Haines-Fairbanks Pipeline: Environmental Issues at Border Pump Station and Rainy Hollow Sites

Report Prepared for

Arctic Environmental Strategy, Action on Waste, Whitehorse, Yukon

By

Royal Roads University

Applied Research Division

April, 1996

ROYAL ROADS UNIVERSITY

2005 Sooke Road Victoria, British Columbia, Canada V9B 5Y2
Tel (604) 391-2511 Fax (604) 391-2500
http://www.royalroads.ca

Brett Hartshorne
Manager
AES - Action on Waste - Yukon
Indian and Northern Affairs Canada
#345, 300 Main St.
Whitehorse, Yukon
Y1A 2B5

15 April, 1996

Dear Brett:

We are very please to submit three copies of our report, *Haines-Fairbanks Pipeline: Environmental Issues at Border Pump Station and Rainy Hollow Sites..*

The report provides a compilation and synthesis of all new and existing information on Border Station and Rainy Hollow in order to obtain a better understanding of the environmental issues at the sites which will assist in the selection of remedial actions. These issues include the sources, type, and distribution of contamination; environmental fate of contaminants; and ecological risk(s) to the Klehini River and other sensitive receptors. In situations where insufficient knowledge is available to address the above issues, recommendations for further investigation are provided.

Section 1 provides an introduction, and the scope and objectives of the report. The methodology used in information collection is presented in **Section 2**, along with a chronological review of cleanup activities, and environmental/scientific investigations and findings at the sites. **Section 3** consists of an interpretation of the contaminant issues based on the information review of Section 2 and the objectives stated in Section 2; information gaps are identified which need to be addressed for future action(s). Conclusions and recommendations are presented in **Section 4** which includes a summary of the contaminant issues and recommendations for further action.

The outstanding environmental issues at the sites have been identified as follows:

- presence of buried debris at the sites which may contain contaminated materials;
- a better understanding of the composition, spatial and vertical distribution, and fate of subsurface hydrocarbon contamination between Border Station, Rainy Hollow and the Klehini River;
- additional investigation of DDT-contaminated soils in and around the Rainy Hollow Trench enclosure and between the facility and the Klehini River;
- investigation of the possibility of dioxins associated as impurities with historic herbicide applications;
- depth of surface hydrocarbon staining at Border Station;
- need for more detailed risk assessment in the terrestrial environment between Border Station and Rainy Hollow, and the Klehini River environment;

The above would be best achieved using an iterative and guided field approach (including the use of field and laboratory techniques) coupled with confirmatory testing. Sufficient information should be obtained to facilitate a detailed risk assessment, a critical evaluation of remedial strategies and estimation of cleanup costs, and the development of a full engineering design.

We trust that this report meets your requirements. If you have any questions or comments, please let us know. We look forward to the possibility of doing additional environmental work with you in the near future.

Sincerely,

W.T. Dushenko

Bill Dushenko,

Applied Research Division

TABLE OF CONTENTS

LIST OF MAPS

LIST OF PHOTOGRAPHS

TABLE

1. INTRODUCTION

1.1 Background

This report has been prompted by contaminant studies conducted at the abandoned Border Pump Station site by UMA/AMBIO (1995) for Indian and Northern Affairs (Whitehorse), and the associated Rainy Hollow airstrip site by Golder Associates (1995) for Environment Canada (Pacific and Yukon Region). Brief historical reviews of the sites are provided in both of the above reports, as well as by K. Bisset and Associates (1995). The Border Station site is situated on an upper bench adjacent to the Old Haines Highway and Rainy Hollow is located on an old flood plain below Border Station and along the shore of the Klehini River (Figure 1). Both areas are located within the Tatshenshini-Alsek Wilderness Park of British Columbia. It is important to note that although the two sites have been treated separately in recent years due to jurisdictional issues, both were operated historically as a single unit and are hydrologically linked. A layout of the sites is provided in Map 1.1.

Subsurface soil and groundwater contamination by DDT and hydrocarbons at the Rainy Hollow site was identified during a preliminary environmental assessment by Golder Associates in the fall of 1994. The study was conducted as part of an emergency response effort by B.C. Ministry of the Environment and Environment Canada to excavate and remove containers of DDT reported to have been buried in a trench there in 1971. As part of a separate preliminary environmental assessment conducted the following summer (UMA/AMBIO, 1995), hydrocarbon contamination of subsurface soil and groundwater at the Border Station site was identified. Border Station was investigated with other sites along the old Haines-Fairbanks Pipeline to provide information for cost-sharing negotiations with the U.S. government on the cleanup of old military installations in the Canadian North. Given the layout of the Border Station and Rainy Hollow sites, the preliminary investigations suggested that hydrocarbons could be undergoing subsurface migration toward the Klehini River, via Rainy Hollow.

The major outstanding environmental issue at these sites is whether or not the large area of groundwater contamination identified at Border Station is migrating or will move in the future through Rainy Hollow to the shore of the Klehini River and toward other ecological receptors. This issue is important for the development of remedial plans for Border Station. Unfortunately, the proposal of further actions at the site have been previously confounded by a number of factors. First, the political and public sensitivity over the DDT issue at Rainy Hollow has made it difficult to obtain contamination information on this site from the B.C. and Federal environment regulatory agencies. Secondly, the hydrocarbon problem at the two sites has previously been examined in isolation. An understanding of subsurface contaminant distributions at both sites is required before environmental impacts can be assessed and appropriate actions proposed.

1.2 Scope and Objectives

A Contribution Agreement was signed between Arctic Environmental Strategy - Action on Waste and Royal Roads University - Applied Research Division on the 2nd day of February, 1996 with the purpose of addressing issues arising directly from preliminary assessments at five sites (including Border Station) along the Haines-Fairbanks Pipeline (UMA/AMBIO, 1995). The objectives included further characterization and investigation of the ecotoxicological significance of contamination using archived samples, which would allow for a narrowing of focus for future detailed investigations. This information is included in a separate report (Royal Roads University, 1996).

The contribution agreement was amended on the 28th day of February, 1996 to include a compilation and synthesis of all new and existing environmental information on Border Station and Rainy Hollow in order in obtain a better understanding of subsurface contaminant distribution between the two sites. This report provides-

- a review of the available information,
- a reassessment of environmental issues at Border-Rainy Hollow site, and

- recommendations for further action.

The information presented here is supplementary to the follow-up studies of the five sites as whole which are provided as a separate report (Royal Roads University - Applied Research Division, 1996).

The specific objectives of this report were to assess the following:

- Have contaminant sources in groundwater at Border Station and Rainy Hollow been confidently identified?

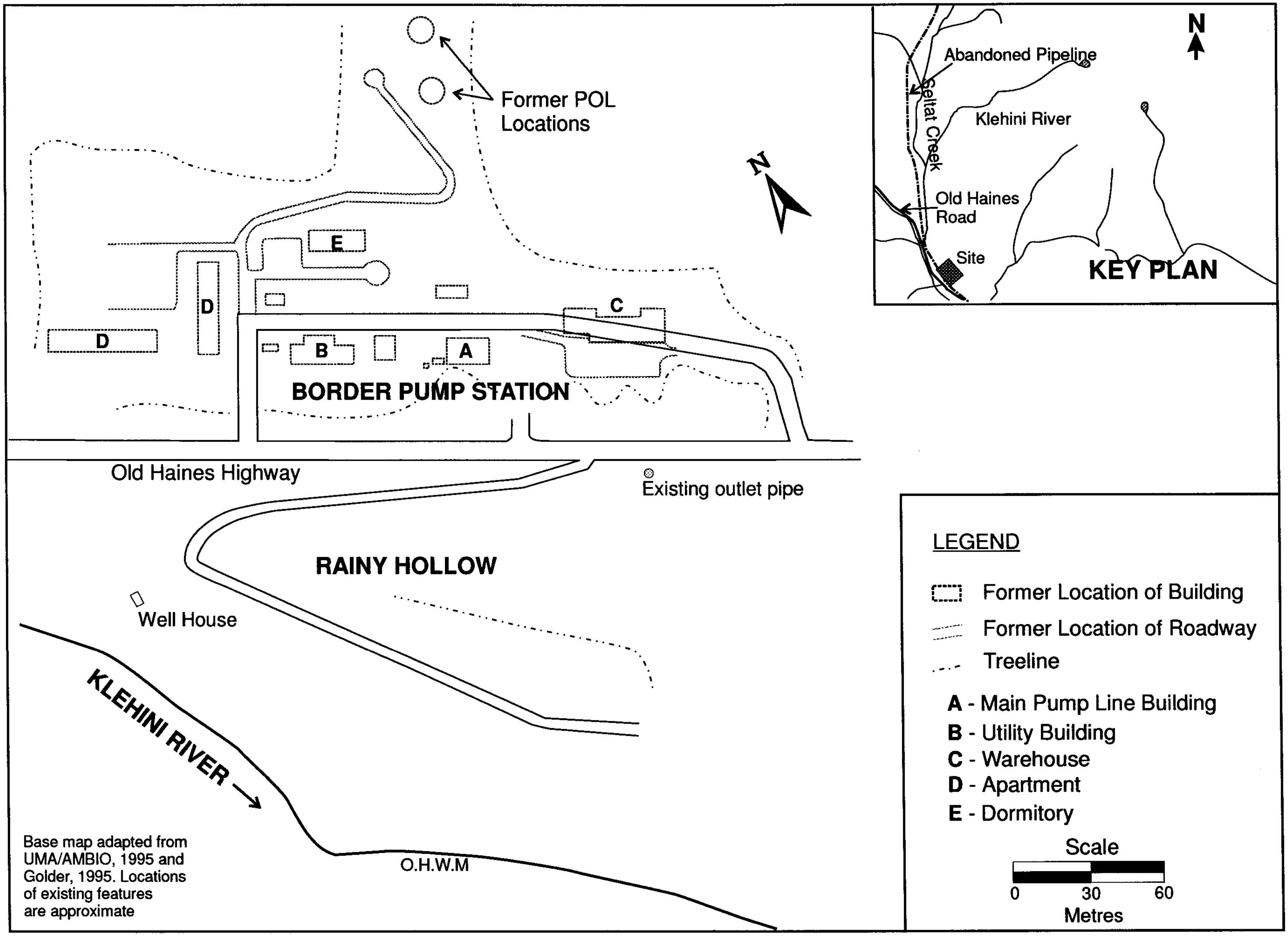
- Were the contaminant source materials at Rainy Hollow and Border Station adequately removed or isolated?

- Has the spatial and vertical extent of groundwater contamination been adequately delineated?

- Can the fate of sub-surface contaminants be adequately predicted? and

- Can the ecological risk to the river and other sensitive receptors be adequately assessed?

Where gaps in knowledge undermine the ability to answer these questions, recommendations for further investigation are provided.



Map 1.1: Layout of Border Pump Station and Rainy Hollow Site

2. INFORMATION REVIEW

2.1 Methodology

In order to achieve the objectives listed in Section 1.2, the first requirement was to compile all new and existing information on the two sites including sources from B.C. Ministry of the Environment, Environment Canada, Indian and Northern Affairs (DIAND) in Whitehorse and associated consultant reports. As part of this task, Steve Grundy from Royal Roads University traveled to the Indian and Northern Affairs office in Whitehorse on March 4-5, 1996 for the purpose of obtaining any outstanding information, along with names of contacts from the different agencies involved. Where possible, discussions were held with agency representatives in Whitehorse. Sources of information from this visit and other areas included the following:

- *Disposal of Asbestos and Scrap Metal Waste at Rainy Hollow* (June 14, 1990) - Letter to Lorne Gay (DIAND, Whitehorse) from Philip Ross (BCMOE);
- *Rainy Hollow - General Plan* - brief salvaging, burning, cleanup and restoration plans received by Indian and Northern Affairs (6 January '92) from Pipe and Piping Supplies (B.C.) Ltd.;
- *Contractor's Plan of Action Letter for the Demolition of the Former Rainy Hollow Site* (21 April, 1992) - to Kevin Ristau (DIAND) from McInroy Disposal Ltd.;
- *Copy of Land Use Permit for the Demolition and Site Restoration of the Rainy Hollow Pumping Station* (21 January, 1992) - issued to Pipe and Piping Supplies (B.C.) Ltd. by Indian and Northern Affairs;
- *Site Assessment & Remedial Response Program Border Pump Station Rainy Hollow, B.C.* (March, 1995) - Report submitted to Environment Canada by Golder Associates;
- *Research of Former Military Sites & Activities in the Yukon* (April, 1995) - Report submitted to AES (DIAND) by K. Bisset & Associates;
- *The Degradation of DDT Using Advanced Oxidation Processes* (28 April, 1995) - Unbound thesis by France Lessard (U. of Ottawa) passed on to Dieter Theiss (EC);

- *Rainy Hollow Groundwater Sampling Program (20-21 June '95)* - Environment Canada (EC), Draft Report;

- *Preliminary Environmental Assessment Haines-Fairbanks Pipeline.* (August, 1995) - Report prepared for AES-Whitehorse (DIAND) by UMA Engineering Ltd. and AMBIO Research Associates, Inc.;

- *Rainy Hollow/Border Pump Station Draft 1996 Work Plan: Detailed Environmental Site Investigation and Remedial Plan Development.* (February, 1996) - Prepared by Peggy Evans, B.C. Ministry of Environment, Lands and Parks.;

- *Preliminary Environmental Assessment Haines-Fairbanks Pipeline: Delineation and Characterization of Metals, Organochlorines and Hydrocarbons at Million Dollar Falls, Blanchard River and Border Station.* (March, 1996) - Report prepared for Indian and Northern Affairs (DIAND) AES by Royal Roads University - Applied Research Division.;

- *Photocopied maps* showing: 1) original land parcel (P.C. 1953-763) and actual construction area of Border Station, and 2) burial locations of demolition debris at Border Station (23 April '92); and

- *Photos* of Border Station during decommissioning.

Interviews were also set up and conducted with the following agency representatives in Whitehorse:

- Vic Enns (Head, Pollution Abatement, EC);

- Brian Levia (YTG, Lands); and

- Kevin Ristau (Land Resources, DIAND).

Other individuals involved with environmental investigations/cleanup at the sites included:

- Alex Grant (Environmental Emergency Response Officer, MOE in Smithers) - technical contact on the Rainy Hollow cleanup;

- Peggy Evans (BC MOE in Victoria) - worked on the Rainy Hollow criteria and DDT disposal methods;
- Ken Wile and Deiter Theiss (Emergencies Section, EC in North Vancouver) - project management authority on the Rainy Hollow cleanup;
- Brad Spencer (EC Lab in Vancouver) - analytical work on all Rainy Hollow samples prior to and during the Golder Investigation.

2.2 Cleanup Operations

A cleanup of the Border Station site was conducted by the B.C. Ministry of Forests in 1987 following the vacation of the last tenants, Stryker Resources/Freport Resources, who used the facilities as a mineral exploration base camp from 1983 to 1987 (Golder Associates, 1995). Details of this effort are not available; it is assumed, however, that cleanup was cosmetic in nature and consisted of the clearing away loose debris to be stockpiled or later salvaged. Buildings and facilities were left intact (Photograph 2.1). Further decommissioning of the site, specifically buildings and facilities, was left up to Indian and Northern Affairs (DIAND) in Whitehorse.

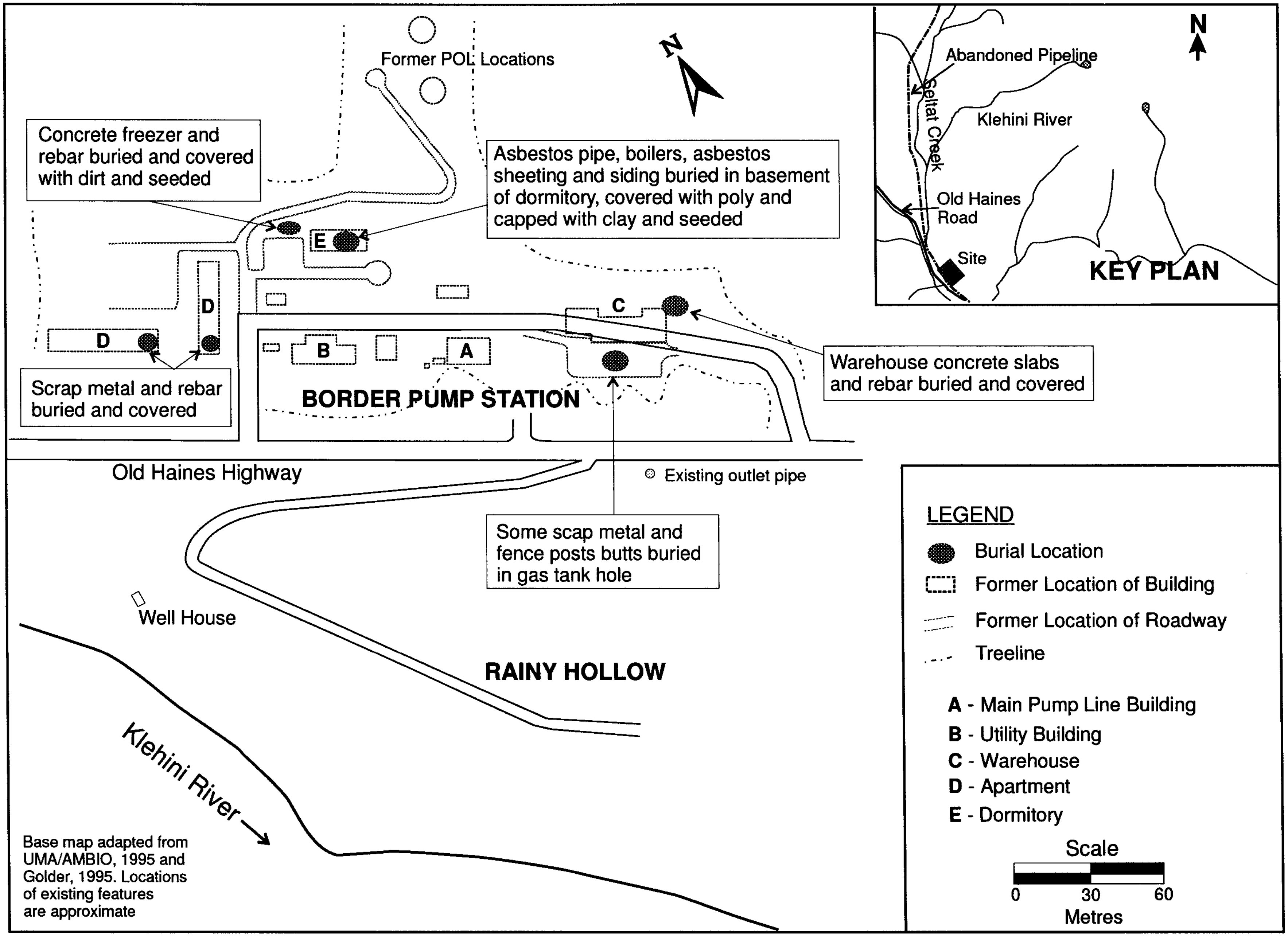
One of the major financial issues associated with decommissioning of the site(s) was the disposal of friable asbestos, scrap metal and fuel contaminated soil at Rainy Hollow (particularly, Border Station). The B.C. Ministry of the Environment (BCMOE, Smithers) recommended in a letter in June of 1990 to Indian and Northern Affairs (DIAND) Field Operations (Whitehorse) that these waste materials could be disposed of more economically on-site in the concrete foundations and basements of the apartment blocks located at Border Station (BCMOE, 1990). The materials were to be adequately isolated by sealing securely in place using either dense clay or impervious cementing material, followed by soil capping to enhance revegetation. The major concern was to ensure that these materials were "segregated and stored to prevent leaching into groundwater". An analysis of excavated soils for contaminants was not considered to be required given its "considerable expense (which) would interfere with accomplishing some level of cleanup at the site". The letter concluded that the above protocol would be "a means of balancing (their) mutual interests".

Salvaging operations began with the removal of the pipeline in 1991-92 followed by the demolition of the buildings on site by DIAND under contract (Golder, 1995). Based on information provided in work plans submitted by Pipe and Piling Supplies (B.C.) Ltd. (January, 1992) and McInroy Disposal Ltd. of Whitehorse (April, 1992), all recoverable materials were dismantled and moved out by truck. Such materials included fuel and water storage tanks, sheet metal, dispensing pumps, storage tank building, antennae, freezer unit, fencing, and a vehicle hoist (Photographs 2.2 and 2.3). Flammable materials were burned, and remaining waste materials including scrap metal, rebar, asbestos sheeting/siding, and boiler pipes were buried in apartment building foundations as recommended by BCMOE (see above). Fuel-contaminated soil was removed and stored in the same manner. Due to space limitations, additional non-contaminating materials including warehouse concrete slabs and rebar, more scrap metal, and fence post butts were buried in the ground at locations near the warehouse/garage/shop building. Burial locations of waste debris were recorded and are provided in Map 2.1. The site was subsequently graded and leveled to conform with the original contours of the site (Photograph 2.4). The contractor seeded the specified burial locations at the dormitory site to promote revegetation.

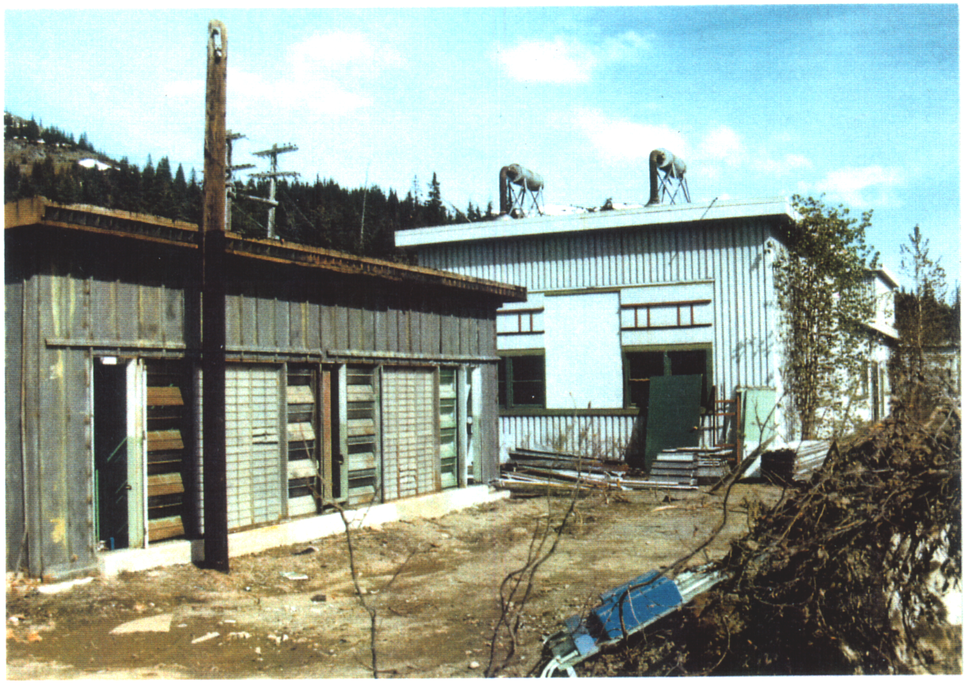
An emergency response team consisting of representatives from CEDA Reactor Ltd. (Edmonton), BCMOE, EC and Golder Associates was assembled in September of 1994 immediately following the discovery of DDT[1] canisters buried in a dump at Rainy. The team was charged with locating additional canisters, delineating the dump area and other possible dump locations, excavating the dump contents, and removing the canisters and contaminated soil from the site.

---

[1] DDT (dichloro-diphenyl-trichorethane)



Map 2.1: Burial Locations of Debris at Border Pump Station



Photograph 2.1: Intact buildings at Border Station showing pumphouse, stockpiled materials and garage/warehouse.

Photograph 2.2: Aerial view of salvage operations at Border Station.

Photograph 2.3: Removal and demolition of facilities at Border Station.

Photograph 2.4: Grading following demolition activities at Border Station

A total of 40 canisters containing estimated DDT concentrations in the range of 378 to 2177 ppm (total) in a liquid hydrocarbon carrier were uncovered. Approximately 550 m^3 of contaminated soil (DDT levels ranging from 2.85-25 ppm) was also removed from the excavation during extremely wet weather. The canisters were placed in overpack drums and removed from the site by Phillip Environmental Services Ltd, along with other materials which were suspected to be contaminated such as DDT lab packs, washwater, drummed solids, empty drums, transformer oil, and unknown solids.

Soils contaminated with DDT were temporarily sorted and stockpiled for contaminant testing, and subsequently moved by truck from Rainy Hollow to a Temporary Storage Facility (bermed, bottom-lined, and covered) constructed at Border Station above the Rainy Hollow site. The location of this facility is indicated in Map 2.2. The Trench location was secured by placing a liner in the excavation which was then backfilled with surface materials, including some of the less-contaminated soils from the excavation (0.22 to 0.62 ppm DDT), and covered with a liner. Golder (1995) notes that heavy precipitation during this period resulted in most of the soils becoming saturated. Soils in the Temporary Storage Facility at the Border Station Site (approximately 550 m^3 in volume) will require eventual disposal or treatment.

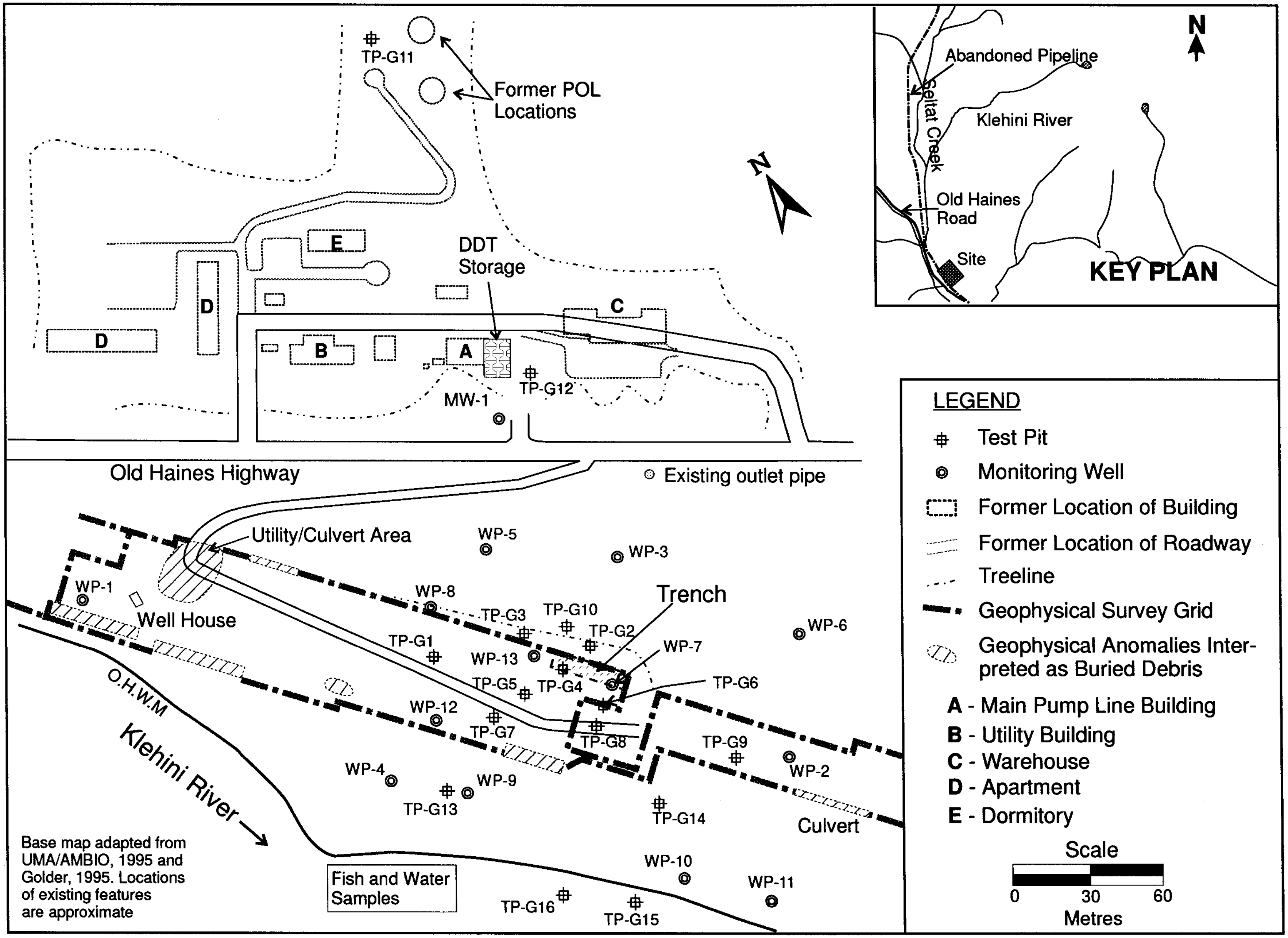
2.3 Environmental Investigations

2.3.1 Golder Associates (Report, 1995) for Environment Canada

A preliminary environmental assessment of Rainy Hollow in the vicinity of the trench area was conducted by Golder Associates in September of 1994, in parallel with the emergency response actions discussed above (Golder, 1995). Time, weather and other constraints limited the assessment to the Rainy Hollow location almost exclusively. The objectives included determining the extent of soil and groundwater contamination by DDT as much as possible (given short time constraints), as well as investigating the presence of other chemical substances based on a list of potential contaminants of concern (PCOC) from an historical review and field evidence: These included hydrocarbons, volatile organic compounds, and metals. Geophysical surveys were first conducted to investigate the site for potential burial areas. Four areas were identified as probable local refuse dumps containing metallic debris; these geophysical anomalies, however, were not investigated due to the constraints mentioned above.

The overall sampling program consisted of the development of a series of 13 test pits for subsurface soil, which were installed in the vicinity of the Trench using a backhoe, as well as three additional pits at the Border Station site above (see Map 2.2). Well points (50 mm diameter) for groundwater sampling were placed in each of the testpits and backfilled. This was done as an alternative to driving the well points directly into the ground, which was not possible due to the coarse nature of the subsurface soils. Well depths ranged from 1.98 to 4.11 m and no sand filters or fine screens were installed. The original excavation soil was used as backfill in the trench starting with the last excavated material first, in an attempt to maintain the homogeneity of the surrounding substrata. Soil and groundwater samples were collected and analyzed for PCOCs.

Hydrocarbons and DDT were reported to be present in intact soils around the trench with an estimated volume of 450 m^3 containing DDT concentrations exceeding 2 ppm (B.C. Environment's 1989 Draft 6 Criteria). A "noticeable lack of soil and groundwater chemistry data for hydrocarbons" was noted around the Trench in the report which may be a reflection of problems encountered with sample preservation and extended holding times. The high field OVM (organic vapour monitor) readings for soils (> 250 ppm) around the Trench, nevertheless, were believed to provide an indication of the presence and release of hydrocarbons and their migration towards the river. It was suggested that further on-site analysis would be required to quantify this. *Detectable hydrocarbons combined with floating product observed on the water table in test pit excavations to the east of the Trench suggested that either hydrocarbon releases (possible source) existed to the northeast in the direction of Border Station or an overflow ("pancaking") effect was occurring from an initial hydrocarbon release at the Trench itself.*



Map 2.2: Locations of Groundwater Well Points, Test Pits and Burial Sites at the Rainy Hollow Site

The highest concentrations of DDT (0.40 - 5.3 ppm) occurred in materials at a depth below the surface greater than 1 m. It was concluded, therefore, that exposure pathways for humans/wildlife were limited. Golder (1995) suggested that most of the soils in the trench walls with concentrations exceeding 5 ppm were removed during the emergency response, but concentrations of DDT exceeding this level were found in soils at the base of the excavation.

Hydrocarbons (< 2 to 33 mg/L) and DDT (1 to 6 µg/L) were also reported to be present in groundwater samples at concentrations below the CCME drinking water criteria, but still exceeded the criteria for freshwater aquatic life. The total concentration of BTEX exceeded 200 µg/L in a groundwater sample from one well point (WP-7) immediately adjacent to the Trench which was reported to be consistent with the historical release of hydrocarbons in the vicinity. Only the concentration of ethylbenzene (40 µg/L) in this sample exceeded the CCME drinking water criteria (2.4 µg/L). Results for concentrations of VOC analysis on all groundwater samples were reported to be below the detection limit, possibly due to the extended holding time of the samples. Concentrations of iron (100 - 13,400 µg/L) and manganese (<1 to 2600 µg/L) were found to be elevated in groundwater samples and exceeded the CCME drinking water criteria which are based solely on aesthetics (i.e., taste) . It was suggested that these high levels may have also resulted from suspended sediments in the groundwater samples. The levels were also low compared with those typically occurring in groundwaters of the Yukon (Golder, 1995).

The report provided the hypothesis that DDT transport in groundwater at some locations at Rainy Hollow may be facilitated by a hydrocarbon carrier which floats on the water table. This was based on the observations that i) the maximum DDT concentration in groundwater (6 µg/L) in the trench area exceeded its solubility limit in water (3.4 µg/L), ii) DDT solubility increases significantly when mixed with hydrocarbons and iii) a distinct plume where the DDT concentration exceeded 1 µg/L (CCME criteria), bordered by WP 12 to the northwest and WP 10 to the southeast, could be traced from the trench area to the shore of the Klehini River. Groundwater flow at Rainy Hollow was determined to be to the southwest from the Trench towards the Klehini River shoreline and the *in-situ* hydraulic conductivity of the stratum was believed to be high (10^{-4} to 10^{-3} m/s) based on its sand and gravel nature. The report also provided a very rough estimate on groundwater loading of DDT to the river based on a number of assumptions about hydraulic conductivity of the substrate and the nature of the aquifer. Potential loading of DDT was estimated to be in the range of 0.4 to 40 mg/year and was considered to be "extremely low given the significant potential for dilution in the glacial waters of the Klehini River". The data, however, were still considered to be preliminary based on the presence of suspended sediments in the groundwater samples. This may have resulted in obtaining DDT concentrations higher than that actually being carried in the groundwater itself.

The potential impact of DDT to biota in the Klehini River was assessed on a preliminary basis by analyzing surface water and fish tissue samples of young Dolly Varden char (*Salvelinus malma*) as part of a biological reconnaissance survey. Concentrations of the isomers DDT, DDE[2] and DDD were found to be below the detection limit for each isomer in both water (<0.05 μg/L) and fish (<0.002 ppm). Concentrations of hydrocarbons analyzed exclusively in the water sample were also below detection including oil and grease (<0.2 mg/L), BTEX and VOC[3]. The report advised that the preliminary data were not scientifically defensible and that the analysis of sediments and porewater, and additional tissue samples of fish and would be required to properly assess potential impact(s) on the Klehini River ecosystem. It was also suggested that the analysis of tissue samples from frequent road-killed raptors, such as Bald Eagles in the area, might provide some indication of DDT biomagnification in higher-end predators.

The study concluded that "both hydrocarbons and pesticides (DDT) are present in the soil and groundwater at the Trench and between the Trench and the River." Concentrations of most contaminants were either at or below the CCME or B.C. environmental criteria. The report also suggested that DDT was probably being moved towards the river dissolved in hydrocarbons, but no defensible conclusions could be derived on the issue of environmental impact(s). It was stressed that only a preliminary assessment had been performed at Rainy Hollow and "further detailed investigations and delineation sampling would be required to develop a remediation

---

2 DDE (dichloro-diphenyl-dichloroethylene), DDD (dichloro-diphenyl-dichloroethane)

3 BTEX (benzene, toluene, ethylbenzene, xylene), VOC (volatile organic compounds)

plan...consistent with the current and future uses of the site". Recommendations from the report included the following:

- obtaining supplementary historical information from all sources to assess information and sampling requirements, and assist in developing a remediation action plan;
- assessing options for treatment and/or off-site disposal of DDT contaminated soils (volume 550 m^3) in the Temporary Storage Facility;
- evaluating exposure pathways and environmental impact(s) of DDT and hydrocarbons in soils and contaminated groundwater discharge to the Klehini River (risk assessment);
- implementing a sampling program at Border Station to investigate suspected soil and groundwater contaminant sources and address associated environmental impacts;
- confirmatory sampling and further delineation of soil and groundwater contamination in the vicinity of the trench, shallow wells near the Klehini, and phase-in with assessments at Border Station to assess source zones and risk management options;
- investigation of other geophysical anomalies identified at Rainy Hollow (i.e., test pits, drilling and monitoring wells); and
- preparation of remedial plan(s) for addressing soil and groundwater contamination at the site(s).

2.3.2 France Lessard (1995) B.A.Sc. Thesis on the Degradation of DDT Using Advanced Oxidation Processes, Department of Chemical Engineering, University of Ottawa

This dissertation was borne out of the presence of a liquid petroleum carrier in groundwater in Rainy Hollow identified in the Golder (1995) report which was believed to have resulted in an increased solubility and, hence, concentration of DDT relative to the groundwater alone. The thesis evaluated the use of advanced oxidation processes (AOP) via ultraviolet light for the destruction of DDT[4] in groundwater, for application at the site. Operating parameters for the process were examined using spiked solutions of DDT in deionized water and various treatments of hydrogen peroxide, liquid petroleum carriers, dissolved solids and pH.

Neither additions of hydrogen peroxide, petroleum carriers or dissolved solids to the solutions were found to have significant effects on the efficiency of DDT degradation. *Hydrogen peroxide was suggested to stabilize and solubilize colloidal DDT, but the direct photolysis of DDT (via UV sunlight) was suggested as being the most likely mechanism of destruction.* Bench-scale studies showed reductions in DDT concentration (20 μg/L and 200 μg/L) to below the detection limit of 0.25 μg/L.

An economic analysis was performed on AOP and revealed that both high capital (up to one million dollars) and operating costs ($89/1000 gal) were associated with a full scale unit relative to other environmental technologies. The low probability of contact between DDT molecules and UV light for photolytic breakdown was explained as a major difficulty in achieving the CCME groundwater discharge criteria of 1 ng/L for DDT. *It was suggested that a combination of AOP with other technologies would be required for the complete removal and destruction of DDT in groundwater to the specified guideline.* Some of the technologies listed included activated carbon, reverse osmosis (cellulose acetate membranes), coagulation/precipitation (lime), oxidation (ozone), ultrafiltration and hydrolysis (alkaline solutions). *The associated costs with AOP alone, however, indicated that this process was not likely to be the treatment of choice for the Rainy Hollow Site.*

Recommendations from the dissertation, nevertheless, included:

- further investigations of the high sensitivity of DDT to sunlight using large holding tanks for groundwater;

---

[4] This process involved the use of ultraviolet light and hydrogen peroxide to generate hydroxl radicals which acted as powerful oxidizing agents to break down DDT into carbon dioxide, water and acids such as HCl, effectively mineralizing the contaminant.

- use of AOP in parallel with pretreatment technology to concentrate solutions of DDT resulting in lower operating and capital costs; and
- a detailed site investigation to determine areas of groundwater contamination and risk assessment.

2.3.3 Environment Canada (1995) Groundwater Sampling Program - Draft Report

In recognition of the sediment problems encountered with groundwater sampling in the Golder (1995) report on Rainy Hollow mentioned above, a second round of groundwater samples were obtained by Environment Canada in June of 1995. *This follow-up study was executed under recommendation by the technical advisory committee for the Rainy Hollow emergency response program to more adequately characterize the DDT levels carried in the groundwater and examine the effect of higher June water tables on these concentrations.*

Twelve wells were re-sampled using measures to ensure that the stirring up of fine solids in the vicinity of the well was minimized and an accurate representation of existing groundwater would be obtained. These procedures included the use of slower sampling rates (200-250 ml/min) using peristaltic pumps, monitoring turbidity during well purging/sampling, working from least to most contaminated wells [based on Golder (1995) results], decontamination of sampling equipment between wells, and better handling and storage of samples. The analytical program for the groundwater samples was dictated in part by observations from the Golder (1995) report and included DDT (and metabolites DDD, and DDE), oil and grease, BTEX, herbicides (2,4,5-T and 2,4-D), and halogenated volatile organic compounds.

Concentrations of DDT and its metabolites in groundwater samples (range <0.05 to 0.21 μg/L) were found to be at least an order of magnitude less than for samples obtained in September of 1994. Three out of the four wells in which DDT was detected (WP1, WP9, WP12 and WP13) contained levels just slightly above the detection limit; herbicides (2,4,5-T or 2,4-D) were not detected in any of the samples. *Hydrocarbon concentrations (<0.2 to 1.4 mg/L) were also at least an order of magnitude less than in well samples with detectable values from September 94.* Xylene was detected in three wells (WP9, WP13 and WP7) at concentrations (4.1-45.7 μg/L) below the CCME drinking water criteria. Oil absorbent swabs taken of floating hydrocarbons found in five of the wells (WP3, WP7, WP10, WP12 and WP13) indicated that light non-aqueous phase liquids were present in only a thin surface film. *The trace samples obtained exhibited a hydrocarbon composition (gas-chromatographic pattern) consistent with diesel.*

Seepage with an orange-red precipitate and "a thin waxy hydrocarbon film" layer was observed to be surfacing from the backfilled trench area 50 m to the south of WP-7. Concentrations of DDT compounds and herbicides (2,4,5-T and 2,4-D) tested for in the water samples from the seepage were found to be below detection, and levels of most dissolved metals were comparable to typical values for groundwater. The only exceptions were iron and manganese which slightly exceeded CCME drinking water guidelines, based on aesthetic values (taste) only. The hydrocarbon film on the surface drainage was suggested to be the result of natural decay from leaf litter.

The report concluded that the significantly lower values for DDT compounds and hydrocarbons obtained compared with the September 94 values were attributable to the lower levels of suspended solids in the June 95 groundwater samples which were obtained using a lower sampling rate. *These results were suggested to indicate that hydrocarbon movement in groundwater either as dissolved constituents or attached to suspended solids was extremely limited. It was also proposed that existing hydrocarbons occurring as thin films on the groundwater surface in some of the wells and those retained in the soils were an historical artifact from old releases of free product which had moved through the site in the past and were now relatively immobile.* The hydrocarbons were suggested to be immobile based on 1) the high hydraulic conductivity of the coarse substrata, 2) the fact that hydrocarbon concentrations in soils were below saturation levels based on the Golder (1995) report, and 3) the wide distribution of low levels of hydrocarbons [well below soil saturation based on Golder (1995)] in substrata down to the river margin. *No recommendations were provided based on conclusions in the report.*

2.3.4 UMA/AMBIO (1995) Report for AES, Indian and Northern Affairs (Whitehorse)

A preliminary environmental investigation was carried out at the Border Pump Station Site in July 95 by UMA Engineering Ltd. and AMBIO Research Associates as one of five sites along the decommissioned Haines-Fairbanks Pipeline targeted for assessment in 1995 through the Arctic Environmental Strategy, Action on Waste Program. *The objective at Border Station was to identify areas of waste disposal and contamination in sub-surface soil and water, assess the need for further action, and provide recommendations.* Investigations were limited to the pump station site only and excluded Rainy Hollow where the airstrip and original dump areas were located.

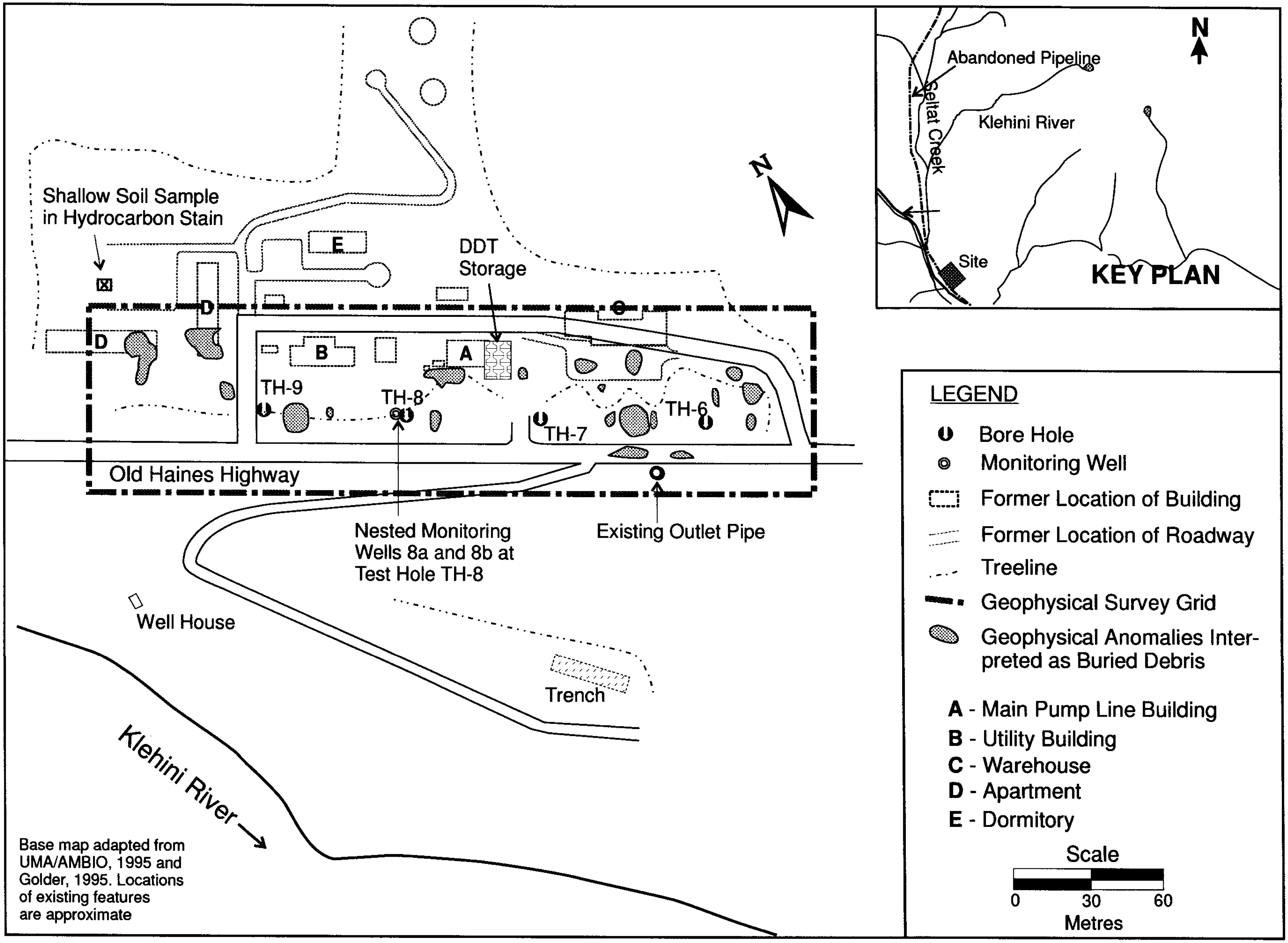
A field investigation was carried out in which a limited electromagnetic (EM) survey over the west side of the site to detect buried metallic debris and identify zones of elevated conductivity, and the sampling of both surface and subsurface soil and groundwater. The EM survey identified numerous anomalies associated with metal debris and former building foundations, along with three zones of elevated conductivity at the eastern portion of the property. Eleven lineal trends were also present scattered across the site which may have been associated with buried pipes or utilities; the locations of these anomalies associated with metallic debris are provided below in Map 2.3.

Two open ended drain pipes (75 and 200 mm, respectively) were discovered, during a visual reconnaissance, protruding from under the south side of Haines Road at the top of the slope above Rainy Hollow. The drainage path passed through an open area in the forest canopy to an area directly above a well point (WP3) at Rainy Hollow. Although low shrubs had grown into the area, the thick detrital nature of the substrate and lack of trees suggested that some discharge from Border Station, possibly of a phytotoxic nature, may have occurred in the past.

Subsurface sampling was achieved using a series of four test holes along the western perimeter of the site; a pair of nested monitoring wells (at depths of 9.25 and 17.5 m) were installed in testhole 8 (TH-8). The locations of these sampling areas are presented in Map 2.3. A total of two groundwater samples and 33 subsurface soil samples were collected. One surface soil sample was also obtained from a hydrocarbon -stained location (approximately 20 m^2) near the north end of the site (refer to Map 2.3). The analytical program consisted of two components: 1) field analyses utilizing immunoassay based test kits for PAHs, TPH, BTEX and PCBs and soil vapour surveys using a photoionization detector; and 2) detailed laboratory analyses for a broad suite of inorganic and organic contaminants.

Concentrations of total extractable hydrocarbons (TEH) in soils were reported to be elevated in TH-7 (up to 1300 μg/g or ppm) which exceeded US federal guidelines adopted in Alaska (200 μg/g) but decreased with depth to below the detection limits (< 50 μg /g at 24 m). A similar gradient, but at lower concentrations was also detected at TH-9 (77 to < 20 μg/g at 23 m). The depth of hydrocarbon contaminated soil at Border Station was suggested to range from 2 m at TH-7 to 9 m at TH-9 and extended to a depth of approximately 20 m. Hydrocarbon contamination was bordered by TH-6 on the southeast side of the site, but the extent of contamination to the north (beyond TH-9) was unclear.

Extremely high concentrations of TEH were found in groundwater from the pair of nested wells at TH-8 (up to 150000 μg/L in the shallower well). The report added that, although these wells did not have adequate time to stabilize before sampling, the extremely high concentrations indicate the possible existence of free product regardless of the presence of particulate matter in the groundwater samples. Elevated concentrations of TEH levels in groundwater were suggested to demonstrate significant subsurface aqueous migration from a source. Although the field test kits frequently reported high levels of TPH, BTEX and PAHs in environmental samples, high BTEX and PAH levels were not corroborated by laboratory analyses for the same standard analytical suite. It was suggested that the positive field test kit results, which were highly reproducible, might have been due to the presence of other related substances which were not part of the standard laboratory analysis suite.



Map 2.3: Locations of Test Holes, Groundwater Wells and Potential Burial Sites at Border Pump Station

Concentrations of DDT (209 ng/g or ppb) and total extractable hydrocarbons (TEH = 3200 μg/g or ppm) were elevated in a surface soil sample from the hydrocarbon stain (mentioned earlier), but it was suggested that the trucking of DDT contaminated material from Rainy Hollow may have caused an elevated background level at the site.

It was concluded that a very large area of hydrocarbon contaminated soil and groundwater existed at Border Station, although the nature of the contamination was not clear from the suite of analytes chosen in the study. The volume of contaminated groundwater and subsurface soil, however, could not be accurately defined based on the preliminary study.

This finding was suggested to agree well with the detection of hydrocarbon contamination in the testpits above the Rainy Hollow Site. Significantly elevated concentrations were not found for any other contaminants including PCBs, other pesticides, herbicides or volatile organic compounds (VOCs). *The primary ecological risk at this site was suggested to be the subsurface aqueous migration of hydrocarbon contaminants through Rainy Hollow to the waters of the Klehini River.*

The UMA/AMBIO report recommended that a thorough review of all information pertaining to Border Station and Rainy Hollow be undertaken prior to any proposed action, which would include the incorporation of analytical results, evaluating previous cleanup efforts and providing recommendations regarding further investigative or remedial actions required.

2.3.5 Royal Roads University (1996) Report for AES, Indian and Northern Affairs (Whitehorse)

As a follow-up to the UMA/AMBIO (1995) report, the Royal Roads University - Applied Research Division (ARD) was commissioned by AES in February 96 to address issues arising from the former study including further investigation of hydrocarbons and other contaminants in the vicinity of Test Hole 8 (TH-8, see Map 2.3), as well as the ecotoxicological significance of petroleum hydrocarbon contamination at Border Station. This was done through the laboratory analysis of archived samples from the UMA/AMBIO investigation including:

- one soil sample collected from TH-7 analyzed for parent and alkylated PAHs, alkanes, hopanes, PCBs, and chlorobenzenes to characterize hydrocarbon contamination;
- two soil samples from TH-8 analyzed for metals, seven for TEH and five for pesticides; and
- one soil sample from TH-9 which was analyzed for inorganic elements.

Metal concentrations in the three soil samples analyzed were well below the CCME R/P criteria. Pesticides and chlorobenzenes, were present at very low levels in the seven soil samples analyzed. Only one of these samples contained a detectable level of PCBs (0.47 ppb) which was comparable to reported background levels. High TEH levels were found in soils from both TH-7 (maximum 2800 µg/g) and TH-8 (maximum 1500 µg/g) with sub-surface maxima occurring at 3 m and 9 m, respectively. *These results confirmed hydrocarbon contamination determined by previous soil vapour survey data from UMA/AMBIO (1985).* Alkylated PAHs were present at considerably higher concentrations (maximum 22000 ng/g or ppb) than individual parent PAHs (maximum 890 ppb). The alkane results indicated that the mid-range nC-12 to nC-20[5] compounds accounted for a substantial portion of TEHs in the sample; ratios of nC-17/pristane (3300:6100 ng/g) and nC-18/phytane (3000:3100 ng/g) were slightly less than 1 suggesting that some hydrocarbon weathering had occurred[6]. Overall, the analytical results indicate that the probable source of subsurface hydrocarbon contamination at Border Station was diesel and/or petroleum distillates. The potential toxicity of the hydrocarbon mixture was not accurately indicated by analytical results for the standard analytical suite of unsubstituted PAHs or BTEX.

---

[5] C-12 refers to the number of carbons present in the hydrocarbon chain; whereas "n" refers to normal hydrocarbons

[6] more weathered samples have nC-17/pristane and nC-18/phytane ratios less than 1; as the more easily degraded normal hydrocarbons (nC-17 and nC-18) are lost, more resistant isoprenoids such as pristane and phytane are conserved.

The presence of high concentrations of alkylated PAHs and a review of their environmental, toxicological and regulatory significance in the report suggested: 1) that these unregulated compounds should be considered to be as toxic as their regulated parent (unsubstituted) PAH compounds, and 2) the importance of taking into account not just surrogate measures such as TEH, but also the specific composition of hydrocarbon contaminants when assessing risk and remedial options at Border Station.

The ARD report recommended that a full sub-surface investigation be conducted using existing testholes, as well as establishing new ones up- and down-gradient to properly delineate the spatial extent of the contaminant plume, ascertain the short- and long-term fate of contaminants, and conduct a detailed examination/prediction of environmental risks.

2.3.6 Rainy Hollow/Border Pump Station: Draft 1996 Work Plan - Detailed Environmental Site Investigation and Remedial Plan Development, Prepared by Peggy Evans (BC MELP)

This draft plan was prepared in February of 1996 by the B.C. Ministry of Lands, Environment and Parks (BC MELP) with the objective of defining an appropriate detailed site investigation of Border Station and Rainy Hollow based on the present level of understanding. The draft briefly provided background information on the site conditions, summarized areas of uncertainty and unresolved issues, and listed key activities for a detailed investigation and remedial plan development.

Major areas of uncertainty and unresolved issues were indicated to be the distribution and levels of contamination (i.e., hydrocarbons and DDT), including boundaries (outer limits) and pathways; and potential human health and ecological impacts based on the long-term effect of site contaminants on the Klehini River and other users (i.e., risk assessment). It was suggested that appropriate remediation objectives and levels of risk would also have to be set for the site in order to develop a remedial strategy. The report recommended that a course of action would have to be determined regarding the disposal of DDT contaminated soils in the temporary storage cell (facility). This would require the additional testing of soils for full characterization, and the identification of the most cost-effective solution based on evaluations of available disposal options.

The proposed work program included exploratory drilling; monitoring well installation, development and sampling; site and groundwater level surveying; contaminant analysis of soils and groundwater; and interpretation and reporting. *Biological sampling and contaminant analyses of tissue was not recommended in the work based on the high-energy dilution capacity of the Klehini River, and perceived difficulties with the sampling of organisms and the interpretation of analytical results.*

The report advocated the use of risk for the development of a remediation plan which would evaluate and recommend options required to reduce risk(s), or verify that they fall within acceptable levels.

3. REINTERPRETATION OF CONTAMINANT ISSUES

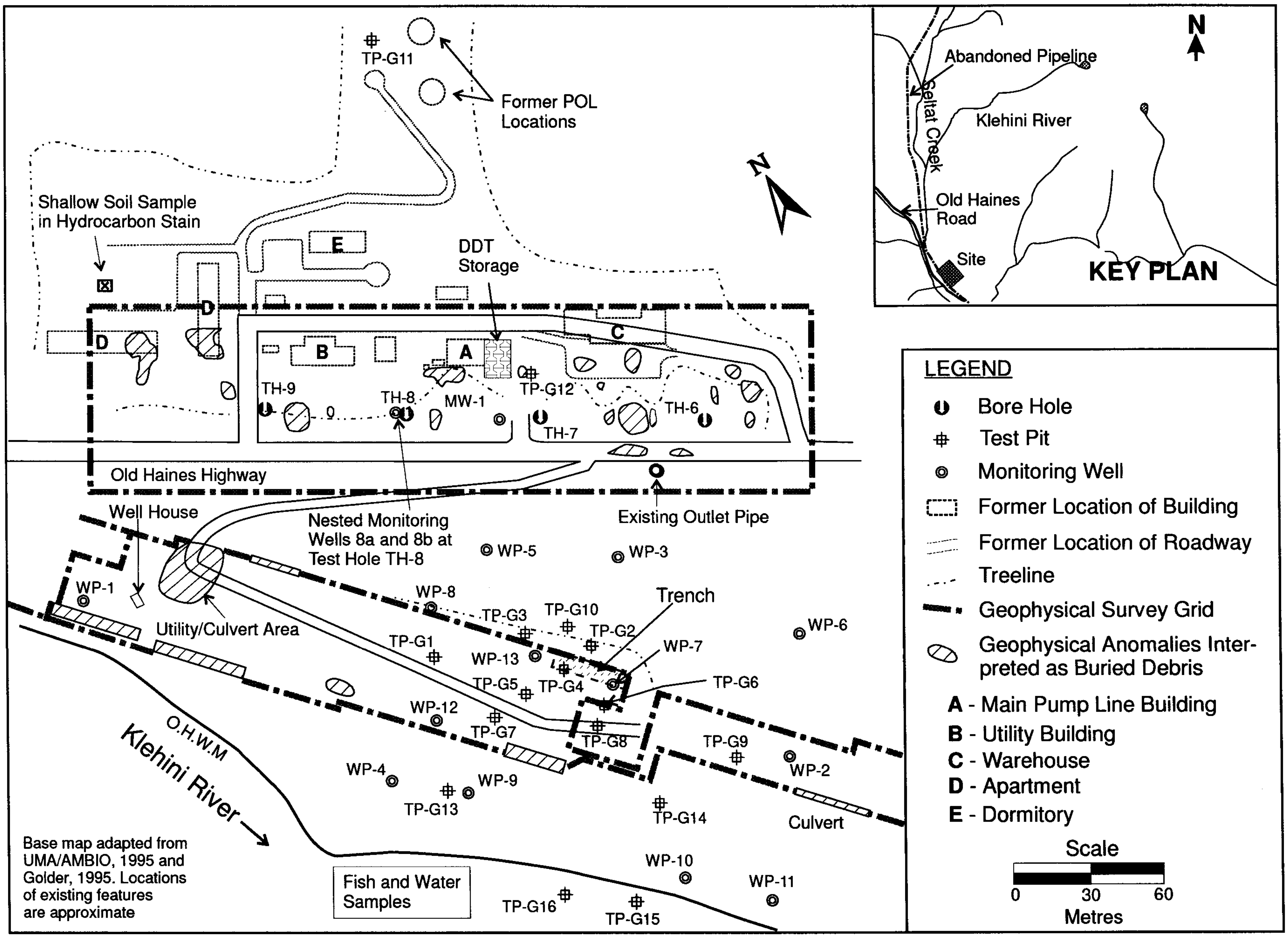
This section serves as an interpretation of contaminant issues based on the information review in Section 2, summarizes the present level of understanding, and identifies information gaps which need to be addressed for future actions. Each of the objective questions stated in Section 2.1 are also addressed here. Site locations and features referred to in the text are illustrated in Map 3.1.

3.1 Primary Contaminant Sources and Contaminants of Concern

Have contaminant sources in groundwater at Border Station - Rainy Hollow been confidently identified?

3.1.1 Burial Locations

Geophysical anomalies identified at the Border Station - Rainy Hollow Site suggest waste materials have been buried in a variety of locations. Many of the targets identified at Border Station are probably the result of waste materials buried in the apartment basements during the site's decommissioning. This is supported by the good agreement found between EM results in July of 1995 (UMA/AMBIO, 1995) (Map 2.1) and specific burial areas identified on maps by the contractor (Map 2.1). The materials probably consist of scrap metal and other relatively non-hazardous materials (e.g., asbestos), but these may have been buried along with fuel contaminated soil. Most of the materials were buried within foundations and would be relatively isolated from the surrounding groundwater and substratum. Additional materials, however, were buried outside of these structures due to space limitations, leaving them in contact with the surrounding substratum. Leachate from contaminated soils could enter the surrounding groundwater. *These materials, buried mostly at locations near the warehouse/garage/shop site should be checked for contaminated soils using test pits. Four other geophysical anomalies (possible burial sites) detected near the Klehini River in September 94 (Golder, 1995) have not* *been assessed for contaminants and also require some investigation including testpits and, possibly, monitoring wells.*



Map 3.1: Summary of Collective Sampling Program (1994 - 1995) at the Border Station - Rainy Hollow Site

3.1.2 Groundwater/Subsurface Contamination Sources

The extent of hydrocarbon contaminated subsurface soil and groundwater at Border Station around TH-7, TH-8 and TH-9 is indicative of historical fuel inputs - either a major spill event or series of repeated or chronic (possibly multiple) inputs. Possible sources include the pipeline, pumphouse, above-ground storage tanks, garage operations or other spills (UMA/AMBIO, 1995). The predominant hydrocarbon product is suggested to be similar to diesel in composition. Since the possible inputs are historical, the issues now is the in-place contaminants currently in the groundwater hydrocarbon plume and their subsurface fate.

Low levels of DDT and its metabolites were found in groundwater at Border Station (UMA/AMBIO, 1995), but there is no evidence of any significant DDT source aside from the possible redistribution of DDT-contaminated soils transported from Rainy Hollow to the Temporary Storage Facility. A major groundwater contaminant source, until its recent removal, was the DDT canister burial site at Rainy Hollow which to contained extremely high concentrations of DDT in soils and elevated levels of hydrocarbons (Golder, 1995).

Other minor sources at Rainy Hollow may also exist, but the issue again becomes the subsurface fate of these in-place contaminants. The presence of detectable hydrocarbons (by soil vapour probe) in test pit excavations to the east of the trench at Rainy Hollow also suggest that a contaminant source may exist to the northeast (up-gradient) which would be more consistent with groundwater flow from the large area of hydrocarbon contamination identified at Border Station.

3.1.3 Surface Contamination Sources

Although trace amounts of DDT have been detected in surface soils at Border Station - specifically in a large soil stain near the north end of the site (UMA/AMBIO, 1995) (Map 3.1) - the concentrations are probably attributable to some redistribution arising from the Rainy Hollow clean-up (see above) as opposed to a second distinct source at Border Station. There is no indication that the levels found at Border Station are a cause for concern.

Similarly, the available soil PCB data in reports by UMA/AMBIO (1995) and Royal Roads University (1996) indicate that there is no major local source of PCB inputs to the sites, and that environmental levels are uniformly low - probably within the range of background concentrations associated with long-range atmospheric transport in the Yukon.

Sources of phenoxy- herbicides (e.g., 2,4-D, 2,4,5-T) are unlikely to exist at the sites given the lack of any detectable concentrations in samples analyzed either as part of the Rainy Hollow (Golder, 1995) or Border Station studies (UMA/AMBIO, 1995). The available data do not address the possibility of residual herbicide contamination associated with chronic application of defoliants along the airstrip, road, pipeline right-of-ways and other clearings, as noted at other Yukon sites (Bissett and Associates, 1995). The environmental persistence of 2,4-D and 2,4,5-T, however, is relatively limited. A more relevant concern might be the associated contamination by polychlorinated dibenzo-*p*-dioxins, a contaminant of commercial phenoxy - herbicide formulations. Some dioxin/furan analyses may be merited.

Some subsurface investigation using testpits may be required to determine the vertical depth of the hydrocarbon stain, along with a closer analysis of its composition. This might include hydrocarbon constituents such as aliphatics, unsubstituted PAHs, alkyl-substituted PAHs, hopanes, and isoprenoids (Royal Roads University, 1996)

3.2 Past Removal of Source Materials

Were the contaminant sources at Border Station - Rainy Hollow adequately removed or isolated?

The removal of DDT canisters, associated materials and the bulk of contaminated soils from the Rainy Hollow Trench site was conducted in September 1994. Although DDT contaminant sources and contaminated soils at Rainy Hollow were reported to have been adequately removed from the trench area (Golder, 1995), confirmatory analysis revealed the presence of contaminated soils at the base of the trench with DDT levels exceeding 5 ppm; these were left in place and covered by a base liner prior to backfilling with less contaminated material. *The high concentrations in these remaining soils below the Trench liner could constitute a continuing source of DDT and hydrocarbon to the surrounding groundwater given the high hydraulic conductivity reported at this site. The heavy precipitation occurring during this period resulted in a saturating of the Trench and its backfill materials which may create surface, and possibly sub-surface leachate problems later on if the containment liners at this location should fail.* The presence of seepage with an orange precipitate (E.C., 1995) suggests some surface migration from the area may already be occurring from this area or from Border Station above (see Section 3.4 below). S*hallow testpits should be done in backfill materials from the Trench, and drill holes and monitoring wells (if necessary) should be installed) immediately adjacent to the Trench to assess the possibility of contaminant source leachate from this area.*

Historical contaminant sources at Border Station were removed some time ago leaving the sub-surface hydrocarbon plume identified in July 95 (UMA/AMBIO, 1995). The size and fate (i.e., migration, persistence and pathways to biological receptors) are still relatively unknown. It is possible that this plume may be passing through subsurface soils in the Trench Area of Rainy Hollow. These issues are addressed in more detail below in Section 3.3.

Soils highly contaminated with DDT (> 2 ppm) still remain in the Temporary Storage Facility at Border Station. The security of the facility was reported to be good as of July 95. *The possibility exists, however, that damage to the containment liners at the Temporary Storage Facility could occur which could remain undetected for some period of time (Evans, 1996).* It is possible (depending on risk assessment) that some form of disposal or treatment of these soils on- or off-site will be required. *A thorough assessment of available remedial options (both removal and on-site treatment) in terms of costs, efficiency and practicality will be required. The installation of monitoring wells outside of the facility is recommended if the facility remains for an extended period.*

3.3 Delineation of Groundwater Contamination

Has the vertical and spatial extent of groundwater contamination been adequately delineated?

The hydrocarbon contamination plume at Border Station was estimated to range from 2 m to a maximum estimated depth of at least 20 m deep based on results for subsurface soils obtained in July 95 (UMA/AMBIO, 1995). Nested groundwater wells at TH-8 suggested higher hydrocarbon concentrations occurred in the upper most layers of the substratum. Insufficient information, however, is available on the vertical extent and seasonable variability of the water table, to ascertain whether the shallower well represents a shallower perched water table isolated from the regional aquifer. Additional information using a system of deeper monitoring wells would be required to investigate this possibility. *The spatial extent of the hydrocarbon plume appears to be limited by TH-6 on the southeast side of Border Station; but its extent to the northwest of TH-9, northeast towards the Temporary Storage Facility and southeast to the old Haines Road is not known and requires investigation.* The high sand-gravel composition indicates high porosity in substratum and hence the potential for groundwater movement down to Rainy Hollow below. *Further subsurface delineation (boreholes and monitoring wells) is required focusing on the areas up- and down-gradient of TH-8 to obtain a better idea of the size and movement of the plume.*

A distinct DDT contaminated groundwater plume (> 1 μg/L, CCME criteria) was identified at Rainy Hollow which extended from the Trench down to the Klehini River, and appears to be bordered by WP 12 to the northwest and WP 10 to the southeast (Golder, 1995); a similar pattern was observed for hydrocarbon contamination and included the area above the Trench. The vertical extent of the contaminant plume, however, has yet to be established; the groundwater well depths used here were considerably shallower (maximum 4.11 m) than those installed at Border Station (maximum 18 m). *The installation of a system of deeper monitoring wells at Rainy Hollow is required to more accurately delineate the vertical extent of the plume and seasonal variability of the groundwater table.*

Measurements of the actual groundwater concentrations of hydrocarbons and DDT at Rainy Hollow are difficult to interpret given the lower levels detected in samples obtained in June 95 (EC., 1995) compared to September 94 (Golder, 1995). This may have resulted from the method of installation of the well points in test pits which may have disturbed the substratum and affected local groundwater characteristics. Attempts to backfill the test pits with the same soil materials using a backhoe to re-establish the original stratigraphy (Golder, 1995) may have undermined the interpretation of the results. The resulting stratigraphic anomalies (e.g., finer particulates) could have resulted in the creation of un-representative groundwater pockets around the wells. *Despite precautions taken by EC (1995) to prevent the suspension of sediments during groundwater sampling, the low values of DDT and hydrocarbons (including the light surface film) may still not, in fact, be truly reflective of the surrounding groundwater.* Observations of hydrocarbons in some of the test pits during the September 94 investigation (Golder, 1995) suggested significant groundwater hydrocarbon contamination. *This should be verified with properly installed monitoring wells in the coarse substrate at Rainy Hollow using the air rotary/casing hammer methods similar to those implemented by UMA/AMBIO (1995) at Border Station.*

3.4 Fate of Sub-surface Contaminants

Can the fate of subsurface contaminants at Border Station - Rainy Hollow be adequately predicted?

The possibility that hydrocarbon contaminated groundwater from the plume at Border Station may be passing through Rainy Hollow is suggested by a number of observations including:

- the presence of an oily sheen (hydrocarbon) on the water table surface of some test pits above the Trench at Rainy Hollow in the direction of Border Station (Golder, 1995);
- similarity in the composition of hydrocarbon product (diesel-like) in subsurface samples at both sites (EC, 1995; UMA/AMBIO, 1995)

- the wide band of subsurface hydrocarbon contamination suggested to extend from above the Trench area down to the Klehini River (Golder, 1995);

- the seepage with an orange precipitate and oily surface film surfacing at Rainy Hollow observed in June 95 (EC, 1995) which may be the result of the interception of contaminated groundwater from Border Station by the impermeable liners installed in the Trench area (see below); and

- The hydraulic conductivity of the stratum in the area which was believed to be high (10^{-4} to 10^{-3} m/s) based on its sand and gravel nature (Golder, 1995; UMA/AMBIO, 1995).

The obvious link between Rainy Hollow and Border Station is the area between the two sites, including the old Haines Highway and the steep wooded slope leading down to the Trench at Rainy Hollow. No formal investigations has been carried out in this area aside from the installation of a well point (WP3; Golder, 1995) at the base of the slope where hydrocarbons were detected in September 94. The existence of outlet pipes at the top of the slope and an old drainage path leading down to the Trench area, however, suggest that some historical surface discharge(s) may have occurred from Border Station (UMA/AMBIO, 1995). *Selected test pits or boreholes and the installation of a series of monitoring wells along the slope would be required to identify the presence of subsurface hydrocarbon contaminant movement from Border Station down to Rainy Hollow. This should also be accompanied by a risk assessment along the slope for receptors (see also Section 3.5).*

The movement of DDT in a hydrocarbon carrier in the groundwater at Rainy Hollow (Golder, 1995) is plausible and consistent with hydrocarbon contamination passing through the area from a hydrocarbon contaminated source at Border Station above. Movement of the DDT plume to the river is also suggested by the groundwater flow in the area to the southwest towards the Klehini River shoreline (Golder, 1995). Conclusions about the hydrocarbon contamination at Rainy Hollow being 1) an historical artifact from old releases, and 2) relatively immobile (EC, 1995) may be inaccurate given the potential problems with the monitoring well installations discussed above (Section 3.3). *A series of drill holes and monitoring wells placed along the area between the Trench and the shore of the Klehini River would provide a better indication of* *subsurface fate of the contaminant plumes at Rainy Hollow and verify whether or not any movement is occurring into the river. This would also be best accompanied by a more detailed analysis of hydrocarbon composition to assess the degree of weathering and relative age of the release.*

The potential surface migration of contaminants to the Klehini River may also be occurring based on the discovery of the leachate with an orange precipitate which surfaced near the Trench and meandered down toward the river bed (EC, 1995). Although the leachate water was not found to contain detectable concentrations of DDT or herbicides, no analysis was done for other hydrocarbons and associated products (such as PAHs); neither was any analysis performed on the precipitate. This surface leachate may originate from wet, saturated contaminated soils in the Trench. *Another plausible explanation is that the impermeable liners installed in the Trench at Rainy Hollow may be interrupting hydrocarbon-contaminated groundwater flow upgradient from Border Station, resulting in the percolating of water to the ground surface.* This would be facilitated during high precipitation and runoff periods. *Some analysis will be required to confirm the nature of the hydrocarbon film on the water surface as well as the composition of the orange precipitate in the sediments.* This information, combined with that of hydrocarbon source signatures could also be used to pinpoint the leachate problem.

3.5 Ecological Risks and Sensitive Receptors

Has the ecological risk to the Klehini River and other sensitive receptors been adequately assessed?

The available evidence does not exclude the possibility that contaminated groundwater is moving through the site and may be reaching the Klehini River. Impacts constituting some degree of ecological risk may occur anywhere along this migration path, particularly where contaminated groundwater surfaces, or connects with other waterbodies. Potential biological receptors at the sites in the terrestrial environment may include vegetation (including sensitive habitats), insects, wildlife, birds, and humans who either visit or habituate the site. In the aquatic environment of the river, receptors may include benthic fauna, macroinvertebrates, phytoplankton and macrophytes (vascular plants), fish at various stages of development (egg to adult) and higher end terrestrial-based predators such as piscivorous birds and mammals. The analysis of risk must be accompanied by some understanding of likely exposure pathways (i.e., ingestion, inhalation, surface absorption) and the potential for biomagnification in order to accurately assess ecological and human risk.

A preliminary assessment of ecological impacts in the river was inconclusive given that DDT compound and hydrocarbon values were below detection in a limited number of surface water and young fish samples (Golder, 1995). The possibility of increases in bioaccumulation of organic contaminants such as DDT with age in fish, however, was not considered. Sediments, porewater, or other organisms at the site have not been analyzed for DDT or hydrocarbons. The preliminary risk assessment in the stream also did not take into account the food chain or chronic effects which could be more serious at a population level than acute effects. Biological sampling is an important component of site-specific risk assessment which should not be discounted at Border Station - Rainy Hollow. *The sampling and contaminant analysis, where possible, of stream sediments, plants, benthic fauna, bottom feeding and pelagic fish (at different life stages) is required to obtain a good understanding of potential impacts in the Klehini River. A similar approach should be used on land in areas along potential contaminant pathways, where contaminant are expected or observed to surface.*

Difficulties arise in assessing ecological risk (or human health risk) due to hydrocarbon contamination from the complex and varied composition as volatile and semi-volatile aliphatics, various heterocyclic organic compounds and as alkyl-substituted and unsubstituted PAHs. This is discussed in more detail in the report by Royal Roads University (1996). TPH levels (or LEPH and HEPH) are useful as surrogate measures of contaminant magnitude and distribution. Levels of unsubstituted PAHs and BTEX compounds in soil and water samples probably under-represent risk and overall hydrocarbon concentration at these sites. Detailed compositional data are required for detailed risk assessment, but present-day interpretation is difficult because of the limited scientific knowledge on many of the individual compounds found in petroleum products.

In order to better define and predict ecological and human health risk, and to carry out financial and logistical planning for site remediation, a better knowledge is needed of contaminated soil and groundwater volumes, contaminant compositions and physical-chemical characteristics that influence the effectiveness of various remedial or disposal technologies (i.e., more thorough surveys and finer-scale contaminant data).

The selection and utilization of assessment criteria will also be important for assessing ecological risk at the site. The B.C. Draft Contaminated Sites Regulations or CCME criteria, alone, are inadequate for describing chronic risks of persistent chlorinated organics, that may undergo biomagnification in northern environments. The major concern here will be introduction to aquatic or terrestrial food webs via sediments, plankton, insects (and their larvae) and/or plants and subsequent increase in contaminant concentrations in animals at higher trophic levels. Application of various generic criteria, regulations, or guidelines for DDT in soil or water at these sites is not recommended, and a detailed risk assessment will be necessary wherever a plausible pathway to a receptor organism exists.

4. CONCLUSIONS AND RECOMMENDATIONS

Two major pieces of information are required in order to adequately select and carry out remedial activities at the Border Station - Rainy Hollow site: 1) a better understanding of the fate of hydrocarbons and associated contaminants in groundwater, and, 2) a detailed ecological and human risk assessment for areas and associated receptors at the site. Recommendations for further work at the Border Station - Rainy Hollow site have most recently been proposed in the 1996 Draft Work Plan by BC MELP (Evans, 1996) which address these two issues.

We agree that the general prescriptive approach taken by the BC MELP report for a detailed investigation is required in which the estimated requirement for the number of samples and analysis is defined in order to estimate the costs of a detailed investigation. *It is recommend, however, that delineation of subsurface areas of contamination would be better achieved by an iterative and guided field approach coupled with confirmatory testing.* This will take advantage of a (PID) VOC sniffer, immunoassay-based field test kits and other methods, with laboratory confirmation of field analytical results for approximately 10% of samples collected. Bore holes nested water wells, test pits, and surface samples would be established using field analytical data to focus in on areas of concern described in Section 3, provide detailed gridded sampling only where necessary, establish background conditions and define the outer boundaries of contamination. The site and sample locations should be surveyed using a total station or differential Global Positioning System (GPS). *All field information necessary to 1) provide a detailed risk assessment (including the sampling and analysis of ecological receptors), and 2) allow for the development of an engineering design of clean up and remediation plans, would be collected in the current fiscal year (1996-97).* This approach is described in more detail below

The outstanding environmental issues and recommended course(s) of action are summarized below in Table 4.1.

Table 4.1 Summary of Outstanding Issues and Recommended Course(s) of Action at Border Station - Rainy Hollow

Issue:	Recommendation:
Presence of buried debris at Border Station (6 locations) and Rainy Hollow (4 locations)	• Confirm non-hazardous nature of buried materials using test pits, sub-surface sampling and contaminant analysis including chlorinated organic compounds, total hydrocarbons, and metals. • If contaminant sources found, characterize contaminated soil volumes (via confirmatory testing) and/or expanded suite of laboratory analyses as appropriate
Subsurface hydrocarbon contamination (soils and groundwater)	• Delineate spatial and vertical distribution of contaminant plumes at Border Station and Rainy Hollow through the installation of a series of new nested wells up- and down-gradient and laterally to known (or suspected) areas of contamination; air rotary/casing hammer methods should be used • Characterize groundwater flow and likely seasonal variations with reference to soil permeability, hydraulic conductivity and other factors. • Estimate flux of specific hydrocarbon and DDT contaminants to Klehini River • Characterize contaminant levels and composition in groundwater plumes and subsurface soils via confirmatory testing (field analytical techniques) and laboratory analysis
DDT-contaminated soils in and surrounding the Rainy Hollow Trench enclosure	• Examine the levels of DDT in subsurface soils within the enclosure, in soils and groundwater around the Trench, and between the facility and the Klehini River as part of overall subsurface investigation • Collect geotechnical and analytical data to evaluate mitigative actions for the above if required • Assess the risk of failure and expected longetivity of the geotechnical liner in the Trench and subsequent contaminant release, based on its engineering design
Phenoxy-herbicide sources	• This is not considered to be likely based on Golder (1995) and UMA (1995) data. • Limited analysis should be conducted for dioxins (as impurities) in areas which may have received chronic herbicide applications (e.g., right of ways, airstrip)

Table 4.1 Summary of Outstanding Issues and Recommended Course(s) of Action at Border Station - Rainy Hollow (cont.)

Issue:	Recommendation:
Surface hydrocarbon stain at Border Station	• Investigate the vertical extent of subsurface contamination using test pits and a targeted analytical screen in conjunction with the overall subsurface investigation
DDT and hydrocarbon contaminated soils in the Temporary Storage Facility	• Collection of surface and subsurface soil samples and analysis to define the concentration distribution of DDT and its breakdown products, levels of hydrocarbon and its specific composition, and the physical and geochemical composition of the materials • Assess the risk of failure and expected longetivity of the geotechnical liner in the facility and subsequent contaminant release, based on its engineering design • Evaluate remedial options in terms of cost, applicability and practicality, including the transport of materials off site • If the installation will remain in place for an extended period of time, wells should be installed in the vicinity of facility to monitor groundwater quality
Need for a risk assessment of impact to the terrestrial environment, particularly between Border Station and Rainy Hollow Similar need for risk assessment in the aquatic environment of the Klehini River	• Assess and predict (where required) hydrocarbon composition, persistence, and impacts through observations and directed sampling of soils, vegetation, and possibly other fauna based on habitat use and exposure pathway(s) • Repeat and extend the electrofishing/gill net fish tissue sampling and analysis program by Golder (1995) with more detailed observations and upstream (control site) and downstream. • The sampling program should be expanded to include other fish and invertbrates with high BSAFs (biological to sediment accumulation factors and/or BMFs (biomagnification factors). • Sediments from quiet eddies at up- and downstream locations should be analyzed for organic contaminants (including DDT and associated compounds) using high resolution analytical methods; include analyses for unsubstituted and alkylated PAHs
Critical evaluation of remedial strategies and estimation of cleanup costs	• Collection of geotechnical data required for an anticipated site cleanup • Accurately estimate volumes of contaminated materials using confirmatory testing methods • Survey in locations of all features including sampling locations using total station (triangulation) methods of other appropriate techniques

5. REFERENCES

Golder Associates, 1995. Site Assessment & Remedial Response Program Border Pump Station Rainy Hollow, B.C. Report submitted to Environment Canada in March, 1995.

K. Bisset & Associates, 1995. Research of Former Military Sites & Activities in the Yukon Report submitted to AES (DIAND) in April, 1995.

France Lessard, 1995. The Degradation of DDT Using Advanced Oxidation Processes. Unbound MA1995). Unbound B.A.Sc. thesis submitted to the University of Ottawa, Department of Chemical Engineering in April, 1995.

Environment Canada (EC), 1995. Rainy Hollow Groundwater Sampling Program (20-21 June '95) - Draft Report.

UMA Engineering Ltd. and AMBIO Research Associates, Inc., 1995. Preliminary Environmental Assessment Haines-Fairbanks Pipeline. Report prepared for AES-Whitehorse (DIAND) in August, 1995.

Evans, Peggy, 1996. Rainy Hollow/Border Pump Station Draft 1996 Work Plan: Detailed Environmental Site Investigation and Remedial Plan Development. Prepared in B.C. Ministry of Environment, Lands and Parks in February, 1996.

Royal Roads University - Applied Research Division (1996). Preliminary Environmental Assessment Haines-Fairbanks Pipeline: Delineation and Characterization of Metals, Organochlorines and Hydrocarbons at Million Dollar Falls, Blanchard River and Border Station. Report prepared for Indian and Northern Affairs (DIAND) AES in March, 1996.