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RAINY HOLLOW AND BORDER PUMP STATION, BRITISH COLUMBIA, CANADA: SUMMARY REPORT FOR ANNUAL MONITORING PROGRAM

Prepared for:

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1. INTRODUCTION

1.1 Background

Rainy Hollow and Border Station are within the Tatshenshini-Alsek Wilderness Park, which was created in 1993 and subsequently designated as a United Nations World Heritage Site in 1994. The sites are also within the southern portion of traditional lands of the Champagne-Aishihik First Nations and Southern Tutchone. Rainy Hollow and Border Station were originally used together as a pump station along the Haines-Fairbanks pipeline. Facilities constructed at the Border Station (the upper bench) consisted of a main line pump building, warehouse-garage-shop building, utility building, wood frame construction family housing (one dormitory and two apartment buildings), a cement cold storage locker building, and petroleum oil and lubricant (POL) storage facilities. The lower bench, Rainy Hollow, was used as an airstrip by small aircraft for light re-supply of the pumping station during construction and operation; it was also used in later years for transporting station personnel to nearby communities. Aviation fuel was probably also located near the airstrip during its operation, along with dumps for station wastes. A small pump house at Rainy Hollow served to deliver water from the Klehini River to Border Station. General site location and site features are included in Drawing 1.

The pump station was operated by the US military from the mid 1950's until it was decommissioned in 1972. Following this, the infrastructure was used as a base camp for the Haines Road re-alignment in 1978 and 1979, and for mineral exploration from 1983 to 1987 (Bisset and Associates, 1995). The station was finally closed in 1987 at which time a cleanup was conducted by BC Ministry of Forests. All of the buildings and facilities were subsequently demolished by the Public Works under contract to DIAND in 1992-3, and buried on site (Royal Roads, 1996a).

In 1994, canisters containing the insecticide DDT[1] were found buried in a dump at Rainy Hollow. This prompted and an Emergency Response and clean up (Golder, 1995). The DDT canisters were excavated. The canisters along with other materials suspected as contaminated including wastewater, empty barrels and transformer oil shipped off-site for disposal. The remaining soils in the "Trench" were excavated. After completion of the excavation, an Arctic grade polyethylene liner was placed in the bottom of the excavation and the "Trench" was filled with surface material. A reinforced polyethylene liner was placed over the back-filled material to prevent water infiltration and the area was fenced off.

Soils removed from the Trench were placed in temporary stockpile. The stockpile was tested and the materials were subsequently relocated by truck from the Rainy Hollow to a "Temporary

[1] The name DDT is derived from Dichloro-Diphenyl-Trichloroethane and is commonly applied to 1,1,1-trichloro-2,2-*bis*-(p-chlorophenyl) ethane (p,p'-DDT) and its other isomeric forms o,p'-DDT and m,p'-DDT. The pesticide formulations contain several similar compounds such as DDE (dichloro-diphenyl-ethylene) and DDD (dichloro-diphenyl-dichloroethane) that are present as impurities or produced through metabolic or photochemical transformation in the environment. The term DDT when used in this report includes the following isomers p,p'-DDT, o,p'-DDT, p,p'-DDD, o,p'-DDD, p,p'-DDE, and o,p'-DDE)

Storage Facility" constructed on the upper bench at Border Station. Approximately 550 m^3 of DDT contaminated soil (concentrations between 2.85 – 25 µg/g) was removed from the Trench and transported to the Temporary Storage Facility during extreme weather conditions. The contaminated soils were placed onto a reinforced polyethylene liner, covered with liners and enclosed in a fence. Contaminated materials in the Temporary Storage Facility were characterized and removed off-site for disposal in 1996 (Royal Roads, 1996b).

A preliminary site investigation conducted during the emergency response indicated that hydrocarbons and DDT were present in soil and groundwater at Rainy Hollow (Golder, 1995). In the following summer, hydrocarbon contamination of subsurface soil and groundwater at the Border Station site was also identified in a study, which was part of preliminary environmental assessments along the Haines-Fairbanks Pipeline that was commissioned by DIAND - Waste Management, Yukon Region (UMA, 1995 and Royal Roads, 1996c).

A detailed site investigation (DSI) and screening-level risk assessment was therefore undertaken at the sites in 1996. This confirmed the presence of DDT and hydrocarbon contamination in subsurface soils and groundwater at the sites (Royal Roads, 1997). There was also some evidence of the migration of these contaminants into the adjacent Klehini River. However, the results of the risk assessment suggested that the concentrations of total DDT and hydrocarbon in groundwater and at the outflow face into the Klehini River did not constitute an elevated risk to aquatic life. Remedial activities were conducted in the summer of 1997, based on the results of the DSI and recommendations arising from the risk assessment. It consisted of the removal of contaminated surface soils with DDT concentrations greater than 10 µg/g, capping of soils with DDT concentrations between 1 - 10 µg/g and site restoration to minimize surface soil erosion. A conceptual model of contaminant transport, including a groundwater-monitoring program was developed (Woodbury, 1997). The groundwater-monitoring program was initiated in 1997 and continued through 2000.

1.2 Scope and Objectives

An application for a Conditional Certificate of Compliance was submitted by DIAND to the British Columbia Ministry of Water, Land and Air Protection (WLAP) in 1997. WLAP is currently reviewing the Rainy Hollow file in support of the application. In order to complete the review and determine that the site has been adequately remediated and monitored to provincial standards and expectations a completion report is required. This include:

- A summary of the follow-up actions to the risk management recommendations;
- A summary of the findings of the monitoring program (i.e., 1996 - 2000) along with all raw data;
- Interpretation of the monitoring data in relation to the risk assessment conclusions as well as statements to the adequacy of the monitoring data to characterize the site conditions; and
- Current status of the site, including the significance of erosion and slight shifting of the river channel.

In October 2001 provincial staff visited the site and noted the presence of exposed barrels at the

site. Samples of the contents of the barrels were obtained by DIAND personnel and subsequently identified as waste oil through commercial laboratory analysis. A summary report is attached to Appendix A. The WLAP has requested additional information confirming that all drums of waste oil/hydrocarbons have been removed from the site following the October 2001 observation.

This report was prepared to address issues presented in the preceding paragraphs.

2. SUMMARY OF DETAILED SITE INVESTIGATION AND RISK ASSESSMENT RECOMMENDATIONS

This chapter contains a summary of the recommendations of the Detailed Site Investigation and Risk Assessment.

2.1 Field and Laboratory Program

A team comprising participants from Royal Roads University, UMA Engineering Ltd., and Golder Associates Ltd. conducted the detailed site investigation (DSI) and screening-level risk assessment in 1996 (Royal Roads, 1997).

The field program, which took place in August and September 1996, included excavation of 24 test pits, drilling of 15 boreholes and installation of monitoring wells in all but one of the boreholes. Locations of test pits and boreholes are given in Drawing 1. The field program was followed by the analysis of over 200 surface or subsurface soil samples for one or more of the following principal contaminants of concern - hydrocarbons, chlorinated pesticides (including DDT), PCBs and metals. Groundwater samples were also analyzed for these contaminants. Samples of sediments, surface water and benthic organisms collected from the Klehini River along with terrestrial vegetation, berries and herbivorous and insectivorous small mammals were also analyzed in order to conduct a screening level risk assessment. Three surface soil samples were also collected along right-of-ways and analyzed for dioxins/furans - possible contaminants associated with the historical application of herbicides containing 2,4,5-T.

The major contaminants of concern at Rainy Hollow and Border Station were found to be:

- DDT in surface soils near the Trench and the Temporary Storage Facility, and on access roads between the two facilities;
- DDT in subsurface soils and groundwater, arising from the historical burial of DDT-containing canisters in a trench at Rainy Hollow; and
- Light hydrocarbons (diesel-like) in subsurface soils and groundwater at Border Station and Rainy Hollow

2.2 Surface Contaminant Distribution

It was noted during the characterization of soils at the Temporary Storage Facility (Royal Roads, 1996a) that some surface soils along the edge of the facility contained detectable concentrations of DDT. As such, one of the objectives of the detailed site investigation was to delineate the extent of surface contamination near the Temporary Storage Facility and around the Trench at Rainy Hollow. To achieve this objective, 66 surface soil samples collected around these facilities were analyzed for DDT (Drawing 2).

High concentrations of DDT (up to 173 μg/g) were detected in samples collected along a transect on the north side of the Trench and to a distance of between 10 and 20 m from the end of the Trench. This area was probably used during the 1994 emergency response for the temporary

placement of the contaminated materials and soils prior to either their removal off-site or transport to the Temporary Storage Facility. In addition to the hotspots, surface soil samples in the vicinities of the Trench and the Temporary Storage Facility, and in areas of vehicular and heavy equipment usage contained DDT at concentrations of up to 27 µg/g. In contrast, all soil samples collected from undisturbed areas had DDT at concentrations that were less than 1 µg/g. DDT concentrations along the major portion of access road surfaces ranged from 0.43 to 27 µg/g. The highest concentration was found in a depression along the eastern entrance to the Temporary Storage Facility, where water and fine particulates would tend to pool. It is clear from the data obtained that, while some airborne redistribution of DDT may have contributed to the contamination, the major mechanism of surface redistribution has been via tracking on heavy equipment and other vehicles. The redistribution was probably intensified during the 1994 emergency response by the adverse weather, which caused the site to be extremely muddy.

Surface contamination with hydrocarbons was limited to two stained areas near the former POL storage area and the apartment complex (D).

The screening level risk assessment included an evaluation of the risk to small mammals and their predators in the terrestrial and riparian habitat within 100 m of the contaminated areas. The human health risks associated with ingestion of DDT-contaminated soil, inhalation of DDT in the gaseous phase, or dermal absorption were also assessed. The human health risk assessment indicated that in the context of the exposure scenarios considered for this site, there was no risk to humans from exposure to DDT and its related compounds at Rainy Hollow.

2.3 Subsurface Contaminant Distribution

The results of the DSI confirmed that some of the subsurface soils and groundwater at Border Station and Rainy Hollow were contaminated with hydrocarbons and DDT. The maximum concentrations of DDT and extractable hydrocarbons detected in sub-surface soil samples are summarized in Drawing 1. The areal extent of these contaminants in groundwater and subsurface soil has been presented in drawings in the DSI report (Royal Roads, 1997).

Hydrocarbon contamination at the upper site were encountered at depths varying from 3 to 25 m. Approximately 4 cm of free product was noted in one well (MW-8B). Laterally, the hydrocarbons originated from the Main Pump Building (A) and the Utility Building (B) and extended towards the lower site. There was a layer of hydrocarbon contaminated soil and groundwater up to 8 m thick beneath the water table at the lower site. Near the Klehini River, this thickness was reduced to about 4 m. Concentrations of extractable hydrocarbons in groundwater samples collected from wells at Border Station ranged from less than 1000 µg/L to a high of 7600 µg/L while a maximum of 10,000 µg/L was found at Rainy Hollow. There were also low but detectable concentrations of ethylbenzene and xylene in the groundwater. Three mini-piezometers were driven to below the water table on the bank of the river. The piezometer in the middle of the string (MP-2) had a concentration of dissolved extractable hydrocarbons (LEPH) of 5900 µg/L. This data indicated the discharge of dissolved hydrocarbons to the river.

Subsurface contamination with DDT was noted at Rainy Hollow in the area where the canisters

were recovered and extended to the river. The highest soil concentrations were directly adjacent to the Trench, and were in the range of 4 to 5 µg/g. Further from the Trench, subsurface soil concentrations were typically less than 2 µg/g. DDT concentrations of up to 0.40 µg/L were detected in groundwater wells installed adjacent to the Trench. The concentrations were significantly reduced by the time groundwater reached the river's edge, with DDT levels in the range of 0.001 to 0.008 µg/L.

The Trench where the DDT canisters were buried was directly in line with the hydrocarbon plume migrating from the upper bench. This presented an unfortunate circumstance since the solubility of DDT might be greatly enhanced in the presence of co-dissolved organic molecules. For example, the solubility of DDT in water saturated with n-octanol was estimated to be 14 µg/L compared to 5.0 µg/L in pure water at 25°C (Chiou et al, 1982).

There was evidence that both DDT and hydrocarbons were being introduced to the Klehini River through the discharge of contaminated groundwater. The results of the risk assessment however, indicated that the actual instantaneous concentrations of these substances in sediment, river water, or stream invertebrates was so low as to preclude any possibility of deleterious biological effects. DDT concentrations were indistinguishable from background levels for sediment and stream invertebrates. Possible risk pathways for contamination of the Klehini River and its inhabitants, therefore, could be confidently ruled out, since the dose to aquatic organisms contributed from contaminated areas at Rainy Hollow via sediment or river water was essentially zero. All aquatic ecological risk pathways were excluded for further risk assessment. The same conclusion, with a similar rationale, was made for petroleum hydrocarbons and aquatic receptors.

2.4 Predicted Fate of Subsurface Contaminants

A conceptual groundwater modeling exercise, based on Domenico and Schwartz (1990), was undertaken in order to predict the subsurface fate of DDT and hydrocarbons at Rainy Hollow. Based on site data on DDT in groundwater samples from various wells, an estimated mean hydraulic conductivity of 2.5 x 10-4 cm/sec, a horizontal gradient between the former location of the trench and the river of 0.075 m/m, an estimated porosity of 0.27, a DDT solubility limit of 3.4 mg/L, and a DDT half-life of 15 years, the groundwater model provided the following predictions:

- The total concentration of DDT in groundwater 80 m from a concentrated source (the distance between the former burial Trench and the bank of the Klehini River) was predicted twenty years after post-burial release to be 0.007 µg/L. This was in excellent agreement with the 1996 groundwater data for mini-piezometer MP-2 (0.0084 µg/L)
- Temporal changes in DDT fluxes at the interface were predicted to occur relatively slowly, and a substantial short-term increase in DDT inputs to the river would not occur.
- The concentration of DDT is predicted to increase at the bank of the Klehini River (outflow face) for about 50 years after the time of release, or about 30 years from 1996, when it is expected to level off. The calculated concentration of DDT that would be measured in the mini-piezometer at steady state would be approximately 0.037 µg/L. Assuming a dilution factor of 20 between the concentration measured in the river and the mini-piezometer a value of 0.002 µg/L is predicted to occur in the river immediately

adjacent to the to the outflow face at some time in the future, when steady state conditions are established.

- Interactive effects of DDT and hydrocarbons in groundwater and subsurface soils have not been accounted for, but were not expected to play a role away from the source of non-aqueous phase hydrocarbons. As fresh water moves the DDT away from the source, DDT fractions in excess of the solubility limit would most likely precipitate into solid form (Pankow and Cherry, 1996). At lower concentrations, the solubility limit (and co-solvent effects) would not be expected to be a major determinant of flux.

For hydrocarbons (primarily diesel source) derived from spills or a possible injection well under the former Border Station pump house –

- There was no evidence of an ongoing source of free-phase hydrocarbons to the groundwater except in monitoring well MW-8B located at the upper bench.

- There is a 95% probability that the mass flux of hydrocarbons to the Klehini River lies within the range of approximately 4,800 to 490,000 g/yr (based on 1996 estimates).

2.5 Summary of Recommendations

The recommendations for site restoration included measures designed to address surface and subsurface DDT and hydrocarbon contamination summarized above, as well as a number of smaller items. These included removal of the snow fence and upper tarp from the Trench facility, re-contouring of the lower site to prevent erosion of surface soils and runoff toward the river, and remediation of discrete hydrocarbon stain locations at Border Station. The recommendations were based on the premise that there was the need for action where the possibility of risk to humans and/or other living organisms were present, or some reasonable expectation that risks could occur in the future. The direct objective of the remedial actions was to eliminate any possibility of risk. The suggested measures within the context of risk management are discussed in the following sub-sections.

2.5.1 Removal or Isolation of DDT-Contaminated surface soils

The most contaminated soils, those falling in the concentration range for total DDT between 10 to 170 µg/g were localized and relatively small; therefore, the removal of these soils from contact with the environment would impose a minimal clean up cost, and strongly minimize any unforeseen effects on flora and fauna within the immediate vicinity of the site. The important principal is that possible exposure pathways for DDT in surface soils to wildlife need to be curtailed. This could be accomplished either by the removal of the soils from the site or through the use of an appropriate physical barrier (partial encapsulation). Immunoassay-based field test kits for DDT appear to be sufficiently reliable to be used in confirmatory testing of any removal or isolation activities.

There was no compelling evidence that the remaining contaminated soils, those with total DDT in the range of 1 to 10 µg/g, constituted a hazard to either humans or wildlife. As precautionary

measures, however, capping of the soils containing 1-10 µg/g total DDT using a 0.5 to 1 m thick layer of clean granular material excavated from nearby will eliminate entirely any operable exposure pathway. Clean fill is available at the upper site as well as further east along the old Haines-Fairbanks Highway in the form of an existing gravel borrow area.

2.5.2 Removal of Snow Fence and Upper Liner from the Rainy Hollow Trench Area

In-situ testing of soils within the upper one metre of the backfilled trench indicated that the range of concentrations of total DDT was 0.13 to 6.3 µg/g while the arithmetic mean was 1.42 µg/g (standard deviation = 2.04 µg/g). The geometric mean was 0.60. If it is assumed that the DDT concentrations are normally distributed within the soils held between the upper and lower liners of the trench, then the upper 95th percentile total DDT concentration is estimated to be 5.4 µg/g. The DDT and hydrocarbon concentrations, therefore, were within the range observed in several surface soil samples outside of the backfilled trench, and the associated estimation of risk is similar. As with other surface soils with DDT concentrations in the 1-10 µg/g range, capping with 0.5 to1 m of clean fill after removal of the upper tarp and snow fence is recommended as a precautionary measure.

Removal of the upper tarp will also have the effect of increasing the local infiltration of surface water from rainfall and snowmelt. This should not, however, increase the flux of DDT away from the source area since the major portion of the DDT source is either beneath the lower tarp in the backfilled trench placed at or near water table depth, or in subsurface soils lateral to the trench.

2.5.3 Remediation of Localized Surface Hydrocarbon Stains

Two discrete hydrocarbon stains were confirmed at the upper site to the northwest, an irregular shaped stain approximately 5 x 10 m in size (vicinity of TP96-03) where the original source was probably a small heating oil or diesel tank and a tar-like stain a short distance away that is limited to a depth of a few millimeters. The former of these two stains will undergo natural remediation within a few decades or less. Hydrocarbon concentrations at a depth of 1 m or more were lower than the B.C. Draft soil standards. Test pits excavated laterally to the stain indicated that no subsurface lateral migration of hydrocarbons has occurred. The degradation of hydrocarbons in the uppermost soils could be enhanced through in place reworking of the soils, which would enhance volatilization, sunlight-mediated photolysis and microbial degradation. This may not be necessary, since no impacts to wildlife populations are likely to occur as a result of the stain, given its small size. The second stain could be removed through the removal of the top few centimetres of soil. This would remove the existing barriers to localized re-vegetation of the area.

2.5.4 Site Re-Contouring and Re-Grading

As a precautionary measure, re-contouring of the lower terrace at Rainy Hollow in the area of the Trench should be considered to eliminate substantial surface runoff toward the Klehini River,

and hence the erosion and entrainment of surface soil particles with low-level DDT contamination. Some re-contouring to limit vehicular access would also enhance re-vegetation of the area and, in the absence of a cap of clean fill, minimize the potential for mobilization of contaminated surface soils as wind-blown dust.

2.5.5 *Initiation of a Small Rodent Study and Terrestrial Wildlife Survey*

A small rodent study was recommended to ascertain the validity of DDT remediation triggers at Rainy Hollow. There was some uncertainty regarding the ecological risks associated with DDT soil contamination in the range of 1 to 10 μg/g. Furthermore, it was not possible to ascertain with absolute confidence the source area for the DDT bioaccumulation measured in a pooled sample of shrews from the site. As discussed above, the possible ecological risks would be eliminated by the complete removal of exposure pathways by capping with clean fill. The re-evaluation of the DDT bioaccumulation in small mammal populations and associated health effects (especially effects on fecundity) before and after removal of the most contaminated soils (total DDT > 10 μg/g) is an option that could be undertaken in order to determine if lower remediation triggers are warranted.

The assessment of human health risk at Rainy Hollow did not incorporate ingestion estimate for the consumption of country food. The existing scientific information and data did not allow any confident prediction of the concentrations likely to be found in moose meat or other food substance in association with local areas of DDT contamination at Rainy Hollow. It is extremely unlikely that the source of DDT at Rainy Hollow could result in any measurable increase relative to background levels in DDT tissue concentrations in either large herbivorous mammals or larger carnivores and omnivores. This is due to the low DDT concentrations in blueberry tissue collected near the site, in conjunction with the extremely small size of the contaminated area relative to the feeding range of most of the animals. The possibility of food chain related risks to humans, however, could be examined directly through the analysis of DDT in a limited number of country food samples.

2.5.6 *Groundwater Monitoring Program*

This was needed to validate and improve predictions of contaminant fate. It was important to determine the average groundwater velocities and directions over an extended period of time. This would enable a revision and update of the dispersion coefficients and a refinement of the estimates of mass loading into the river. It was suggested that three wells be chosen for water level monitoring, with emphasis on wells installed on the lower terrace. One well should have a continuous recorder installed and the other two could be manually recorded at a frequency of twice per month. This would only be necessary over the spring, summer and fall months in 1997 and 1998.

2.6 Remedial Action Plan and Implementation

The results and recommendations of the DSI summarized in the preceding sections were presented to the Rainy Hollow Working Group at a meeting held at Royal Roads University on

February 21, 1997. Participants at the meeting comprising representatives from DIAND, Champagne and Aishihik First Nations, BC Ministry of Environment Land and Parks, Royal Roads University, Golder Associates, and UMA Engineering Ltd. reviewed the recommendations above and verbally approved a cleanup plan. Remedial actions proposed in the plan included:

- The curtailment of the possible exposure pathways for DDT in surface soils to wildlife and humans by the removal and off-site disposal of soils with total DDT concentrations exceeding 10 μg/g from the vicinity of the former Temporary Storage Facility and near the Trench at Rainy Hollow.

- The isolation of the remaining DDT-contaminated soils with total DDT concentration in the range of 1 to 10 μg/g and hydrocarbon-contaminated soils with concentrations exceeding 1000 μg/g by capping using a minimum of 0.5m of clean granular material.

- The development of a long-term groundwater monitoring program to validate and improve predictions of contaminant fate. This included the monitoring of groundwater levels and DDT concentrations in the existing wells, in addition to the verification of the DDT contaminant transport model used.

The implementation of the remediation action plan to meet the recommendations discussed above are presented in Chapter 3: Remedial Activities and Chapter 4: Monitoring Program.

3. REMEDIAL ACTIVITIES

This chapter summarizes remedial activities that were undertaken to meet the recommendations of the Detailed Site Investigation and Risk Assessment presented in Chapter 2.

3.1 Removal or Isolation of DDT-Contaminated surface soils

The removal and/or isolation of DDT-contaminated soils were accomplished between 1996 and 1998 as described in the next subsections.

3.1.1 Removal of Temporary Storage Facility (1996)

Royal Roads characterized the concentrations of DDT and hydrocarbons in the materials at the Temporary Storage Facility in May-June of 1996 (Royal Roads, 1996c). The investigation also addressed soil contaminant leachability (BC Special Waste Extraction Procedure), bioassays (static acute trout), and physical characteristics of the soil pile. The total volume of the soil pile was estimated to be approximately 330 m^3 with DDT and its metabolites in collected soil samples ranging in concentration between 3.58 to 57 µg/g. Elevated concentrations (2.34 to 4.71 µg/g) were also detected in the retaining berm. Hydrocarbons in the soil were mostly diesel, with measurable quantities of heavy oils (lubricants and grease). Contaminated soils in the Temporary Storage Facility along with substrate in the retaining berms were removed on October 15, 1996 and transported to an industrial landfill in Alberta for disposal. The area was then re-graded and covered with clean granular material.

3.1.2 1997 Remedial Activities

The process was initiated with the development of the construction specification by UMA Engineering (UMA, 1997) based on the recommendations presented in Chapter 2. The specifications were then employed for site remediation between August 20 and September 14, 1997. The clean up project team consisted of representatives from: DIAND Waste Management, Whitehorse (Project Authority); Champagne-Aishihik First Nations, Haines Junction, YT (Construction Contractor and Stakeholder Consultations); Royal Roads University (Scientific/Technical Coordinator) and UMA Engineering Ltd. (Engineering Consultant).

A total of 226 tonnes of surface soils contaminated with total DDT concentrations exceeding 10 µg/g were excavated from the vicinity of the former Temporary Storage Facility and near the Trench at Rainy Hollow. This was to curtail the possible exposure pathways for DDT in surface soils to wildlife and humans. The excavated soils were taken to the East Peace Industrial Waste Treatment and Disposal Site, Peace River, Alberta for disposal. The remaining DDT-contaminated soils with total DDT concentration in the range of 1 to 10 µg/g and hydrocarbon-contaminated soils with concentrations exceeding 1000 µg/g were capped using a minimum of 0.5m of clean granular material. Capping material was hauled in from a borrow area along Haines Highway designated by the Department of Highways, Yukon Territorial Government.

Eighteen monitoring wells required for the long-term monitoring program were reset to below

ground surface. The purpose of this task was to reduce the visibility of the monitoring wells at the site and minimize the potential for tampering. In addition, 11 wells, which were no longer needed for monitoring purposes, were cut off at a depth of 1m below ground surface and sealed. The excavated areas around the wells were backfilled to surface and graded to match existing contours.

A report of remedial activities, including confirmatory sampling, was prepared for DIAND in January 1998 (Royal Roads, 1998). Copies of this report were subsequently submitted to WLAP – Contaminated Sites in Victoria, Environmental Protection in Smithers and Parks in Smithers.

The site remediation report (Royal Roads, 1998) was reviewed in a meeting of the Rainy Hollow Working Group on March 30, 1998 at Royal Roads University. Participants included representatives from DIAND Waste Management (Mark Palmer and Brett Hartshorne), WLAP (P. Evans and M. Macfarlane), Champaign and Aishihik First Nations (K. Hudson and G. Allison) and Royal Roads (M. Dodd and D. Bright). Recommendations arising out of this meeting included the following:

- Additional confirmatory sampling, especially along the access roads to the Temporary Storage Facility at Border Station to address elevated levels of DDT.
- Preparation of maps showing all sampling locations to-date at the sites.

A review of previous information was conducted and maps documenting all sampling locations were presented in a report that was submitted to DIAND in 1999 (Royal Roads, 1999). Copies of the report were submitted to WLAP – Contaminated Sites in Victoria and Environmental Protection in Smithers.

Additional confirmatory sampling was conducted in August and October 1998. A synopsis of the program is given in the next section.

3.1.3 1998 Remedial Activities

Representatives from Royal Roads and DIAND Waste Management, Whitehorse conducted the field program on August 8, 1998. Forty-two surface soil samples were collected from locations along the access roads and the edge of the cap along a 10-m grid line. All the samples were analyzed using immunoassay test kits. Ten split replicate samples were also analyzed at Axys Analytical Laboratory using gas chromatography with mass spectrometric detection (GC-MS). Both the field test kit and laboratory results indicated that the concentrations of DDT in most of the samples were less than 1.0 µg/g. However, two locations in depressions along the access road east of the Temporary Storage Facility had DDT in excess of 10 µg/g. Contaminated soils in these two areas were excavated on October 29 and 30, 1998. The excavated soils were placed into 16 Mega Bag™ (Trimeg Holdings, Alberta) each with a capacity of 1 m^3.

Field test kit and laboratory data for samples collected after excavation indicated successful removal of soils containing DDT at concentrations exceeding 10 µg/g. The excavated areas along with other locations identified as containing DDT with concentrations between 1 – 10 µg/g were capped with clean granular material. These areas were then re-graded to conform to the natural contours. Confirmatory sampling locations and results are given in Drawings 3 and 4.

A report of the cleanup activities was submitted to DIAND Waste Management in March 1999 (Royal Roads, 1999). Copies of this report were also forwarded to WLAP – Contaminated Sites in Victoria and Environmental Protection in Smithers.

A validation of the DDT immunoassay test kits used for site investigation and remediation was also conducted in the 1999 report (Royal Roads, 1999). Over the course of the DSI and remedial activities (1996 – 1998), 200 soil samples collected from Border Station and Rainy Hollow were analyzed with the immunoassay field test kits. Out of these, 39 samples were analyzed using both field test kits and laboratory gas chromatographic methods, which represents 19% of total analyzed by test kits. A majority of the concentrations obtained using the field test kits agreed with the laboratory data. However, there was one false negative (underestimation of DDT concentration by the field test kit) and eight false positives (i.e., overestimation of the true DDT concentration). While some analyses were over-sensitive in no case did a sample determined to contain less than 1 µg/g DDT using the field test kits have a real total DDT concentration greater than 1 µg/g. According to the US EPA SW846-4000 Method for Immunoassay, the maximum permissible false negative rate is 5% while producing as few false positive results (nominally less than 20%). The results obtained at Rainy Hollow (2.5% occurrence of false negatives and 20% false positives) are therefore, within acceptable limits indicating that the EnviroGard™ DDT in Soil Test Kit served as a useful tool for field analysis.

3.2 Removal of Snow Fence and Upper Liner from the Rainy Hollow Trench Area

This was addressed during the 1997 remediation program. The snow fence, upper liner and all tires used to hold down the liner were removed. These were placed into the stockpile of contaminated soils and shipped off-site for disposal. Soil at the northern end of the "trench" was excavated and the remaining material, which contained DDT at concentrations between was 0.13 to 6.3 µg/g was capped with at 0.5 m of clean fill (See Drawing 3).

3.3 Remediation of Localized Surface Hydrocarbon Stains

Surface hydrocarbon stains were present at the former POL storage area and two discrete areas at the upper site (Border Station). Hydrocarbon concentrations at a depth of 1 m or more were lower than the B.C. Draft soil standards. Test pits excavated laterally to the stain indicated that no subsurface lateral migration of hydrocarbons had occurred. The impacts to wildlife populations from these stains were deemed minimal given their small sizes relative the foraging range. The stains however provided a barrier to localized re-vegetation of the area. These stained areas were therefore capped with a minimum of 0.5 m of clean fill. Capping was accomplished between August 25 to 29, 1997. The limits of the area to be capped were laid out on the basis of the results of the 1996 Detailed Site Investigations and as presented in the Construction Specifications (UMA, 1997). The steep nature of the temporary roadway leading to the former POL area, as well as the confined space for maneuvering required the use of only the small end dump trucks to haul clean fill to this location. This increased the time required to complete the cap. Once the cap was completed, the temporary roadway was graded to blend with the natural slope of the hillside. The total volume of soil placed in the former POL locations was approximately 1450 m^3 while 126 m^3 of fill was placed over the other two localized stained

areas.

3.4 Site Contouring and Re-Grading

Following the removal of contaminated soils and addition of at least 0.5 m of clean fill, the sites were re-graded and contoured to minimize substantial surface runoff.

3.5 Initiation of a Small Rodent Study and Terrestrial Wildlife Survey

The small rodent study and further wildlife survey was recommended as an option if lower remediation triggers are warranted following the removal of soils containing DDT in excess of 10 μg/g and capping those with concentrations between 1 – 10 μg/g. No further actions were undertaken since the triggers used were deemed satisfactory.

4. GROUNDWATER MONITORING PROGRAM

It was evident from the results of the Detailed Site Investigation and Risk Assessment that subsurface DDT and hydrocarbon contaminated material remained in place at Rainy Hollow. There was evidence that both DDT and hydrocarbons were being introduced to the Klehini River through the discharge of contaminated groundwater. The results of the risk assessment however, indicated that the actual instantaneous concentrations of these substances in sediment, river water, or stream invertebrates was so low as to preclude any possibility of deleterious biological effects. A conceptual groundwater modeling exercise was undertaken in order to predict the subsurface fate of DDT and hydrocarbons at Rainy Hollow. This was expanded and evaluated in a follow up document (Woodbury, 1997). The conceptual model of contaminant transport predicted an increase in DDT concentrations at the bank of the Klehini River (outflow face) for about 50 years after the time of release and expected to level off. The monitoring program was recommended to:

- Confirm the original predictions of the fate and concentrations of DDT;
- Allow, if necessary, refinements to the model, thus ensuring the long-term validity of contaminant fate predictions;
- Permit further intervention at the site, including a possible re-evaluation of remedial/risk-management strategies, through comparison with pre-defined action triggers, and
- Provide assurances that other contaminants such as hydrocarbons and various metals are not entering the Klehini River at potentially deleterious concentrations.

Schedules, parameters and work plan recommended in the monitoring program included:

- Measurement of water levels at three locations on the lower bench area. There are MW-19A, MW-22 and MW-18. Monitoring in MW-19A will be carried out using a continuous recorder and MW-18 and MW-22 on a twice per-month frequency from May to October in 1997, 1998 and 1999.
- Annual sampling of water from monitoring wells WP-7, WP-13, MW-21A, MW-21B, MW-17A, MW-17B and MW-18, from mini-piezometers MP-1, MP-2 and MP-3, and at three points along the Klehini River.
- Field determination of the electrical conductivity, temperature and pH of the water samples and laboratory analysis for DDT and BTEX in predefined subsets of the wells.
- In addition, pursuant to discussions at the Rainy Hollow Working Group meeting of March 1998, it was deemed necessary to analyze these samples for metals as well as light extractable petroleum hydrocarbons (LEPHs - C10-C18).

4.1 METHODS

4.1.1 Field Investigations

Field programs were conducted over two day periods in August each year. The field team comprised representatives from either one or more of these organizations - Royal Roads, DIAND Waste Management, Whitehorse and UMA Engineering, Winnipeg. Activities conducted in the first year included the collection of groundwater and surface water samples, and installation of

two continuous water level monitors. Data was retrieved from the loggers during subsequent annual visits.

4.1.2 Sampling Locations

Seven locations were targeted for groundwater sampling and these are shown on Drawing 5. The wells comprised:

- MW-16 located on the upper bench to ascertain the migration of hydrocarbons towards Rainy Hollow;
- MW-17A&B and MW-19A&B which are two sets of nested wells situated along the groundwater flow path from the upper bench and up gradient from the DDT Trench at Rainy Hollow;
- WP-7, WP-13 and MW-21, which are located down gradient from the Trench; and
- MW-18, which is not directly influenced by either the DDT Trench or hydrocarbon contamination from the upper bench and was therefore selected to provide data on the lower site background conditions
- Samples were also collected from the three mini-piezometers (MP-1, MP-2 and MP-3) situated along the bank of the Klehini River.

Surface water samples were obtained from three locations along the Klehini River (Drawing 6) as follows:

- Kle-1: Downstream of the confluence of Seltat Creek and Klehini River, at approximately 1.1 km north of Rainy Hollow
- Kle-2: Inside of gravel bar adjacent to mini-piezometer MP-2
- Kle-4: South of Rainy Hollow, at approximately 1 km downstream of the site.

4.1.3 Groundwater Levels

Two Solinst M5 Leveloggers™ (Model No. 300, Serial No. 3312 and 3313) were installed in monitoring well MW-19B on August 23, 1997. One Levelogger was set below the water level to measure the depth of water in the well. The second Levelogger was placed in the borehole above the highest expected water level to measure barometric pressure. The two Leveloggers were set to record daily at 1200 hrs. Subsequent year activities included the retrieval of data from the Leveloggers. Following consultations and comments received from WLAP, a site visit was conducted on September 28, 1999 during which the Levelogger placed above the water level in MW-19B was retrieved and installed into MW-18.

The static groundwater level in each of the wells identified above was recorded annually during site investigations. The information gathered from the Leveloggers was deemed sufficient to document fluctuations in groundwater flow as such the recommended twice per-month frequency of manual groundwater measurement in MW-18 and MW-22 was not conducted.

4.1.4 Sampling

The static water level in each well was measured using a Solinst™ water level meter equipped with an interface probe (Solinst Model No. 122). Each well was purged and sampled using dedicated Waterra™ tubing and foot valve installed during the detailed site investigation. At least three well volumes of water were withdrawn from the well and discarded. Each well was purged until three consecutive readings of pH, conductivity and temperature were within ten percent. Following this samples were collected and placed into appropriate pre-cleaned sampling jars supplied by ALS Environmental (Formerly Analytical Services Laboratory), Vancouver BC and Axys Analytical Laboratories, Sidney BC (Axys).

Grab surface water samples from the Klehini River were collected directly into the appropriate sampling containers. The container was held at the base and the neck plunged below the surface (25 - 40 cm) and tilted such that the neck pointed to the water flow during filling.

Samples earmarked for dissolved metals analyses were field filtered using disposable in-line 700 cm^2 x 0.45 µm membrane filter (Gelman Sciences). The filtered sample was placed directly into a 250 mL plastic container and preserved with nitric acid. A field QA/QC program, which incorporated measures to ensure the integrity of the water samples collected, was utilized. This included the collection of a field duplicate sample from MP-2 each year.

4.1.5 Laboratory Analysis

Laboratory analyses for volatile petroleum hydrocarbons (VPH) including benzene, toluene, ethylbenzene and xylene (BTEX), and extractable petroleum hydrocarbons (EPH) were conducted at ALS using gas chromatography with either photo-ionization detection (GC-PID) or flame ionization detection (GC-FID). Under the British Columbia Contaminated Sites Regulations, extractable hydrocarbons are classified into Light Extractable Petroleum Hydrocarbons (LEPH) and Heavy Extractable Petroleum Hydrocarbons (HEPH). The concentration of LEPH in a sample is obtained by initially quantifying extractable petroleum hydrocarbons (EPH) in the range C10 to C19. The concentrations of un-substituted PAHs that fall in this range are then obtained in a separate analysis and subtracted from the total EPH (C10 to C19) to arrive at a concentration for LEPH. Similarly, HEPH comprise the EPH fraction from C19 to C31, after subtracting concentrations of un-substituted PAHs that fall in this range. Results obtained to date over the first two years for Rainy Hollow and Border Station Rainy Hollow indicated that un-substituted PAHs did not constitute a significant part of the EPH fraction (i.e., uniformly less than 1% of the EPH total concentration, or below detection). As such data for EPH (C10 toC19) and LEPHs have been directly comparable. Corresponding results have also been obtained for EPHs (C19 to C31) and HEPHs. To this end, hydrocarbons in the C10 to C31 range were determined as EPH [(C10 to C19) and (C19 to C31)], rather than LEPH and HEPH during the subsequent monitoring programs.

DDT and its metabolites were analyzed by high-resolution gas chromatography/mass spectrometry at Axys. The following six DDT compounds which represent the parent isomers and their metabolites were determined; p, p'-DDT, o, p'-DDT, p, p'-DDE, o, p'-DDE, p, p'-DDD

and o, p'-DDD. Unless otherwise specified in the discussion DDT concentrations refer to the sum of all six compounds.

4.2 Results and Discussions

4.2.1 Groundwater Levels

Groundwater levels measured manually from August 1996 to 2000 are summarized in Table 1. The raw data is given in Appendix A.1. No data is available for 1997. The levels measured in the wells over the monitoring period are in close agreement, which suggest no dramatic change in horizontal gradient. Slight variations across wells and across years (i.e., in the range of a cm) are attributed to different measuring techniques by various field personnel. Therefore the groundwater flux to the Klehini River is also expected to be unchanged.

Data from the Solinst Levelogger installed in MW-19, which was retrieved on September 14, 2000, is presented graphically in Figure 4.1. The raw data is provided in Appendix B.

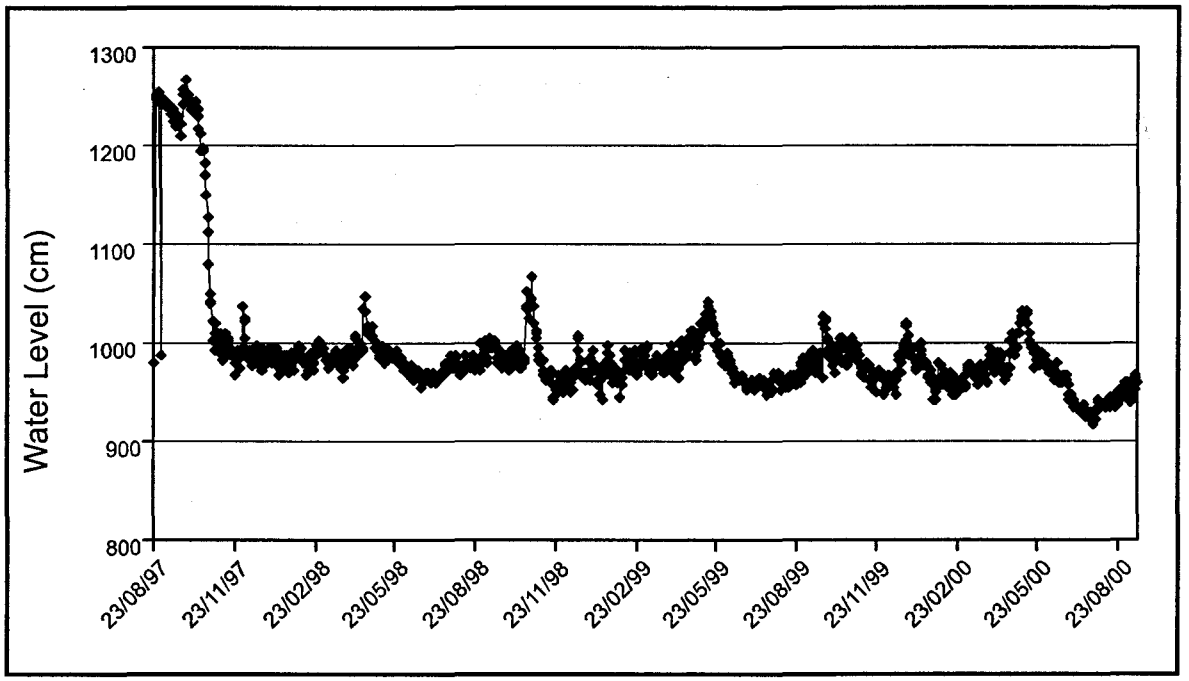


Figure 4.1: Groundwater levels at MW-19 recorded using an automated Solinst Levelogger from August 1997 and August 2000

The logger initially showed values of 1200 to 1250 cm corresponding to a water table elevation (measured manually) of about 95.8 m. During October 1997, the readings dropped off by 250 cm and fluctuated within a fairly narrow range (maximum variation of 100 cm) until the end of the recording interval in August 2000. The reading on August 8, 1998 of 969 cm corresponded to a manually recorded water level of about 96 m. The drop in reading in October 1997 cannot be readily rationalized. It may represent a drift in the transducer. Apart from the dramatic adjustment in pressure readings, the water level appears to vary by about 30 cm with the

occasional spikes of 50 cm or more. The short spikes in water level correlate to spring, where the snow pack melts into the overburden and recharges the water table. There are also occasional spikes in the late fall that likely correlate to significant late season precipitation events.

The Levelogger set above the water column in MW-19 was retrieved and re-installed into MW-18 in September 1999. Data from this well was also retrieved on September 14, 2000. The maximum spike noted was about 50 cm (Figure 4.2). This was comparable to data from MW-19.

Thus, it does not appear that there are significant seasonal changes to the groundwater table as such no major external impact, such as spring recharge or high river stage would be expected to influence groundwater levels.

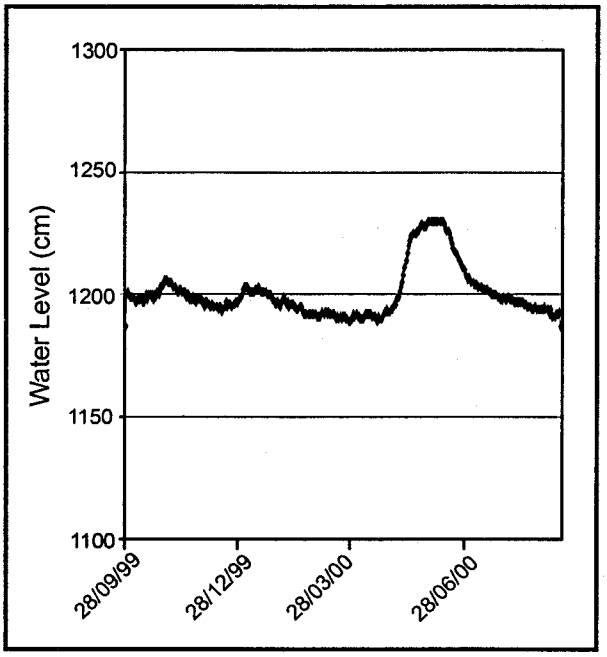


Figure 4.2: Groundwater levels at MW-16 recorded using an automated Solinst Levelogger from August 1999 and September 2000

4.3 Results for DDT

4.3.1 Groundwater

The concentrations of DDT in the water samples collected from 1996 to 2000 are given in Tables 2 to 6. These results are also presented graphically in Figure 4.3 below.

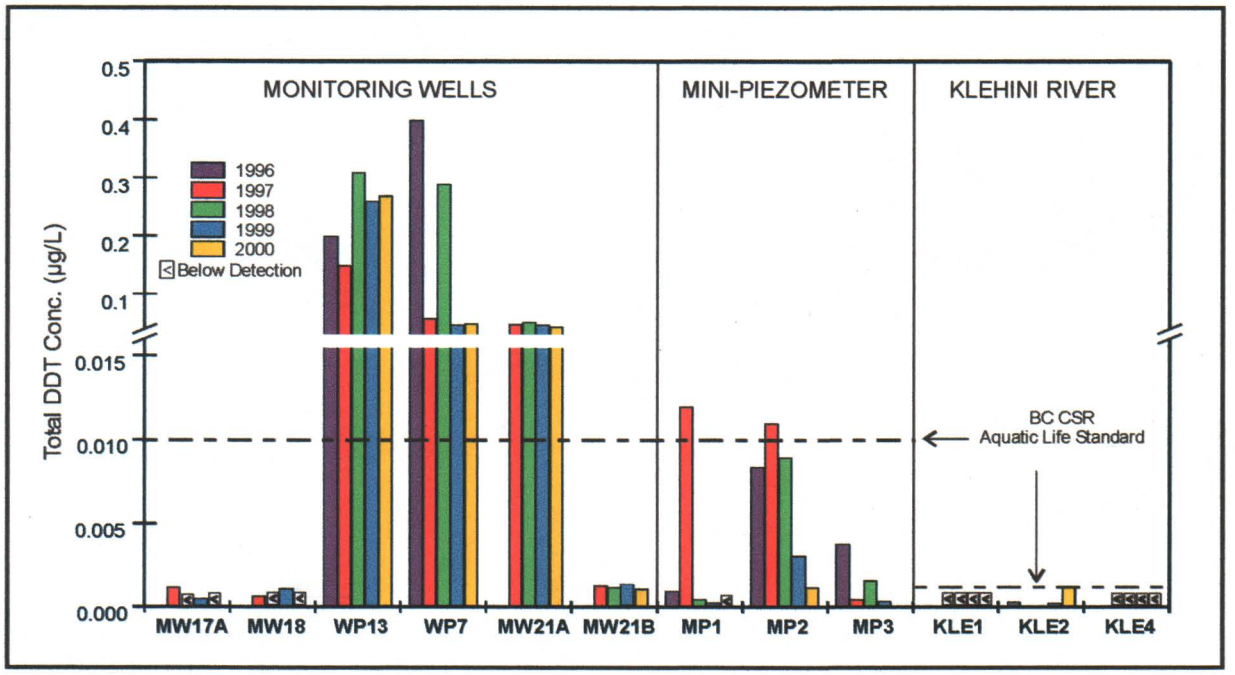


Figure 4.3: Total DDT Concentrations in Groundwater and Surface Water Samples Collected Annually at Rainy Hollow from 1996 to 2000

Detectable levels of p,p'-DDD, o,p'-DDD and p,p'-DDE (maximum of 0.00067 µg/L) were found in MW-17A over the monitoring period. This well is located up gradient of the Trench where the DDT containing canisters were recovered in 1994. The three isomers listed above were also detected in MW-18, which is located west of the Trench and is not directly influenced by contamination from either the Trench or the upper bench. The maximum total concentration detected in these two wells was 0.0011 µg/L. As depicted in Figure 4.3, concentrations in these two wells were generally comparable to each other over the monitoring period. Commercial DDT pesticide formulations usually contain 70 – 80% of the p,p'-DDT isomer and up to 30% of the o,p'-DDT isomer. Both DDE and DDD isomers occur in small quantities as impurities in technical DDT mixtures. Once introduced into the environment, the parent DDT isomers undergo transformations through biotic and abiotic processes to yield more DDD and DDE isomers. DDD is produced through reductive dechlorination under anaerobic conditions while oxidative dehydrochlorination under aerobic conditions yields DDE (Foght et al. 2001; Jing F. 2001). It is believed that DDE is the most recalcitrant of the three and the ratio of DDE to DDT increases with time following release into the environment; i.e., a more recent spill would have a greater proportion of DDT compared to DDD and DDE. The low concentrations of DDD and DDE detected in MW-17 and MW-18 may have been generated from the anaerobic transformation of

DDE detected in MW-17 and MW-18 may have been generated from the anaerobic transformation of the parent DDT isomers introduced through historical spraying or aerial dispersion of DDT-contaminated dust particles.

Total DDT concentrations in excess of the BC CSR standard for aquatic life use (AW) of 0.01 µg/L were found in groundwater samples obtained from the two wells located immediately down gradient of the Trench (WP-7 and WP-13) over the monitoring period. The principal isomer in samples from both these wells was p,p'-DDD, the initial degradation product of DDT by anaerobic dechlorination. The levels in WP-13 were relatively uniform over the entire monitoring period whereas there was a slight inter-annual variation in DDT concentrations for WP-7. The 1999 and 2000 data for WP-7 were, however, comparable to the 1997 result.

Detectable concentrations of DDT were also found in the nested wells located along the groundwater migration pathway to the Klehini River. Comparable levels (around 0.05 µg/L were found in the shallow well (MW-21A: screen set at between 0.5 to 2 m below ground surface). The concentrations in the deeper well (MW-21B), with the screen set at 2.5 to 5 m below the ground surface, were an order of magnitude lower (about 0.001 µg/L).

Samples from the mini-piezometer installed to intercept groundwater flow from the Trench before it enters the Klehini River had an average of 0.009 µg/L of total DDT between 1996 and 1998. This average was comparable to the concentration of 0.007 µg/L predicted by the conceptual model. There was a decrease in 1999 (0.003 µg/L) and in 2000 (0.001 µg/L). Thus no significant increase in DDT concentration was noted over the five-year period. This is consistent with the groundwater model predictions that "Temporal changes in DDT fluxes at the interface are predicted to occur relatively slowly, and a substantial short-term increase in DDT inputs to the river is not predicted to occur".

Apart from one anomalous data point of 0.012 µg/L obtained in 1997, the concentrations in samples from MP-1 (up gradient of MP-2) and MP-3 (down gradient of MP-2) were consistently close to or below the limits of detection. The mini-piezometers are set at the edge of the river below the present high water mark and are susceptible to removal during spring break up. This was the case for MP-1 in 1997 and a new one was re-installed. The anomalous data was due to o,p'-DDT and p,p'-DDT which was probably introduced as a contaminant during the installation of the new mini-piezometer. The dominant isomer was p,p'-DDT and not p,p'-DDD, which was the major species in the groundwater plume.

DDT concentrations in the surface water samples collected from the Klehini River are also included in Figure 4.3. Total DDT at KLE-1 (upstream of the site) and KLE-4 (downstream of the site) were generally below detection or less than 0.001 µg/L, which is the BC CSR AW standard of 0.001 µg/L, taking into account a ten-fold dilution of groundwater in the actual aquatic receiving environment. Similar results were also obtained for KLE-2 except for the 2000 data. A total DDT concentration of 0.0013 µg/L was found at in the sample obtained from KLE-2 in September 2000. The sampling location was near the mini-piezometer MP-2 in an overflow channel separated from the main river by a gravel bar. The concentrations of DDT detected in the surface water sample was similar to that obtained from groundwater in MP-2 (see Table 4.6).

This suggested that there was virtually no dilution of groundwater discharge into the side channel. Water level in the main river channel was very low at the time of sampling as such flow through the side channel was very slow and effectively stagnant. It should be noted that the concentration of 0.0013 µg/L detected in the surface water sample is less than the maximum concentration of 0.002 µg/L predicted to occur in the river immediately adjacent to the to the groundwater outflow face at some time in the future, when steady state conditions are established.

4.4 Hydrocarbons

The concentration of hydrocarbons in groundwater samples was measured as monocyclic aromatic hydrocarbons (benzene, toluene, ethylbenzene and xylenes) VHs (volatile hydrocarbons, C6 to 10), VPH (volatile petroleum hydrocarbons, calculated) and EPH (extractable hydrocarbons). Results obtained from the Detailed Site Investigations (Royal Roads, 1997) and the 1998 monitoring programs (Royal Roads, 1999) indicated that PAHs do not constitute a significant part of the EPH fraction, and site groundwater data for EPHs (C10 to19) and LEPHs have been directly comparable. Corresponding results were also been obtained for EPHs (C19 to 31) and HEPHs. To this end, extractable hydrocarbons were determined as EPH, rather than LEPH and HEPH during the 1999 and 2000 monitoring program.

4.4.1 Monocyclic Aromatic Hydrocarbons (MAHs)

The concentrations of the components of this group of hydrocarbons including benzene, ethylbenzene, toluene and xylenes (BTEX) have been consistently low and below the respective BC CSR standard for aquatic life (Table 7). Monitoring wells MW-17A and 17B, a set of nested wells situated between the upper bench and the lower bench along the groundwater flow path contained detectable concentrations of ethylbenzene, toluene and xylenes while the highest concentrations of these compounds were found in WP-7 directly down gradient of the trench. The concentrations at MW-17 may represent the migration of hydrocarbons from the upper bench and that at WP-7 reflects residuals from the DDT canisters along with contributions from the upper bench. The concentrations at the groundwater discharge by the Klehini River (mini-piezometers) were considerably lower.

4.4.2 Volatile and Extractable Petroleum Hydrocarbons

Detectable concentrations of, VPH and LEPH or EPH (C10 to 19) were found in groundwater samples obtained from various monitoring wells and mini-piezometers (Table 8); HEPH or EPH (C19-32) levels were all below detection except for one sample. The HEPH or EPH (C19-31) concentration of 1700 µg/L detected in MP-1 in 1996 may be attributed to contamination from the mini-piezometer upriser, which appeared to contain a heavy oil coating used during the manufacture. VPH (C6 to 10) concentrations in MW17 and WP-7 exceeded the BC CSR AW standard of 1,500 µg/L over the monitoring period.

EPH (C10-19) concentrations obtained during the monitoring program are summarized in Figure 4.4 below.

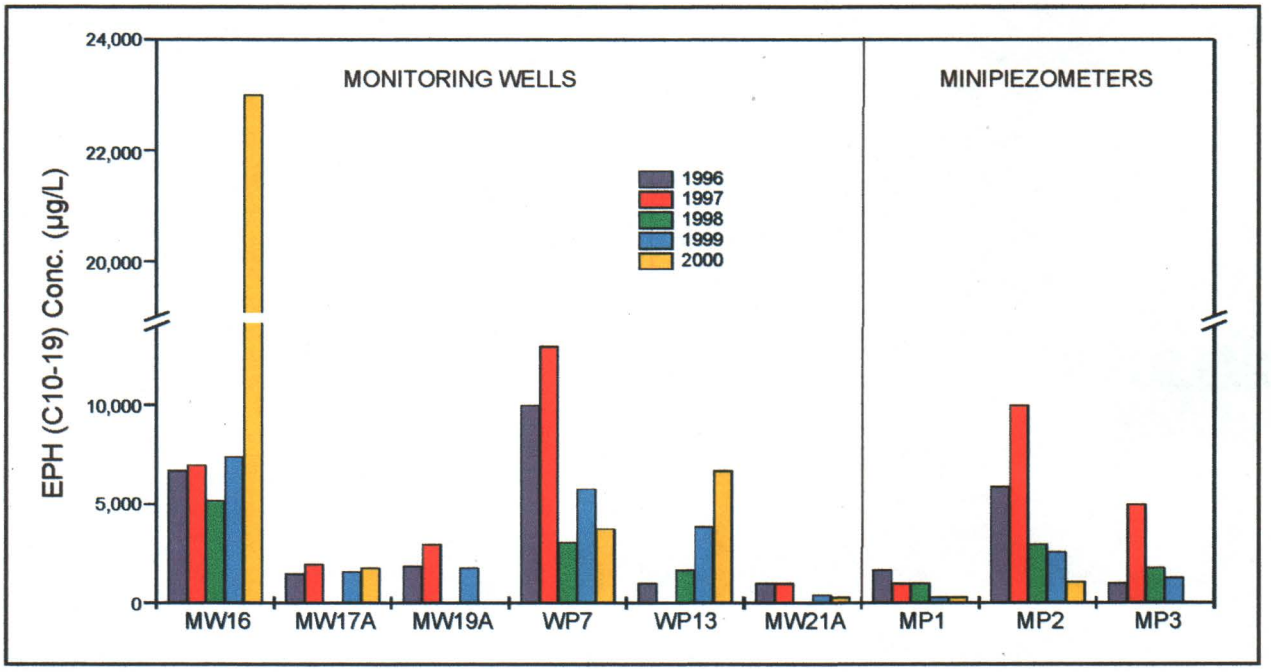
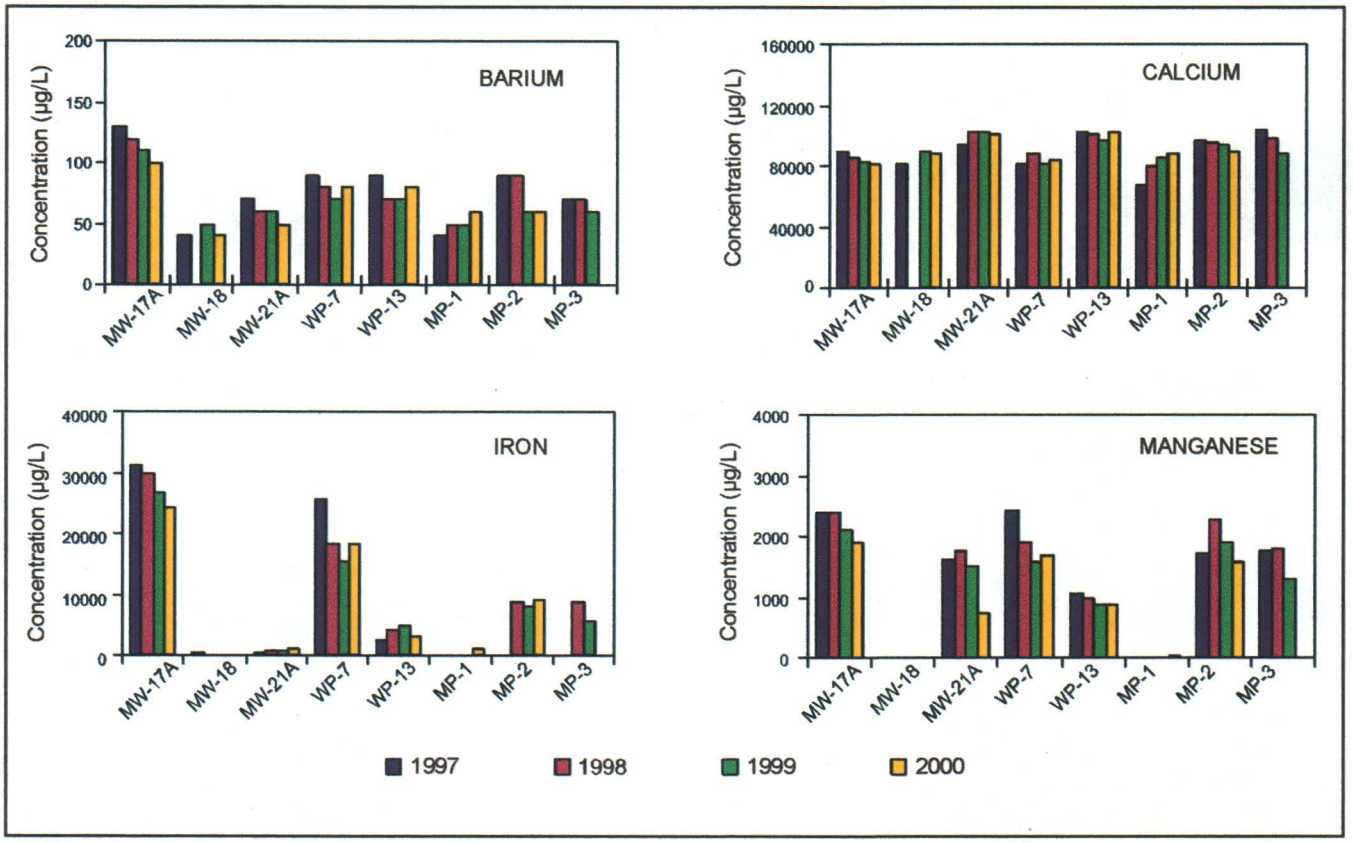


Figure 4.4: Extractable Petroleum Hydrocarbons (EPH C10-19) Concentrations in Groundwater and Surface Water Samples Collected Annually at Rainy Hollow from 1996 to 2000

The highest EPH (C10-19) concentration (23,000 µg/L) was found in 2000 in MW-16, which is situated on the upper bench along the groundwater migration flow to Rainy Hollow. This concentration was four times higher than results from the previous years. Monitoring wells MW-17A and 17B, a set of nested wells situated between the upper bench and the lower bench along the groundwater flow path also contained elevated concentrations EPH (C10 – 19). The concentrations were however, comparable to each other over the monitoring period. EPH (C10-19 levels in WP-13, immediately down gradient of the Trench showed an increasing trend while all other wells indicated decreasing hydrocarbon levels over the monitoring period. Hydrocarbon concentrations in samples from the mini-piezometers also generally showed a decreasing trend.

There were only slight changes in detectable metals concentrations in the monitoring wells over the monitoring period. The inter-annual variation in each well was not very significant as



illustrated by the concentrations of barium, calcium, iron and manganese in Figure 4.6.

Figure 4.6: Inter-Annual Variation of Barium, Calcium, Iron and Manganese Concentrations in Groundwater Water Samples Collected at Rainy Hollow from 1997 to 2000

Barium and calcium concentrations did not vary much between wells while iron and manganese concentrations were depended on well locations. The highest iron and manganese levels were found in MW-17A and WP-7. 3. Elevated iron and manganese concentrations in ground water is directly attributable to dissolution from the solid phase. Iron and manganese form oxyhydroxides in well oxygenated environments which have limited solubility in water. Under reducing conditions as found in sub-oxic or anaerobic environments, the oxyhydroxides go into solution thereby increasing dissolved miron and manganese concentrations. Other metals such as cadmium, copper, nickel, chromium, lead and zinc are known to adsorb to the abundant binding sites on iron and manganese oxyhydroxides, expecially hydroxy- (OH-) groups. Unlike iron and manganese, this latter group of metals react under highly anoxic conditions to form insoluble metal sulfide complexes provided that a large enough pool of free sulfides exist, removing them from solution. Generally, conditions that decrease the oxygen concentration in groundwater (i.e., enhance

reducing conditions) favour the solubilization of iron and manganese. The subsurface anoxia in shallow groundwater at Rainy Hollow is enhanced by hydrocarbon contamination. Aerobic bacteria utilize the hydrocarbons as a food source. The enhanced bacterial productivity in groundwater causes oxygen depletion with subsequent solubilization of iron and manganese into groundwater. Thus the highest dissolved iron and manganese concentrations were found in MW-16 (not shown on the plot), MW-17A and WP-7, which are situated along the hydrocarbon-contaminated groundwater migration flow towards the Klehini River. Samples from these wells contained elevated concentrations of EPH (C10-19) – see Figure 4.4. Elevated concentrations of manganese were also noted in samples from MP-2 and MP-3. This could be attributed to additional contributions from the metal up-riser pipes as with the zinc contamination discussed previously.

Groundwater samples collected in 1998 were also analyzed for total metals to ascertain the relative contribution of particulate matter to metal loading in groundwater. Total metals concentrations are given in Table 14. As with dissolved metals concentrations, arsenic, antimony, beryllium, boron, mercury, molybdenum, selenium and silver were below detection while elevated levels of other metals such as aluminum, iron, manganese and zinc were noted. A comparison of total the aluminum and iron concentrations to their respective dissolved concentrations are given in Figure 4.7. Higher aluminum and iron levels were generally associated with particulate matter as illustrated in the figure. MW-17A, WP-7 and MP-3, however, contained a greater ratio of dissolved iron. This was attributed to solubilization of iron hydroxides as discussed in the preceding paragraph.

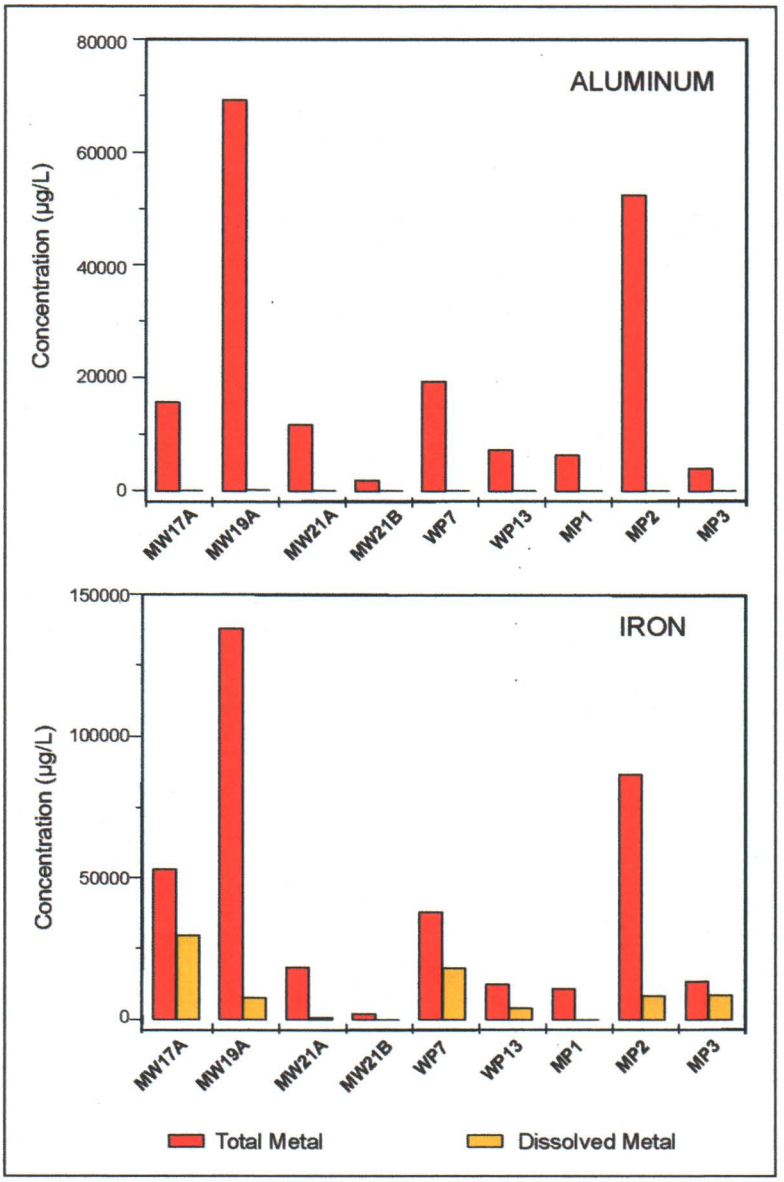


Figure 4.7: Comparison of Total Metal to Dissolved Metal Concentrations in Groundwater Samples Collected from Rainy Hollow in 1998

4.5.2 Surface Water

The monitoring of total metals in surface water was initiated in 1998 pursuant to discussions at the Rainy Hollow Working Group meeting of March 1998. Total metals concentrations obtained over the monitoring period is given in Table 15. Most of the concentrations were either below detection or below their respective BC CSR aquatic life standard. Furthermore the concentrations detected in 2000 were significantly lower than those obtained in the preceding years. This is illustrated using aluminum, iron, manganese and zinc concentrations in Figure 4.8. Metal concentrations in samples from KLE-2, directly adjacent to the site and KLE-4 (downstream of the site) were higher compared to the up-stream background sample (KLE-1). A comparison of total metal to dissolved metal concentrations (Table 16) indicated that the elevated concentrations were associated with particulate matter.

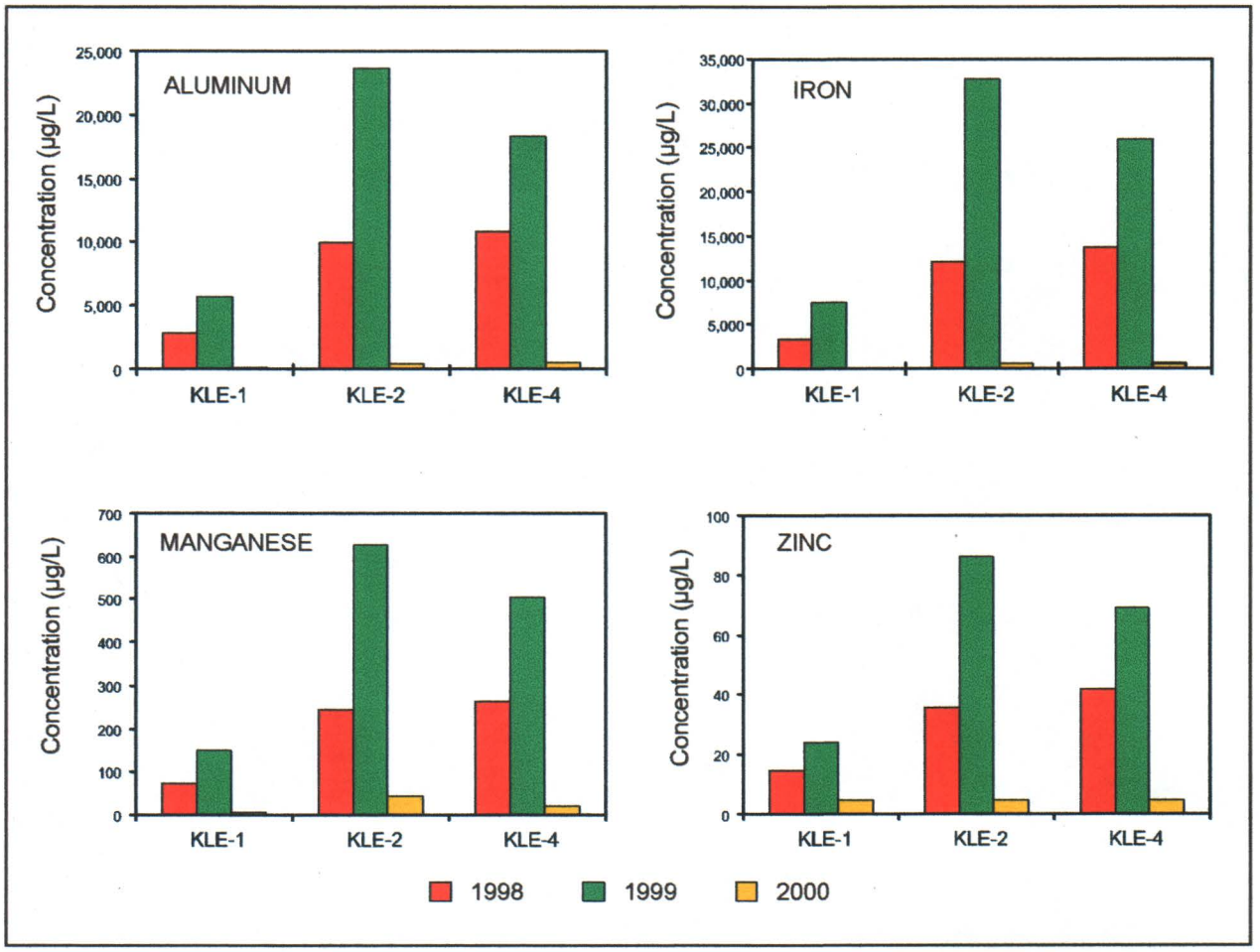


Figure 4.8: Total Meal Concentrations in Surface Water Samples Collected Annually from the Klehini River near Rainy Hollow

5. SITE INSPECTIONS

DIAND Waste Management personnel visit the site in July 2002 to assess current site condition and document any significant erosion and shifting of the river channel. Vegetation re-establishment in capped areas was also assessed. Photographs were taken and a summary report was prepared. This report is attached to Appendix A. This summary report also contains information regarding the barrel discovered in October 2001. A synopsis of the findings is reproduced below.

- The drum containing used motor oil was removed and disposed of in the fall of 2000. Laboratory analysis of a sample of the contents did not indicate any potential contaminants of concern such as DDT, PCBs, VOCs and metals. No additional drums were discovered.

- Slight erosion and shifting of the river channel was observed near MP-3. This was downstream of the Trench and was not anticipated to impact the site.

- Site re-vegetation was at a natural rate.

6. CONCLUSIONS

Based on the recommendations of the Detailed Site Investigation and Risk Assessment site remediation was conducted in 1997. Surface soils contaminated with total DDT concentrations exceeding 10 µg/g were excavated from the vicinity of the former Temporary Storage Facility and near the Trench at Rainy Hollow. This was to curtail the possible exposure pathways for DDT in surface soils to wildlife and humans. The excavated soils were taken to the East Peace Industrial Waste Treatment and Disposal Site, Peace River, Alberta for disposal. The remaining DDT-contaminated soils with total DDT concentration in the range of 1 to 10 µg/g and hydrocarbon-contaminated soils with concentrations exceeding 1000 µg/g were capped using a minimum of 0.5m of clean granular material. Capping material was hauled in from a borrow area along Haines Highway designated by the Department of Highways, Yukon Territorial Government. Additional excavation, capping and confirmatory sampling, especially along the access roads to the Temporary Storage Facility was undertaken in 1998 at Border Station to address elevated levels of DDT along portions of the road.

The snow fence, liner and all tires used to hold down the liner over the Trench were removed and shipped off-site for disposal. Soil at the northern end of the Trench containing DDT in excess of 10 µg/g was excavated and the remaining material, which contained DDT at concentrations between was 0.13 to 6.3 µg/g was capped with at 0.5 m of clean fill. Following the removal of contaminated soils and addition of at least 0.5 m of clean fill, the sites were re-graded and contoured to minimize substantial surface runoff.

A monitoring program was conducted using recommendations of the risk assessment and modifications suggested by the Rainy Hollow Working Group. The data obtained over the monitoring period, as presented in Chapter 4, indicates a remarkable overall consistency in the concentrations of DDT and hydrocarbons in groundwater and surface water samples collected from Rainy Hollow and Border Station over a five-year period.

Water levels reflect seasonal and annual variations, however the normal range of fluctuation is in the order of 50 cm. The horizontal gradient, and resultant groundwater flux to the Klehini River over the past four years has been relatively constant. Spikes in water levels are associated with spring recharge and late season precipitation. Any impact on groundwater flux to the river associated with these events is nominal as they are of short duration.

Based on previous investigations, it is estimated that mini-piezometer MP-2 is located in the approximate centre of the DDT-contaminated groundwater plume. The concentrations of DDT in samples collected from MP-2 indicate a slight decrease in 1999 and 2000. DDT concentrations in water samples from the Klehini River within 2 to 3 m of where contaminated groundwater would enter the river (KLE-2) have also been below 0.001 µg/L except for the 2000 data. The concentration obtained in surface water in 2000 was comparable to that found in the adjacent mini-piezometer. This suggested that there was virtually no dilution of groundwater discharge into the side channel. Water level in the main river channel was very low at the time of sampling as such flow through the side channel was very slow and effectively stagnant. It should be noted that the concentration of 0.0013 µg/L detected in the surface water sample is less than the

maximum concentration of 0.002 µg/L predicted by the model to occur in the river immediately adjacent to the to the groundwater outflow face at some time in the future, when steady state conditions are established. Hydrocarbon concentrations have also showed a similar decreasing trend. The results are therefore consistent with the groundwater model predictions that "Temporal changes in DDT fluxes at the interface are predicted to occur relatively slowly, and a substantial short-term increase in DDT inputs to the river is not predicted to occur". A similar conclusion can be drawn with respect to hydrocarbons.

Overall, the post-remediation monitoring data for Rainy Hollow/Border Station are consistent with modelling predictions undertaken as part of the 1996 environmental risk assessment. The data to date adequately characterizes the site conditions.

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Table 1: Static Groundwater Levels for Monitoring Wells

Well Number	Groundwater Elevation (m)			
	1996	1998	1999	2000
WP-7	96.11	96.07	96.30	96.07
WP-13	96.08	96.18	96.40	96.18
MW-16	98.20	98.80	99.00	98.65
MW-17A	97.39	97.28	97.42	97.16
MW-18	96.30	96.10	96.32	96.18
MW19A	96.22	95.95	96.19	-
MW-21A	93.85	93.98	94.01	93.83
MW-21B	93.87	93.67	93.72	93.55

Table 2: DDT Concentration in Water Samples Collected from Border Station and Rainy Hollow in September 1996

Sample ID	Monitoring Wells							Mini-Piezometers			Klehini River		
	MW-17A	MW-17B	MW-19	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2	MP-3	Kle-1	Kle-2	Kle-4
o,p' DDE	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.00001	<0.00001	<0.00002	<0.000001	<0.000001	<0.000004
p,p' DDE	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.00001	0.00003	0.00006	<0.000003	<0.000004	<0.000009
o,p' DDD	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0001	0.002	0.00079	<0.000006	0.00008	<0.000005
p,p' DDD	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.2	0.00007	0.0058	0.0022	0.000004	0.00023	<0.000006
o,p' DDT	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.00018	<0.00018	0.00028	<0.00002	<0.000009	<0.00005
p,p' DDT	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0015	0.0008	0.00043	0.00002	<0.00002	0.00002
Total DDT	-	-	-	-	-	**0.4**	**0.2**	**0.00048**	**0.00863**	**0.00376**	**0.000024**	**0.00031**	**0.00002**

Notes:

1. All concentrations are expressed in micrograms per litre (µg/L)
2. < = less than the detection limit indicated
3. Shaded area indicates total DDT exceeds the BC CSR aquatic life standard of 0.01µg/L

Table 3: DDT Concentration in Water Samples Collected from Border Station and Rainy Hollow in August 1997

Sample ID	Monitoring Wells							Mini-Piezometers				Klehini River		
	MW-17A	MW-17B	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2	MP-3-1	MP-3-2	Kle-1	Kle-2	Kle-4
o,p' DDE	<0.00012	<0.00008	<0.00005	<0.00017	<0.0001	0.00026	0.0003	<0.00032	0.00048 N Q	<0.00079	0.00074	<0.00006	<0.00003	<0.00019
p,p' DDE	0.00024 N Q	0.00012 N Q	0.00015	<0.00027	0.00014 N Q	0.0019	0.0015	<0.0013	0.00061 N Q	<0.0011	<0.00029	<0.00012	0.00012 N Q	<0.00011
o,p' DDD	0.00029	<0.00004	<0.00003	0.01	0.00067	0.011	0.035	0.00072	0.002	0.0013 NQ	0.00085	<0.00004	<0.00003	<0.00005
p,p' DDD	0.00067	<0.00007	<0.00013	0.039	0.0005	0.044	0.11	0.00098	0.0076	0.0033	0.002	<0.00004	<0.00003	<0.0001
o,p' DDT	<0.0001	<0.00007	<0.00012	<0.00016	<0.00015	<0.00087	<0.00014	0.0032	0.00035 N Q	0.0012 NQ	<0.0013	<0.00005	<0.00004	<0.00015
p,p' DDT	<0.00016	<0.00015	0.00051	0.0003	<0.0008	0.0022	0.0015	0.0076	<0.00043	<0.0012	0.00088	<0.00011	<0.00004	<0.00013
Total DDT	**0.00096**	-	**0.00066**	**0.049**	**0.0012**	**0.059**	**0.15**	**0.012**	**0.0096**	**0.0033**	**0.0045**	-	-	-

Notes:

1. A field duplicate sample (MP-3-1 and MP-3-2) was collected at MP-3
2. All concentrations are expressed in micrograms per litre (µg/L)
3. < = less than the detection limit indicated
4. NQ = Peak detected but did not meet quantification criteria
5. Shaded area indicates total DDT exceeds the BC CSR aquatic life standard of 0.01µg/L

Table 4: DDT Concentration (µg/L) in Water Samples Collected from Border Station and Rainy Hollow in 1998.

Sample #	Monitoring Wells						Mini-Piezometers				Klehini River		
	MW-17A	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2A	MP-2B	MP-3	Kle-1	KLE-2	Kle-4
o,p' DDE	<0.0002	<0.0003	<0.0001	<0.0003	0.0015 NQ	0.00046	<0.0003	<0.0011	<0.0011	<0.0007	<0.0006	<0.0006	<0.0005
p,p' DDE	<0.0003	<0.0004	0.00041	<0.0003	0.011	0.0029	0.0005	<0.00016	<0.00016	<0.0009	<0.0008	<0.0006	<0.0007
o,p' DDD	<0.0002	<0.0003	0.011	0.00053	0.054	0.062	<0.0004	0.0019	0.0023	<0.0010	<0.0004	<0.0005	<0.0006
p,p' DDD	<0.0002	<0.0004	0.041	0.00067	0.22	0.24	<0.0009	0.0068	0.0069	0.0016	<0.0008	<0.001	<0.0009
o,p' DDT	<0.0003	<0.0002	0.00033	<0.0002	<0.001	<0.0006	<0.0006	<0.0018	<0.0004	<0.0011	<0.0007	<0.0004	<0.0007
p,p' DDT	<0.0005	<0.0004	0.00065	<0.0005	0.0042	0.00075	<0.0014	<0.0013	<0.0011	<0.0017	<0.0013	<0.0006	<0.0007
Total DDT	-	-	**0.053**	**0.0012**	**0.29**	**0.31**	**0.0005**	**0.0087**	**0.0092**	**0.0016**	-	-	-

Notes:

1. A field duplicate sample (MP-2A and MP-2B) was collected at MP-2
2. All concentrations are expressed in micrograms per litre (µg/L)
3. < = less than the detection limit indicated
4. NQ = Peak detected but did not meet quantification criteria
5. Shaded area indicates total DDT exceeds the BC CSR aquatic life standard of 0.01µg/L

Table 5: DDT Concentration in Water Samples Collected from Border Station and Rainy Hollow in August 1999

Sample ID	Monitoring Wells							Mini-Piezometers				Klehini River		
	MW-17A	MW-17B	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	MP-3	Kle-1	Kle-2	Kle-4
o,p' DDE	<0.00013	<0.00022	<0.00022	<0.00025	<0.00019	<0.00056	<0.00031	<0.00010	<0.00045	<0.00032	<0.00046	<0.00018	<0.00038	<0.00044
p,p' DDE	0.00027	0.00025	0.00026	0.0003	0.0002	0.0017	0.00065	0.00028	0.00019	0.00026 NQ	<0.00040	0.00033 NQ	0.00025	<0.00016
o,p' DDD	0.00011	<0.00015	0.00027	0.011	0.00065	0.011	0.061	<0.00010	0.00049 NQ	0.00052 NQ	<0.00022	<0.00020	<0.00012	<0.00018
p,p' DDD	0.00016	<0.00016	0.0060	0.036	0.00064	0.035	0.20	<0.00011	0.0014	0.0015	0.0032 NQ	<0.00007	<0.00013	<0.00019
o,p' DDT	<0.00014	<0.00020	<0.00013	<0.0021	<0.00038	<0.00054	0.00099	<0.00011	0.0015	0.0016	0.00035	<0.00024	<0.00016	<0.00022
p,p' DDT	<0.00020	<0.00029	<0.00019	<0.0031	<0.00055	<0.00079	0.0017	<0.00013	<0.00020	<0.00015	<0.00016	<0.00012	<0.00012	<0.00028
Total DDT	**0.00054**	**0.00025**	**0.0011**	**0.047**	**0.0015**	**0.048**	**0.26**	**0.00028**	**0.0031**	**0.0031**	**0.00035**	**-**	**0.00025**	**-**

Notes:

1. A field duplicate sample (MP-2-1 and MP-2-2) was collected at MP-2
2. All concentrations are expressed in micrograms per litre (µg/L)
3. < = less than the detection limit indicated
4. NQ = Peak detected but did not meet quantification criteria
5. Shaded area indicates total DDT exceeds the BC CSR aquatic life standard of 0.01µg/L

Table 6: DDT Concentration in Water Samples Collected from Border Station and Rainy Hollow in September 2000

Sample #	Monitoring Wells							Mini-Piezometers			Klehini River		
	MW-17A	MW-17B	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	Kle-1	Kle-2	Kle-4
o,p' DDE	<0.00025	<0.00049	<0.00064	<0.00045	<0.00058	<0.00042	<0.00041	<0.00035	<0.00034	<0.00031	<0.00026	<0.00037	<0.00036
p,p' DDE	<0.00022	<0.00064	<0.00083	0.00058	<0.00075	0.0002	0.00016	<0.00032	<0.00031	<0.00028	<0.00023	<0.00034	<0.00033
o,p' DDD	<0.00013	<0.00026	<0.00029	0.01	0.00048	0.011	0.069	<0.00013	0.00037	0.00021	<0.00014	0.00034	<0.00014
p,p' DDD	<0.00013	<0.00031	<0.00035	0.034	0.00059	0.037	0.2	<0.00013	0.00098	0.00078	<0.00014	0.00094	<0.00014
o,p' DDT	<0.00017	<0.00036	<0.00042	<0.00069	<0.00055	<0.00051	<0.00065	<0.00013	<0.00018	<0.00021	<0.00017	<0.00019	<0.00017
p,p' DDT	<0.000019	<0.00048	<0.00056	<0.00092	<0.00072	<0.00068	0.00014	<0.00015	<0.00020	<0.00024	<0.0002	<0.00022	<0.0002
Total DDT	-	-	-	**0.04458**	**0.00107**	**0.0482**	**0.2693**	-	**0.00135**	**0.00099**	-	**0.00128**	-

Notes:

1. A field duplicate sample (MP-2-1 and MP-2-2) was collected at MP-2
2. All concentrations are expressed in micrograms per litre (µg/L)
3. < = less than the detection limit indicated
4. Shaded area indicates total DDT exceed the BC CSR aquatic life standard of 0.01µg/L

Table 7: Concentrations of Monocyclic Aromatic Hydrocarbons in Water Samples Collected Annually at Rainy Hollow from 1996 to 2000

1996	MW-16	MW-17A	MW-17B	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-21	MP-22	MP-3	CSR AW
Benzene	<0.5	--	--	--	<0.5	<0.5	<0.5	<0.5	--	--	--	<0.5	3000
Ethylbenzene	1.1	--	--	--	<0.5	<0.5	24	<0.5	--	--	--	3.3	7000
Toluene	<1	--	--	--	<1	<1	10	<1	--	--	--	<1	3000
meta- & para-Xylene	1.1	--	--	--	<0.5	<0.5	54	0.6	--	--	--	3.9	--
ortho-Xylene	1.6	--	--	--	<0.5	<0.5	12	<0.5	--	--	--	0.9	--
1997	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-21**	**MP-22**	**MP-3**	
Benzene	<0.5	0.7	0.7	<0.5	<0.5	<0.5	0.9	--	<0.5	<0.5	--	<0.5	3000
Ethylbenzene	1	32	23.6	<0.5	<0.5	<0.5	23.2	--	<0.5	2.5	--	0.8	7000
Toluene	<0.5	2.2	1.7	<0.5	<0.5	<0.5	1.5	--	<0.5	<0.5	--	0.7	3000
meta- & para-Xylene	1.5	31.1	26.2	<0.5	<0.5	<0.5	50	--	<0.5	3.3	--	1.2	--
ortho-Xylene	0.7	3.8	3.5	<0.5	<0.5	<0.5	13.5	--	<0.5	1.2	--	<0.5	--
1998	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-21**	**MP-22**	**MP-3**	
Benzene	<0.5	<0.5	--	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3000
Ethylbenzene	1.6	19	--	--	<0.5	<0.5	25.6	<0.5	<0.5	4.5	4.5	3	7000
Toluene	<0.5	1.2	--	--	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	3000
meta- & para-Xylene	2	20.2	--	--	<0.5	<0.5	64.9	<0.5	<0.5	7.4	7.5	4.3	--
ortho-Xylene	0.7	2.7	--	--	<0.5	<0.5	14.9	<0.5	<0.5	2.2	2.3	1.4	--
1999	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-21**	**MP-22**	**MP-3**	
Benzene	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3000
Ethylbenzene	0.9	19.8	15.1	<0.5	<0.5	<0.5	16.8	<0.5	<0.5	3.1	1.2	2.2	7000
Toluene	<0.5	1.1	1.1	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	3000
meta- & para-Xylene	0.8	21.2	15.9	<0.5	<0.5	<0.5	35.8	<0.5	<0.5	3.7	1.8	2.7	--
ortho-Xylene	<0.5	4	2.3	<0.5	<0.5	<0.5	9.6	<0.5	<0.5	1.3	0.5	0.9	--
2000	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-21**	**MP-22**	**MP-3**	
Benzene	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--	3000
Ethylbenzene	0.9	13	14.4	<0.5	<0.5	<0.5	1.5	<0.5	<0.5	5.9	0.4	--	7000
Toluene	<0.5	1.4	1.4	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	0.5	<0.5	--	3000
meta- & para-Xylene	1	15.8	12.7	<0.5	<0.5	<0.5	36.3	<0.5	<0.5	7.8	6.9	--	--
ortho-Xylene	<0.5	3.3	2.8	<0.5	<0.5	<0.5	13.9	<0.5	<0.5	3.3	2.6	--	--

Notes: all concentrations in µg/L

Table 8: Concentration of Volatile and Extractable Hydrocarbons (µg/L) in Water Samples Collected Annually at Rainy Hollow from 1996 to 2000

1996	MW-16	MW-17A	MW-17B	MW-18	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	MP-3	CSR AW
VPH	500	--	--	--	200	<100	*2800*	400	--	--	--	1000	1500
EPH (C10-18)	*6700*	1500	1700	<1000	<1000	<1000	*10,000*	<1000	<1000	*5900*	--	<1000	5000
EPH (C19-31)	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	1700	<1000	--	<1000	--
LEPH	--	--	--	--	--	--	--	--	<1000	*5900*	--	<1000	500
HEPH	--	--	--	--	--	--	--	--	1700	<1000	--	<1000	--
1997	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-2-1**	**MP-2-2**	**MP-3**	**CSR AW**
LH (C5-9)	600	3600	2800	<100	200	<100	1800	--	<100	300	--	300	--
VPH	300	*1600*	1300	<100	<100	<100	800	--	<100	100	--	200	1500
EPH (C10-18)	*7000*	2000	2000	<1000	1000	<1000	*13,000*	--	<1000	*10,000*	--	5000	5000
EPH (C19-31)	<1000	<1000	<1000	<1000	<1000	<1000	<1000	--	<1000	<1000	--	<1000	--
1998	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-2-1**	**MP-2-2**	**MP-3**	**CSR AW**
VH (C6-10)	800	1200	--	--	300	100	1400	300	<100	700	900	1200	15000
VPH (C6-10)	800	1200	--	--	300	100	1300	300	<100	700	800	1200	1500
EPH (C10-19)	*5200*	--	--	--	--	--	3100	1700	500	2800	3500	1800	5000
EPH C19-32	<1000	--	--	--	--	--	<1000	<1000	<1000	<1000	<1000	<1000	--
LEPH	*5200*	--	--	--	--	--	*3100*	*1700*	500	*2800*	*3500*	*1800*	500
HEPH	<1000	--	--	--	--	--	<1000	<1000	<1000	<1000	<1000	<1000	--
1999	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-2-1**	**MP-2-2**	**MP-3**	**CSR AW**
VH (C6-10)	1100	1800	1900	<100	<100	<100	2100	200	<100	600	400	600	15000
VPH (C6-10)	1100	*1700*	*1800*	<100	<100	<100	*2100*	200	<100	600	400	600	1500
EPH (C10-19)	*7400*	1600	1800	<300	400	<300	*5800*	3900	<300	3800	1400	1300	5000
EPH C19-32	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	--
2000	**MW-16**	**MW-17A**	**MW-17B**	**MW-18**	**MW-21A**	**MW-21B**	**WP-7**	**WP-13**	**MP-1**	**MP-2-1**	**MP-2-2**	**MP-3**	**CSR AW**
VH (C6-10)	4500	2000	2300	<100	200	<100	2400	200	<100	500	600	--	15000
VPH (C6-10)	*4500*	*1900*	*2200*	<100	200	<100	*2400*	200	<100	500	600	--	1500
EPH (C10-19)	*23,200*	1800	1400	<300	<300	300	3800	*6700*	<300	1000	1100	--	5000
EPH C19-32	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	--	--

Notes: VPH = Volatile Petroleum Hydrocarbons; VH = Volatile Hydrocarbons (C6-10); LH = Light Hydrocarbons (C6-9); n/a = no data available; Shaded area exceed the BC CSR standard for freshwater aquatic life (AW).

Table 9: Concentrations of Polycyclic Aromatic Hydrocarbons in Groundwater Samples Collected from Rainy Hollow in 1996 and 1998

Sample ID	1996			1998							CSR AW
	MP-1	MP-2A	MP-3	MW-16	WP7	WP13	MP-1	MP-2A	MP-2B	MP-3	
Acenaphthene	<0.5	<0.5	<0.5	2.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	60
Acenaphthylene	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
Acridine	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.5
Anthracene	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1
Benzo(a)anthracene	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.01	0.01	0.01	1
Benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.1
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--
Benzo(g,h,i)perylene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--
Chrysene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--
Dibenz(a,h)anthracene	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	--
Fluoranthene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2
Fluorene	<0.1	<0.1	<0.1	2.4	0.7	<0.1	<0.1	0.3	0.3	0.3	120
Indeno(1,2,3-c,d)pyrene	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	--
Naphthalene	<0.2	1.1	1.5	0.01	7.5	0.4	<0.2	2.5	4.2	3.1	10
Phenanthrene	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	3
Pyrene	0.02	<0.02	<0.02	0.04	0.03	<0.02	<0.02	0.02	<0.02	<0.02	0.2

Notes: All concentrations are in microgram per litre (µg/L)

Table 10: Concentration of Dissolved Metals in Groundwater Samples Collected at Rainy Hollow in 1997

Sample ID	Monitoring Wells								Mini-Piezometers			BC CSR AW
	MW-16	MW-17A	MW-18	MW-19A	MW-21A	MW-21B	WP-7	WP-13	MP-1	MP-2	MP-3	
Hardness mg/L CaCO3	172	241	232	109	263	282	222	293	188	264	279	--
Dissolved Metals												
Aluminum	<50	50	150	60	<50	<50	140	490	<50	<50	<50	--
Antimony	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	200
Arsenic	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	50
Barium	120	130	40	50	70	70	90	90	40	90	70	10,000
Beryllium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	53
Cadmium	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	0.1-0.6*
Calcium	61,400	89,600	81,800	38,200	94,200	100,000	80,800	103,000	67,400	96,400	104,000	--
Chromium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	9
Copper	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	20 – 90*
Iron	32,200	31,300	210	7,740	390	30	25,700	2,620	<30	<30	<30	--
Lead	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	40 - 300
Magnesium	4,410	4,300	6,800	3,300	6,800	7,750	4,830	8,700	4,800	5,660	5,100	--
Manganese	4,070	2,370	7	691	1,610	2,210	2,410	1,040	13	1,720	1,750	--
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	250-1500*
Selenium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Silver	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.5-100*
Thallium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3
Uranium	<1	<1	2	<1	2	2	<1	2	1	<1	<1	3000
Zinc	14	5	30	7	<5	<5	29	22	21	7,190	2,910	75-2400*

Notes:

1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated
3. * = Standard varies with hardness as mg/L $CaCO_3$

Table 11: Concentration of Dissolved Metals in Groundwater Samples Collected at Rainy Hollow in 1998

Sample #	Monitoring Wells						Mini-Piezometers				BC CSR AW
	MW-17A	MW-19A	MW-21A	MW- 21B	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	MP-3	
pH (Field)	6.35	6.30	7.14	7.16	6.88	7.16	7.33	7.31	7.31	7.19	
Conductivity (µS/cm)	413	177	456	480	438	457	370	425	425	420	
Hardness mg/L CaCO3	229	96	286	298	238	285	221	260	256	265	
Dissolved Metals											
Aluminum	<50	170	60	<50	60	<50	<50	110	70	<50	--
Antimony	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	200
Arsenic	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	50
Barium	120	40	60	70	80	70	50	90	90	70	10,000
Beryllium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	53
Boron	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	50,000
Cadmium	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	0.1-0.6*
Calcium	85,100	33,600	103,000	107,000	88,000	101,000	80,000	95,900	94,600	98,700	--
Chromium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	9
Copper	<10	<10	<10	<10	<10	<10	<10	<10	<10	50	20 – 90*
Iron	29,700	7,790	830	60	18,300	4,090	90	8,640	8,400	8,700	--
Lead	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	40 - 300
Magnesium	4,100	3,000	6,800	7,400	4,600	7,700	5,200	4,900	4,800	4,500	--
Manganese	2,400	575	1,760	2,530	1,900	977	10	2,280	2,250	1,800	--
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	250-1500*
Selenium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Silver	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.5-100*
Thallium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3
Uranium	0.2	0.1	1.3	1.9	0.2	1.2	1.3	0.1	<0.1	<0.1	3000
Zinc	<5	<5	<5	<5	5	<5	<5	3,590	5,820	1,390	75-2400*

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated
3. Standard varies with hardness as mg/L $CaCO_3$
4. A field duplicate sample MP-2-1 and MP-2-2 was collected at MP-2

Table 12: Concentration of Dissolved Metals (µg/L) in Groundwater Samples Collected from Rainy Hollow in 1999

Sample ID	Monitoring Wells					Mini-Piezometer				BC CSR AW
	MW-17A	MW-18	MW-21A	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	MP-3	
pH	6.24	7.05	6.47	6.20	6.20	6.70	6.55	6.55	6.45	
Conductivity (µS/cm)	593	665	672	575	631	554	607	607	582	
Hardness mg/L CaCO3	223	255	285	223	269	236	254	256	237	
Dissolved Metals										
Aluminum	<5	40	10	33	73	13	12	10	15	--
Antimony	<200	<200	<200	<200	<200	<200	<200	<200	<200	200
Arsenic	<200	<200	<200	<200	<200	<200	<200	<200	<200	50
Barium	110	50	60	70	70	50	60	60	60	10,000
Beryllium	<5	<5	<5	<5	<5	<5	<5	<5	<5	53
Boron	<100	<100	<100	<100	<100	<100	<100	<100	<100	50,000
Cadmium	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.1-0.6*
Calcium	83,000	89,000	103,000	82,000	96,400	85,600	93,600	94,700	88,500	--
Chromium	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	<10	9
Copper	<10	<10	<10	<10	<10	<10	<10	<10	<10	20 – 90*
Iron	26,800	40	640	15,400	4,870	<30	8,030	8,560	5,720	--
Lead	<1	<1	<2	<1	<1	<1	7	5	3	40 - 300
Magnesium	3,900	7,400	6,800	4,400	6,900	5,400	4,800	4,800	4,000	--
Manganese	2,100	<5	1,500	1,590	888	<5	1,900	1910	1,310	--
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel	<50	<50	<50	<50	<50	<50	<50	<50	<50	250-1500*
Selenium	<1	<1	<2	<1	<1	<1	<1	<1	<1	10
Silver	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5-100*
Sodium	3,000	18,000	11,000	3,000	5,000	8,000	3,000	3,000	2,000	--
Thallium	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	3
Uranium	0.24	1.86	1.2	0.11	0.76	1.28	0.07	0.07	0.08	3000
Zinc	<5	<5	<5	<5	<5	<5	3,120	2,620	1,460	75-2400*

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated
3. Standard varies with hardness as mg/L $CaCO_3$
4. A field duplicate sample MP-2-1 and MP-2-2 was collected at MP-2

Table 13: Concentration of Dissolved Metals (µg/L) in Groundwater Samples Collected from Rainy Hollow in 2000

Sample ID	Monitoring Wells					Mini-Piezometer			BC CSR AW
	MW-17A	MW-18	MW-21A	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	
pH	6.96	7.56	7.22	6.93	7.1	7.46	6.95	6.95	
Conductivity (µS/cm)	488	545	568	489	572	490	507	507	
Hardness mg/L CaCO3	219	249	281	228	281	246	237	247	
Dissolved Metals									
Aluminum	17	80	25	63	102	499	21	<5	--
Antimony	<200	<200	<200	<200	<200	<200	<200	<200	200
Arsenic	<200	<200	<200	<200	<200	<200	<200	<200	50
Barium	100	40	50	80	80	60	60	60	10,000
Beryllium	<5	<5	<5	<5	<5	<5	<5	<5	53
Boron	<100	<100	<100	<100	<100	<100	<100	<100	50,000
Cadmium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.5	0.1-0.6*
Calcium	81,500	88,500	101,000	83,700	102,000	88,300	87,500	91,300	--
Chromium	<10	<10	<10	<10	<10	20	<10	<10	10
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	9
Copper	<10	<10	<10	<10	<10	<10	<10	<10	20 – 90*
Iron	24,300	40	980	18,200	3,330	920	9010	7850	--
Lead	<1	<1	<1	<1	<1	2	6	4	40 - 300
Magnesium	3700	6800	6700	4600	7900	6000	4400	4600	--
Manganese	1900	7	730	1680	876	29	1560	1620	--
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel	<50	<50	<50	<50	<50	<50	<50	<50	250-1500*
Selenium	<1	<1	<1	<1	<1	<1	<1	<1	10
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5-100*
Sodium	3,000	17,000	12,000	3,000	7,000	10,000	3000	3000	--
Thallium	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	3
Uranium	0.24	1.75	0.8	0.13	1.27	1.52	0.02	0.01	3000
Zinc	<5	<5	<5	<5	<5	53	7220	10600	75-2400*

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated
3. Standard varies with hardness as mg/L $CaCO_3$
4. A field duplicate sample MP-2-1 and MP-2-2 was collected at MP-2

Table 14: Concentration of Total Metals (µg/L) in Groundwater Samples Collected at Rainy Hollow in 1998

Sample #	Monitoring Wells						Mini-Piezometers				BC CSR AW
	MW-17A	MW-19A	MW-21A	MW- 21B	WP-7	WP-13	MP-1	MP-2-1	MP-2-2	MP-3	
pH (Field)	6.35	6.30	7.14	7.16	6.88	7.16	7.33	7.31	7.31	7.19	
Conductivity (µS/cm)	413	177	456	480	438	457	370	425	425	420	
Hardness mg/L CaCO3	229	96	286	298	238	285	221	260	256	265	
Dissolved Metals											
Aluminum	15,600	69,300	11,700	1,880	19,400	7,300	6,380	46,500	58,600	3,920	--
Antimony	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	200
Arsenic	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	50
Barium	340	900	150	80	210	130	100	380	420	90	10,000
Beryllium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	53
Boron	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	50,000
Cadmium	2	20	<2	3	<2	<2	<2	6	6	<2	0.1-0.6*
Calcium	91,000	65,500	108,000	106,000	93,600	102,000	87,100	181,000	186,000	106,000	--
Chromium	30	210	30	<10	40	20	120	180	250	<10	10
Cobalt	20	80	20	<10	10	<10	<10	40	50	<10	9
Copper	120	590	60	20	70	40	30	270	290	20	20 – 90*
Iron	53,200	138,000	18,500	2,160	38,000	12,500	11,000	86,700	97,500	13,400	--
Lead	40	100	10	100	20	10	<10	720	590	30	40 - 300
Magnesium	12	54	13	8	13	11	9	42	47	7	--
Manganese	2,660	2,180	1,550	2,470	2,110	1,060	223	3,560	3,670	1,810	--
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel	<50	190	<50	<50	<50	<50	90	100	130	<50	250-1500*
Selenium	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10
Silver	<1	2	<1	<1	<1	<1	<1	1	1	<1	0.5-100*
Thallium	<1	3	<1	<1	<1	<1	<1	<1	<1	<1	3
Uranium	0.7	3.8	2.0	2.0	1.7	1.8	1.7	4.4	4.0	0.4	3000
Zinc	171	653	96	13	129	55	36	53,100	40,200	5,590	75-2400*

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated
3. Standard varies with hardness as mg/L $CaCO_3$
4. A field duplicate sample MP-2-1 and MP-2-2 was collected at MP-2

Table 15: Concentration of Total Metals in Surface Water Samples Collected at Annually at Rainy Hollow from 1998 to 2000

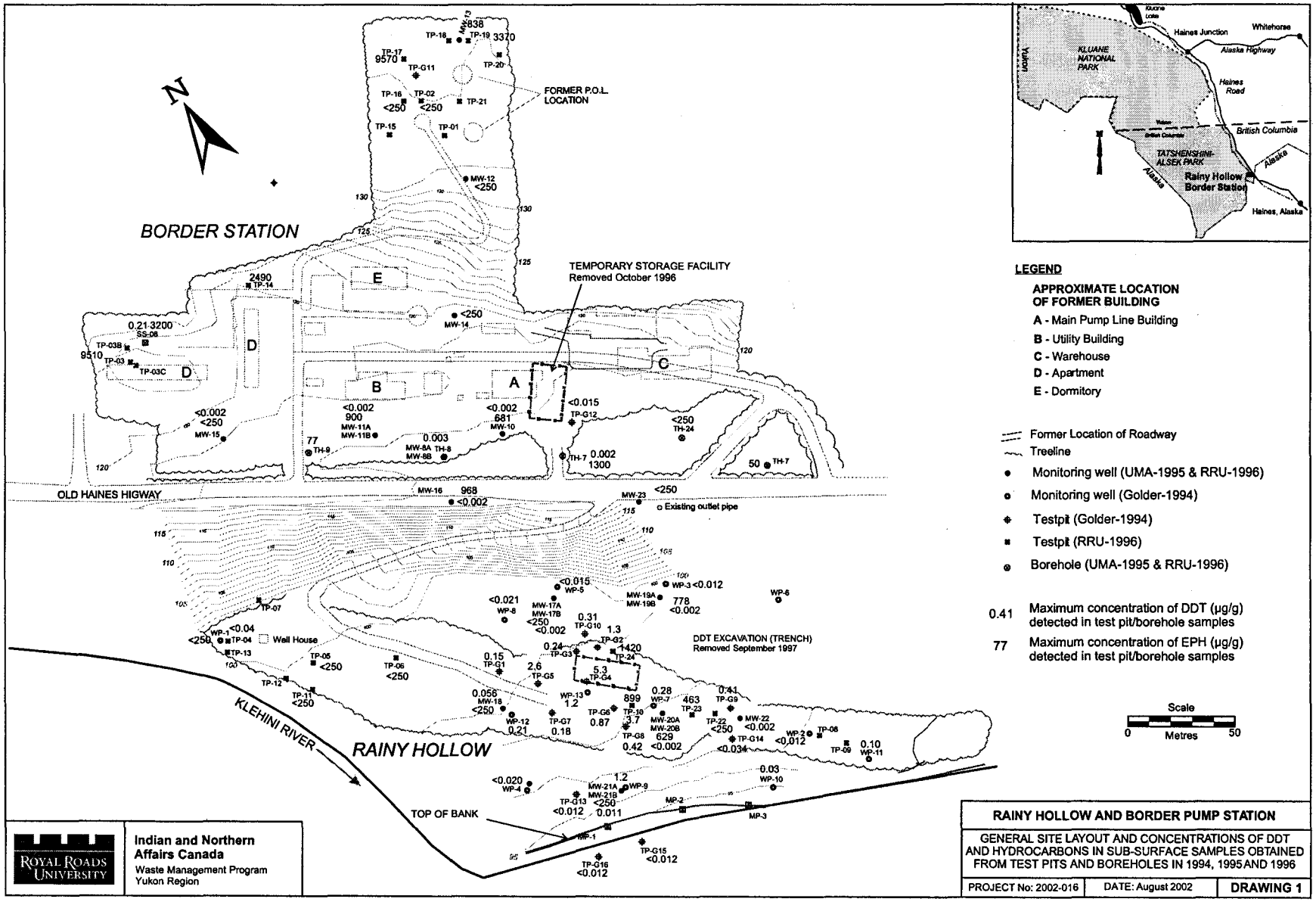
Sample ID	1,998			1999			2000 Metals			BC CSR AW
	KLE-1	KLE-2	KLE-4	KLE-1	KLE-2	KLE-4	KLE-1	KLE-2	KLE-4	
Hardness mg/L $CaCO_3$	24	38	37	60.7	185	155	17.8	83.7	45	
Total Metals										
Aluminum T-Al	2,870	9,890	10,800	5640	23700	18300	69	485	550	--
Antimony T-Sb	<200	<200	<200	0.4	0.5	0.5	<200	<200	<200	200
Arsenic T-As	<200	<200	<200	1.9	5.8	4.9	<200	<200	<200	50
Barium T-Ba	20	60	70	40	130	110	0.04	0.13	0.11	10,000
Beryllium T-Be	<5	<5	<5	<1	<1	<1	<10	20	<10	53
Boron T-B	<1	<1	<1	<100	<100	100	<5	<5	<5	50,000
Cadmium T-Cd	<2	<2	<2	0.13	0.3	0.26	<0.2	<0.2	<0.2	0.1-0.6*
Calcium T-Ca	11,800	23,900	22,400	17400	46700	39700	6,330	29,000	15,200	--
Chromium T-Cr	<10	20	30	12.4	65.6	51	<10	<10	<10	10
Cobalt T-Co	<10	<10	<10	3.6	16.1	12.9	<10	<10	<10	9
Copper T-Cu	<10	20	20	10	40.5	28	<10	<10	<10	20 – 90*
Iron T-Fe	3,380	12,000	13,700	7460	32700	26000	70	680	570	--
Lead T-Pb	<10	<10	<10	1.69	5.25	5.18	<1	<1	<1	40 - 300
Magnesium T-Mg	2100	6700	7500	4200	16700	13600	500	2800	1700	--
Manganese T-Mn	72	245	264	150	626	504	<5	44	20	--
Mercury T-Hg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Molybdenum T-Mo	<30	<30	<30	<30	<30	<30	<30	<30	<30	10,000
Nickel T-Ni	<50	<50	<50	6	29	23	<50	<50	<50	250-1500*
Selenium T-Se	<10	<10	<10	<1	<1	<1	<1	<1	<1	10
Silver T-Ag	<1	<1	<1	0.04	0.14	0.14	<0.1	<0.1	<0.1	0.5-100*
Sodium	--	--	--	2000	3000	2000	<2000	3000	<2000	--
Thallium T-Tl	<1	<1	<1	0.09	0.11	0.08	<0.1	<0.1	<0.1	3
Uranium T-U	0.9	1.0	0.9	0.8	1.1	1	0.87	0.87	0.68	3000
Zinc T-Zn	15	36	42	24	86	69	<5	<5	<5	75-2400*

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated

Table 16: Comparison of Total Metal to Dissolved Metal Concentrations in Surface water samples Collected near Rainy Hollow in 1998

Sample ID	KLE-1		KLE-2		KLE-4	
	Total Metals	Dissolved Metals	Total Metals	Dissolved Metals	Total Metals	Dissolved Metals
Aluminum	2,870	120	9,890	520	10,800	220
Antimony	<200	<200	<200	<200	<200	<200
Arsenic	<200	<200	<200	<200	<200	<200
Barium	20	<10	60	<10	70	<10
Beryllium	<5	<5	<5	<5	<5	<5
Cadmium	<2	<2	<2	<2	<2	<2
Calcium	11,800	8,570	23,900	13,200	22,400	12,700
Chromium	<10	<10	20	<10	30	<10
Cobalt	<10	<10	<10	<10	<10	<10
Copper	<10	<10	20	<10	20	<10
Iron	3,380	110	12,000	360	13,700	210
Lead	<10	<10	<10	<10	<10	<10
Magnesium	2100	700	6700	1,400	7500	1,200
Manganese	72	9	245	21	264	14
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	<30	<30	<30	<30	<30	<30
Nickel	<50	<50	<50	<50	<50	<50
Selenium	<10	<10	<10	<10	<10	<10
Silver	<1	<1	<1	<1	<1	<1
Thallium	<1	<1	<1	<1	<1	<1
Uranium	0.9	0.6	1.0	0.4	0.9	0.4
Zinc	15	10	36	<5	42	<5

Notes: 1. All concentrations are expressed in micrograms per litre (µg/L) unless otherwise stated
2. < = less than the detection limit indicated



Indian and Northern Affairs Canada
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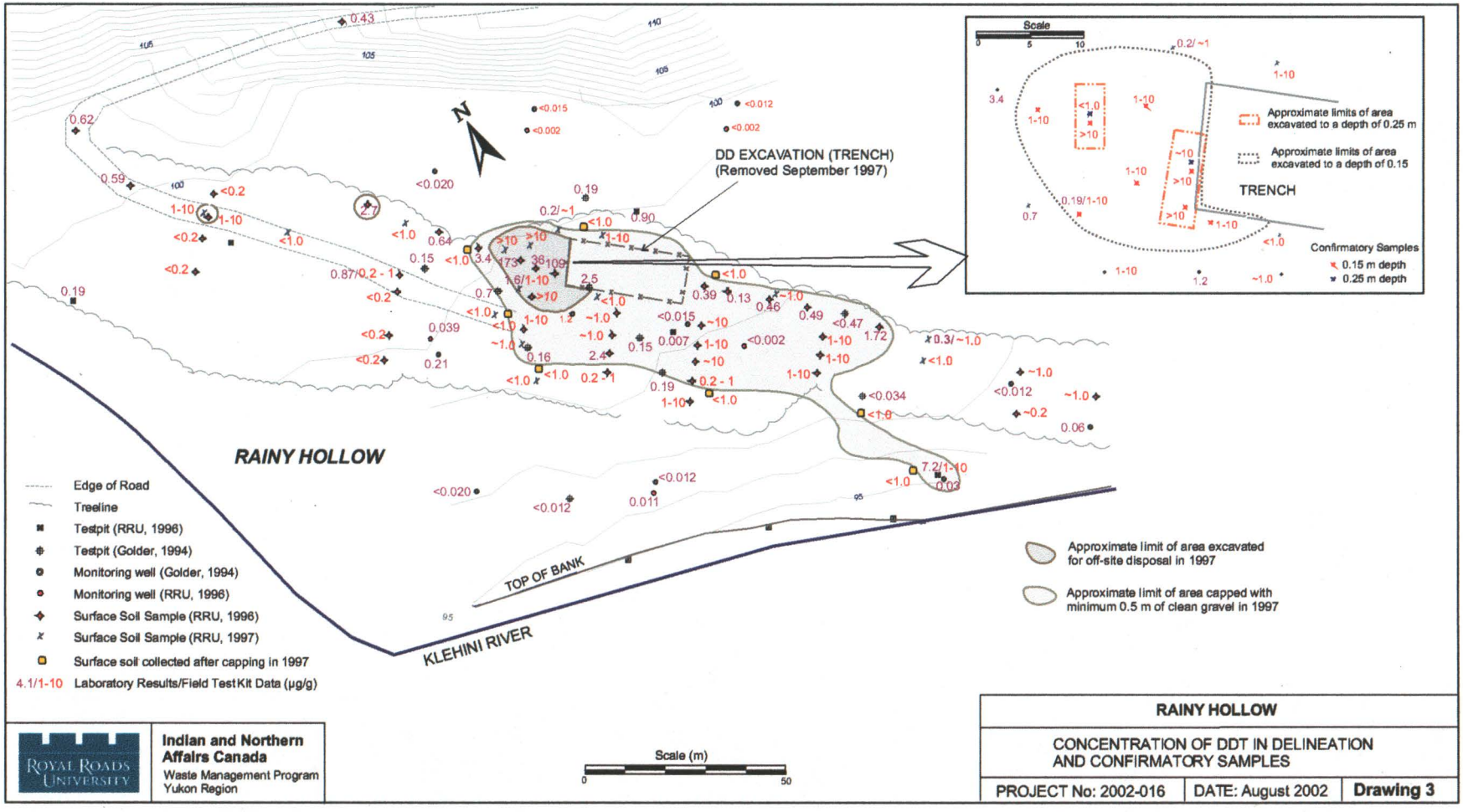
Yukon Region

ROYAL ROADS UNIVERSITY

RAINY HOLLOW AND BORDER PUMP STATION

GENERAL SITE LAYOUT AND CONCENTRATIONS OF DDT AND HYDROCARBONS IN SUB-SURFACE SAMPLES OBTAINED FROM TEST PITS AND BOREHOLES IN 1994, 1995 AND 1996

PROJECT No: 2002-016	DATE: August 2002	DRAWING 1



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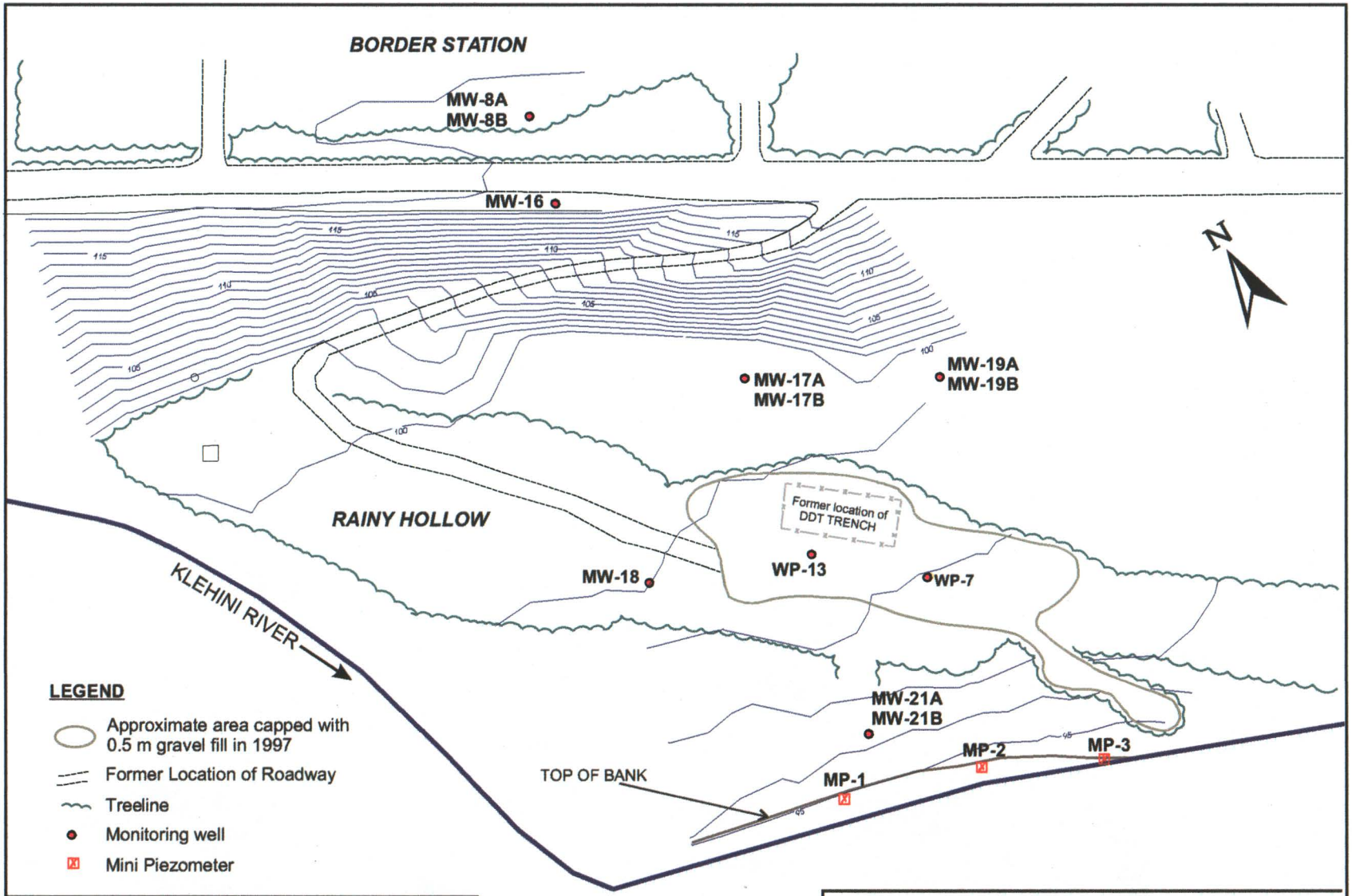
Yukon Region

RAINY HOLLOW

CONCENTRATION OF DDT IN DELINEATION AND CONFIRMATORY SAMPLES

PROJECT No: 2002-016	DATE: August 2002	**Drawing 3**



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RAINY HOLLOW AND BORDER PUMP STATION

LOCATIONS OF MONITORING WELLS AND MINI-PIEZOMETERS

PROJECT No: 2002-016	DATE: August 2002	**Drawing 5**