.3
Endrin	ND	2	ND	0.6	ND	ND	ND	0.2
b-Endosulfan	ND	3	ND	0.9	ND	ND	ND	0.3
p,p'-DDD	ND	2	ND	0.6	ND	ND	ND	0.2
Endrin aldehyde	ND	3	ND	0.9	ND	ND	ND	0.3
p,p'-DDT	ND	3	ND	0.9	ND	ND	ND	0.3
Endosulfan sulfate	ND	2	ND	0.6	ND	ND	ND	0.2
Toxaphene	ND	200	ND	60	ND	ND	ND	20
Chlordane	ND	30	ND	9	ND	ND	ND	3
Aroclor 1016	ND	20	ND	6	ND	ND	ND	2
Aroclor 1221	ND	20	ND	6	ND	ND	ND	2
Aroclor 1232	ND	20	ND	6	ND	ND	ND	2
Aroclor 1242	ND	20	ND	6	ND	ND	ND	2
Aroclor 1248	ND	20	ND	6	ND	ND	ND	2
Aroclor 1254	ND	20	ND	6	ND	ND	ND	2

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LES 50 SOCIÉTÉS LES MIEUX GÉRÉES

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(mg/kg)

Novamann ID	78000		77999		77997	77998		
Parameter	LT 54 S	DL	LT 50 S	DL	LT 31 S	LT 47 S	BLANK	DL
Aroclor 1260	ND	20	ND	6	ND	ND	ND	2

Recovery of Surrogates
(%)

Parameter	LT 54 S		LT 50 S		LT 31 S	LT 47 S	BLANK
D6-PHENOL	94		120		87	110	150
TRIFLUOROMETHYL-M-CRESOL	110		120		88	140	140
D5-NITROBENZENE	45		63		*	66	54
D10-ANTHRACENE	68		91		75	99	70
D12-BENZO(A)PYRENE	55		58		56	68	75

ND = Not detected
DL = Detection Limit

Please note that the above results have not been corrected for QC recoveries.

* Due to interference the recovery could not be determined.

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INTERNATIONAL

REPORT DATE: 25/10/94

NOVAMANN JOB #: 9403893

ACID AND BASE NEUTRAL ORGANICS IN WATER
(ug/L)

Novamann ID	77995	77996			
Parameter	LT 42 W	LT 55 W	DL	BLANK	DL
Di-N-butyl phthalate	120	130	3	30	1
Fluoranthene	ND	ND	3	ND	1
Benzidine	ND	ND	60	ND	20
Pyrene	ND	ND	3	ND	1
Benzyl butyl phthalate	ND	ND	3	ND	1
Benz(a)anthracene	ND	ND	3	ND	1
3,3'-Dichlorobenzidine	ND	ND	6	ND	2
Chrysene	ND	ND	3	ND	1
Bis(2-ethylhexyl)phthalate	5.5	6.4	3	3.3	1
Di-N-octyl phthalate	ND	ND	3	ND	1
Benzo(b+j+k)fluoranthene	ND	ND	3	ND	1
Benzo(a)pyrene	ND	ND	3	ND	1
Indeno(1,2,3-cd)pyrene	ND	ND	10	ND	4
Dibenz(a,h)anthracene	ND	ND	10	ND	4
Benzo(ghi)perylene	ND	ND	10	ND	4
a-BHC	ND	ND	9	ND	3
Lindane	ND	ND	9	ND	3
b-BHC	ND	ND	9	ND	3
Heptachlor	ND	ND	9	ND	3
Aldrin	ND	ND	6	ND	2
Heptachlor epoxide	ND	ND	20	ND	5
a-Endosulfan	ND	ND	20	ND	5
p,p'-DDE	ND	ND	6	ND	2
Dieldrin	ND	ND	9	ND	3
Endrin	ND	ND	20	ND	5
b-Endosulfan	ND	ND	20	ND	5
p,p'-DDD	ND	ND	6	ND	2
Endrin aldehyde	ND	ND	9	ND	3
p,p'-DDT	ND	ND	9	ND	3
Endosulfan sulfate	ND	ND	6	ND	2
Chlordane	ND	ND	9	ND	3
Toxaphene	ND	ND	60	ND	20
Aroclor 1016	ND	ND	60	ND	20
Aroclor 1221	ND	ND	60	ND	20
Aroclor 1232	ND	ND	60	ND	20
Aroclor 1242	ND	ND	60	ND	20
Aroclor 1248	ND	ND	60	ND	20
Aroclor 1254	ND	ND	60	ND	20
Aroclor 1260	ND	ND	60	ND	20

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ACID AND BASE NEUTRAL ORGANICS IN WATER
(ug/L)

Novamann ID	77995	77996			
Parameter	LT 42 W	LT 55 W	DL	BLANK	DL
Phenol	ND	ND	3	ND	1
2-Chlorophenol	ND	ND	3	ND	1
2-Nitrophenol	ND	ND	3	ND	1
2,4-Dimethylphenol	ND	ND	3	ND	1
2,4-Dichlorophenol	ND	ND	3	ND	1
4-Chloro-3-Methylphenol	ND	ND	3	ND	1
2,4,6-Trichlorophenol	ND	ND	3	ND	1
2,4-Dinitrophenol	ND	ND	3	ND	1
4-Nitrophenol	ND	ND	3	ND	1
2-Methyl-4,6-dinitrophenol	ND	ND	3	ND	1
Pentachlorophenol	ND	ND	3	ND	1
Bis(2-chloroethyl)ether	ND	ND	3	ND	1
1,3-Dichlorobenzene	ND	ND	3	ND	1
1,4-Dichlorobenzene	ND	ND	3	ND	1
1,2-Dichlorobenzene	ND	ND	3	ND	1
Bis(2-chloroisopropyl)ether	ND	ND	3	ND	1
N-Nitroso-di-N-propylamine	ND	ND	3	ND	1
Hexachloroethane	ND	ND	9	ND	3
Nitrobenzene	ND	ND	3	ND	1
Isophorone	ND	ND	3	ND	1
Bis(2-chloroethoxy)methane	ND	ND	3	ND	1
1,2,4-Trichlorobenzene	ND	ND	3	ND	1
Naphthalene	ND	ND	3	ND	1
Hexachlorobutadiene	ND	ND	9	ND	3
Hexachlorocyclopentadiene	ND	ND	20	ND	5
2-Chloronaphthalene	ND	ND	3	ND	1
Dimethyl phthalate	ND	ND	3	ND	1
Acenaphthylene	ND	ND	3	ND	1
2,6-Dinitrotoluene	ND	ND	9	ND	3
Acenaphthene	ND	ND	3	ND	1
2,4-Dinitrotoluene	ND	ND	9	ND	3
Fluorene	ND	ND	3	ND	1
Diethyl phthalate	ND	ND	3	ND	1
4-Chlorophenyl phenyl ether	ND	ND	3	ND	1
N-Nitrosodiphenylamine	ND	ND	6	ND	2
4-Bromophenyl phenyl ether	ND	ND	3	ND	1
Hexachlorobenzene	ND	ND	3	ND	1
Phenanthrene	ND	ND	3	ND	1
Anthracene	ND	ND	3	ND	1

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ANNEX C

Photos from selected survey sites

Photograph 1: Arial photograph of the Pajuoste airfield showing the main features of the site, the wooded and grassed areas and drainage ditches.

Photograph 2: Tank containing brown liquid near the fuel storage tank area.

Photograph 3: Collecting a soil sample from the drilling rig auger during the establishment of Well 2 near the fuel storage site.

Photograph 4: Debris scattered in an area containing building foundations. The two buildings were former warehouses behind which run the railway lines.

Photograph 5: Drums visible outside one of the buildings forming part of the chemical storage area. Sample Lit II-1 containing 1,2 dichloroethane was taken from one of these drums.

Photograph 6: One of the buildings in the chemical storage area. Several barrels inside the building were sealed and not sampled. Lit II-2 was taken from an open drum inside this building.

Photograph 7: Sampling soil at the toe of the landfill. This sample, LT54S, containing very high levels of petroleum products.

Photograph 8: The main building at the radar facility in the centre of the airfield.