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WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

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INITIAL ENVIRONMENTAL EVALUATION ADDENDUM

(3) of 3

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FOREWORD

This report comprises the Addendum to the Initial Environmental Evaluation report that consists of 4 Volumes filed with the Regional Environmental Review Committee in support of an application to develop the Carmacks Copper Project. From additional geotechnical information collected in February 1995, and response to the initial feasibility study, the proponent has made changes to the mine plan. This volume presents these changes and the resulting changes to the waste and water management plan, impact assessment, monitoring program, and reclamation plan. An additional section has been included that specifically provides a response to government comments.

Volume I of the series is entitled "Biophysical Assessment of the Williams Creek Mine Site" and describes in detail the existing baseline conditions for both the abiotic and biotic components of the environment. The information in this Volume was prepared by **P.A. Harder and Associates Ltd.**

Volume II, of the series "Community Profiles and Socioeconomic Impact Assessment", completed by **Hallam Knight Piésold Ltd.** provides a detailed description of the communities of Whitehorse and Carmacks and the projected effects of the Carmacks Copper mine development on these communities.

Volume III, "Archaeological Impact Assessment", which provides a description of the heritage resource investigations of the Williams Creek area and an analysis of the potential impacts of the proposed development was completed by **Antiquus Archaeological Consultants Ltd.** in 1993.

Volume IV, "Environmental Impact Assessment", completed by **Hallam Knight Piesold Ltd.** presents a summary of the project design, the waste and water management plans, a summary of the environmental baseline, an environmental impact assessment, the proposed environmental monitoring program, and the conceptual reclamation plan.

WESTERN COPPER HOLDINGS LTD.

CARMACKS COPPER PROJECT

INITIAL ENVIRONMENTAL EVALUATION (IEE) ADDENDUM

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

SECTION 1.0 - PROJECT DESCRIPTION

1.1 PROJECT LOCATION

Western Copper Holdings Limited (WCHL) is proposing to develop the Carmacks Copper property located 38 km northwest of the village of Carmacks, Yukon. The property has diluted mineable ore reserves of approximately 15.4 million tonnes grading 1.01% at a 0.35% copper cutoff. The orebody is located in the upper reaches of Williams Creek approximately 9 km upstream from the Yukon River confluence. Williams Creek is a small tributary originating in the Dawson Range and draining northeast into the Yukon River downstream of Carmacks. The creek has a total drainage area of approximately 88 km^2 with a mainstem length of approximately 15.5 km. The site is accessed from Carmacks via the Mt. Freegold Road and a 13 km seasonal access road at Mile Post 32 on the Mt. Freegold Road.

The following description of the regional and local geological setting, ore reserve estimates, mine and process facility design and ancillary facilities, has been derived from the draft Feasibility Study (Kilborn Engineering Ltd., 1994).

1.1.1 Regional Geology

The Carmacks region lies within the Intermontane Belt, which has been subdivided into the Yukon Cataclastic Terrane, Yukon Crystalline Terrane and Whitehorse Trough subdivisions. Units of the Whitehorse Trough subdivision lie east of the Hoochekoo Fault and east of the Carmacks Copper property. This subdivision comprises an Upper Triassic intermediate to basic volcanic (Povoas) formation capped by carbonate reefs (Lewes River Group) and Lower Jurassic greywacke, shale and conglomerate derived from the underlying Upper Triassic Granitic rock (Laberge Group).

Yukon Cataclastic Terrane subdivision includes hornblende-biotite-chlorite gneiss with interfoliated biotite granite gneiss, Permian Selwyn Gneiss, intruded by Upper Triassic Klotassin Suite-Minto Pluton and Granite Mountain Batholith. Weakly foliated, mesocratic, biotite-hornblende, Granite

Mountain granodiorite contains screens or pendants of strongly foliated feldspar-biotite-hornblende-quartz gneiss which host the Carmacks Copper deposit.

The Yukon Crystalline Terrane subdivision, which is extensively exposed southwest of the Carmacks Copper deposit, includes quartz-mica schist with quartzite, marble and amphibolite, Early Palaeozoic age and possibly equivalent to Pelly Gneiss, intruded by Cretaceous and Jurassic granites and syenites.

1.1.2 Property Geology

The Carmacks Copper Project lies within the Yukon Cataclastic Terrane. The deposit is hosted by feldspathic-mafic gneisses that form a roof pendant within upper Triassic hornblende-biotite-granodiorite of the Granite Mountain Batholith. The deposit comprises the No.1 Zone, which is one of 14 defined zones within the vicinity of the property. The No. 1 Zone extends over a 700 m strike length and at least 450 m down dip and is open at depth.

Copper-gold mineralization at Carmacks Copper is hosted by feldspathic-biotite-hornblende-quartz gneisses, all of which are silica undersaturated and mafic rich. The deposit is differentiated into southern and northern halves. The northern half is more regular in thickness, dip angle, width and down dip characteristics. The southern half splays into irregular intercalations, terminating against sub-parallel faults down dip. The north and south halves are partially offset by a cross-cutting fault.

The majority of the copper (approximately 85%) in the No.1 Zone is in the form of secondary mineralization such as malachite, azurite tenorite and cuprite with very minor additional secondary copper minerals. Other secondary minerals include limonite, goethite, specular hematite and gypsum. Primary copper mineralization is restricted to bornite and chalcopyrite. Other primary minerals include magnetite, gold, molybdenite, native bismuth, bismuthinite, arsenopyrite, pyrite, pyrrhotite and carbonate.

The upper 250 m of the No.1 Zone is oxidized. Within oxidized areas, pyrite is virtually absent and pyrrhotite is entirely absent. Weathering has resulted in 1% to 3% pore space, and the rock is therefore permeable. Secondary copper and iron minerals line and in-fill the vacated pore spaces, forming irregular and coliform masses. Primary sulphide minerals and magnetite are disseminated and form narrow massive bands or heavy disseminations within bands. Non-copper sulphides are uncommon. Gypsum occurs in microveinlets and carbonate occurs in irregular patches or microveinlets. Gold occurs as native grains rarely greater than 5 microns in size, and most commonly occur in cavities with limonite or in limonite adjacent to sulphides (also in malachite, plagioclase and chlorite).

Secondary copper mineralization does not appear to be preferential to any particular rock type. In the northern half of the No.1 Zone, copper mineralization forms high and low grade zones both along strike and down dip which transcends lithologic boundaries. The higher grades tend to form the footwall zone, while lower grades form the hanging wall zone. Primary mineralization below the oxidized layer comprises chalcopyrite, bornite, molybdenite, magnetite, pyrite and pyrrhotite. Primary copper mineralization appears to be zoned from bornite and then to chalcopyrite and finally to pyrite and pyrrhotite in a southerly direction. Narrow veinlets of anhydride were found in the deepest drill hole.

1.2 RESERVES

Thirty foot composites were compiled with the use of PC-EXPLOR software for all diamond drill holes and trenches intersecting the No.1 Zone. Both multivariate and univariate statistical tests were applied to the database. Results indicate that the coefficient of variation for total copper and oxide copper is less than 0.8. Gold has a higher coefficient of correlation with total copper than copper oxide.

Diluted mineable reserves total 15.4 million tonnes with an average grade of 0.93% copper, with a cut-off grade of 0.35% copper. On the basis of current reserves, the mine life is expected to be 8.66 years. The open pit will have a long narrow configuration, with a length of approximately 732 m, a maximum width of 183 m and a maximum depth of 274 m.

1.3 ENGINEERING DESIGN

In order to optimize capital costs, mining will initially focus on a starter-pit of higher grade, lower strip ratio material. The pit will be expanded with successive push-backs which will allow optimization of the ore and waste production.

Fact sheet on mine plan:

Total oxide ore reserves	15.5 x 10^6 tons
Ore production	1.764 x 10^6 tonnes per year
Waste:ore strip ratio	4.25:1
Acid consumption	25 kg/tonne ore
Operating pH	1.5
Leachate application rate	0.0244 $m^3/hr/m^2$
	1,137 m^3/hour
Active area under leach	47,000 m^2
Pregnant solution recovery from heap	1,117 m^3/hour
Copper production rate	38 tonnes/day
120 day leach cycle	74.7% recovery
240 day leach cycle	80.0% recovery

Design assumptions:

Area of leach pad (ultimate)	31.0 ha
Maximum height of leach pad	150 m
Height of leach pad lifts	8 m
In-heap storage requirements (24 hr-1 in 10 yr storm event + min 24 hr operating volume + 95th percentile of in-heap stored water volume during leaching operation)	80,000 m

Events pond storage requirements (Difference between 24 hr-1 in 100 yr storm event & provision for millsite solutions + complete active leach area draindown + emergency freeboard storage)	75,000 m^3
Area of crushing plant	25 m x 150 m
Area of plant buildings	50 x 50 m
Unit weight ore (crushed)	1.6 tonnes/m^3
Unit weight waste (broken)	1.6 tonnes/m^3
Maximum grade of haul roads	8%
Porosity of crushed ore	20%

1.4 MINE OPERATION

Open pit mining will require some preproduction development. In order to obtain sufficient ore for the first year of production a total of 617,000 tonnes of waste rock will be removed and stockpiled. Some of this material will be required for the construction of storage areas, plant site and road building. Approximately 0.50 m of top soil and till covering the undisturbed areas of the property where the open pit, waste rock dump, leach pad, and water storage pond are located will be removed in the preproduction stage and will be stockpiled for reclamation.

Open pit mining will consist of a single pit designed to mine No. 1 Zone. The pit will be mined in 30 foot (9.14 m) benches at an average strip ratio of 4.25 tonnes of waste per tonne of ore. The pit will be mined initially at a strip ratio of 1.96 increasing to 5.29 and falling back to 3.75 in the last year of operation.

1.4.1 Drilling

The majority of the waste rock and all of the ore will require drilling and blasting. The near surface waste and the topsoil not requiring drilling and blasting will be ripped with a dozer for removal. Drill patterns will be established on benches prepared by a bulldozer equipped with a ripper tooth. The diesel powered rotary drill will drill holes 35 feet (10.7 m) deep of which 5 feet (1.5 m) is for subgrade, resulting in bench heights of 30 feet (9.14 m).

1.4.2 Blasting

The explosive used on site will be almost exclusively ammonium nitrate-fuel oil (ANFO). Explosives consumption is projected to average 0.20 kg/t. Primacord, nonelectric detonator and boosters will be used for detonation. Blast holes will be charged with ANFO by means of a truck mounted ANFO mixing/dispensing unit.

Approximately 30% of the holes are anticipated to be wet. Eighty-three percent of these holes will be lined with plastic liners that will be used to keep the explosive dry, while the remaining 17% will be loaded with a water-resistant slurry, (5% of the total). The blasts will be initiated by an electric detonator, primacord, nonelectric caps in the blast holes and boosters. Where practical, the ore and waste will be blasted separately in order to reduce the amount of ore loss and waste dilution. Blast initiation will take place along strike as much as possible to assist in minimizing dilution. It is anticipated that the ore and waste will be well fragmented. If not, the drill pattern will be tightened up until a manageable distribution of rock sizes is attained; the objective will be to provide a minus 36 inch product to the crusher.

1.4.3 Loading and Hauling

The equipment unit selected for loading will be two 14.0 yd^3 (10.7 m^3) front end loaders. There will be a third loader of equivalent size on the property for a period when the required waste stripping is high. One loader will spend some time at the crusher feeding from the stockpile. The loader will provide some clean-up of spill rock in the loading areas but will be assisted by a rubber-tired dozer that will be available for areas beyond the reach of the loader. In the event that the pit loader breaks down, the front end loader that feeds the crusher from the stockpile will be available as a back-up unit.

The open pit haulage equipment will be a fleet of 95 ton (86 tonne) capacity, off-highway trucks. The trucks will be mechanical drive units and will be well suited to the haul profiles of the mine. The trucks also match up well to the loading units as they are filled with four passes. These units will be used to haul ore, waste and overburden.

1.4.4 Crushing and Conveying

Surge capacity for variations in the mine production schedule is provided by a coarse ore stockpile located prior to the crusher. The design capacity of the crushing plant will be 551 tonnes per hour resulting in a required operating availability of 67%.

Mined ore with a maximum lump size of 900 mm will be delivered to the coarse ore stockpile by truck. The ore will be reclaimed from the stockpile and fed to the primary crusher feed hopper using a front end loader. Ore will be drawn from the hopper to the primary jaw crusher by a vibrating grizzly feeder with a slot opening of 152 mm. The grizzly oversized material will be crushed to a nominal 178 mm in a 1,067 mm x 1,220 mm jaw crusher operating with a discharge setting of 178 mm. The grizzly undersized material and the crusher product will be combined on the primary crushing product conveyor which will advance to the screen feed conveyor. A single 2,440 mm x 7,315 mm triple deck screen will close both the secondary and tertiary crushers. The 76 mm top deck screen oversize will provide the feed to the secondary 1,950 mm standard cone crusher. The secondary crusher is equipped with a 300 kW motor and will produce a nominal 52 mm product. The second and third decks of the screen will be combined forming the feed to the tertiary 1,560 mm shorthead cone crusher. The tertiary cone crusher is equipped with a 187 kW motor and will produce a nominal 19 mm product. The feed to the triple deck screen is composed of the discharges of the primary, secondary and tertiary screens. The 100 percent passing 19 mm screen product sized material will be transferred to the pad loading conveyors in the heap leach pad area.

The pad loading conveyor system will begin with a series of high powered portable conveyors which will transport the ore up the ramp to the operating elevation of the pad. The ramp conveyors are followed by a series of standard portable conveyors which will transport the ore to the section of the pad being loaded. A high lift conveyor will transfer the ore to the conveyor stacker feed conveyor which in turn transfers the ore to the radial stacker.

1.5 HEAP LEACH PAD OPERATION

1.5.1 Leach Pad Location

Preliminary geotechnical investigations were carried out by Knight Piésold Ltd. (1993) at four separate sites (Volume 4, Section 2) which were originally selected as potential locations of the leach pad. Results of the investigations indicated that some degree of thaw settlement and loss of mechanical strength are anticipated for soils found at all four sites. As none of these sites were considered adequate, further investigations were conducted in February/March 1995. This survey resulted in the selection of the leach pad location identified in Figure 1.1. Further details on the site investigation program are presented in the Knight Piesold Ltd. report titled "Western Copper Holdings Ltd., Carmacks Copper Project, Report on Preliminary Design" (May 1995).

1.5.2 Design and Operation

The proposed leach pad site was chosen for its proximity to the open pit and to minimize impact on surface drainage courses. The site is generally characterized having a moderate south facing terrain with discontinuous permafrost. The storage capacity for the leach pad is 9.6 million m^3 or approximately 16.3 million tonnes of ore. The pad sizing slightly exceeds the diluted ore reserves of 14.1 million tonnes by approximately 15 %.

The leach pad has been designed as a valley heap with a retaining embankment. The total area of the heap leach pad will be 310,000 m^2. The ore will be placed on the pad in 8 metre lifts and will be irrigated by a leachate solution of weak sulphuric acid combined with 20% raffinate from the solvent extraction circuit at an application rate of approximately 0.0244 $m^3/hr/m^2$. The nominal net flow rate for solution addition will be 1137 m^3/hr giving an active area under leach of 47,000 m^2. The nominal flow rate for solution removal will be 1,117 m^3/hr.

The heap leach facility will comprise an area of 310,000 m^2 divided into 2 cells. The location of the leach pad relative to the overall project site is shown on Figure 1.1. The general layout of the leach pad is shown on Figure 1.2. The leach facility will comprise a leach pad, a retaining embankment and an events pond.

The site will be stripped of topsoil and ash. A retaining embankment will be constructed to elevation 803 metres at the downstream toe of the heap for stability purposes and to provide storage capacity for in-heap pregnant solution. This retaining embankment will be a zoned earthfill/mine waste rock embankment. The upstream face of the embankment will be lined with a 5 metre wide low-permeability compacted till seal zone. Re-shaping of the pad surface will be kept to a minimum and be restricted to the grading of surface irregularities, enhancement of drainage paths and compensation for settlement. A perimeter berm 2 metres high will extend from the crest of the retaining structure around the perimeter of the leach pad.

The shaped surface will be ripped, disced, inspected to ensure that there are no large protruding stones, moisture conditioned if required, and compacted to the designated density. Details on the liner system are presented in Section 1.5.2.4. The soil liner comprising processed glacial till will be prepared on the inside face of the perimeter berms and the retaining embankment, and in the basin of the leach pad facility.

Beneath the composite liner, a network of foundation drains will serve as the main leak detection system. The drains will be excavated and constructed to minimize seepage forces on the engineered liner system and will serve as a process monitoring component of the engineered liner system (Figures 1.3 and 1.4).

The leachate collection piping system will comprise of a network of perforated 100 mm diameter corrugated polyethylene tubing (CPT) collection pipes spaced approximately 30 metres centre to centre along perforated main collection headers (450 mm diameter CPT). The leachate collection system will be covered by 500 mm of overliner which will comprise of -19 mm crushed leach ore.

The events pond comprises a prepared basin subgrade, construction of an embankment, and lining of the basin facility with a double geomembrane liner and leachate collection system. The events pond area shall be stripped of vegetation, topsoil and ash. The basin will be shaped and the subgrade will be prepared to a smooth surface, free of any protruding rocks, roots, etc. which could damage the liner. A confining embankment will be constructed from mine waste or suitable available on-site materials. The upstream face of the embankment will be lined with a compacted till seal zone. The engineered liner system for the events pond will comprise a 60 mil HDPE inner geomembrane and a 60 mil HDPE outer geomembrane with a geonet between the two geomembranes. The geonet will drain towards the low point along the embankment toe and into a leak detection and removal system. Typical sections and details are shown on Figure 1.5.

The design includes for a lined trench from the edge of the process plant site to the leach pad to fully contain the barren and leachate pipelines.

Surface runoff will be diverted from the roads and process plant site area into a sediment storage pond prior to release into the natural drainage course.

1.5.2.1 Solution Management

Pregnant solution storage will be contained behind the retaining embankment and will be pumped from three leachate collection sumps to the process plant site for processing. The pregnant solution storage area provides secure confinement of these solutions by using a composite engineered liner system with a leak detection system. A lined spillway and overflow channel connects the in-heap storage area to the events pond as shown on Figure 1.2.

The storage requirements have been determined and are tabulated below:

In Heap Storage Requirements	Volume (m^3)
•. 24 hr - 1 in 10 year Storm Event	12,000
•. Minimum 24 hour operating volume	28,000
•. 95th percentile of in-heap stored water volume during leaching operations	40,000
Total	80,000

Events Pond Storage Requirements	Volume (m^3)
•. Difference Between 24 hr - 1 in 100 year storm event and 24 hr 1 in 10 year storm event	5,000
•. Provision for millsite solutions	3,000
•. Complete active leach area draindown	57,000
•. Emergency Freeboard Storage	10,000
Total	75,000

1.5.2.2 In-Heap Storage

The in-heap storage for leachate has been calculated using the following data from metallurgical testing of the leaching process in column tests:

- Ore specific gravity 2.7
- Dry density of ore in heap 1.6 t/m^3

The saturated moisture content of the leach ore is calculated to be 25%. The residual moisture content of the ore was determined to be 16%. Therefore the storage capacity for leachate will be 0.144 m^3 of leachate/m^3 of ore.

The in-heap storage volume below the invert of the spillway is 556,000 m^3 which provides leachate storage capacity of 80,000 m^3. Provision for 1 metre of freeboard above the invert elevation of the spillway has been included in the storage capacity calculations. The in-heap storage capacity is shown on Figure 1.6.

1.5.2.3 Events Pond Storage

The events pond is designed to provide additional storage for a major storm event or a process breakdown resulting in complete draindown of the heap or both. The events pond will be directly linked to the leach pad by a lined spillway and overflow ditch. The events pond which is situated down slope from the heap leach pad as shown on Figure 1.2; has a storage capacity of 75,000 m^3 (Figure 1.7).

1.5.2.4 Liner System Design

The engineered liner system for the leach pad is a composite liner system utilizing a 60 mil High Density Polyethylene (HDPE) geomembrane, placed directly on a low hydraulic conductivity compacted soil liner. To be effective, the two layers must be in close contact so that any leakage through imperfections in the geomembrane are retarded through the soil liner as a limited point source. Without this contact, leakage through the geomembrane can spread and hence leak through a larger soil area, thus increasing the total leakage rate through the liner system.

The liner system for the in-heap storage area will be a 60 mil HDPE geomembrane in direct contact to a 500 mm thick soil liner. Beyond the limits of the in-heap storage area, the liner system is a 60 mil HDPE geomembrane in direct contact to a 300 mm thick soil liner.

The foundation drainage constructed in the subgrade will serve as a leak detection system. The foundation drainage collection header will be monitored to detect process solutions and convey the outflow into the events pond for recycle.

1.6 SOLVENT EXTRACTION / ELECTROWINNING (SX/EW)

The extraction and electrowinning process for recovering copper from the pregnant solution has been extracted from the draft Feasibility Study (Kilborn Engineering Ltd., 1994) and summarized in the following paragraphs.

Pregnant leachate solution (PLS) is pumped to the **solvent extraction** (SX) building. The PLS is first combined with an organic reagent diluted in kerosene, which extracts the copper from the PLS. From this extraction, the aqueous component or raffinate is reconstituted with a sulphuric acid solution to lower the pH to 1.5 before being recycled as barren solution back onto the heap leach pad. Only one-fifth of the solution recovered from the pile will be processed. The remaining PLS is adjusted as described above, and recycled to the leach pad.

The organic phase (copper laden organic stream from the solvent extraction process) is transferred to a **stripping** stage where the organic solvent is mixed with a concentrated acid solution containing approximately 200 g/L sulphuric acid. The barren organic stream (copper-poor organic solvent) is recycled back to the solvent extraction stage and the copper-rich electrolyte is transferred to the **electrowinning** (EW) process.

During electrowinning, copper is recovered from the electrolyte by electrolytic plating of copper onto cathodic plates and the barren electrolyte is then recycled back to the stripping stage. The copper plates are harvested weekly and shipped to customers as copper cathode.

1.7 WASTE ROCK STORAGE FACILITY

1.7.1 General

The waste rock storage area for the project will be located north of the open pit. The site was chosen to minimize haul distances from the pit and to minimize impact on surface drainage. The site is generally characterized as a frozen, poorly drained, gentle north-east facing terrain. The storage capacity of the waste rock storage area is 31 million m^3 or approximately 60 million tonnes of waste rock produced from the open pit. Additional waste rock storage may be provided by extending the waste rock storage area vertically.

1.7.2 Design Criteria

The primary design criteria for the waste rock storage area are as follows:

- Provide a stable and cost effective configuration for staged waste rock storage with particular attention to permafrost and foundation conditions.
- Minimize surface runoff while providing for collection of direct runoff.
- Incorporate field observation and performance monitoring during initial stages of waste rock placement to ensure on-going stability and performance of the waste rock storage area.

1.7.3 Layout

The waste rock storage area will be constructed in stages which will be dictated by initial field observations and performance monitoring of the waste rock advancement. Staged waste rock placement will allow the permafrost to slowly degrade allowing pore pressures to dissipate. Construction of main, lateral, and perimeter drainage ditches are provided to achieve full dewatering of the foundation. The drainage ditches will intercept and convey water to the stilling basin (Figure 1.8) to settle out primary sediment prior to release into the water storage pond where any secondary sediment will be contained.

1.8 WATER STORAGE DAM DESIGN

1.8.1 Design Criteria

The water storage dam is required to provide makeup water to the leaching operation and to provide sediment control and polishing for runoff and any effluent released from the site. The heap leach facility will require makeup water in every year of operation. The statistical analysis of the heap leach water balance presented in the Knight Piésold Ltd. report, 1995, Section 4.4 predicts that the maximum annual makeup water requirement which has a probability of exceedence of 5% is 168,000 m^3. The design criteria for the water storage dam therefore are as follows:

- To provide a minimum of 168,000,m^3 of makeup water annually.
- To provide sufficient storage for the runoff from a 24 hour storm with a return period of 10 years.
- To provide adequate flood routing capacity to safely pass the peak runoff from a storm event with a return period of 100 years.
- To allow for embankment crest settlements due to permafrost degradation and thaw consolidation.
- To provide adequate seepage control so as to maintain the required water storage.

1.8.2 General Arrangement

The general arrangement of the water storage dam is shown in plan on Figure 1.9 with sections and details on Figure 1.10. The main features of the water storage dam are as follows:

- The embankment forming the dam will be a homogeneous embankment constructed from sands and gravel excavated from a borrow area 300 m to the south east of the facility. The embankment will be constructed to a crest elevation of 656 m at each abutment ramping up at 10 percent to 658.5 m. The upstream embankment slope will be 3:1 for ease of liner installation and the downstream slope will be 2.5:1 to ensure embankment stability.

- The storage basin and the upstream face of the embankment will be prepared and lined with a single 60 mil HDPE geomembrane.

- A cofferdam will be constructed at the upstream end of the basin to divert Williams Creek around the dam site while construction of the facility is in progress. Runoff will be diverted though a diversion ditch to the south east abutment.

- An underdrain will be placed along the creek alignment in the basin foundation. This will convey any residual flows not diverted during construction and will ensure that adverse uplift groundwater pressures do not form during the operation of the pond.

- After construction is complete, the cofferdam will be removed and the runoff and creek flows will be directed into the basin.

- A decant structure will constructed in the north corner of the facility adjacent to the embankment. It will comprise a 1200 mm diameter galvanized steel corrugated, slotted pipe wet well. The pipe will be supported on a concrete pad which will be cast on protective layers of liner and filter fabric above the basin liner. The pipe will be surrounded by plus 100 mm cobbles which will allow the free flow of water into the wet well. Access to the wet well will be by an access ramp constructed from random fill. A pump will be set in the wet well and an insulated pump house will be constructed on top of the structure.

- A spillway will be constructed in the south east abutment. The spillway will be lined with 60 mil HDPE liner which will provide erosion protection and good hydraulic characteristics.

The depth-area-capacity relationship for the water storage dam is shown on Figure 1.11. The embankment crest elevation of 658.5 m was determined as follows:

Full Supply Level	654.0 m
Freeboard Allowance	1.5 m
Allowance for Embankment Settlement	3.0 m
Embankment Crest Elevation	658.5 m

With an allowance for 2 m of ice thickness, the water storage pond will provide a minimum of 250,000 m^3 of water, which exceeds the design requirement of 168,000m^3 by a significant safety margin.

Preliminary stability analyses have been carried out for the water storage dam for static and earthquake loading based on a free draining design of the fill and the geomembrane liner. The analyses assumes that thawing of the foundation will result in a low strength layer with an undrained shear strength of 33 kPa obtained from laboratory testwork. The factor of safety for static failure is 1.8 and for failure due to earthquake loading is 1.3.

1.9 POWER SUPPLY

The proposed operations will require a reliable power supply of approximately 6.9 MW to maintain the crushing plant, the conveyors, solvent extraction / electrowinning process, and ancillary services. Power will be delivered to the site via an overhead 138 kV, 3-phase powerline at 60 hertz from a substation provided by the Yukon Electric Company. Two possible routes are available for the powerline; one following the incoming road from the Mt. Freegold Road, and the other from the Klondike Highway (Highway No.2), across the Yukon River and paralleling the Williams Creek valley to the mine site. Emergency standby power will be provided by a 1 mVA diesel generator located adjacent to the SX/EW facility.

1.10 ROAD ACCESS AND TRANSPORTATION

Transportation of employees, supplies, reagents and copper cathode will be via the Mt. Freegold road and the existing exploration road. In order to accommodate the heavier loads and added traffic, the route will require upgrading. The final route will follow the existing exploration road as near as possible and will only depart from the existing right-of-way to comply with grade and road curvature restrictions.

Two possible routes for the access road are currently being considered. The first route would follow the existing access road that connects with the Mt. Freegold Road. The second route would run adjacent to proposed powerline. The Mt. Freegold road will be upgraded to 80 km/hr secondary road standards for sections which were not upgraded in 1991.

Two bridges will be replaced to meet highway transport truck loadings, one at 1.5 km from Carmacks over the Nordenskiold River and the other at 25.5 km from Carmacks at Crossing Creek. Road upgrades on the 13 km exploration tote road off the Mt. Freegold road will consist of a 5 m wide minimum all-weather gravel road including widening at curves and 8 m wide turnouts at 250 m intervals.

In addition, the mine site access road will require two new bridge crossings: one over Merrice Creek at km 7 and one over Williams Creek at km 11.5. The maximum grade will be 8% with a design speed of 60 km/h.

1.11 ANCILLARY FACILITIES

The operations area will comprise the administration building (388.5 m^2), separate solvent extraction and electrowinning buildings, shops-warehouse building (1102 m^2) and cold storage area. Laboratory facilities (200 m^2) will be located adjacent to the solvent extraction building. The warehouse will be supplemented by reagent storage containers at the process plant. A separate shed will be built for oxygen and acetylene gas bottle storage.

Explosives will be stored on site in a pre-fabricated magazine selected and located to conform to territory and federal regulations. Ammonium nitrate prills will be stored near the magazine.

Sulphuric acid used in the heap leach process will be hauled into site from Skagway via 40-tonne tanker trucks. In Skagway, sulphuric acid will be held in eight 2,500-tonne capacity tanks, 10 m in diameter and 8.5 m in height. At the mine site, acid will be stored in two tanks of the same dimensions located within a lined and bermed containment area capable of retaining a spill of 110% capacity of either tank.

The accommodations area will consist of a 146-person camp complete with trailer bunkhouses, a kitchen, mine dry and recreational amenities for 100 men, 20 women and 24 ancillary staff and visitors. A first aid station will be constructed adjacent to the assay laboratory with an ambulance and fire truck on site for emergency situations.

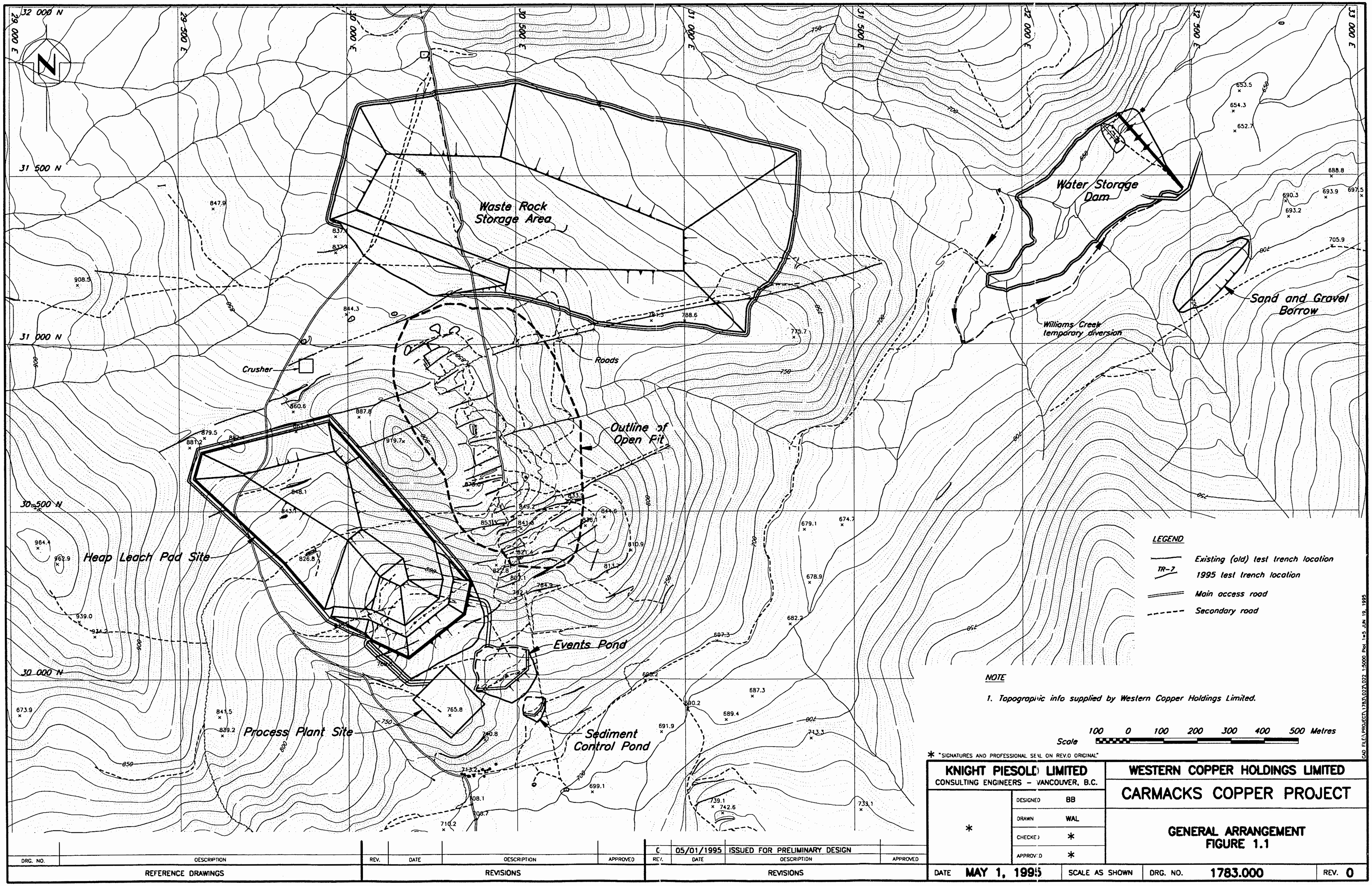
1.12 EMPLOYMENT AND PROCUREMENT POLICY

The company will endeavour to hire as many residents as possible from the Yukon for those jobs which they are qualified. In addition, the project is of sufficient size that some training can be provided for those people recruited from the region, who require the necessary skills for job placement. This will not only increase the benefits to the territory but also tend to reduce the turnover and cost of transportation to and from the site.

Job training will be carried out by the line supervisors under the direction of the mine manager. Courses will include orientation, environmental responsibility, general safety, spill response, fire control, WHMIS, first aid, mine rescue and related training.

Apprenticeship and professional training programs will depend on the requirements of the operations and implemented in association with, for example, regional colleges, universities, vocational and technical institutes and Canada Manpower and Immigration.

It is intended that the goods and services will be procured locally and regionally wherever possible, provided that price, delivery and quality are competitive and consistent with the company's objectives and specifications. Local and regional suppliers will be encouraged to become conversant with the project's requirements and tendering procedures, and to tender on those for which they are qualified.



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31 500 N
31 000 N
30 500 N
30 000 N
29 000 E
29 500 E
30 000 E
30 500 E
31 000 E
31 500 E
32 000 E
32 500 E
33 000 E
N
Waste Rock Storage Area
Water Storage Dam
Sand and Gravel Borrow
Williams Creek temporary diversion
Crusher
Roads
Outline of Open Pit
Heap Leach Pad Site
Events Pond
Sediment Control Pond
Process Plant Site
LEGEND
Existing (old) test trench location
TR-7
1995 test trench location
Main access road
Secondary road
NOTE
1. Topographic info supplied by Western Copper Holdings Limited.
Scale
100 0 100 200 300 400 500 Metres
* "SIGNATURES AND PROFESSIONAL SEAL ON REV.0 ORIGINAL"
KNIGHT PIESOLD LIMITED
CONSULTING ENGINEERS - VANCOUVER, B.C.
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
DESIGNED BB
DRAWN WAL
CHECKED *
APPROVED *
GENERAL ARRANGEMENT
FIGURE 1.1
DATE MAY 1, 1995
SCALE AS SHOWN
DRG. NO. 1783.000
REV. 0
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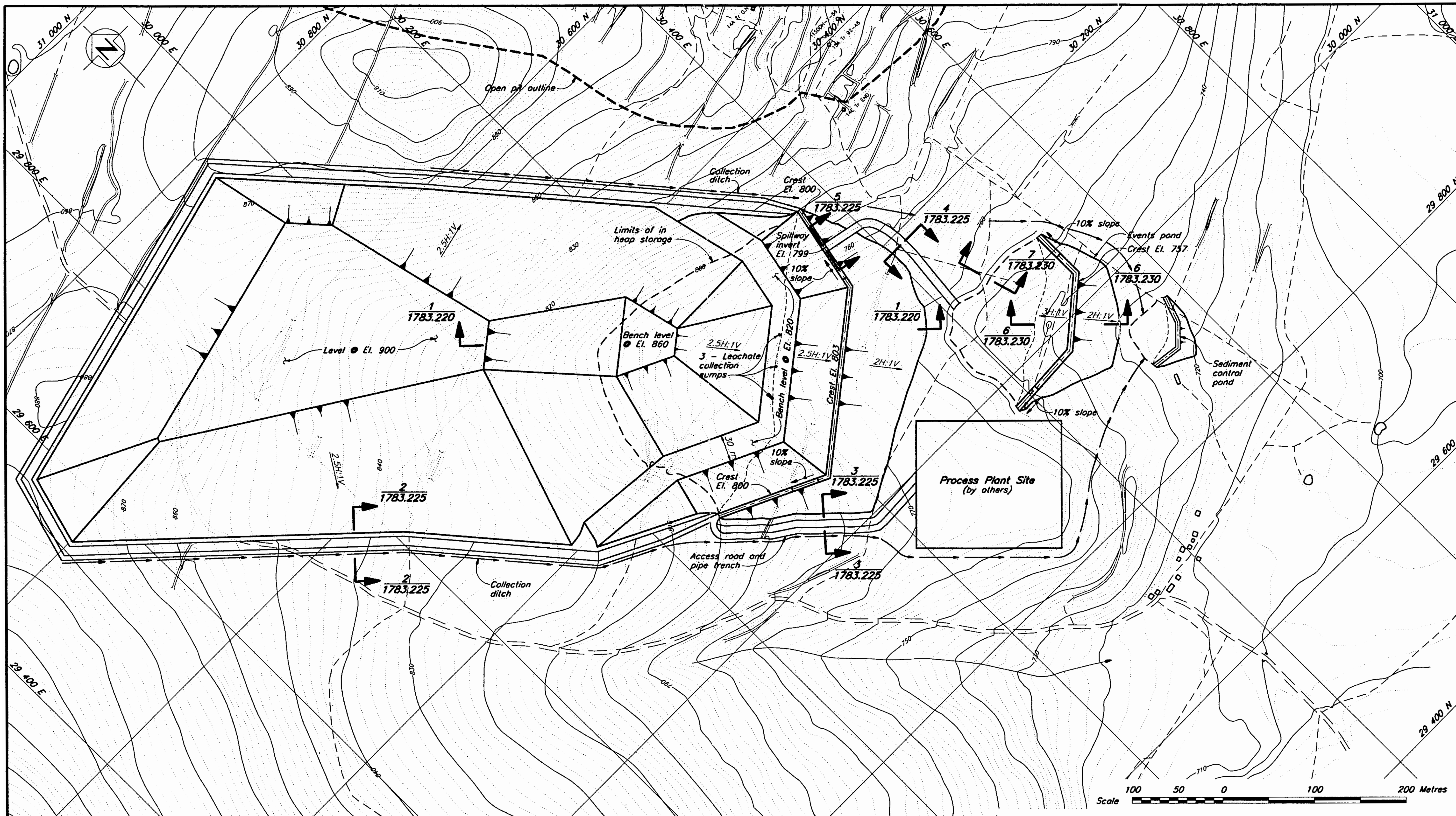

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KNIGHT PIESOLD LIMITED CONSULTING ENGINEERS – VANCOUVER, B.C.		WESTERN COPPER HOLDINGS LIMITED
*	DESIGNED BB DRAWN NSD CHECKED * APPROVED *	CARMACKS COPPER PROJECT LEACH FACILITY GENERAL LAYOUT FIGURE 1.2
DATE MAY 1, 1995	SCALE AS SHOWN	DRG. NO. 1783.200 REV. 0

REV.	DATE	DESCRIPTION	APPROVED
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DRG. NO.	DESCRIPTION

REFERENCE DRAWINGS

REV.	DATE	DESCRIPTION	APPROVED

REVISIONS

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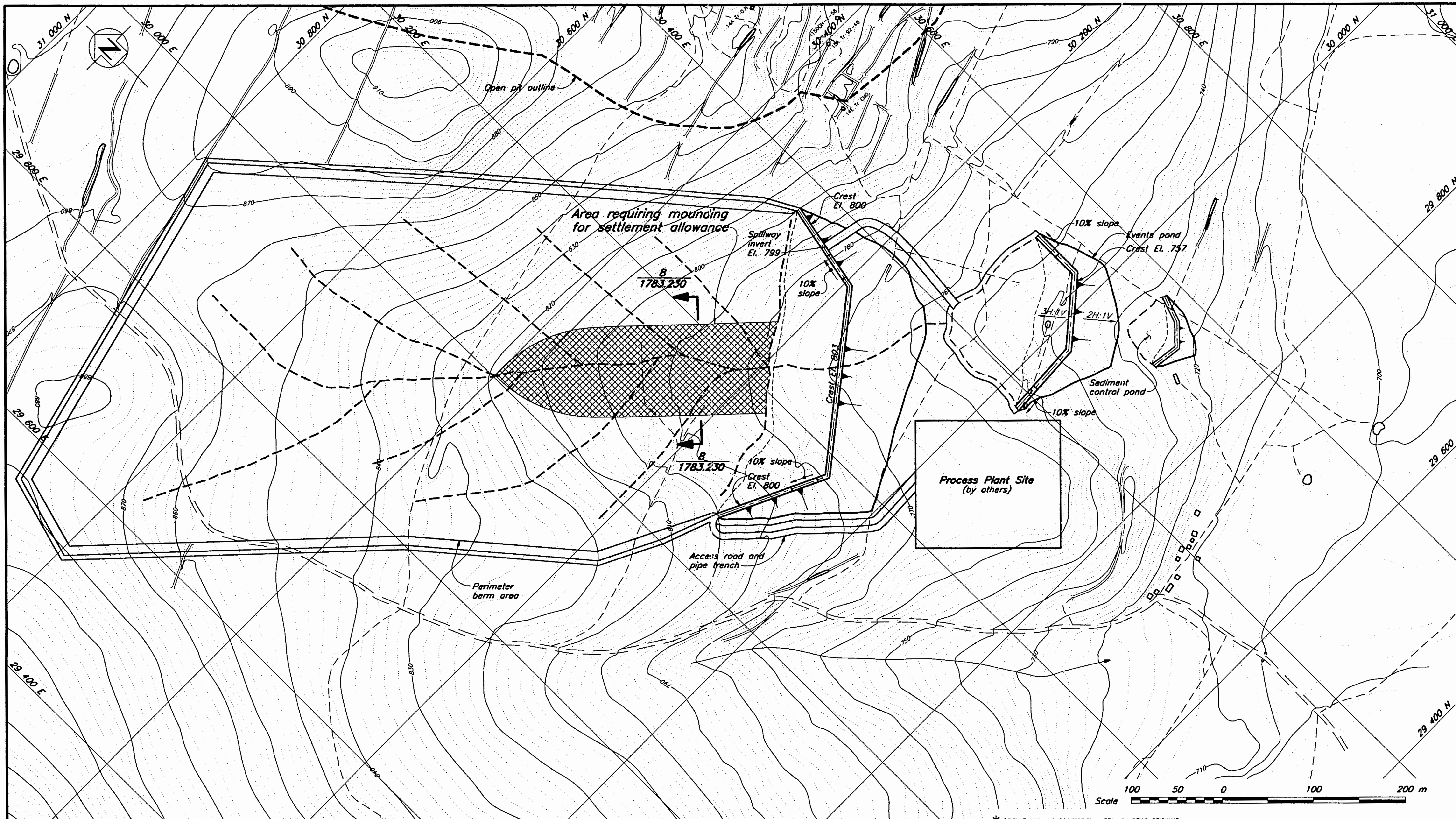

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						0	05/01/1995	ISSUED FOR PRELIMINARY DESIGN	
REFERENCE DRAWINGS		REVISIONS				REVISIONS			

KNIGHT PIESOLD LIMITED
CONSULTING ENGINEERS – VANCOUVER, B.C.

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	DRAWN	NSD
	CHECKED	*
	APPROVED	*

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

LEACH FACILITY
FOUNDATION DRAINAGE AND GRADING PLAN
FIGURE 1.3

DATE **MAY 1, 1995** SCALE AS SHOWN DRG. NO. **1783.205** REV. **0**

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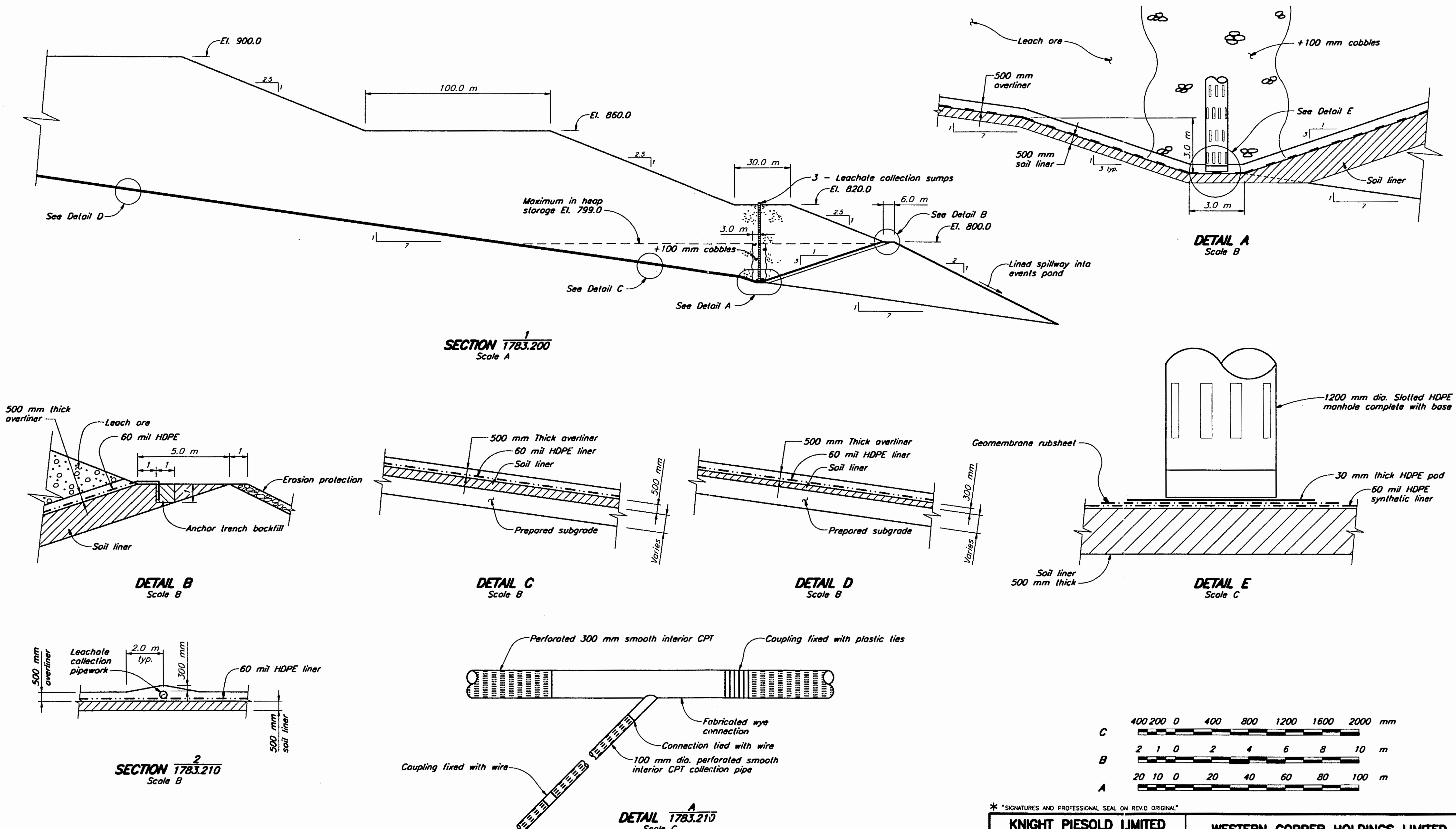

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DESIGNED: BB	CARMACKS COPPER PROJECT
DRAWN: NSD	LEACH FACILITY SECTION AND DETAILS SHEET 1 OF 3 FIGURE 1.5
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APPROVED: *	
DATE: MAY 1, 1995	SCALE: AS SHOWN — DRG. NO. 1783.220 — REV. 0

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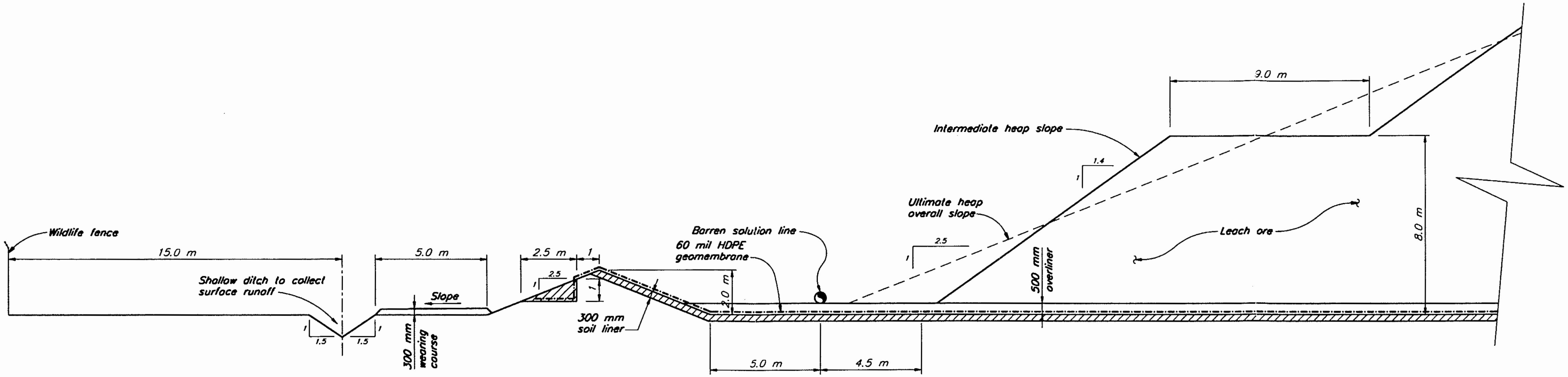
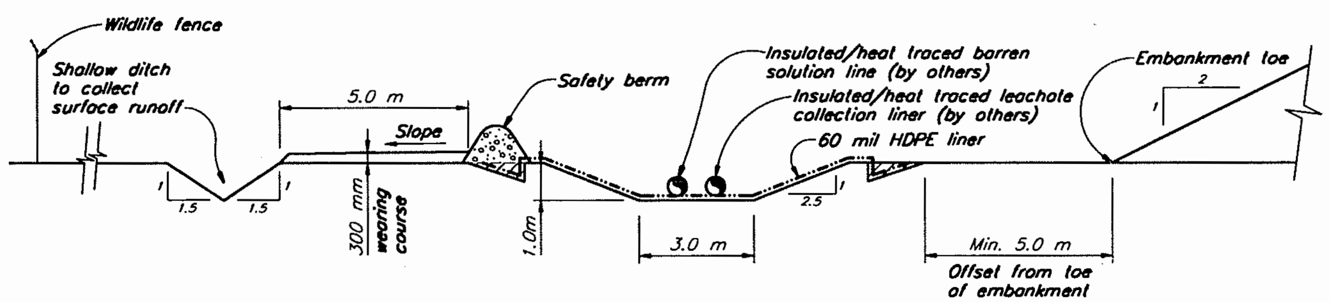
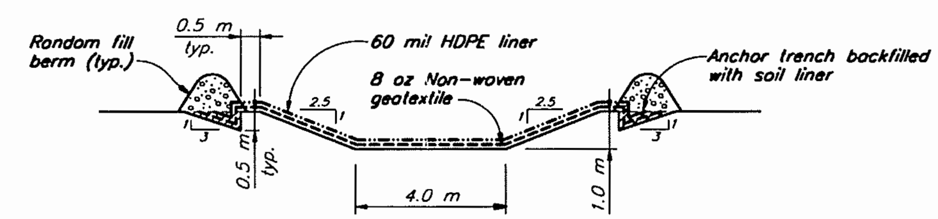


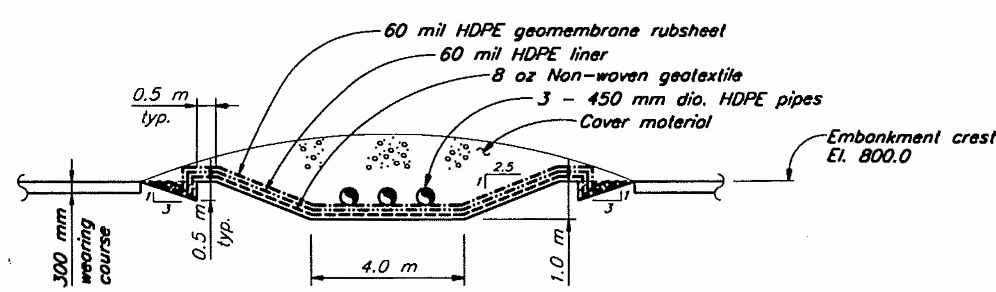
SECTION 2/1783.200
HEAP LEACH PAD PERIMETER SECTION



SECTION 3/1783.200
TYPICAL PIPE TRENCH



SECTION 4/1783.200
SPILLWAY INTO EVENTS POND



SECTION 5/1783.200
SPILLWAY THROUGH EMBANKMENT CREST

Scale 2 1 0 2 4 6 8 10 Metres

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KNIGHT PIESOLD LIMITED
CONSULTING ENGINEERS - VANCOUVER, B.C.

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CHECKED	*
APPROVED	*

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
LEACH FACILITY
SECTION AND DETAILS
SHEET 2 OF 3
FIGURE 1.5

DATE MAY 1, 1995 | SCALE AS SHOWN | DRG. NO. 1783.225 | REV. 0

REV.	DATE	DESCRIPTION	APPROVED
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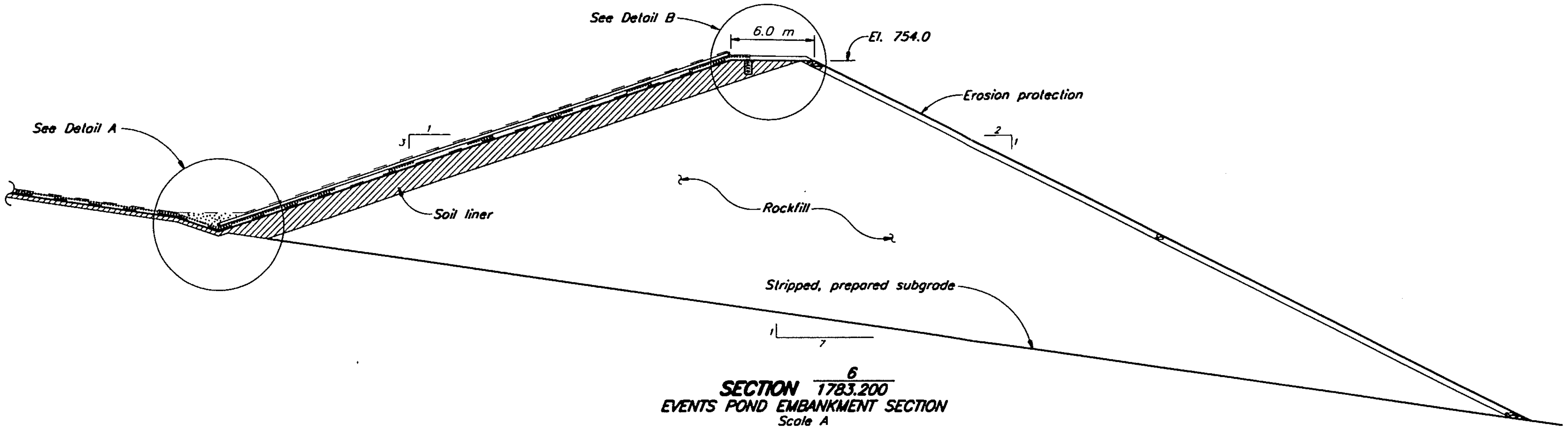
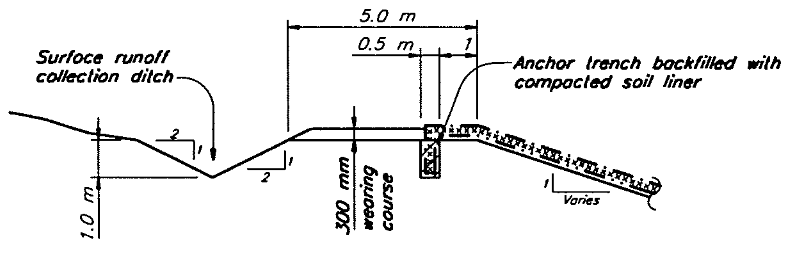
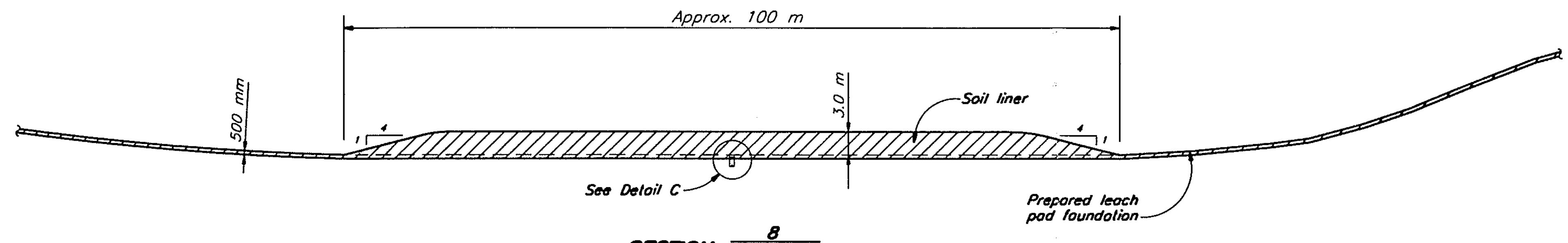
REV. | DATE | DESCRIPTION | APPROVED — REVISIONS



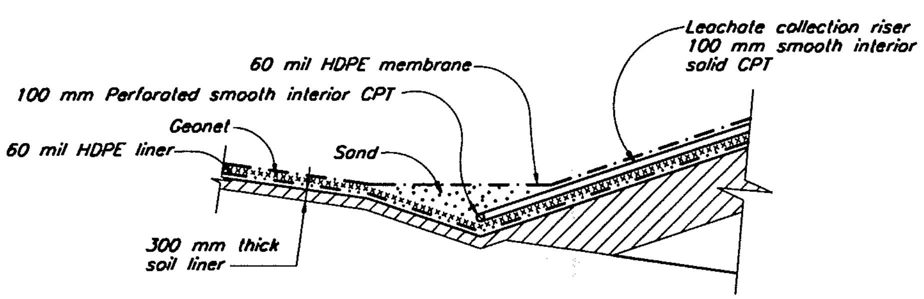
SECTION 6 / 1783.200
EVENTS POND EMBANKMENT SECTION
Scale A



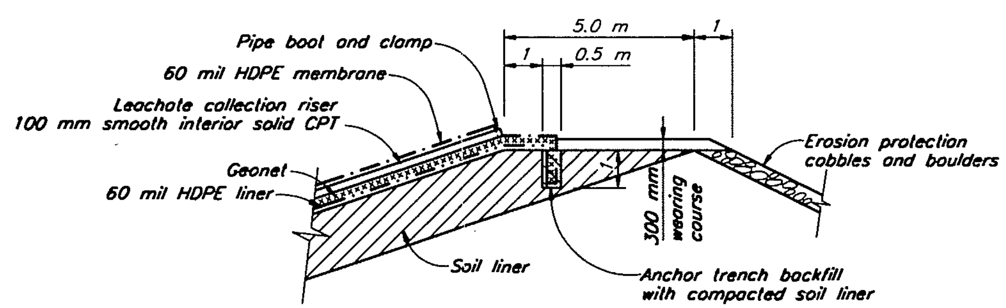
SECTION 7 / 1783.200
EVENTS POND PERIMETER ROAD AND DIVERSION DITCH
Scale B



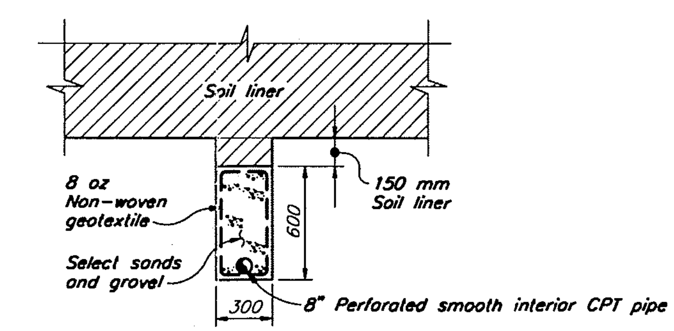
SECTION 8 / 1783.205
MOUNDING FOR SETTLEMENT ALLOWANCE
NTS



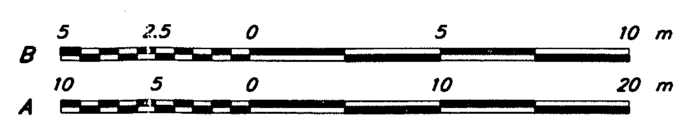
DETAIL A
LEAK DETECTION AND REMOVAL SYSTEM
Scale B



DETAIL B
LEAK DETECTION AND REMOVAL SYSTEM
Scale B



DETAIL C
FOUNDATION DRAIN / LEAK DETECTION SYSTEM
NTS



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	DRAWN	NSD
	CHECKED	*
	APPROVED	*

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

LEACH FACILITY
SECTION AND DETAILS
SHEET 3 OF 3
FIGURE 1.5

DATE MAY 1, 1995 | SCALE AS SHOWN | DRG. NO. 1783.230 | REV. 0

DRG. NO.	DESCRIPTION
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REVISIONS			

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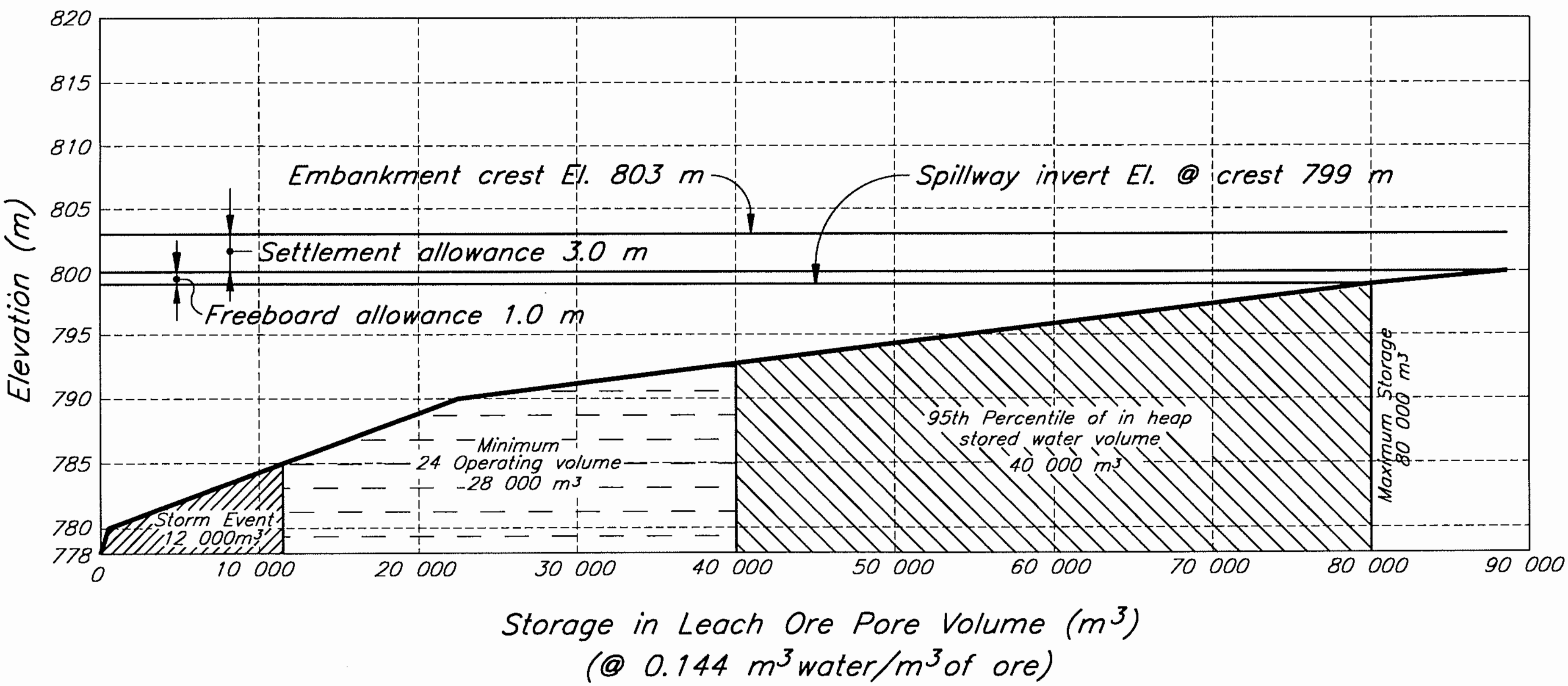
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
IN-HEAP STORAGE CAPACITY



May 1, 1995

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FIGURE 1.6

H1811\IEE\A2

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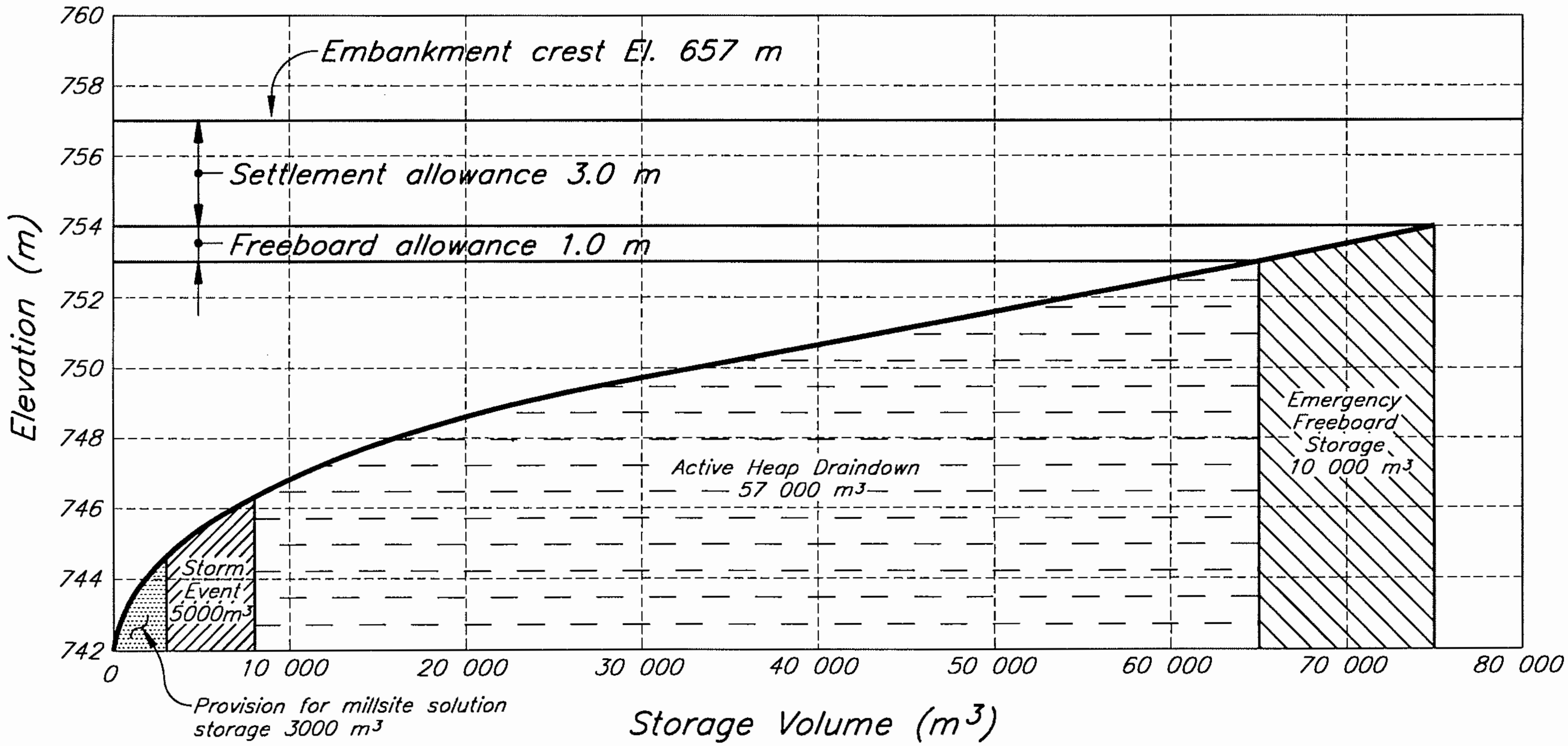
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
EVENTS POND
STORAGE CAPACITY



May 1, 1995

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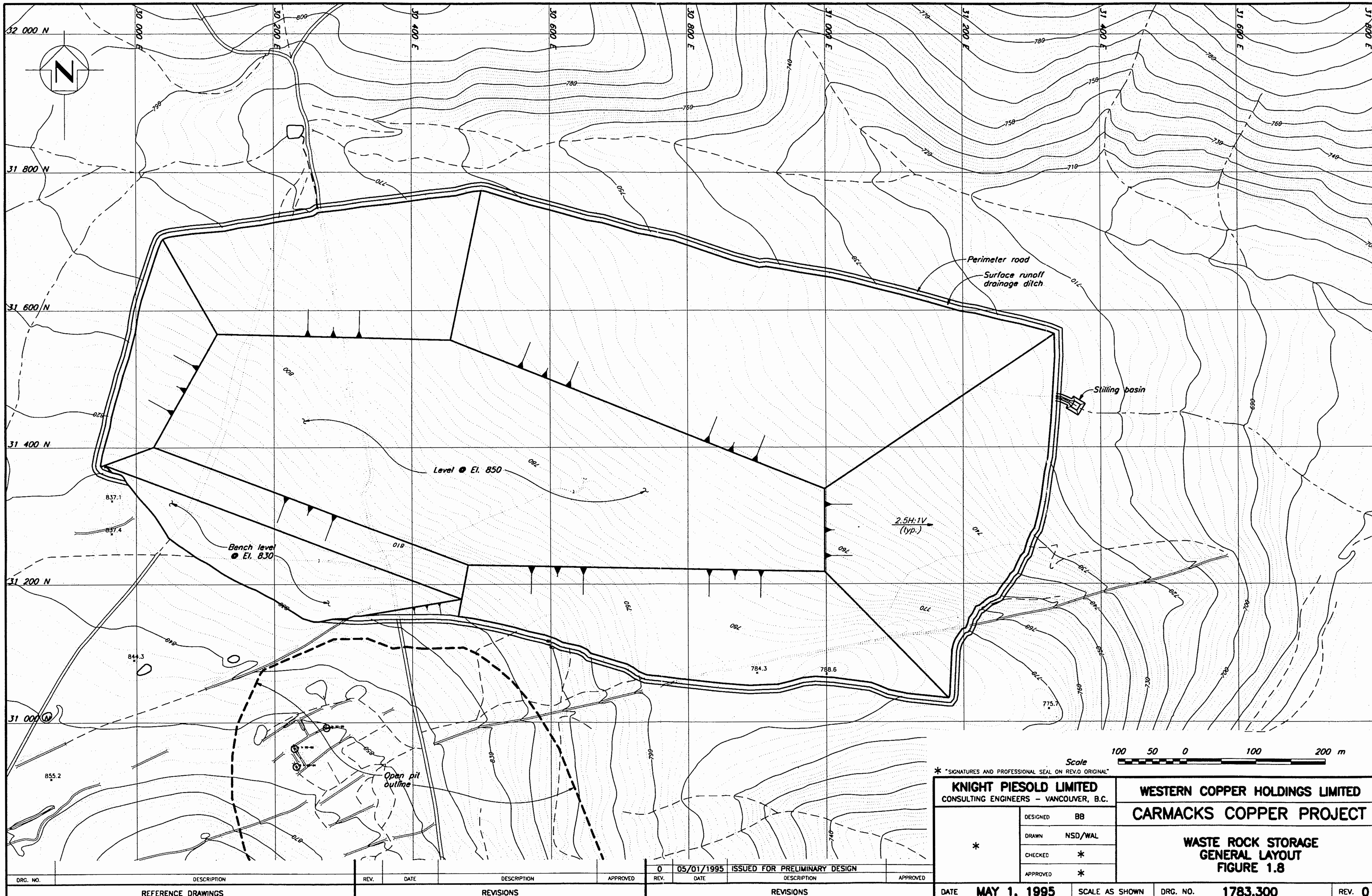
FIGURE 1.7

H1811\IEE\A3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31 800 N
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31 400 N
31 200 N
31 000 N
30 000 E
30 200 E
30 400 E
30 600 E
30 800 E
31 000 E
31 200 E
31 400 E
31 600 E
31 800 E
Perimeter road
Surface runoff drainage ditch
Stilling basin
Level @ El. 850
Bench level @ El. 830
2.5H:1V (typ.)
Open pit outline
837.1
837.4
844.3
855.2
784.3
768.6
775.7
Scale
100 50 0 100 200 m
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KNIGHT PIESOLD LIMITED
CONSULTING ENGINEERS - VANCOUVER, B.C.
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
DESIGNED BB
DRAWN NSD/WAL
CHECKED *
APPROVED *
WASTE ROCK STORAGE
GENERAL LAYOUT
FIGURE 1.8
DATE MAY 1, 1995
SCALE AS SHOWN
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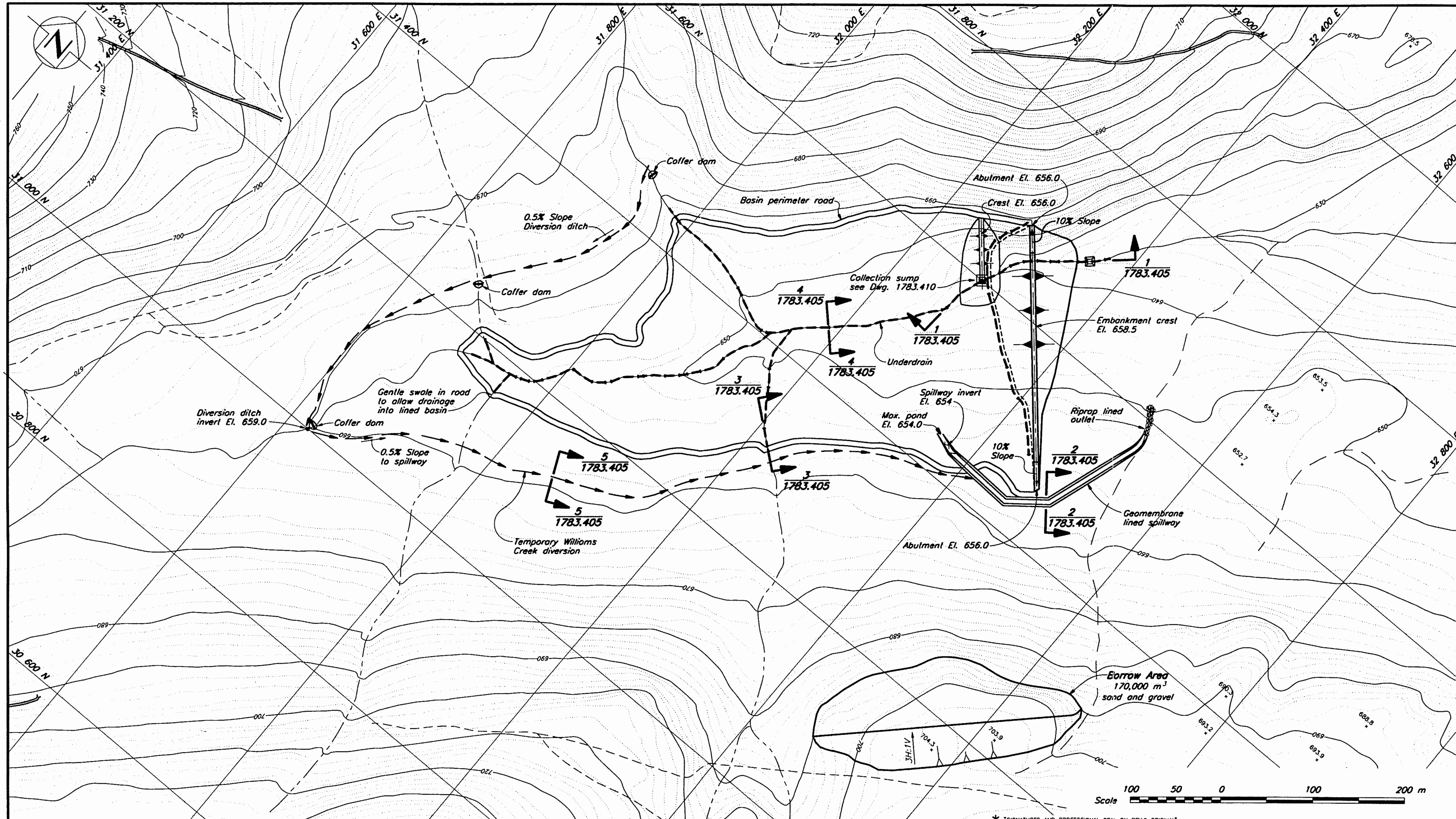

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DESIGNED	BB
DRAWN	NSD/WAL
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APPROVED	*

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

WATER STORAGE DAM GENERAL LAYOUT FIGURE 1.9

DATE **MAY 1, 1995** | SCALE AS SHOWN | DRG. NO. **1783.400** | REV. **0**

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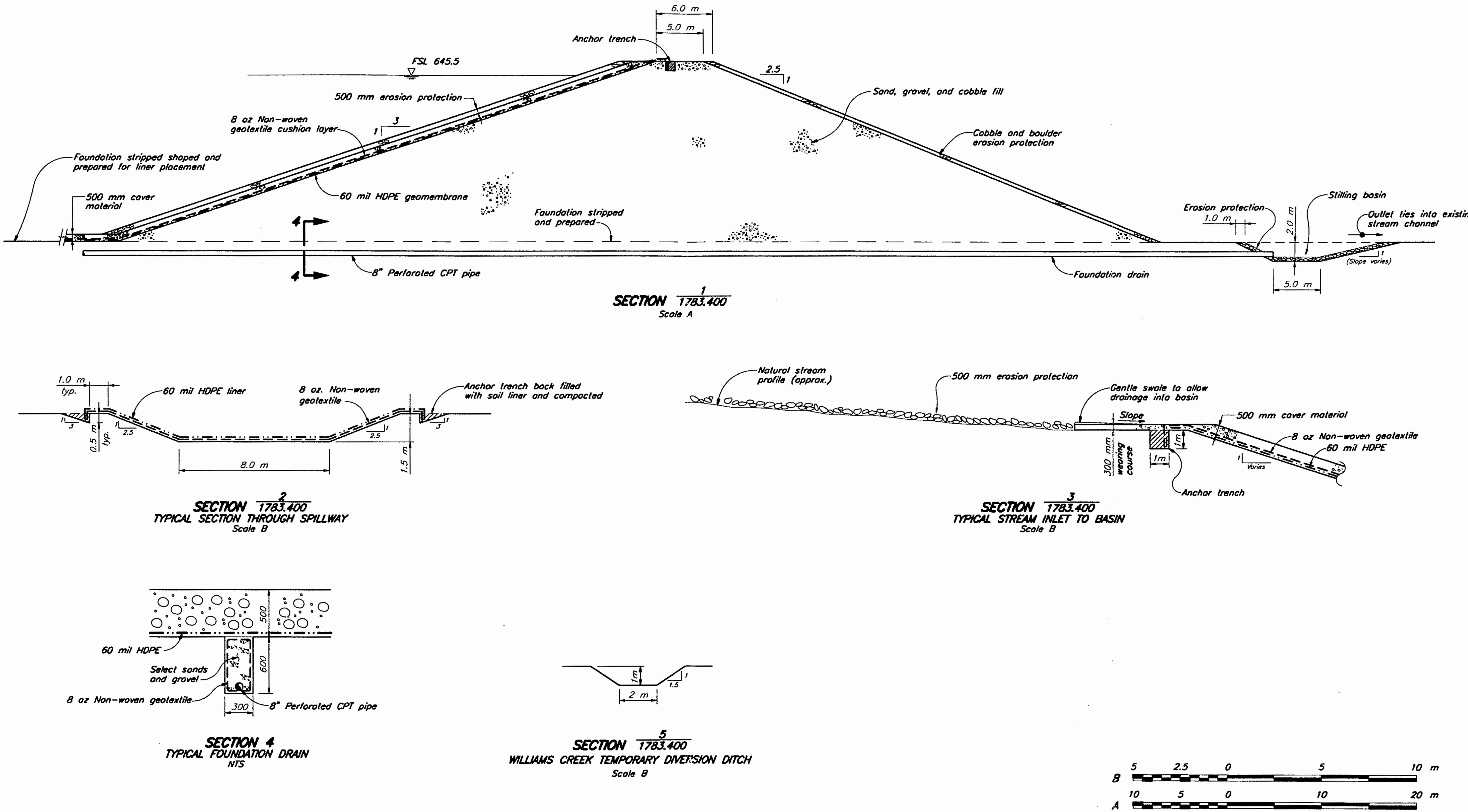
REV.	DATE	DESCRIPTION	APPROVED

REVISIONS



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*	DESIGNED BB	CARMACKS COPPER PROJECT
	DRAWN NSD/WAL	WATER STORAGE DAM SECTION AND DETAILS FIGURE 1.10
	CHECKED *	
	APPROVED *	
DATE MAY 1, 1995	SCALE AS SHOWN	DRG. NO. 1783.405 REV. 0

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REFERENCE DRAWINGS	

REV.	DATE	DESCRIPTION	APPROVED
REVISIONS			

REV.	DATE	DESCRIPTION	APPROVED
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REVISIONS			

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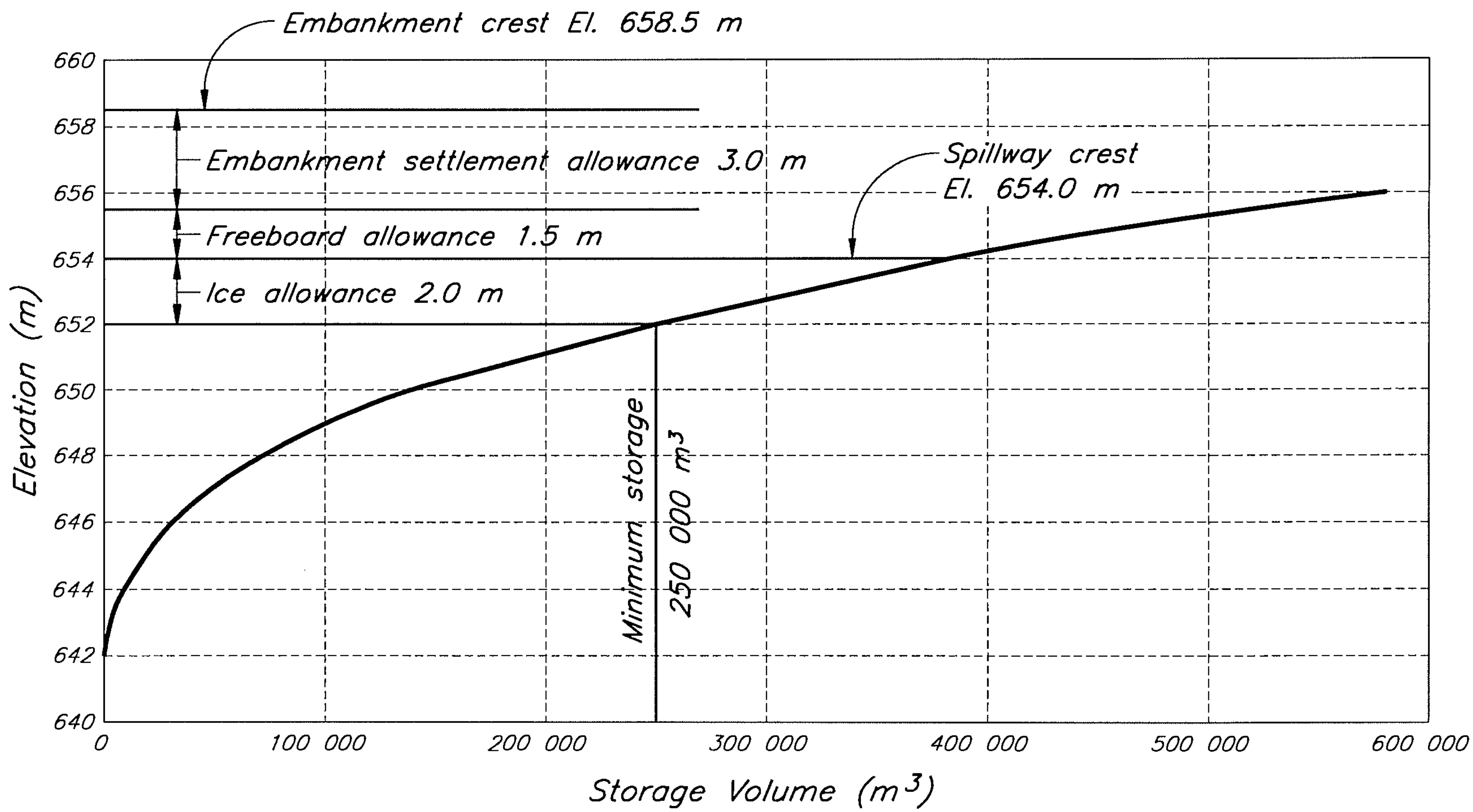
WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

WATER STORAGE DAM
STORAGE CAPACITY



May 1, 1995

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FIGURE 1.11

H1811\IEE\A4

SECTION 2.0 - METEOROLOGY

2.1 GENERAL

The Williams Creek basin is located in an area characterized by moderate annual precipitation totals and extreme variations in temperature. Average annual precipitation is approximately 300 mm to 400 m, with July being the wettest month. Almost half of the annual precipitation falls as snow as daily temperatures are below freezing from October through May. Average monthly temperatures range from a low of approximately -30°C in January to a high of approximately 13°C in July.

Temperature and precipitation data were collected during the summer of 1992, and records are available for June, July and August of that year. This data was recorded in the exploration camp at an approximate elevation of 700m. In September 1994, an automatic meteorological station was established on the site at elevation 1009 m, and continuous records are available from that time until January 1995. This station is still in operation and additional data is currently being collected.

2.2 TEMPERATURE

Temperature recordings were taken at the site in June, July and August, 1992, September through December 1994, and January 1995. This data is summarized in Table 2.1, with concurrent regional data provided for comparison. A number of regional stations are operated in the area by Atmospheric Environment Services (AES). The two closest and most relevant stations are those at Carmacks and Pelly Ranch (Fort Selkirk), located approximately 40 km southeast and 60 km northwest of the site, respectively.

As Carmacks is the closest station, and as its records are more closely correlated to the limited site records, its records were chosen as the basis for generating long-term monthly temperature values for the Carmacks Copper Project area. Values for the Williams Creek area were estimated by adjusting Carmacks values by a lapse rate of approximately 6°C per 1000 m of elevation (ie. less 2°C for 325 m). This lapse rate agrees fairly well with the difference between concurrent site and regional temperature records and is in keeping with the standard lapse rate for B.C. of 6°C per 1000 m for moist air and 10°C per 1000 m for dry air. Estimated average monthly temperature values are shown in Table 2.2. As can be seen, July is the warmest month, with an average daily temperature of approximately 12.8°C, while January is the coldest month with an average daily temperature of approximately -30.6°C.

2.3 FREEZE-THAW INDEXES

Monthly and annual freeze-thaw indexes for the Williams Creek watershed are presented in Table 2.3. These values were estimated on the basis of regional values for Carmacks and Pelly Ranch which were obtained from AES climate normals for the period of 1951-1980. The regional values were adjusted according to the relative average monthly temperatures estimated for the site and the regional stations for the period of 1951-1980. These adjustments generally assumed a linear relationship between freeze-thaw indexes and average monthly temperature, which may be a little simplistic, but given the available data, seems reasonable. Annuanl air freezing, air thawing and air heating indices for the Carmacks Copper Project site have been estimated at 3550 degree days, 1676 degree days and 8427 degree days, respectively.

2.4 MEAN ANNUAL PRECIPITATION

Precipitation recordings were taken at the site in June, July and August, 1992, September through December 1994, and January 1995. This data is summarized in Table 2.4, with concurrent regional data provided for comparison. The 1992 data indicates that the site receives substantially more precipitation than either AES station, while the 1994-95 data indicates that the site receives substantially less. Despite the fact that these records are for different times of the year, the discrepancy between records casts some doubt on the quality of the site data, particularly that for

1992. According to the record, the month of August 1992 experienced three storms with return periods of approximately 2 years, 5 years and 50 years, respectively. While this is possible, it is highly unlikley.

Since there is insufficient site specific data to generate an estimate of mean annual precipitation or to properly define a relationship between regional and site data, long-term synthetic data was generated for the site by adjusting regional data by a estimated regional orographic factor. Precipitation data for Carmacks and Pelly Ranch was adjusted by an orographic factor of + 8% per 100 m of elevation gain. The mean annual precipitation for Carmacks is estimated at 276.5 mm, at elevation 525 m, while that at Pelly Ranch is estimated at 298.9 mm, at elevation 454 m. Therefore, by weighting these values on the basis of their distances and elevations relative to the mouth of Williams Creek, an annual precipitation estimate for Williams Creek at its mouth (elevation 497 m) was determined to be 285.5 mm. Applying an 8% orographic factor to this value results in an estimated mean annual precipitation of 375 mm for the Carmacks Copper Project area, at an elevation of 850 m.

Carmacks and Pelly Ranch data was chosen over other AES data as the basis for the analysis due to the close proximity of the stations and the site.

The orographic factor was obtained from "Climate of Yukon" (Wahl et al., 1987) and is based on a detailed study of precipitation for the Mayo-Elsa and Faro-Anvil regions. Although it is stated in the text that this relationship may not apply in other areas of the Yukon, it is the best data available and was selected as a reasonable value on that basis.

2.5 MONTHLY PRECIPITATION DISTRIBUTION

Because site precipitation data covers only a few months and gives little indication of long-term average monthly precipitation, it was assumed that the monthly precipitation distribution for the project area is the same as that for Carmacks. However, the proportions of precipitation that fall as rain and snow were adjusted to account for the fact that as the Carmacks Copper Project area is at a higher elevation, and therefore slightly cooler (about 2°C based on a lapse rate of approximately 6°C per 1000m), a greater percentage of precipitation falls as snow in the Project area than at Carmacks.

On the basis of temperature differences between Carmacks and the Carmacks Copper Project area, it is projected that precipitation on the Carmacks Copper Project area falls mainly as snow in October and entirely as snow between November and April. Precipitation records at Carmacks indicate that on average 66.4% of precipitation falls as rain and 33.6% falls as snow. In comparison, an estimated 62% of precipitation falls as rain and 38% falls as snow at the Carmacks Copper Project area. Long-term monthly precipitation data was generated in the same fashion as the annual precipitation estimate. Monthly precipitation values for Pelly Ranch, Carmacks and the Carmacks Copper Site are given in Table 2.5. As can be seen, July is generally the wettest month and March and April are the driest.

2.6 WET AND DRY YEAR PRECIPITATION

Wet and dry year return period precipitation values were estimated by assuming an underlying normal distribution with a mean of 375 mm and a standard deviation of 75 mm. A curve fitting exercise was undertaken with the Carmacks data and it was found to follow a normal distribution. The standard deviation value was determined with a coefficient of variation of 0.20, which was calculated from 14 years of Carmacks data (1964-75,80,83). Various wet and dry year return precipitation values are given in Table 2.6. These values were calculated with the formula:

return period flow = mean ± (standard deviation x distribution coefficient).

2.7 EXTREME 24 HOUR PRECIPITATION

Return period precipitation values are presented in the form of intensity-duration-frequency (IDF) curves (see Figure 2.1 and Table 2.7). These curves were generated from data in the "Rainfall

Frequency Atlas of Canada (RFAC)" (Environment Canada, 1985). These curves were compared with IDF curves generated for Carmacks and Pelly Ranch by AES, and all three sets of curves closely agree. However, since the RFAC values are slightly higher for long duration storms, they were selected as a conservative measure.

2.8 SNOW PACK

John Gibson and Associates established and monitored three snow survey courses in the upper-middle area of the Williams Creek watershed for the period of January 31, 1992 to May 16, 1992. Site #1 was located on a south facing slope just east of the exploration camp at elevation 739 m. Site #2 was located on south facing slope just west of the camp at elevation 876 m. And Site #3 was located on a north facing slope southwest of the camp at elevation 755 m. The results of this snow course program are shown in Table 2.8, along with concurrent data for three regional stations operated by Indian and Northern Affairs Canada (INAC). Site #1's values agree very closely with those of Mt. Nansen, while sites #2 and #3 indicate that Williams Creek has a slightly later melt period than Mt. Nansen.

As the period of record is only one year, the statistical significance of this data is difficult to determine. Therefore, snow course records for the Minto Creek basin, a neighbouring watershed, were also examined. These records were also recorded by John Gibson and Associates, who operated three snow course sites in the Minto Creek watershed during the 1993/1994 winter. These sites are located near the headwaters of the basin at elevations of 914 m, 823 m and 823 m. In a similar fashion to the Williams Creek data, the results of this snow course program are shown in Table 2.9, along with concurrent data for three regional stations operated by Indian and Northern Affairs Canada (INAC). Both sets of records indicate that the snow pack records recorded at Mt. Nansen most closely correspond to the site records, and therefore Mt. Nansen long-term records were used to estimate long-term average snow melt values for the Carmacks Copper Project area. It is estimated that on average approximately 70% of the snow pack melts in April with the remaining 30% melts in May.

2.9 COMBINED RAINFALL AND SNOWMELT DISTRIBUTION

For the purpose of water balance modelling, it is necessary to estimate the water inflow to a pond (ie. water storage pond) due to direct precipitation. Approximately 38% of annual precipitation falls as snow during the months of September through to May. However, during this period temperatures are very cold and consequently very little snowmelt occurs. Therefore, it was assumed that 100% of snowfall accumulates as snow pack and does not contribute to pond water until the spring melt. Distribution of direct precipitation was therefore estimated by combining rainfall and snowmelt distribution values. These values are shown in Table 2.10.

2.10 EVAPORATION

No evaporation records are available for the Carmacks Copper Site. However, lake evaporation values are recorded at the AES meteorological station at Pelly Ranch. Lake evaporation values for the Carmacks Copper Project area were estimated by applying an orographic adjustment factor to long-term Pelly Ranch values. Pelly Ranch data indicates a mean annual evaporation value of 454.1 mm, at elevation 454 m, with measurable evaporation only occurring during the months of May through to September. The Ministry of Environment's "Manual of Operational Hydrology Manual in B.C." (Coulson et al, 1991) suggests a reduction of evaporation with elevation equal to 10% per 350 m rise in elevation. As the climates of B.C. and the Yukon are very similar, this adjustment factor was adopted. Based on the above values , the mean annual evaporation for the Carmacks Copper Project area, at the proposed heap leach pad elevation of 850 m, is estimated to be 404 mm, and at the proposed water storage pond elevation of 675 m, is estimated to be 427 m. Monthly evaporation values are shown in Table 2.11. Maximum evaporation occurs in July with little or no evaporation during the months of October through April.

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TABLE 2.1
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1992 JUNE TEMPERATURE (°C)

June	Pelly Ranch	Carmacks	Site
1	11.8	10.3	
2	12.0	10.5	
3	13.3	12.3	
4	10.8	11.0	
5	10.0	7.0	
6	9.3	M	
7	8.5	17.0	
8	7.3	8.5	
9	9.8	11.0	12.0
10	13.3	12.3	12.5
11	14.0	15.5	16.5
12	15.8	6.0	16.0
13	17.8	M	13.0
14	14.8	28.0	14.0
15	15.0	14.0	15.0
16	14.8	13.8	12.5
17	10.5	13.0	11.0
18	13.8	13.0	13.0
19	14.5	6.0	10.0
20	14.5	M	10.0
21	14.3	20.5	8.5
22	13.5	11.5	9.5
23	12.5	13.3	7.0
24	8.5	8.8	9.5
25	10.5	10.0	9.0
26	14.3	4.0	10.5
27	17.0	M	13.0
28	18.0	30.5	16.0
29	19.3	19.0	17.5
30	20.5	10.0	16.5
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Average	14.1	13.7	12.4

Notes:
1) Averages are for concurrent days of data only.
2) M = missing data.

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TABLE 2.1 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1992 JULY & AUGUST TEMPERATURE (°C)

Jul	Pelly Ranch	Carmacks	Site
1	20.8	21.0	18.5
2	22.8	21.5	18.5
3	19.5	21.0	14.5
4	17.5	13.0	15.0
5	15.3	21.0	14.0
6	16.0	14.3	14.0
7	14.5	14.5	14.0
8	15.8	16.5	16.0
9	14.0	15.0	14.5
10	15.3	8.0	12.0
11	16.0	M	12.5
12	16.0	25.0	13.0
13	15.5	11.5	13.0
14	15.8	14.0	13.0
15	16.0	13.5	13.0
16	12.3	12.8	13.0
17	16.3	13.8	14.0
18	14.8	17.0	12.0
19	15.8	15.5	13.0
20	14.5	14.0	11.0
21	12.5	14.3	12.5
22	13.8	14.5	11.5
23	15.0	15.5	12.0
24	15.8	9.0	12.5
25	16.0	M	14.0
26	16.3	23.5	12.0
27	11.8	12.3	10.5
28	15.0	13.5	12.5
29	13.5	12.0	13.5
30	13.8	11.8	12.5
31	12.5	16.3	14.0
Average	15.5	15.4	13.4

Aug	Pelly Ranch	Carmacks	Site
1	13.3	23.5	14.0
2	12.0	23.5	11.5
3	12.8	13.5	14.5
4	16.8	14.8	18.5
5	18.5	17.0	15.0
6	18.3	16.0	10.0
7	15.5	11.0	22.0
8	17.8	M	15.0
9	17.0	22.0	14.0
10	16.8	17.5	14.0
11	13.8	15.0	13.3
12	14.8	14.5	11.5
13	14.3	13.0	8.5
14	8.0	6.0	5.5
15	9.5	M	6.0
16	10.5	M	5.0
17	9.0	19.5	7.0
18	5.8	8.5	8.0
19	8.8	11.0	10.5
20	10.8	12.3	8.5
21	10.5	0.0	10.5
22	11.8	M	11.0
23	12.3	23.0	13.0
24	15.0	10.0	14.8
25	13.5	14.0	15.0
26	9.5	12.0	8.5
27	8.0	10.5	8.5
28	10.3	3.0	10.0
29	9.5	M	7.0
30	7.5	16.0	7.5
31	12.8	8.5	5.0
Average	12.5	13.7	11.5

Notes:
1) Averages are for concurrent days of data only.
2) M = missing data.

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TABLE 2.1 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1994 SEPTEMBER & OCTOBER TEMPERATURE (°C)

Sept	Pelly Ranch	Carmacks	Site
1	7.8	8.3	
2	7.8	M	
3	6.5	M	
4	7.5	9.0	
5	6.3	M	
6	9.3	9.0	
7	7.0	9.0	
8	4.5	8.0	
9	7.5	4.5	
10	1.5	M	
11	2.5	3.0	
12	3.3	M	
13	6.3	6.0	
14	9.0	7.5	7.6
15	14.5	11.5	9.3
16	12.0	11.0	9.4
17	7.0	M	7.8
18	7.3	M	6.3
19	6.3	8.0	7.8
20	3.5	4.8	4.6
21	4.8	4.3	6.3
22	6.8	6.8	5.4
23	6.0	M	5.5
24	6.8	M	4.4
25	4.8	9.3	7.6
26	4.0	4.5	3.8
27	2.8	4.8	1.6
28	2.8	3.0	1.5
29	3.3	4.0	2.3
30	2.8	2.3	2.0
Average	5.6	5.4	5.3

Oct	Pelly Ranch	Carmacks	Site
1	-1.5	M	0.8
2	3.3	M	3.8
3	4.8	M	4.6
4	7.0	6.3	5.5
5	4.0	6.0	4.9
6	5.8	5.3	4.9
7	2.5	5.8	4.4
8	4.8	M	2.4
9	1.8	M	2.2
10	0.3	M	-0.5
11	-3.0	-2.0	-1.7
12	1.5	2.5	2.1
13	-1.8	-3.0	0.9
14	-1.0	M	-0.3
15	0.0	M	0.6
16	5.0	M	2.9
17	1.5	M	0.9
18	-3.0	-1.0	-4.7
19	-4.8	-1.3	-1.8
20	-2.0	-1.3	-2.1
21	-3.0	-0.5	-3.1
22	-6.0	M	-6.6
23	-10.5	M	-7.5
24	-3.0	M	-2.4
25	-1.8	-0.3	-0.6
26	-8.0	-3.8	-3.6
27	-8.0	-8.0	-3.0
28	-7.0	-3.8	-3.0
29	-6.8	M	-5.4
30	-4.5	M	-6.6
31	-8.8	-9.8	-10.2
Average	-1.9	-0.6	-0.7

Notes:
1) Averages are for concurrent days of data only.
2) M = missing data.

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TABLE 2.1 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1994 NOVEMBER & DECEMBER TEMPERATURE (°C)

Nov	Pelly Ranch	Carmacks	Site
1	-14.3	-11.5	-12.0
2	-8.0	-7.5	-11.1
3	-1.5	-0.8	-1.6
4	-8.3	-6.0	-5.8
5	-12.5	M	-9.7
6	-11.5	-12.0	-12.6
7	-12.5	-11.8	-10.8
8	-10.8	-10.5	-12.0
9	-14.8	-14.3	-15.7
10	-9.8	-13.3	-6.0
11	-6.5	-10.0	-7.0
12	-21.5	-20.5	-13.6
13	-18.8	M	-15.6
14	-19.3	M	-17.0
15	-18.8	-18.5	-18.5
16	-25.0	-21.5	-18.3
17	-19.5	-14.0	-14.5
18	-13.3	-12.5	-10.3
19	-29.0	-22.5	-17.1
20	-23.3	M	-18.4
21	-15.5	M	-14.8
22	-20.0	-15.0	-19.9
23	-27.5	-25.8	-27.4
24	-28.0	-26.5	-28.8
25	-34.3	-25.8	-28.6
26	-32.3	M	-23.2
27	-28.0	-23.8	-20.9
28	-28.3	M	-19.7
29	-27.8	-24.5	-20.7
30	-26.8	-24.0	-26.0
Average	-18.2	-16.2	-15.6

Dec	Pelly Ranch	Carmacks	Site
1	-35.0	-28.8	-27.0
2	-34.0	M	-29.4
3	-20.5	M	-22.4
4	-11.8	M	-5.5
5	-14.5	M	-9.5
6	-32.0	-19.3	-24.3
7	-31.5	-26.0	-27.5
8	-43.0	-37.5	-30.2
9	-40.3	M	-32.3
10	-35.3	M	-29.6
11	-30.8	M	-27.4
12	-21.8	M	-11.6
13	-11.0	-11.0	-2.1
14	-18.0	-9.5	-3.5
15	-27.3	-23.0	-13.5
16	-27.3	M	-16.8
17	-29.5	M	-16.3
18	-25.0	M	-12.9
19	-22.8	M	-7.7
20	-21.5	-12.8	-4.9
21	-15.5	-10.5	-4.9
22	-16.5	-12.3	-5.3
23	-22.0	-16.3	-9.3
24	-32.0	M	-15.1
25	-29.3	M	-23.1
26	-26.8	M	-24.4
27	-39.5	M	-23.5
28	-36.8	-33.3	-20.1
29	-22.0	-20.5	-13.9
30	-21.5	M	-5.3
31	-30.0	M	-10.0
Average	-25.5	-20.1	-14.3

Notes:
1) Averages are for concurrent days of data only.
2) M = missing data.

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TABLE 2.1 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1995 JANUARY TEMPERATURE (°C)

Jan	Pelly Ranch	Carmacks	Site
1			-15.0
2			-15.8
3			-17.0
4			-20.9
5			-23.3
6			-24.2
7			-24.8
8			-27.8
9			-28.1
10			-24.9
11			-23.0
12			-22.0
13			-18.9
14			-10.3
15			-13.1
16			-15.6
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
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Average			

Notes:
1) Averages are for concurrent days of data only.
2) M = missing data.

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TABLE 2.2
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
MEAN MONTHLY TEMPERATURE DATA (°C)

Long-term regional values

Station	Years of Record	Elev. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pelly Ranch	1961 - 1990	454	-27.9	-21.7	-11.9	-0.2	7.5	13	15.1	12.5	6.5	-2.3	-16.7	-25.5	-4.3
Carmacks	1963 - 1990	525	-28.6	-18.2	-11.6	-0.1	7.2	12.9	14.8	12.5	6.9	-1.6	-14.7	-24.7	-3.8
Williams Creek (est.)	N/A	850	-30.6	-20.2	-13.6	-2.1	5.2	10.9	12.8	10.5	4.9	-3.6	-16.7	-26.7	-5.8

Notes:

1) Pelly Ranch and Carmacks values from AES climate normals for 1961-1990.

2) Carmacks March and April values from AES climate normals for 1951 to 1980.

2) Williams Creek site values estimated by adjusting Carmacks data by a lapse rate of approximately 6 °C/1000 m (ie. 2°C for 325m).

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TABLE 2.4
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1992 JUNE PRECIPITATION (mm)

Jun	Pelly Ranch	Carmacks	Site
1	0.0	4.8	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.4	0.0	0.0
5	0.4	0.0	0.0
6	2.4	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0
9	0.0	0.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	1.0
13	T	0.0	9.8
14	12.2	6.2	1.0
15	0.2	T	2.0
16	0.6	0.6	0.0
17	0.8	0.0	2.0
18	0.0	0.0	0.0
19	0.0	0.0	0.0
20	4.8	0.0	10.0
21	0.6	2.4	18.0
22	2.2	1.2	2.0
23	0.8	T	1.0
24	2.6	1.4	0.0
25	4.2	1.4	2.0
26	0.0	0.0	0.0
27	0.0	0.0	0.0
28	0.0	0.0	0.0
29	0.0	0.0	0.0
30	0.0	0.0	0.0
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Total	32.0	18.0	48.8

Notes:
1) Totals are for concurrent days of data only.
2) C = precipitation occurred, amount unknown, value accumulated in next days value.
3) T = Trace of precipitation.

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TABLE 2.4 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1992 JULY & AUGUST PRECIPITATION (mm)

Jul	Pelly Ranch	Carmacks	Site
1	0.0	0.0	0.0
2	2.6	0.0	0.0
3	T	2.0	6.0
4	1.2	0.0	1.0
5	7.8	7.0	10.0
6	2.6	17.4	14.0
7	0.6	5.2	2.0
8	0.0	T	0.0
9	0.0	0.0	3.0
10	0.0	0.0	16.0
11	0.8	0.0	11.0
12	6.0	8.2	4.0
13	3.0	14.0	0.0
14	0.0	0.5	0.0
15	0.0	0.0	2.0
16	3.0	0.0	3.0
17	0.8	T	0.0
18	0.0	0.0	0.0
19	1.0	T	0.0
20	0.2	1.4	3.0
21	9.2	3.0	0.0
22	0.4	0.0	0.0
23	0.0	0.0	4.0
24	T	0.0	6.0
25	1.1	0.0	0.0
26	0.0	4.0	0.0
27	0.0	T	2.5
28	1.8	0.0	0.0
29	2.2	2.8	2.0
30	0.0	2.8	4.0
31	0.0	0.4	10.0
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Total	19.7	68.7	103.5

Aug	Pelly Ranch	Carmacks	Site
1	0.2	0.0	5.0
2	5.4	0.4	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	6.0
6	0.0	3.5	0.0
7	3.2	0.0	8.0
8	0.0	0.0	1.0
9	0.0	9.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.4	0.0	0.0
14	9.6	0.0	0.0
15	T	0.0	0.0
16	0.0	0.0	0.0
17	7.2	3.0	30.0
18	1.8	1.2	2.0
19	0.0	0.0	0.0
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.2	0.0	0.0
23	0.0	0.0	0.0
24	0.0	0.0	0.0
25	1.0	0.0	4.0
26	0.2	T	14.0
27	5.4	2.8	46.0
28	5.2	0.0	3.0
29	6.8	0.0	0.0
30	0.0	0.0	24.0
31	0.8	8.0	0.0
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Total	26.0	27.9	143.0

Notes:
1) Totals are for concurrent days of data only.
2) C = precipitation occurred, amount unknown, value accumulated in next days value.
3) T = Trace of precipitation.

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TABLE 2.3
WESTERN COPPER HOLINGS LIMITED
CARMACKS COPPER PROJECT
FREEZE - THAW INDEXES (DEGREE-DAYS)

Long-term regional values

Parameter	Station	Years of Record	Elev. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Air Freezing Index (below 0°C)	Pelly Ranch	1951 - 1980	454	919.6	618.5	400.9	62.6	1.7	0.0	0.0	0.0	3.6	121.6	466.7	821.5	3416.7
	Carmacks	1951 - 1980	525	876.6	549.6	355.8	51.7	1.7	0.0	0.0	0.0	2.5	106.6	424.6	750.6	3119.7
	Williams Creek (est.)	N/A	850	932	627	418	100	1.7	0	0	0	10	130	487	844	3550
Air Thawing Index (above 0°C)	Pelly Ranch	1951 - 1980	454	0.1	0.9	3.0	49.7	225.8	386.3	460.4	384.3	198.6	35.7	3.2	0.1	1748.1
	Carmacks	1951 - 1980	525	0.1	1.3	3.5	51.9	220.3	376.1	449.5	382.9	198.8	42.1	3.2	0.0	1729.7
	Williams Creek (est.)	N/A	850	0	0	0	35	219	377	450	380	195	20	0	0	1676
Air Heating Index (below 18°C)	Pelly Ranch	1951 - 1980	454	1477.5	1126.4	955.9	553.0	333.9	155.7	102.0	175.0	345.0	643.9	1003.6	1379.4	8251.3
	Carmacks	1951 - 1980	525	1434.0	1057.5	910.8	540.2	338.5	165.2	113.1	176.7	343.4	622.6	959.7	1308.6	7970.3
	Williams Creek (est.)	N/A	850	1490	1135	973	600	340	164	113	170	360	655	1025	1402	8427

Notes:

1) Pelly Ranch and Carmacks values from AES climate normals for 1951-1980.

2) Carmacks March and April values from AES climate normals for 1951 to 1980.

3) Williams Creek site values estimated by adjusting Carmacks and Pelly Ranch data on the basis of monthly temperature records and estimates.

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TABLE 2.4 (CONTINUED)
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
1994 SEPTEMBER & OCTOBER PRECIPITATION (mm)

Sept	Pelly Ranch	Carmacks	Site
1	0.8	0.0	
2	0.0	T	
3	0.4	C	
4	0.0	C	
5	0.0	2.4	
6	0.0	0.3	
7	0.0	0.0	
8	0.4	0.0	
9	0.2	1.0	
10	0.0	0.0	
11	5.6	3.2	
12	0.0	0.4	
13	T	0.0	
14	0.0	0.0	0.0
15	0.0	0.0	0.0
16	0.0	0.0	0.0
17	0.0	0.0	0.0
18	1.2	1.0	0.6
19	0.0	0.0	0.0
20	0.0	0.0	0.2
21	8.8	3.6	6.8
22	0.0	2.4	0.5
23	T	C	0.0
24	4.0	C	1.8
25	T	6.5	1.4
26	0.2	5.0	0.0
27	0.0	1.8	0.0
28	0.0	0.0	0.0
29	0.0	0.0	0.0
30	0.0	0.0	0.0
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Total	14.2	20.3	11.3

Oct	Pelly Ranch	Carmacks	Site
1	0.0	0.0	0.0
2	T	5.0	0.0
3	0.0	2.5	0.2
4	0.8	7.0	4.9
5	0.2	0.4	0.0
6	0.0	0.0	0.0
7	2.2	C	0.0
8	T	3.0	0.0
9	2.6	0.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	0.0	0.0	0.0
15	2.0	C	0.0
16	0.2	2.8	0.0
17	1.0	0.4	0.0
18	1.0	0.0	0.0
19	7.0	0.5	0.0
20	3.8	1.0	0.0
21	1.8	0.2	0.0
22	0.0	0.0	0.0
23	0.0	0.0	0.0
24	0.0	0.0	0.0
25	0.0	0.2	0.0
26	0.4	1.0	0.0
27	0.0	0.0	0.0
28	1.0	C	0.0
29	3.0	C	0.0
30	0.4	5.0	0.0
31	T	0.0	0.0
--------	----------	----------	--------
Total	27.4	29.0	5.1

Notes:
1) Totals are for concurrent days of data only.
2) C = precipitation occurred, amount unknown, value accumulated in next days value.
3) T = Trace of precipitation.

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TABLE 2.5
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
PRECIPITATION DATA

Regional Values

Precipitation Station	Years of Record	Elevation	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pelly Ranch	1961 - 1990	454 m	rain (mm)	0	0	0.3	3.3	22.8	37	51.7	33.8	26.7	8.3	0.5	0	184.4
			% precip.	0.0%	0.0%	0.1%	1.1%	7.6%	12.4%	17.3%	11.3%	8.9%	2.8%	0.2%	0.0%	61.7%
			snow (mm)	19.8	15.3	10.2	7.8	0.2	0	0	0.1	1.1	16.1	22.7	21.2	114.5
			% precip.	6.6%	5.1%	3.4%	2.6%	0.1%	0.0%	0.0%	0.0%	0.4%	5.4%	7.6%	7.1%	38.3%
			precip.(mm)	19.8	15.3	10.5	11.1	23	37	51.7	33.9	27.8	24.4	23.2	21.2	298.9
			% precip.	6.6%	5.1%	3.5%	3.7%	7.7%	12.4%	17.3%	11.3%	9.3%	8.2%	7.8%	7.1%	100.0%
Carmacks	1963 - 1990	525m	rain	0	0	0.2	1.1	18.3	34.5	55.1	39.3	29.5	5.2	0.4	0	183.6
			% precip.	0.0%	0.0%	0.1%	0.4%	6.6%	12.5%	19.9%	14.2%	10.7%	1.9%	0.1%	0.0%	66.4%
			snow	17.9	12.3	6.8	5.7	1.8	0	0	0.1	1.1	14	17.9	15.3	92.9
			% precip.	6.5%	4.4%	2.5%	2.1%	0.7%	0.0%	0.0%	0.0%	0.4%	5.1%	6.5%	5.5%	33.6%
			precip.(mm)	17.9	12.3	7	6.8	20.1	34.5	55.1	39.4	30.6	19.2	18.3	15.3	276.5
			% precip.	6.5%	4.4%	2.5%	2.5%	7.3%	12.5%	19.9%	14.2%	11.1%	6.9%	6.6%	5.5%	100.0%

Estimated Site Values

Precipitation Station	Years of Record		Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Williams Creek	long - term	850 m	rain (mm)	0	0	0	0	18	47	75	53	36	4	0	0	233
			% precip.	0.0%	0.0%	0.0%	0.0%	4.9%	12.5%	19.9%	14.2%	9.5%	1.0%	0.0%	0.0%	62.0%
			snow (mm)	24	17	9	9	9	0	0	0	6	22	25	21	143
			% precip.	6.5%	4.4%	2.5%	2.5%	2.4%	0.0%	0.0%	0.0%	1.6%	5.9%	6.6%	5.5%	38.0%
			precip.(mm)	24	17	9	9	27	47	75	53	42	26	25	21	375
			% precip.	6.5%	4.4%	2.5%	2.5%	7.3%	12.5%	19.9%	14.2%	11.1%	6.9%	6.6%	5.5%	100.0%

Notes:

1) Precipitation estimate for elevation 850 m.

2) Estimate made by modifying Carmacks Data:

Data from Canadian Climate Normals: 1961 - 1990

Annual Precipitation : Mean annual value for Williams Creek at its mouth plus orographic allowance (8% per 100m) ie. 286 mm x 1.08^((850-497)/100) = 375 mm.

Precipitation for Williams Creek at its mouth estimated from AES Carmacks and Pelly Ranch data. Orographic allowance from text "Climate of Yukon".

Precipitation Distribution : Precipitation distribution same as Carmacks, however proportion falling as rain and snow has been altered slightly. Williams Creek site is approximately 2 °C colder than Carmacks.

Assume no rain in March, April and November, and less rain in May and October.

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TABLE 2.6
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
WET AND DRY YEAR PRECIPITATION

Annual Precipitation:	mean =	375 mm
	standard deviation =	75 mm

Return Period	Precipitation (mm)
1:10 year dry (mean - 1.282 s.d.)	279
1:20 year dry (mean - 1.645 s.d.)	252
1:10 year wet (mean + 1.282 s.d.)	471
1:20 year wet (mean + 1.645 s.d.)	498
1:50 year wet (mean + 2.054 s.d.)	529
1:100 year wet (mean + 2.326 s.d.)	549
1:200 year wet (mean + 2.575 s.d.)	568

Notes:

1) Precipitation estimates for elevation 850 m. Estimates for other elevations can be made by increasing values 8% per 100 m increase in elevation..
2) Mean value estimated from Pelly Ranch and Carmacks data (AES Climate Normals 1961 - 1990) plus an orographic allowance.
3) Standard deviation estimated from a C.V. value of 0.20. calculated with 14 years of Carmacks data (1964 - 1975. 80. 83).

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TABLE 2.7
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
SITE IDF CURVES

Developed from the "Rainfall Frequency Atlas of Canada".

Duration	Mean	St. Dv.	Factor	Year
5 min	3	2	-0.164	2
10 min	4.1	2.2	0.719	5
15 min	4.2	3	1.305	10
30 min	6.1	2.5	1.635	15
1 hr	8.1	4	1.866	20
2 hr	10	4	2.044	25
6 hr	15	6	2.592	50
12 hr	19	6.1	3.137	100
24 hr	20	7	3.679	200
			18.1741	PMP

Return Period Rainfall Amounts (mm)

Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs	PMP
5 min	2.7	4.4	5.6	6.3	6.7	7.1	8.2	9.3	10.4	39.0
10 min	3.7	5.7	7.0	7.7	8.2	8.6	9.8	11.0	12.2	43.7
15 min	3.7	6.4	8.1	9.1	9.8	10.3	12.0	13.6	15.2	58.2
30 min	5.7	7.9	9.4	10.2	10.8	11.2	12.6	13.9	15.3	51.1
1 hr	7.4	11.0	13.3	14.6	15.6	16.3	18.5	20.6	22.8	80.2
2 hr	9.3	12.9	15.2	16.5	17.5	18.2	20.4	22.5	24.7	82.1
6 hr	14.0	19.3	22.8	24.8	26.2	27.3	30.6	33.8	37.1	123.1
12 hr	22.5	29.2	33.7	36.2	38.0	39.3	43.5	47.7	51.8	161.1
24 hr	23.6	31.3	36.4	39.3	41.3	42.9	47.7	52.4	57.2	182.6

* Calculations include an orographic factor = 1.25 for durations of 12 hours and more.

Rainfall Intensity (mm/hr)

Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs	PMP
5 min	32.1	53.3	67.3	75.2	80.8	85.1	98.2	111.3	124.3	468.3
10 min	22.4	34.1	41.8	46.2	49.2	51.6	58.8	66.0	73.2	262.4
15 min	14.8	25.4	32.5	36.4	39.2	41.3	47.9	54.4	60.9	233.0
30 min	11.4	15.8	18.7	20.4	21.5	22.4	25.2	27.9	30.6	102.3
1 hr	7.4	11.0	13.3	14.6	15.6	16.3	18.5	20.6	22.8	80.2
2 hr	4.7	6.4	7.6	8.3	8.7	9.1	10.2	11.3	12.4	41.0
6 hr	2.3	3.2	3.8	4.1	4.4	4.5	5.1	5.6	6.2	20.5
12 hr	1.9	2.4	2.8	3.0	3.2	3.3	3.6	4.0	4.3	13.4
24 hr	1.0	1.3	1.5	1.6	1.7	1.8	2.0	2.2	2.4	7.6

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TABLE 2.8
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
WILLIAMS CREEK SNOWMELT DATA

1992 Snow Survey Summary

Station Name	Elevation (m)	Approx. Dist. from Site (km)	1992 Snowpack Data (mm)								% Snow Melt			
			March 1		April 1		May 1		May 15		March	April	15-May	>May 15
			snow	water eq.	snow	water eq.	snow	water eq.	snow	water eq.				
Williams #1	739	n/a	60.0	104.0	70.0	120.0	22.0	84.0	0.0	0.0	0%	30%	70%	0%
Williams #2	876	n/a	69.0	110.0	73.0	130.0	36.0	129.0	11.0	38.0	0%	1%	70%	29%
Williams #3	755	n/a	70.0	150.0	74.0	132.0	36.0	103.0	9.0	36.0	12%	19%	45%	24%
Mt. Nansen	1021	50 SW	54.0	92.0	60.0	102.0	25.0	68.0	0.0	0.0	0%	33%	67%	0%
Casino Creek	1065	50 SE	67.0	124.0	70.0	135.0	83.0	207.0	83.0	207.0	0%	0%	0%	100%
Mt. Berdoe	1035	90 NW	76.0	165.0	72.0	170.0	50.0	126.0	38.0	115.0	0%	26%	6%	68%

Long-term Snow Survey Summary

Station Name	Elevation (m)	Years of Record	Water Equivalent (mm)				% Snow Melt			
			March 1	April 1	May 1	May 15	March	April	15-May	> May 15
Mt. Nansen	1021	20	69.0	75.0	15.0	0.0	0%	80%	20%	0%
Casino Creek	1065	16	104.0	124.0	124.0	69.0	0%	0%	44%	56%
Mt. Berdoe	1035	19	95.0	108.0	60.0	19.0	0%	44%	38%	18%

Estimated Long-term Williams Creek Site Snow Melt Distribution

Station Name	% Snow Melt		
	March	April	May
Williams Creek	0%	70%	30%

Notes:

1) Mt. Nansen, Casino Creek and Mt. Berdoe data from Yukon Territory Snow Survey Bulletin.

2) Estimates of long-term Williams Creek values are based on long-term Mt. Nansen records.

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TABLE 2.9
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
MINTO CREEK SNOWMELT DATA

1994 Snow Survey Summary

Station Name	Elevation (m)	Approx. Dist. from Site (km)	1994 Snowpack Data (mm)								% Snow Melt		
			March 1		April 1		May 1		May 15		March	April	May
			snow	water eq.	snow	water eq.	snow	water eq.	snow	water eq.			
Minto #1	914	n/a	53.4	98.0	55.9	112.0	0.0	0.0	0.0	0.0	0%	100%	0%
Minto #2	823	n/a	52.1	86.5	51.7	93.0	0.0	0.0	0.0	0.0	0%	100%	0%
Minto #3	823	n/a	51.0	84.0	43.0	78.0	0.0	0.0	0.0	0.0	7%	93%	0%
Mt. Nansen	1021	50 SW	48.0	73.0	52.0	73.0	0.0	0.0	0.0	0.0	0%	100%	0%
Casino Creek	1065	50 SE	51.0	83.0	61.0	83.0	22.0	56.0	0.0	0.0	0%	33%	67%
Mt. Berdoe	1035	90 NW	56.0	97.0	60.0	110.0	9.0	51.0	0.0	0.0	0%	54%	46%

Long-term Snow Survey Summary

Station Name	Elevation (m)	Years of Record	Water Equivalent (mm)				% Snow Melt		
			March 1	April 1	May 1	May 15	March	April	May
Mt. Nansen	1021	18	70.0	77.0	16.0	0.0	0%	79%	21%
Casino Creek	1065	16	107.0	126.0	128.0	74.0	0%	0%	100%
Mt. Berdoe	1035	19	97.0	110.0	61.0	20.0	0%	45%	55%

Estimated Long-term Minto Site Snow Melt Distribution

Station Name	% Snow Melt		
	March	April	May
Minto	0%	80%	20%

Notes:
1) Mt. Nansen, Casino Creek and Mt. Berdoe data from Yukon Territory Snow Survey Bulletin.
2) All May 15th snow pack is assumed to melt by the end of May.
3) Estimates of long-term Minto Creek values are based on long-term Mt. Nansen records.

TABLE 2.10
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
ESTIMATED RAINFALL AND SNOWMELT DISTRIBUTIONS

Total Annual Precipitation at elevation 850 m = 375 mm

Location	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Williams Creek Site	Rainfall	0	0	0	0	18	47	75	53	36	4	0	0	233
	% rainfall	0.0%	0.0%	0.0%	0.0%	7.9%	20.2%	32.1%	22.9%	15.3%	1.6%	0.0%	0.0%	100.0%
	% precip.	0.0%	0.0%	0.0%	0.0%	4.9%	12.5%	19.9%	14.2%	9.5%	1.0%	0.0%	0.0%	62.0%
	Snowmelt	0	0	0	100	43	0	0	0	0	0	0	0	143
	% snowmelt	0.0%	0.0%	0.0%	70.0%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	% precipitation	0.0%	0.0%	0.0%	26.6%	11.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	38.0%
	Total Precipitation	0	0	0	100	61	47	75	53	36	4	0	0	375
	% precipitation	0.0%	0.0%	0.0%	26.6%	16.3%	12.5%	19.9%	14.2%	9.5%	1.0%	0.0%	0.0%	100.0%

Notes:

1) For water balance modeling, the total precipitation values should be used to represent water inflow due to direct precipitation.

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TABLE 2.11
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
MEAN MONTHLY POND EVAPORATION (mm)

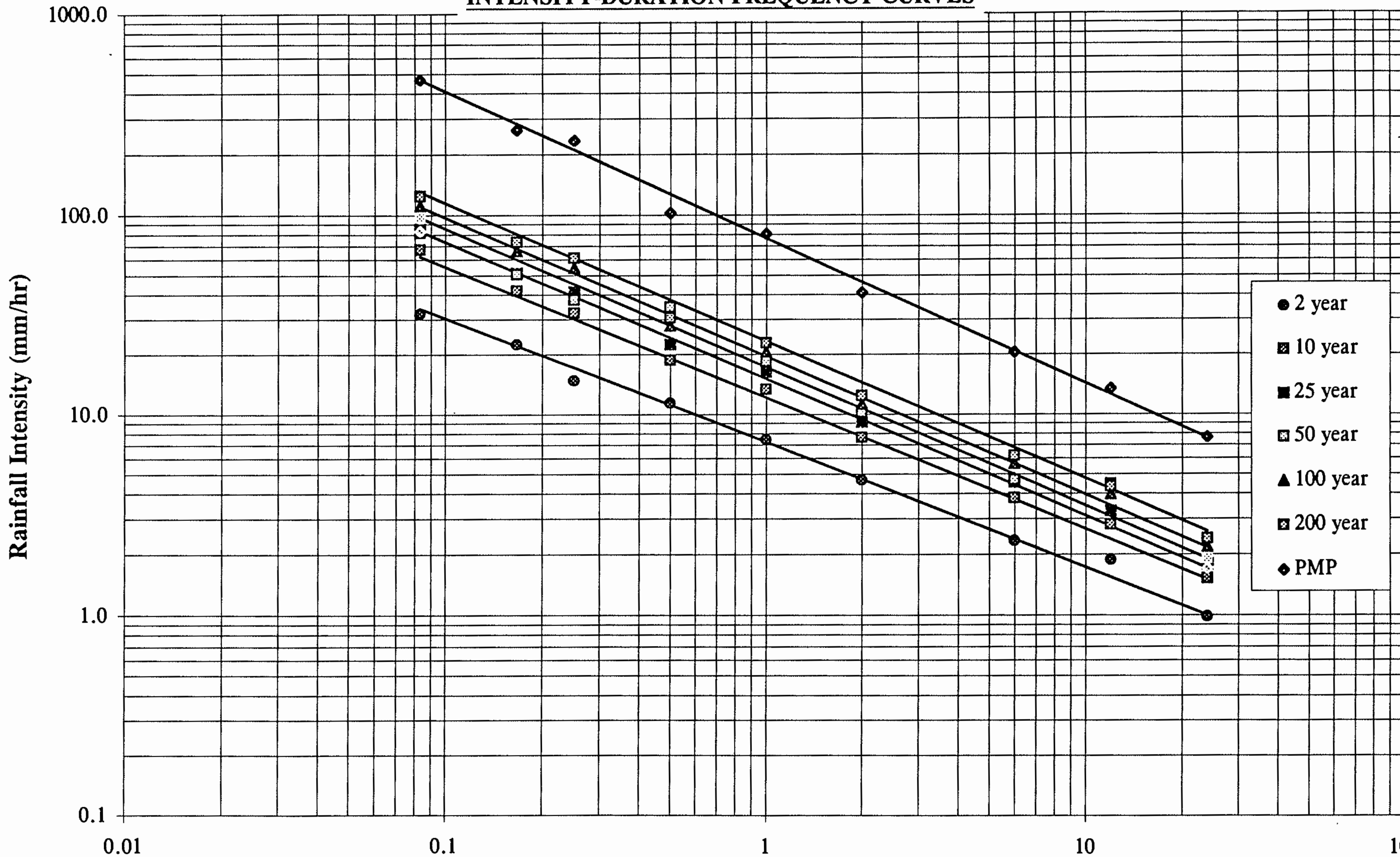
Station	Elevation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pelly Ranch	454 m	0	0	0	0	105	121.3	111.2	80	36.6	0	0	0	454.1
Williams Creek Site	675 m	0	0	0	0	99	114	105	75	34	0	0	0	427
Williams Creek Site	850 m	0	0	0	0	93	108	99	71	33	0	0	0	404

Notes:

1) Pelly Ranch values from 28 years of data collected from AES station 2100880, at elevation 454 m.

2) Williams Creek site data generated by reducing Pelly Ranch values by 10% per 350m rise in elevation, as suggested by the MOE Manual of Operational Hydrology in B.C.
ie. 675 - 454 = 221 and 221/350 x 10% = 6%.

FIGURE 2.1
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
INTENSITY-DURATION-FREQUENCY CURVES



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SECTION 3.0 - HYDROLOGY

3.1 GENERAL

Streamflows in the Yukon are generally characterized by peak flows in the spring and low flows in the winter. Maximum discharges typically occur during the spring as the result of snow melt or-rain-on-snow events, with flows gradually decreasing following the disappearance of snow. Sizeable flood events may also occur in the late summer due to intense rainstorms. These rainfall events are particularly significant on small basins. The smallest discharges of the year occur in mid-winter. Ice develops on all rivers and many streams freeze entirely, reducing their winter flows to zero.

3.2 DESCRIPTION OF WATERSHED

The Williams Creek watershed which consists of two principal basins, Williams Creek and its tributary, Nancy Lee Creek. Each creek drains approximately half of the 88 km^2 drainage area. Williams Creek has a main channel length of approximately 15.5 km, an average slope of 3%, and a basin elevation range of approximately 500 m to 1000m. The creek flows into the Yukon River about 40 km northwest of the town of Carmacks. Nancy Lee Creek has a channel width of approximately 13 km, an average gradient of 2.8% and a basin elevation that ranges from 518 to 882 m. It flows east into Williams Creek, approximately 1.3 km upstream of the Yukon River confluence.

3.3 REGIONAL STREAMFLOW STATIONS

Streamflow values are recorded at a number of locations throughout the Yukon by Water Survey of Canada (WSC) and INAC. Those stations most relevant to the Williams Creek basin are Big

Salmon River, South Big Salmon River, Big Creek (near the mouth), Nordenskiold River, Thistle Creek and Scroggie Creek (Table 3.1).

3.4 SITE STREAMFLOW RECORDS

Since 1991, John Gibson and Associates have maintained a number of staff gauges and automatic level recorders at various locations on the Williams Creek watershed. Significant amounts of flow data have been recorded at three locations on the creek, as shown on Figure 3.1. Data from 1991 and 1992 were obtained from staff gauges, while 1993/94 data was obtained using a Stevens automatic water level recorder. Data from 1992, 1993 and 1993 are summarized in Table 3.2 and Figures 3.2 to 3.6. The 1991 data is not summarized in Table 3.2 because it is short-term and discontinuous, and therefore not significant.

3.5 MEAN ANNUAL RUNOFF

Determining runoff estimates for the Williams basin is extremely difficult due to the paucity of-site-specific and relevant regional data. Flow records for Williams Creek are only available for short periods during the years of 1992 to 1994, and they do not adequately represent long-term runoff values and patterns. Therefore, regional streamflow records were used to generate synthetic long-term records for the site on the basis of concurrent site and regional records. Unfortunately, regional data in the Yukon is available for only a few rivers and all have drainage basins much larger than Williams Creek. To further complicate matters, the climate and hydrology of the Yukon are extremely basin specific, with adjacent basins sometimes exhibiting dramatically different runoff regimes. Due to extremely cold and lengthy winters, much of the Yukon freezes solid for several months each year, resulting in a significant snowmelt component of runoff. In addition, total runoff volumes and distributions are very dependent on basin elevations on account of freezing levels and orographic influences.

Clearly, there are many factors which influence runoff and consequently considerable uncertainty is associated with deriving runoff estimates. The reader will note that many references are made throughout this text to the fact that streamflow values are best estimates, based on accepted hydrological practices and sound engineering judgement, and are believed to be reasonably precise given their intended use. The numerous references are not intended to undermine the validity of the estimates but to make the reader aware of the uncertainty involved in their determination. As more site specific data becomes available, estimated values can be refined.

The following describes the procedures used to estimate runoff values for Williams Creek at the location of the proposed water storage dam.

Regional discharge values were used to estimate Williams Creek long-term average annual runoff. After examining all available flow records it was determined that Big Creek is the most representative basin with long-term records (WSC station 09AH003), since it is unregulated and located adjacent to the Williams Creek basin. Therefore, runoff estimates were made by using Big Creek data to determine rainfall runoff coefficients and snowmelt runoff values. Mean annual flow for Big Creek is estimated as 143 mm (7.96 m^3/s).

Big Creek drains a basin with an area of 1750 km^2, a mean elevation of approximately 1150 m and maximum elevations in excess of 1900 m. In contrast, Williams Creek drains a basin with an area of approximately 88 km^2, a mean elevation of approximately 800 m and maximum elevations up to 1000 m. In particular, for the water balance model, the area of interest is in the upper reaches of the catchment. The drainage basin above the proposed water storage pond has an area of approximately 31 km^2 and a mean elevation of approximately 830 m. The location of the basin draining into the water storage pond is shown on Figure 3.7.

Runoff and concurrent estimated rainfall records for Big Creek and Williams Creek were examined in order to determine the percentage of runoff due to rainfall or snowfall. The results of this analysis are shown in Table 3.3 and indicate that the runoff coefficients for the after freshet periods (ie rainfall-runoff only) of Williams Creek flow range from approximately 8% to 20.7%. The 9.1% value is based on actual concurrent rainfall and runoff records, while the 8% and 20.7% values are based on estimated rainfall and actual runoff values. The large difference between the estimated and actual 1992 rainfall values should be noted. It is believed that the site measured values may be incorrect as they are abnormally large.

The results of the analysis also indicate that the average annual runoff coefficient for Big Creek (29.1%) is essentially the same as the average runoff coefficient during the rainfall-only months of July, August and September (29.9%). Therefore, it is reasonable to assume that the average annual runoff coefficient for Williams Creek is also similar to its rainfall runoff coefficient. While it is understood that this approach is slightly simplistic, it does serve to provide the basis for reasonable approximations.

From the results of Tables 3.2 and 3.3, it is clear that the rainfall runoff coefficient for Williams Creek is much less than the 30% value of Big Creek. As the two basins are very similar in terms of location, vegetation, topography, etc., one would expect their runoff coefficients to also be similar. However, the basins are substantially different in size which may account for some of the difference. In addition, it is believed that a significant portion of runoff in Williams Creek may be lost due to streambed infiltration. As the site data indicates that flows are extremely low in Williams Creek, and as it is more prudent to err on the low side when estimating annual and monthly flows, a rainfall runoff coefficient of 15% was adopted. This value is approximately half way between the 8% and 20.7% values calculated in Table 3.3. The 9.1% value was not given direct consideration because it was based on actual precipitation values, while this runoff coefficient will only be used in connection with estimated precipitation values. Therefore, based on a runoff coefficient of 15% and an annual precipitation estimate of 370 mm, annual runoff in Williams Creek at the location of the proposed water storage pond is estimated to be 56 mm.

3.6 MONTHLY RUNOFF DISTRIBUTIONS

Since site streamflow data is limited, and as the only regional streamflow stations service basins of much greater size and with much greater relief than Williams Creek, available streamflow records did not provide an adequate basis for estimating runoff distribution. Consequently, rainfall and snowmelt records were used to estimate the runoff distribution. For the basin draining into the proposed water storage pond, the monthly runoff distribution was estimated to be the result of combining estimated rainfall and snowmelt distributions. The rainfall and snowmelt distributions were assumed to be the same as those used for estimating the distribution of direct precipitation. The estimated monthly distribution of runoff for Williams Creek is shown in Table 3.4.

3.7 WET AND DRY YEAR RETURN PERIOD RUNOFF

Wet and dry year return period runoff values were estimated for Williams Creek at the location of the proposed water storage pond. The estimates were made by assuming that annual runoff values have an underlying normal distribution with a mean of 56 mm and a standard deviation of 19 mm. The standard deviation values were determined with a coefficient of variation value of 0.34, which was calculated from 18 years of Big Creek data. Estimates of return period runoff are given in Table 3.5., and associated runoff coefficients are given in Table 3.6. Monthly distributions during both high and low flow years are assumed to be the same as the distribution during an average year. This assumption is substantiated by the results of Table 3.7. This table compares wet, dry and average year distributions for Big Creek. As can be seen, the values have large standard deviations and thus the wet and dry distributions do not significantly differ from the average distribution.

3.8 SEVEN-DAY AVERAGE LOW FLOW

During winter visits to the Williams Creek site to collect snowpack data, Williams Creek was found to be dry and frozen solid. As the long-term average winter temperatures for the Williams Creek basin are estimated at values considerably below freezing, it is reasonable to assume that the complete freezing of the creek is an annual occurrence. Therefore, the seven day average low flow is estimated to be 0 m^3/s.

3.9 PEAK INSTANTANEOUS FLOWS

Peak instantaneous flows are required for the Carmacks Copper Project in order to design a spillway and dam construction bypass for the water storage facility. As there are no peak flow records for the Williams Creek basin, return period peak flows were derived with three different estimating procedures, the results were compared, and reasonable estimates was made on the basis of all three values. The three flow estimating procedures used are the Janowicz Method, regional frequency analysis, and HEC-1 modelling, and the results of these analyses are shown in Table 3.8.

The first approach was to use a regional procedure developed for INAC by Janowicz (1989). Janowicz developed his method through a regional flood frequency analysis of flow data from 86 stations operated in the Yukon by INAC and WSC. This technique allows return period discharges to be estimated on the basis of watershed area and stream channel gradient. It should be noted that this method may tend to underestimate peak flows for small catchments as it is based upon data from large catchments which tend to not respond in as "peaky" a fashion. In addition, the method only distinguishes between basins with slopes of less than or greater than 4.5%, and does not account for degrees of steepness beyond this. Details of this analysis are shown in Table 3.9. Values for both mountain and interior regions are provided. The Williams Creek basin is classified as interior, but mountain values are also presented for comparitive purposes.

The second approach was to base estimates on values generated by frequency analyses of peak flow data for Big Creek and Thistle Creek (Table 3.10). All flood frequency values were generated with Environment Canada's Consolidated Frequency Analysis software CFA88. Flood frequency values were derived by averaging the 3 Parameter Lognormal and Log Pearson Type III values. The Extreme Value and Wakeby estimates were discarded as they produced the high and low values for the longer return periods. Estimates for Williams Creek were made by adjusting the Big Creek and Thistle Creek values by catchment area ratios raised to the power of 0.8 (ie. $31.0/1750)^{0.8} = 0.040$).

As with the first approach, this technique has its shortfalls. Although it attempts to account for differing basin sizes, it does not account for various other significant basin characteristics such as slope and surface cover. However, the model creeks are reasonably representative of the area of interest in the Williams Creek basin, and therefore the method provides reasonable estimates of peak flows.

The final approach was to use the HEC-1 computer program, a hydrologic package developed by the Hydrologic Engineering Centre of the U.S. Army Corps of Engineers. This model is the recognized industry standard in North America for generating runoff hydrographs from precipitation data. Inputs to the HEC-1 model include precipitation, precipitation distribution, and various physical characteristics of the watershed. Ideally, the model should be calibrated with site rainfall and concurrent storm runoff data. However, as this is not available, the input parameters were estimated from regional data and site characteristics. A summary of the input parameters is given in Table 3.11. Two key inputs which require some explanation are precipitation and curve number.

Precipitation values were taken from the IDF curve data for 24 hour storm events and the Type I distribution was selected to reflect the changing rainfall intensities throughout the storm period. The fact that the model does not directly account for a rainfall on snow event is a source of error in this analysis. However, as records for Big Creek indicate that almost all peak flow events occur during the freshet, an effort was made to model freshet conditions. This was achieved by assuming a very high antecedent moisture condition, which in turn demanded a very high runoff curve number.

As annual precipitation in the Williams Creek basin is only between 300 mm and 400 mm, and as annual pond evaporation exceeds annual precipitation, the moisture content of soil-cover complexes is generally very low, and the antecedent moisture condition can generally be considered dry (AMC I). During successive large rainfall events, it would be reasonable to assume that the antecedent moisture condition is moderate (AMC II). These two conditions represent low and moderate runoff potential. However, during the freshet the ground is saturated from snowmelt, and/or partially frozen and essentially impervious. In this case, the basin can be considered to have a high antecedent moisture condition (AMC III), and this condition was assumed for the analysis.

The curve number (CN) value selected for the basin draining into the water storage pond is 83. This value was selected on the basis of the following:

gravely-sand, silty-sand, clayey-sand
large permeability range 10^{-1} to 10^{-6} cm/s (soil group B)
fair hydrologic condition (between 30% and 70% ground cover density)
forestland, coniferous or deciduous
AMC III

Again, as with the two previous methods, the HEC-1 model has its limitations. Clearly, there is considerable uncertainty associated with estimating each model parameter. However, with carefully chosen inputs the model can produce reasonable flow estimates, and the results of this analysis are in agreement with the Janowicz and regional values.

After carefully considering the results of all three techniques, "best estimated" peak flow values were estimated and are presented in Table 3.12. These values were generated by increasing the regional Big Creek values by 10%. This increase is somewhat arbitrary but results in conservative, yet reasonable, values. The 200 year return period estimated peak flow is 12.1 m^3/s.

TABLE 3.1
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
REGIONAL STREAMFLOW RECORDS

Description	Station No.	Years of Record	Measurement Period	Control	Distance Between Sites (km)	Basin Area (km^2)	Approx. Mean Basin Elev. (m)	Mean Annual Runoff	
								(m^3/s)	(mm)
Big Salmon River	09AG001	30	year round	unregulated	140 SE	6760	1300	68.8	321
South Big Salmon River	09AG003	11	year round	unregulated	140 SE	515	2000	4.2	258
Big Creek Near the Mouth	09AH003	17	year round	unregulated	25 NW	1750	1150	8.0	143
Nordenskiold River	09AH004	10	year round	unregulated	50 SE	6370	1000	16.3	80
Thistle Creek	29CD001	8	thaw	partially regulated	190 NW	210	750	0.6	88
Scroggie Creek	29DD003	9	thaw	partially regulated	150 NW	730	750	1.6	68
Williams Creek	n/a	n/a	n/a	unregulated	n/a	31	830	n/a	n/a

Notes:
1) Data for stations 09AG001 to 09AH004 supplied by Water Survey of Canada (WSC). Gauges operated year round.
2) Data for stations 29CD001 and 29DD003 supplied by Dept. of Indian and Northern Affairs Canada (INAC). Gauges not operated during freeze perio
3) Distance between sites refers to distances between centers of basin areas.
4) Williams Creek area is not the entire basin but just the area upstream of the location of the proposed water storage pond.

TABLE 3.2
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
SITE STREAMFLOW VALUES

Years of Record	Streamflow Station	Area (km^2)	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1992	Williams Creek	12.8	m^3/s						0.02	0.09	0.03					
	(staff gauge)		mm						4.7	18.6	5.4					
	Big Creek	1750	m^3/s	1.10	0.45	0.49	1.37	52.20	33.70	36.20	12.40	16.50	4.92	2.02	1.10	13.54
	(09AH003)		mm	1.7	0.6	0.7	2.0	79.9	49.9	55.4	19.0	24.4	7.5	3.0	1.7	243.9
	ratio Williams/Big		%						9%	34%	29%					
1993	Williams Creek	23.9	m^3/s						0.04	0.03	0.04	0.07	**0.09**			
	(data logger No. 2)		mm						4.7	3.5	3.3	7.1	**10.0**			28
	Big Creek	1750	m^3/s	0.48	0.24	0.19	5.33	36.00	10.00	12.60	13.50	7.22	**2.07**	1.89	1.33	7.64
	(09AH003)		mm	0.7	0.3	0.3	7.9	55.1	14.8	19.3	20.7	10.7	**2.9**	2.8	2.0	137.7
	ratio Williams/Big		%						31%	18%	16%	67%	348%			
1994	Williams Creek	23.9	m^3/s					**0.07**	0.03	**0.04**						
	(data logger No. 2)		mm					**3.07**	3.69	**3.82**						
	Big Creek	1750	m^3/s						8.59							
	(09AH003)		mm						12.7							
	ratio Williams/Big		%						29%							

Notes:

1) Big Creek data from Water Survey of Canada (WSC).

2) Bold values are for period of record only, not entire month. October '93 is for 1-28, May '94 is for 19-31 and July '94 is for 1-24.
Comparitive Big Creek values are for comparitive periods of record.

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TABLE 3.3

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

ESTIMATED RUNOFF COEFFICIENT

Creek	Mean Basin Elevation	Basin Area	Time Period	Total Flow (mm)	Estimated Precipitation (mm)	Runoff Coeff.
Williams 1992	830	12.84	June 10 to August 31	26.73	295 (1) 129	9.1% 20.7%
Williams 1993	830	23.92	June 17 to October 28	23.41	not available	n/a
Williams 1994	830	23.92	May 22 to July 24	8.44	106	8.0%
Big Creek	1150	1750	1975-93	143.0	491	29.1%
Big Creek	1150	1750	June 1975-93	26.0	60	43.3%
Big Creek	1150	1750	Jul, Aug, Sep 1975-93	64	214 (2)	29.9%
Big Creek	1150	1750	Apr, May, Jun 1975-93	69.4	118	58.8%

Notes:

1) Actual measured site precipitation. There is some doubt as to the validity of this value as it is so large. This is the only precipitation value in the table which is not estimated.

2) Jul, Aug, Sep 1975-93 runoff likely contains very little snowmelt.

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TABLE 3.4
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
ESTIMATED RAINFALL AND SNOWMELT DISTRIBUTIONS

Total Annual Runoff at the Water Storage Pond = 56 mm

Location	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Williams Creek Site	Rainfall	0	0	0	0	3	7	11	8	5	1	0	0	35
(water storage pond)	% rainfall	0.0%	0.0%	0.0%	0.0%	7.9%	20.2%	32.1%	22.9%	15.3%	1.6%	0.0%	0.0%	100.0%
	% runoff	0.0%	0.0%	0.0%	0.0%	4.9%	12.5%	19.9%	14.2%	9.5%	1.0%	0.0%	0.0%	62.0%
	Snowmelt	0	0	0	15	6	0	0	0	0	0	0	0	21
	% snowmelt	0.0%	0.0%	0.0%	70.0%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	% runoff	0.0%	0.0%	0.0%	26.6%	11.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	38.0%
	Total Runoff (mm)	0	0	0	15	9	7	11	8	5	1	0	0	56
	Total Runoff (m^3/s)	0.00	0.00	0.00	0.18	0.11	0.08	0.13	0.09	0.06	0.01	0.00	0.00	0.06
	% runoff	0.0%	0.0%	0.0%	26.6%	16.3%	12.5%	19.9%	14.2%	9.5%	1.0%	0.0%	0.0%	100.0%

Notes:

1) For water balance modeling, the total runoff values should be used to represent water inflow due to precipitation on the basin draining into the water storage pond.

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TABLE 3.5
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
WET AND DRY YEAR RUNOFF

1) At Water Storage Pond

Annual Runoff	mean =	56 mm
	standard deviation =	19 mm

Return Period	Runoff (mm)
1:10 year dry (mean - 1.282 s.d.)	32
1:20 year dry (mean - 1.645 s.d.)	25
1:10 year wet (mean + 1.282 s.d.)	80
1:20 year wet (mean + 1.645 s.d.)	87
1:50 year wet (mean + 2.054 s.d.)	95
1:100 year wet (mean + 2.326 s.d.)	100
1:200 year wet (mean + 2.575 s.d.)	105

Notes:

1) Estimates assume a normal distribution of annual runoff.

2) Standard deviation estimated from a C.V. value of 0.34, calculated with 18 years of WSC Big Creek flow data (1975 - 1993).

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TABLE 3.6
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
WET AND DRY YEAR RUNOFF COEFFICIENTS

Return Period	Runoff (mm)	Precipitation (mm)	Runoff Coefficient
average year	56	370	0.15
1:10 year dry	32	275	0.11
1:20 year dry	25	248	0.10
1:10 year wet	80	465	0.17
1:20 year wet	87	492	0.18
1:50 year wet	95	522	0.18
1:100 year wet	100	542	0.18
1:200 year wet	105	561	0.19

Notes:

1) Runoff and precipitation estimates are for the basin draining into the water storage pond.
Average elevation of the basin is 830 m.

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TABLE 3.7
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
DRY, WET AND AVERAGE YEAR STREAMFLOW DISTRIBUTIONS

Streamflow Station	Years of Record	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Big Creek (DRY)	1989	m3/s	0.40	0.18	0.08	0.18	10.60	7.88	6.13	4.74	3.96	2.47	1.13	0.52	3.19
		%	1.1%	0.5%	0.2%	0.5%	27.7%	20.6%	16.0%	12.4%	10.3%	6.5%	3.0%	1.3%	100.0%
	1981	m3/s	0.18	0.17	0.17	0.23	12.80	4.72	18.40	14.00	5.89	4.80	1.61	0.43	5.28
		%	0.3%	0.3%	0.3%	0.4%	20.2%	7.4%	29.0%	22.1%	9.3%	7.6%	2.5%	0.7%	100.0%
	1977	m3/s	0.22	0.20	0.15	0.51	17.60	17.90	15.80	3.92	4.28	2.79	0.70	0.09	5.35
		%	0.3%	0.3%	0.2%	0.8%	27.4%	27.9%	24.6%	6.1%	6.7%	4.3%	1.1%	0.1%	100.0%
	average	%	0.6%	0.4%	0.2%	0.5%	25.1%	18.6%	23.2%	13.5%	8.8%	6.1%	2.2%	0.7%	100.0%
	st. dev.		0.4%	0.1%	0.0%	0.2%	4.3%	10.4%	6.6%	8.0%	1.9%	1.6%	1.0%	0.6%	
Big Creek (WET)	1992	m3/s	1.10	0.45	0.49	1.37	52.20	33.70	36.20	12.40	16.50	4.92	2.02	1.10	13.54
		%	0.7%	0.3%	0.3%	0.8%	32.1%	20.7%	22.3%	7.6%	10.2%	3.0%	1.2%	0.7%	100.0%
	1990	m3/s	0.26	0.11	0.07	21.80	76.80	17.00	8.48	3.65	19.00	5.88	0.96	0.32	12.90
		%	0.2%	0.1%	0.0%	14.1%	49.8%	11.0%	5.5%	2.4%	12.3%	3.8%	0.6%	0.2%	100.0%
	1991	m3/s	0.21	0.26	0.37	2.77	49.60	23.10	18.10	18.00	20.50	5.75	3.59	2.15	12.03
		%	0.1%	0.2%	0.3%	1.9%	34.4%	16.0%	12.5%	12.5%	14.2%	4.0%	2.5%	1.5%	100.0%
	average	%	0.3%	0.2%	0.2%	5.6%	38.7%	15.9%	13.4%	7.5%	12.2%	3.6%	1.5%	0.8%	100.0%
	st. dev.		0.3%	0.1%	0.1%	7.4%	9.6%	4.9%	8.4%	5.1%	2.0%	0.5%	0.9%	0.6%	
Big Creek (AVERAGE)	average	%	0.3%	0.2%	0.2%	2.1%	28.2%	18.2%	20.4%	14.0%	10.5%	4.0%	1.3%	0.6%	100.0%

Notes:

1) Big Creek data from Water Survey of Canada (WSC).

2) Given the large standard deviation values, wet and dry distributions are not significantly different than the average distribution.

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TABLE 3.8
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
HEC-1 PEAK INSTANTANEOUS FLOW ESTIMATES

HEC-1 Analysis

Basin	Area (km^2)	Return Period (years)	24 hr Rainfall (mm)	Peak Discharge (m^3/s)
Water Storage Pond	31	2	24	1.7
		10	36	5.0
		25	43	7.7
		50	48	9.8
		100	52	11.7
		200	57	14.3

Notes: All flow estimates assume the ground is either saturated and/or partially frozen.

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TABLE 3.9
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
JANOWICZ ESTIMATES OF PEAK INSTANTANEOUS FLOWS

Janowicz Technique

Basin	Area (km^2)	Region	Return Period (years)	Regression Constant "a"	Regression Constant "b"	Peak Discharge (m^3/s)
Williams Creek (water storage pond)	31	Mountain	2	0.085	1.007	2.7
			10	0.257	0.923	6.1
			25			
			50	0.5	0.873	10.0
			100	0.631	0.855	11.9
			200			
Williams Creek (water storage pond)	31	Interior	2	0.083	0.951	2.2
			10	0.176	0.917	4.1
			25			
			50	0.277	0.897	6.0
			100	0.324	0.89	6.9
			200			

Notes:
Estimating technique developed by Rick Janowicz, Senior Hydrologist with the Department of Indian and Northern Affairs Canada (INAC).

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TABLE 3.10
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
REGIONAL FREQUENCY ESTIMATES OF PEAK INSTANTANEOUS FLOWS

Regional Analysis - Big Creek

Basin	Area	Return Period	Peak Flows (based on various distributions)				
	(km^2)	(years)	Extreme Value	3-P Lognormal	Log Pearson III	Wakeby	Best Guess
Big Creek	1750	2	116	115	114	115	115
		10	195	201	207	203	204
		25	223	236	240	243	238
		50	245	265	265	277	265
		100	262	290	284	305	287
		200	277	315	300	332	308
Williams Creek (water storage pond)	31	2	4.6	4.6	4.5	4.6	4.6
		10	7.7	8.0	8.2	7.7	7.7
		25	8.9	9.4	9.5	8.9	8.9
		50	9.7	10.5	10.5	9.7	9.7
		100	10.4	11.5	11.3	10.4	10.4
		200	11.0	12.5	11.9	11.0	11.0

Regional Analysis - Thistle Creek

Basin	Area	Return Period	Peak Flows (based on various distributions)				
	(km^2)	(years)	Extreme Value	3-P Lognormal	Log Pearson III	Wakeby	Best Guess
Thistle Creek	210	2	17.5	17.4	17.5	17.4	17.5
		10	29	29.9	29.1	29.8	29.5
		25	34.6	36.1	34.6	36.7	35.4
		50	39.7	41.8	39.4	42.9	40.6
		100	44.4	47.1	43.8	48.7	45.5
		200	49.2	52.5	48.3	54.7	50.4
Williams Creek (water storage pond)	31	2	3.8	3.8	3.8	3.8	3.8
		10	6.3	6.5	6.3	6.4	6.4
		25	7.5	7.8	7.5	7.9	7.7
		50	8.6	9.0	8.5	9.3	8.8
		100	9.6	10.2	9.5	10.5	9.8
		200	10.6	11.4	10.5	11.8	10.9

Notes

1) All peak flow values generated with WSC's flood frequency software CFA88.

2) Values based on 15 years of Big Creek data and 14 years of Thistle Creek data.

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TABLE 3.11
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
HEC-1 INPUT PARAMETERS

Input Parameter	Estimated Value
Time of Concentration (Tc)	4 hrs
Basin Area	31.0 sq. km
Storage Coefficient	4 hrs
Curve Number (CN)	83
Initial Abstraction (Ia)	10.4 mm
Starting Flow	0.11 m^3/s
End Flow	0.11 m^3/s
24 hr - 1 in 2 Year Precipitation	24 mm
24 hr - 1 in 10 Year Precipitation	36 mm
24 hr - 1 in 25 Year Precipitation	43 mm
24 hr - 1 in 50 Year Precipitation	48 mm
24 hr - 1 in 100 Year Precipitation	52 mm
24 hr - 1 in 200 Year Precipitation	57 mm
Precipitation Distribution	SCS Type 1
Unit Hydrograph Type	Clark
Rate of Decay	1.001 (0.1% per hour)

Notes:

1) Assume antecedent moisture condition (AMC) III for all return periods. This assumes that peak storms occur during the freshet when the ground is saturated and/or partially frozen.

2) Initial abstraction = 0.2S.

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TABLE 3.12
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
PEAK INSTANTANEOUS FLOWS

Summary of Return Period Peak Flow Estimates (m^3/s)

Basin	Area (km^2)	Technique	Return Period (years)					
			2	10	25	50	100	200
Water Storage Pond	31	Janowicz - Mountain	2.7	6.1		10	11.9	
		Janowicz - Interior	2.2	4.1		6	6.9	
		Regional - Big Creek	4.6	7.7	8.9	9.7	10.4	11
		Regional - Thistle Creek	3.8	6.4	7.7	8.8	9.8	10.9
		HEC-1	1.7	5	7.7	9.8	11.7	14.3
		Best Estimate	5.1	8.5	9.8	10.7	11.4	12.1

Notes:
1) "Best Estimates" were generated by increasing regional-Big Creek values by 10%.

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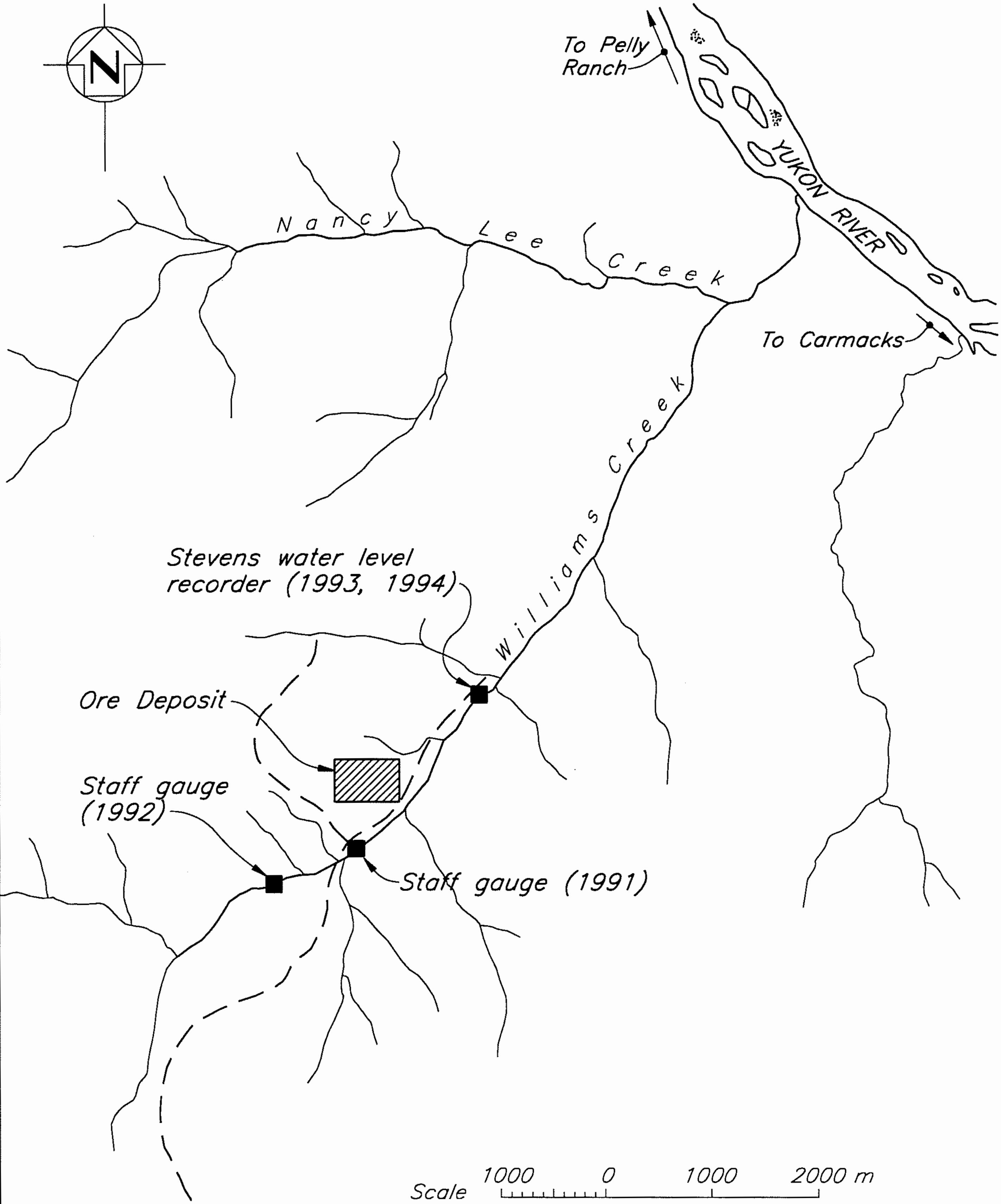
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
HYDROLOGY STATION LOCATIONS



May 1, 1995

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ENVIRONMENTAL CONSULTANTS

FIGURE 3.1

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FIGURE 3.2
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT - WILLIAMS CREEK
SUMMARY OF DAILY DISCHARGES IN m^3/s - 1991 TO 1994

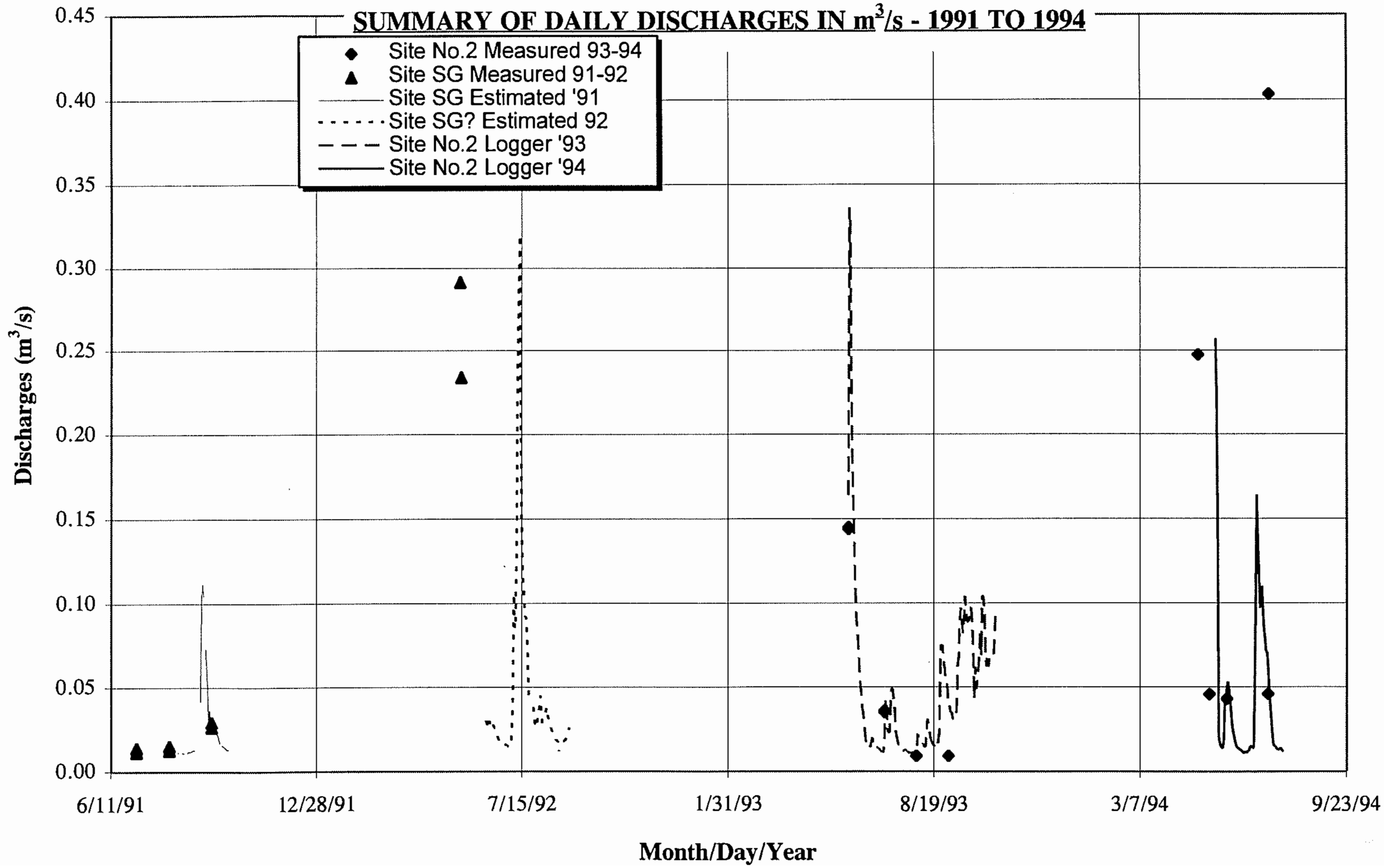

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FIGURE 3.3

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT - WILLIAMS CREEK

DAILY DISCHARGES IN m^3/s - 1991

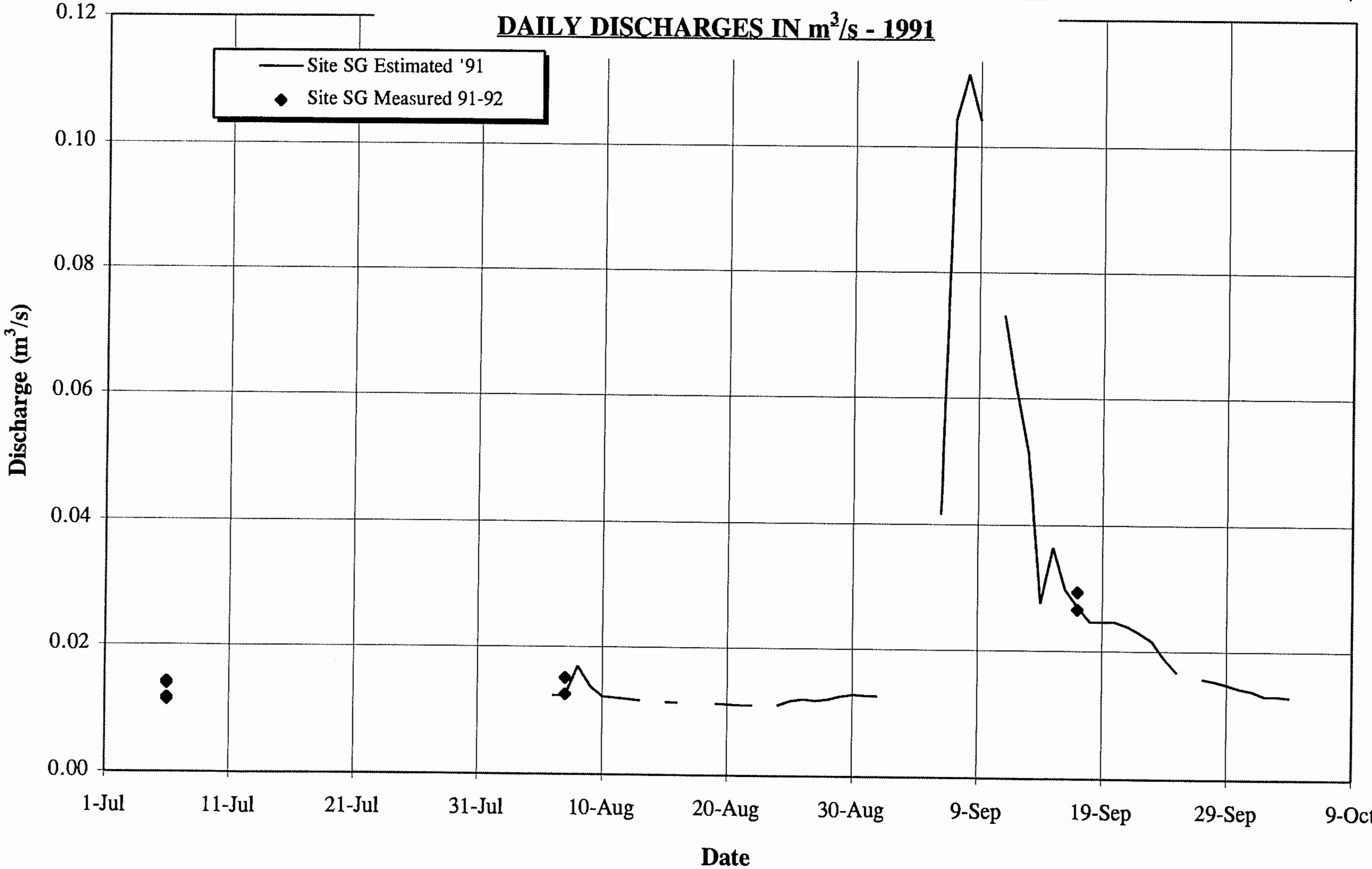

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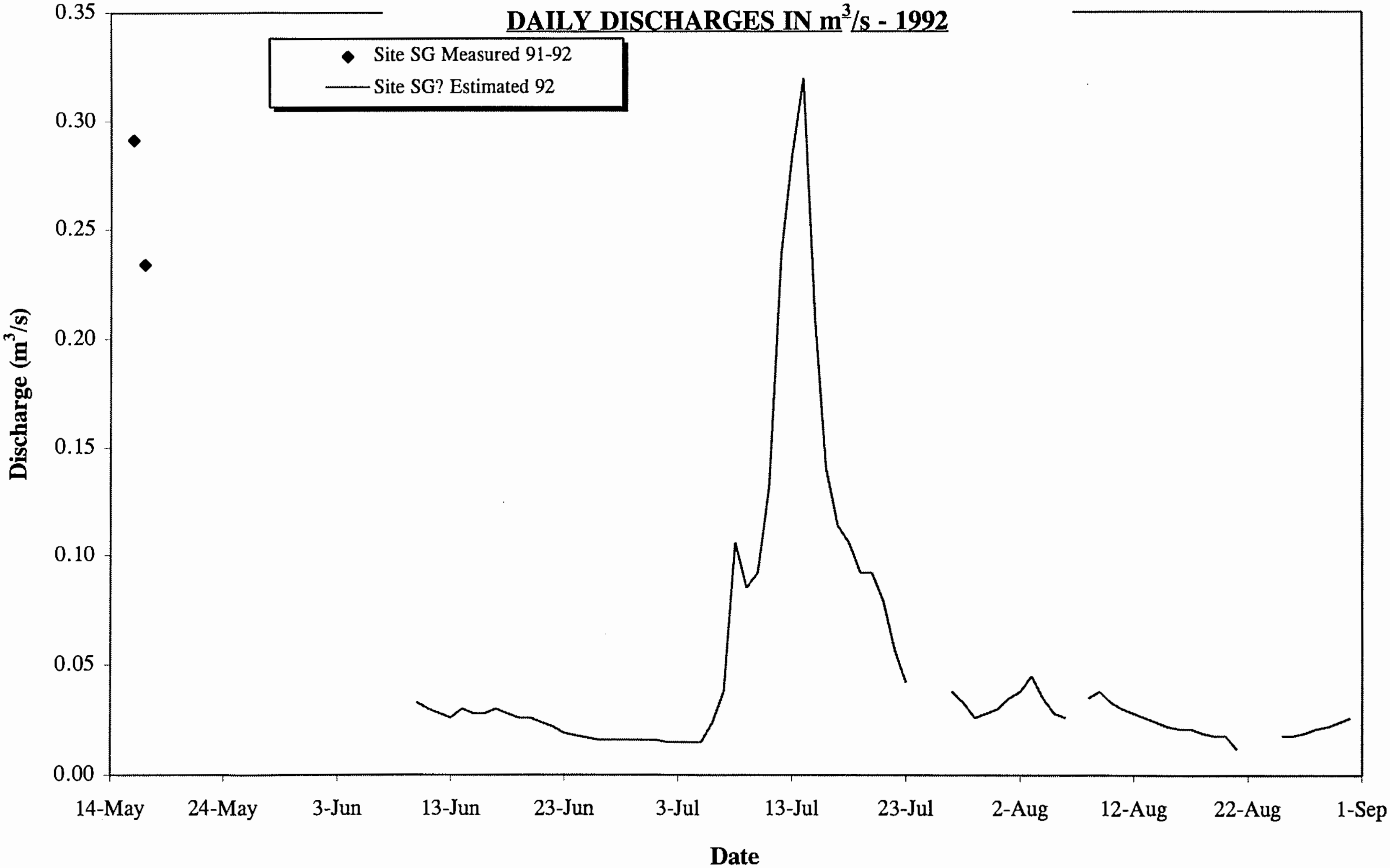
FIGURE 3.4
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT - WILLIAMS CREEK
DAILY DISCHARGES IN m^3/s - 1992



J:\JOB\DATA\1783\HYDMET\OTHERS\HYDRODAT.XLS Chart3.5
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FIGURE 3.5
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT - WILLIAMS CREEK
DAILY DISCHARGES IN m^3/s - 1993

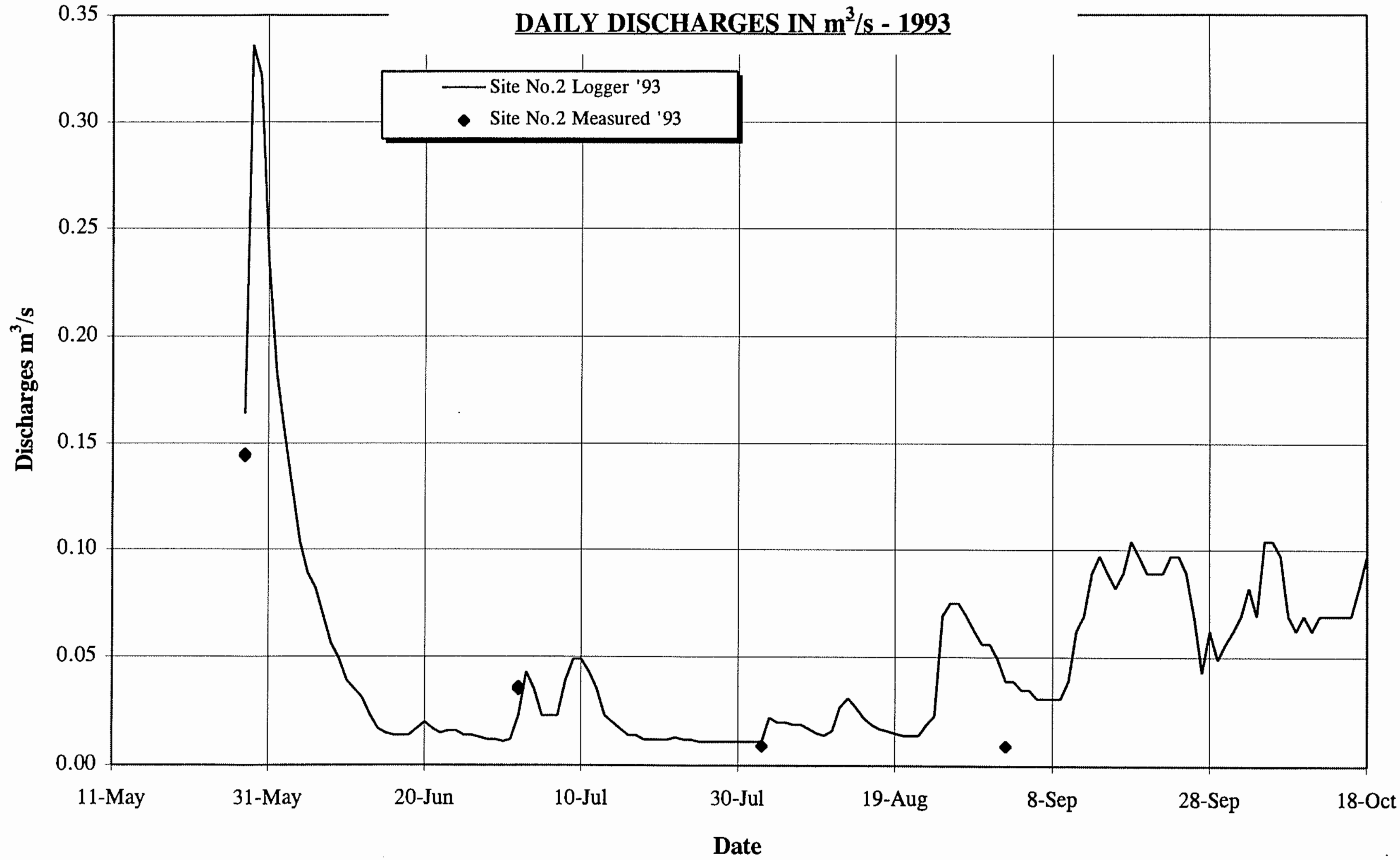
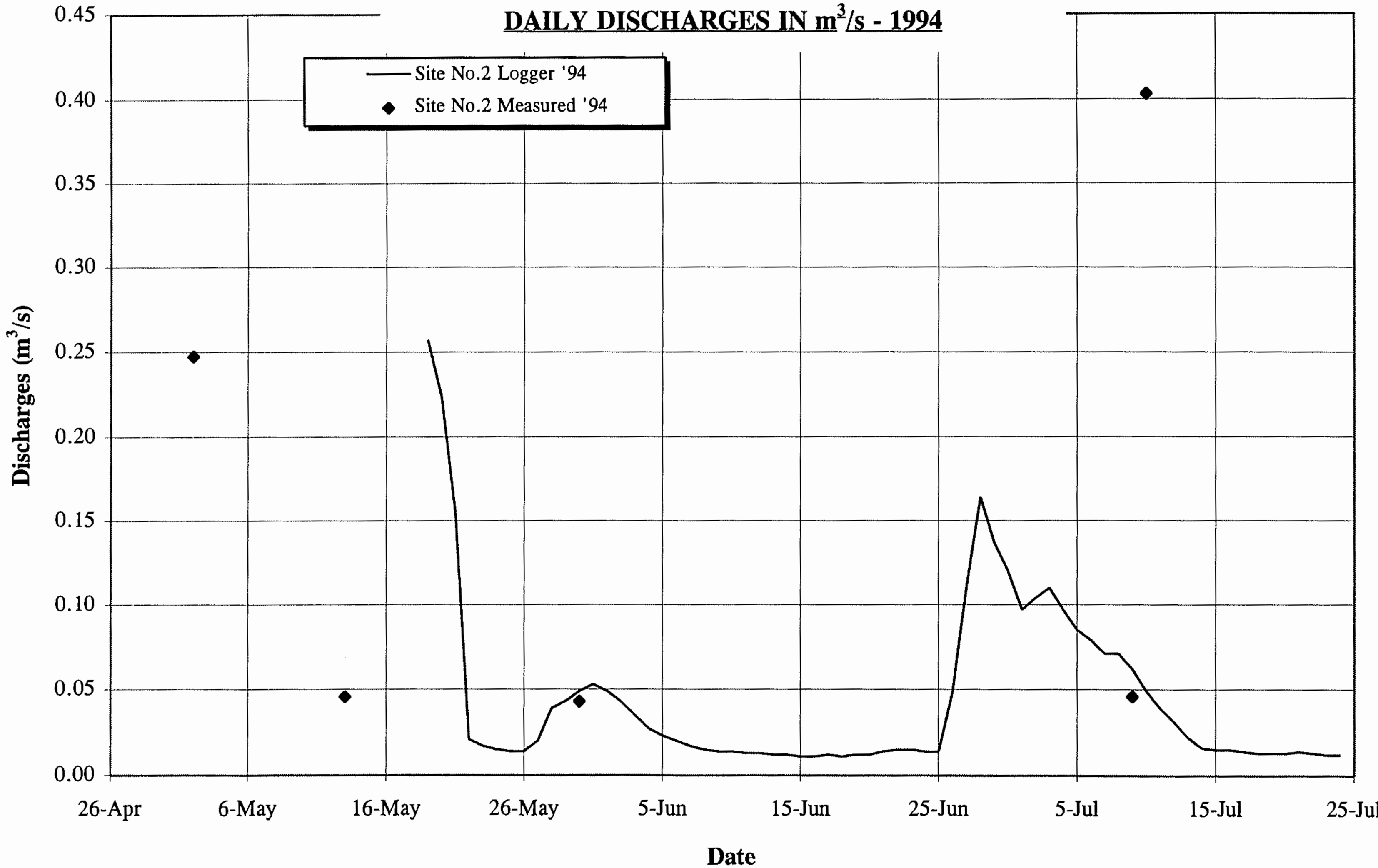


FIGURE 3.6
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT - WILLIAMS CREEK
DAILY DISCHARGES IN m^3/s - 1994



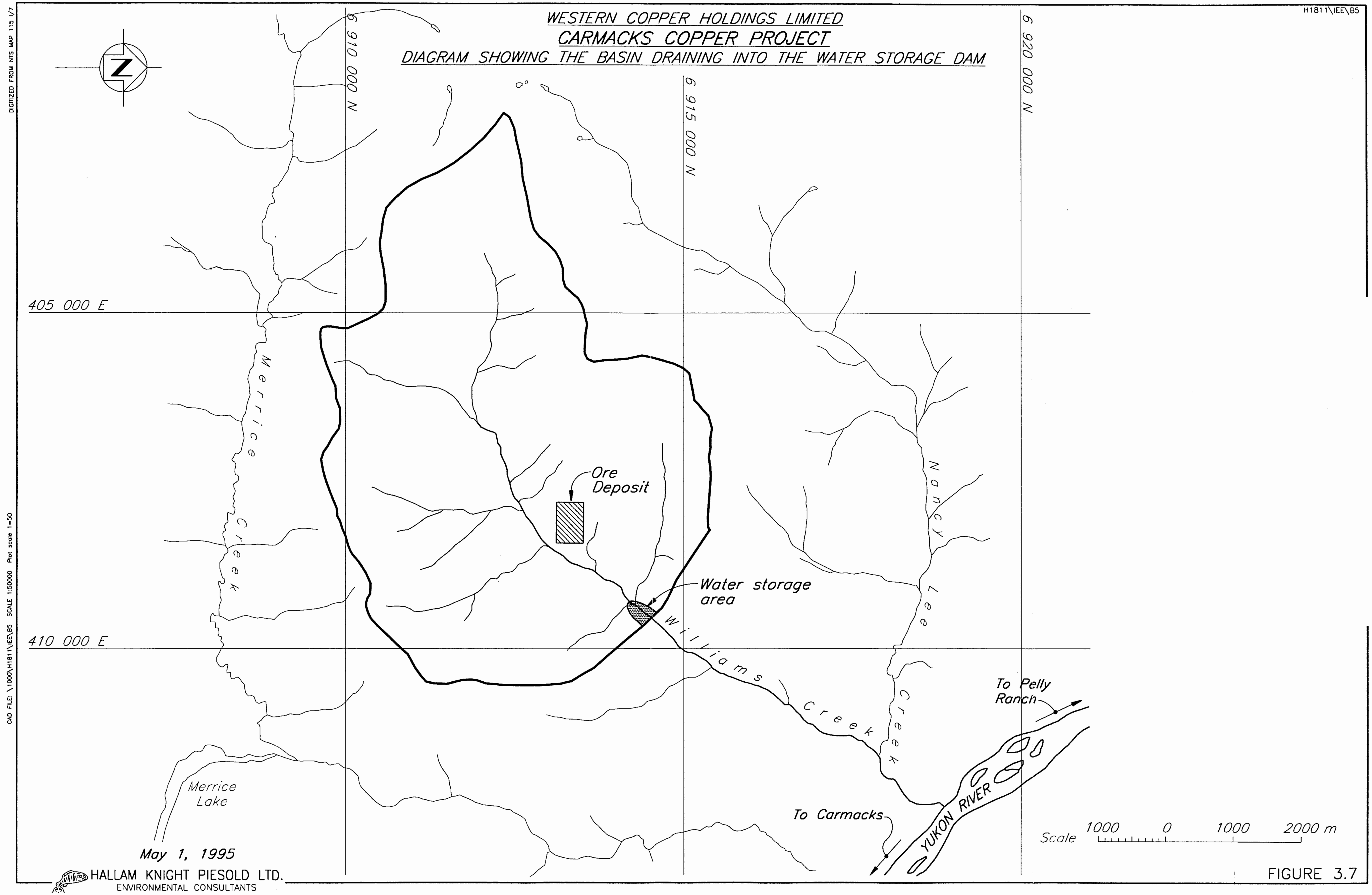

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
DIAGRAM SHOWING THE BASIN DRAINING INTO THE WATER STORAGE DAM
H1811\IEE\B5
DIGITIZED FROM NTS MAP 115 I/7
CAD FILE: \1000\H1811\IEE\B5 SCALE 1:50000 Plot scale 1=50
6 910 000 N
6 915 000 N
6 920 000 N
405 000 E
410 000 E
Merrice Creek
Ore Deposit
Water storage area
Nancy Lee Creek
Williams Creek
To Pelly Ranch
Merrice Lake
To Carmacks
YUKON RIVER
Scale 1000 0 1000 2000 m
May 1, 1995
HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 3.7

SECTION 4.0 - REVISED WATER AND WASTE MANAGEMENT PLANS

4.1 WATER BALANCE

A mine plan water balance developed by Knight Piésold Ltd. (1995) is presented in Tables 4.1 to 4.3; values have been calculated for Years 1, 4 and 9 during operation for 10 year wet, dry and average precipitation. A diagram of the Williams Creek watershed and a water balance flowchart are illustrated in Figures 3.7 and 4.1, respectively. The leaching and extraction processes have been designed to operate on the basis of 100% recycle of process streams. There will be no discharge of process effluents to Williams Creek. The only releases to Williams Creek will be from the water storage pond, which will include wash water from the offices-shops-dry-laboratory complex, and crusher and general site runoff and approximately 50% of the waste rock runoff. The remaining 50% of the waste rock runoff and 100% of the open pit water will be pumped to the process circuit to be used as make-up water. The events pond will remain empty and will only be used during emergency storm events or pump failure.

Potable water requirements for the proposed operations, which are projected to average 22 m^3/day will be pumped from Williams Creek adjacent to the ancillary facilities. Water required for road watering has been approximated at 190 m^3/day for June, July, August and September and will be taken from the water storage pond.

Based on estimates from an average precipitation year, total releases from the water storage pond are projected to range from average 0.055 m^3/s in Year 1 of production, to 0.056 m^3/s in Year 9. Maximum releases are predicted to occur in April and have been estimated at 0.199 m^3/s. Minimum releases will occur in October of Years 1 and 9 at which time they are expected to be 0 m^3/s, respectively.

Discharges from the laboratory wastes and floordrains will be re-routed to the PLS stream and returned to the process stream in order to minimize losses. Domestic sewage will be treated in a septic tank and exfiltration field.

Assuming that septic field exfiltrate does not return to Williams Creek as groundwater in the immediate term, the average net reduction in recharge to Williams Creek from all sources is projected to be 6% to 16%, depending on a 10-year wet precipitation year, an average year or a 10-year dry precipitation year. Water reduction in Williams Creek are a result of:

- domestic use
- road watering
- water retained in the ore (heap leach) stockpile,
- water retained in the waste rock stockpile
- increased evaporation from the ore and waste rock stockpiles
- increased evaporation from the fresh water storage pond.

4.2 WASTE CHARACTERIZATION

4.2.1 Waste Rock Storage

Mining operations will generate approximately 7.5 million tonnes of waste rock per year over the 8 years of mining for a total waste production of approximately 60.01 million tonnes, yielding a life of mine average stripping ratio of 4.25:1. This waste will be stored in a permanent location north of the open pit.

Trenching (Knight Piésold Ltd., 1992) indicates that overburden in the vicinity of the deposit and waste rock dump is not extensive; a typical soil profile consists of several inches of roots and organic material, overlying up to 1 foot of white volcanic ash which in turn overlies several inches of stratified dark brown/black organic silt on top of several feet of silty clay interlaced with some cobble and boulders.

4.2.2 Mineralogy of Waste Rock

Three waste rock samples were thin sectioned and petrographically described: the first sample was a diorite, highly silicified and originally probably undersaturated in silica, accompanied by secondary epidote and almost compete chlorotization of biotite, although hornblende and sphene remain fresh. The second sample was identified as a quartz diorite. Relatively weak hydrothermal alteration is shown by partial biotite breakdown with development of some epidote and chlorite. The third waste rock sample was identified as hornblende diorite. There was weak hydrothermal alteration of biotite noted and weak supergene montmorillonite alteration present. Minor limonite indicates slight permeability. There is less than 1% magmatic magnetite present and a small additional amount derived from partial alteration of sphene to carbonate, plus magnetite and/or rutile. Mineralogy of the three waste rock samples is presented in Table 4.4. The full petrography and mineralogy report is presented in Appendix 1.

4.2.3 Multielemental Scan of Waste Rock

A comprehensive waste rock characterization program was initiated by Western Copper Holdings Ltd. (1992) to determine the necessary design criteria for a detailed waste management plan. A total of 23 discrete samples (0.6 m intervals) of waste rock obtained from 6 individual diamond drill holes representing the various waste types were submitted for detailed ICP analyses. Results, which are summarized in Table 4.5, indicate that waste rock is relatively high with respect to arsenic (average 197 ppm), bismuth (average 4.12 ppm), cadmium (average 0.92 ppm), copper (average 177 ppm) and silver (average 0.25 ppm), when compared to global crustal averages. Given the mineral composition of the ore, higher than normal levels of copper, cadmium, arsenic and silver would be expected. Major metals that were found to be equivalent to, or significantly lower than crustal averages were barium, chromium, cobalt, iron, lead, manganese, molybdenum, nickel and zinc. Although the concentrations of calcium (1.11%) and magnesium (0.52%) were low, so were concentrations of iron (1.75%) and sulphur (2.28 ppm).

Combined, these data indicate that the waste rock would be expected to contain very little oxidizable sulphides or pyrite and very little propensity to generate acid leachate. Nevertheless, waste rock dump runoff settling pond releases should be monitored closely for soluble arsenic, cadmium and copper.

4.2.4 Acid Base Accounting of Waste Rock and Ore

4.2.4.1 Static Testing

Representative samples of composite ore used in metallurgical pilot plant studies and composite samples of ore from drill core were submitted for acid-base accounting, in part to determine the leachability and acid consumption characteristics. In addition, each of the 23 samples of waste rock submitted for ICP analyses were submitted for acid-base accounting. Figures 4.2 to 4.7 show the location of the ABA samples in relation to the ore body and open pit walls.

Results, which are presented in Tables 4.6a and 4.6b and graphically illustrated on the Klingmann Diagram in Figure 4.8, indicate that both the ore and the waste rock, which have long been oxidized, contain very little remaining oxidizable sulphur. Total sulphur in the trench sample composites, which is primarily chalcopyrite and bornite, averages 0.08%, yielding an average maximum acid generating potential of 2.6 t/1000 t H_2SO_4. The neutralization potential of the three metallurgical composites averaged 11.6 t/1000 t, yielding a net neutralization potential of 9.0 t/1000 t. This value is consistent with the projected acid consumption of 25 kg/tonne for leaching purposes.

Samples of ore from drill core averaged 0.06% sulphur and maximum acid generating potential of 2.00 t/1000 t H_2SO_4. The neutralization potential averaged 19 t/1000t and a net neutralization potential of 17 t/1000 t. Both the metallurgical composites and individual drill hole samples contained NP/AP Ratios of greater than 4:1 indicating that the ore falls in the upper left quadrant of the Klingmann Diagram and will not be acid generating.

Only one sample of the 23 waste rock samples tested was found to contain concentrations of sulphur above the detection limit of 0.01% (0.01 to 0.02%). Maximum acid generating potential using the detection limit as worst case was calculated to be 0.31 t/1000 t H_2SO_4. Average neutralization potential of waste rock was found to be 28 t/1000 t (10.1 to 89.8 t/1000 t) and a net neutralization potential of greater than 27 t/1000 t (9.8 to 89.5 t/1000 t). The overall NP/AP Ratio averages an overwhelming neutralization potential of 90:1.

4.2.4.2 Data Analyses

All results from static acid-base accounting of high and low grade ore, spent ore and waste rock were plotted on a Klingmann Diagram (Figure 4.8). The Klingmann Diagram, consists of a plot of sulphur content vs. NP/AP Ratios on a log/log scale. Quadrants are defined horizontally by an NP/AP Ratio of 4:1 and vertically by the sulphur content of 0.3%.

Sample results which fall below the 0.3% sulphur range are regarded as having insufficient sulphur content to sustain acid generation. Sample results located above an NP/AP Ratio of 4:1 are regarded as containing sufficient buffering capacity to neutralize any oxidation products of the contained sulphur. Samples which fall below an NP/AP Ratio of 4:1 and above the 0.3% sulphur boundary are regarded as being strongly acid generating.

In the case of the Carmacks Copper samples, the two spent ore samples (leach tailings) are regarded as potentially acid generating. However, this is because the samples, although stripped of their sulphides and obviously non-acid generating, still contain residues of sulphuric acid.

No federal guidelines are currently in place with regards to testing protocols for acid rock drainage; however, as a reference guideline the "ARD [acid rock drainage] Guidelines for Mine Sites in British Columbia (January 1995)" has been used for this analysis. This policy outlines three acid-base accounting (ABA) criteria, as follows:

- **Criteria 1, Material With A Paste pH Less Than 3.5**

  All waste with a paste pH of less than 3.5 is considered a potential source of acid drainage.

- **Criteria 2, Material Containing Greater Than 0.3% Sulphur**

All waste containing greater than 0.3% sulphur or paste pH of less than 5.0 should be submitted to static acid-base accounting tests in order to assess its acid generating potential. Waste containing 0.3% sulphur can be regarded as containing an equivalent 0.9% pyrite (as FeS_2). This amount of sulphur would theoretically be capable of producing approximately 9.6 t/1000t of sulphuric acid. If the pyrite is highly reactive, it could require in excess of 38.4 t/1000t carbonate equivalent to provide the necessary neutralization capability.

- **Criteria 3, Material Having an NP/AP Ratio of Less Than 4:1**

All waste having an NP/AP (neutralizing potential : maximum potential acidity) ratio of less than 4:1 should be submitted to kinetic testing in order to determine if the release rates of available neutralization potential will be sufficient to counter the production of sulphuric acid during the oxidation of sulphides. This ratio was selected based on the worst case known to date. The rate of carbonate release is a function of solubility and is generally faster than the production rate of sulphuric acid which is a function of oxidation. Consequently, it is important to determine if there is sufficient neutralization potential, given the higher rate of depletion, to counter the generation of sulphuric acid over the long-term.

4.2.4.3 Kinetic Test Program

Kinetic tests consist of various forms of leaching to determine the rate of either acid, alkalinity or metal releases under various simulated conditions and include column leach tests, humidity cell tests, B.C. Special Waste Extraction Procedure (SWEP) tests, and simulated rainfall leachability tests.

Given that the ore and waste rock contains little or no sulphur as confirmed by both ICP and acid-base accounting tests, kinetic test using columns or humidity cells would not have produced any useable data, even in the long term, and were therefore deleted from the test program. The open pit mine walls will be also be composed mainly of waste rock which has been shown to be highly acid consuming with a NP/AP Ratio ranging from 20:1 to 200:1.

Special Waste Extraction Procedure (SWEP) Testing of Ore and Waste Rock

Special Waste Extraction Procedure (SWEP) tests were completed by Western Copper Holdings Ltd. (in 1994) on each of the three composite ore samples used in the pilot plant metallurgical tests in order to determine concentrations of metals liberated by weak acid leaching. Although SWEP tests resulted in the leaching of significant levels of copper, as would be expected from a copper ore, the leachate quality was found to be well within the allowable limits of a waste extractate, and therefore, the ore would not be classified as a Special Waste. Concentrations of acceptable concentrations for SWEP leachate (B.C. Regulations) are presented in Table 4.7. Results, which are compared to the metal concentrations in pregnant leach solution (PLS) from the pilot plant in Table 4.8, indicate that significantly more mineralization will be extracted from the ore in the leaching process than would be by the SWEP test.

SWEP testing was also conducted on six composite waste rock samples. Results are presented in Table 4.9. SWEP testing of waste rock resulted in the significant leaching of copper (2.05 ppm), aluminum (2.93 ppm), barium (2.91 ppm) and iron (6.21 ppm), but levels were not above B.C. Regulations SWEP Leachate Quality Standards. Therefore, the waste rock is not considered a special waste.

Sequential Extraction of Waste Rock

Sequential extraction testing was conducted on a waste rock composite to determine the potential of resolubilization of metals from the rock. The testing consists of five consecutive extractions which are increasingly more chemically aggressive. This test is designed to partition metals into five components: ion exchangeable metals, carbonate bound metals, iron and manganese oxide bound metals, organic matter and sulphide bound metals, and silicate and refractory iron oxide bound metals. Results are presented in Table 4.10 and details on methodology are presented in Appendix 2.

Metals in fractions from Leach 1 and Leach 2 are made available by the presence of excess cations and in the presence of mild acid conditions, respectively. The metals present in these fractions have been considered to be the most available under natural environmental conditions for the purpose of this analysis.

The following metals were present at high concentrations in Leach 1 and/or 2 fractions: aluminum (118.76 ppm), barium (83.35 ppm), cadmium (2.36 ppm), copper (43.62 ppm), iron (142.76 ppm) and lead (5.8 ppm).

4.2.5 Nitrogen Loadings from Waste Rock and Ore

The use of explosives during operations can have a detrimental effect on water quality. The use of nitrogen-based explosives in surface mining has the potential to impair water quality for drinking, aquatic life and recreation due to potential toxicity of nitrates, nitrites and ammonia, and their role in promoting algal growth.

Approximately 30% of the holes are anticipated to be wet. Eighty-three percent of these holes will be lined with plastic liners that will be used to keep the explosive dry, while the remaining 17% will be loaded with a water-resistant slurry. On the basis of the average mine production of 1.76×10^6 t ore per year and 7.50×10^6 t waste per year and powder factor of 0.20 kg/t, projected peak explosives use will total 1852 t/a. Approximately 20% (252 t/a) will be used in ore production and 80% (1500 t/a) will be used in waste production.

Some of the residual nitrogen based compounds from blasting will report to the milling operation combined with the ore, a portion will be combined with the waste, and a portion is expected to report to open pit drainage. For purposes of this evaluation, nitrogen losses from ore, waste and mine water, are prorated in accordance with tonnage of waste and ore and a loss of 15% from both sources to mine water is assumed.

Using the methods outlined by Pommen (1982) total losses in open pit operations are expected to amount to approximately 1% of the nitrogen content of AN/FO explosives and 6% for slurry.

Based on a nitrogen content of AN/FO being 33% and slurry being 25%, projected annual losses of nitrogen to each of the mine rock reporting to the mill, waste rock dump and mine water settling ponds are presented in Table 4.11. Methods to minimize losses of explosives will be employed.

Approximately 15% (1.46 t/a) of the nitrogen from open pit blasting will report to the in-pit mine water settling pond and will be pumped out and directed to the process cycle to be used as makeup water. Approximately 85% (1.59 t/a) of the nitrogen from ore production will report to the processing plant.

Assuming that all residual nitrogen compounds reporting to the waste rock dump on an annual basis are solubilized and removed from the waste rock dump each year (i.e. no retention of nitrogen from year-to-year) and in direct proportion to annual runoff, combined nitrogen loadings to and from the waste rock dump settling pond would total 6.75 t/a.

4.2.6 Raffinate Characterization

Results from the raffinate and neutralized raffinate and the percent reduction in metals after neutralization are presented in Table 4.12. Several metals were extremely elevated in the raffinate, including aluminum (574 ppm) and iron (1274 ppm). A substantial decrease in the levels of the following metals was noted after neutralization: antimony (89.8%), arsenic (83.3%), cadmium (87.7%), chromium (96.6%), copper (97.9%), iron (99.8%) and zinc (98.5%).

In order to further characterize and determine the mobility of neutralized raffinate precipitates, SWEP testing and sequential extraction was completed for the precipitates. Results from the SWEP and sequential extraction tests are presented in Table 4.13 and 4.14, respectively.

Based on the SWEP data, neutralized raffinate precipitate is not classified as a special waste. Sequential extraction results indicate that high levels of the following metals were present in Leach 1 and 2 fractions and are therefore most likely to be available under average environmental conditions: aluminum (12,182 ppm), cadmium (2.42 ppm), iron (2750.6 ppm), manganese (319.12 ppm), mercury (5.82 ppm) and strontium (87.3 ppm).

4.2.7 Leach Pad Foundation Characterization

Acid-base accounting was completed for the foundations of the leach pad and events pond. Results are presented in Table 4.15. These materials, including the till layer which will be used as a soil liner contain 0.02 to 0.03 % sulphur, have a net neutralizing potential of 8.9 to 41.5, and NP/AP ratios of 18.1 to 133.9.

In order to determine the solubilization of metals in the till layer resulting from seepages, ICP analysis was completed on acid leached till. Results are presented in Table 4.16. The samples were adjusted to pH 2.0 with H_2SO_4, leached for 24 hours and filtered. An ICP analysis was completed on the filtered supernatant. Levels of metals released from the till layer are low and are not considered to affect the surrounding environment in the event of a leak.

4.3 WATER TREATMENT

Since the leach pad and process plant are designed to be 100% recycle, there will be no release of process streams to the environment. Processes will, in-fact, operate at a slight water deficit and fresh make-up water is required on a more-or-less continuous basis. However, in the event that there is a need to bleed the system of excess water (i.e. dispose of a portion of the raffinate), tests were carried out to determine the treatability of raffinate and the acceptability of treated supernatant for release to the waste rock dump settling pond, if necessary.

A sample of raffinate from the metallurgical pilot plant test work was subjected to neutralization using a slurried milk-of-lime to a pH of 10. The neutralizing process results in the precipitation of contained metals as hydroxides and sulphates. Results of analyses, as shown in Table 4.12, indicate that supernatant quality after lime treatment could be treated to limits which are well within levels specified by the Metal Mine Liquid Effluent Regulations (MMLER) for a dischargeable effluent. The treated supernatant was further subjected to a 96-hr LT_{50} acute toxicity test using rainbow trout. Results indicate that the treated supernatant would be non-toxic at 100% concentration.

However, treatment plant discharge, if required, would not be released directly to Williams Creek. It would be first directed to a settling pond to remove any residual precipitates and then the pond decant would be directed to the waste rock dump settling pond where it would be diluted before release to the environment. If required, precipitates would be disposed of as landfill in a lined storage facility in the vicinity of the process plant.

Neutralization of the heap leach pad will be required following closure to create a walk-away situation in perpetuity so that water treatment is not necessary. Bench scale tests are currently in progress to optimize the neutralization process. Details on the proposed closure plan are presented in Section 9.2.

TABLE - 4.1

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT

MONTHLY WATER BALANCE FOR WATER STORAGE POND - AVERAGE YEAR PRECIPITATION

General Assumptions :

Annual Precipitation =	370 mm	Runoff Coefficient =	0.15	Proportions of Total Precipitation :	
Drainage Area above Water Storage Dam =	31,000,000 m^2	Mean Runoff =	56 mm	Rainfall =	0.62
Waste Rock Dump Area =	816,000 m^2			Snowmelt =	0.38
Water Storage Pond Area =	82,000 m^2 (@ El. 654 m)				
Max. Water Storage Pond Volume =	380,000 m^3				

YEAR 1

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DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	73.6	52.5	35.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	18.1	46.3	229
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.4	42.2	0.0	141
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow for system (excluding pond and dump)	332,495	237,200	158,479	16,573	-	-	-	-	-	444,396	272,284	209,234	1,670,661
Direct Precipitation on Pond	6,038	4,308	2,878	301	-	-	-	-	-	8,070	4,945	3,800	30,340
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	48,070	34,293	22,912	2,396	-	-	-	-	-	64,249	39,366	30,250	241,536
Road watering	5,890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	2/13	7/45	1/13	-	-	-	-	-	-	9/61	12/79	7/44	3/40
Freshwater make-up for the Heap Leach Pad	-	-	12,621	27,233	28,444	16,253	16,253	16,253	16,253	-	-	-	133,310
Reduction in flows (%)	1.74%	2.43%	10.45%	-	-	-	-	-	-	0.13%	0.22%	2.71%	8.62%
Overflow Spill	371,914	263,407	162,582	-	-	-	-	-	-	516,055	308,287	228,067	1,744,889

YEAR 4

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	73.6	52.5	35.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	18.1	46.3	229
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.4	42.2	0.0	141
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow (excluding pond and dump)	332,495	237,200	158,479	16,573	-	-	-	-	-	444,396	272,284	209,234	1,670,661
Direct Precipitation on Pond	6,038	4,308	2,878	301	-	-	-	-	-	8,070	4,945	3,800	30,340
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	48,070	34,293	22,912	2,396	-	-	-	-	-	64,249	39,366	30,250	241,536
Road watering	5890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	7/46	2/15	9/86	-	-	-	-	-	-	9/61	12/79	10/63	8/95
Freshwater make-up for the Heap Leach Pad	715	5,566	8,455	16,334	17,544	17,544	17,544	17,544	17,544	-	-	86	118,872
Reduction in flows (%)	1.93%	4.50%	8.16%	88.30%	-	-	-	-	-	0.13%	0.22%	2.75%	7.86%
Overflow Spill	371,199	257,841	166,748	2,254	-	-	-	-	-	516,055	308,287	227,981	1,759,327

YEAR 9

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	73.6	52.5	35.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	18.1	46.3	229
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.4	42.2	0.0	141
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow (excluding pond and dump)	332,495	237,200	158,479	16,573	-	-	-	-	-	444,396	272,284	209,234	1,670,661
Direct Precipitation on Pond	6,038	4,308	2,878	301	-	-	-	-	-	8,070	4,945	3,800	30,340
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	48,070	34,293	22,912	2,396	-	-	-	-	-	64,249	39,366	30,250	241,536
Road watering	5890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	2/13	3/20	3/25	-	-	-	-	-	-	9/61	12/79	7/44	5/53
Freshwater make-up for the Heap Leach Pad	-	1,530	6,079	13,958	16,186	16,186	16,186	16,186	16,186	-	-	-	102,497
Reduction in flows (%)	1.74%	3.00%	6.85%	75.97%	-	-	-	-	-	0.13%	0.22%	2.71%	7.00%
Overflow Spill	371,914	261,877	169,124	4,630	-	-	-	-	-	516,055	308,287	228,067	1,775,702

Notes:
1) For details of General Assumptions see Knight Piesold's report "Western Copper Holdings Limited, Carmacks Copper Project, Report on Preliminary Design Ref. No. 1783/1) Volume I of II - Main Report", May, 1995.
2) Calculations assume that the pond is full at the beginning of each year.
3) Freshwater make-up values assumed to be equal to 10th percentile in Figure 4.3, Report 1783/1.
4) Waste rock runoff dilution is calculated by the ratio of waste rock runoff to the net outflow (not including the waste rock runoff).

TABLE - 4.2

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT

MONTHLY WATER BALANCE FOR WATER STORAGE POND - 10 YEAR DRY PRECIPITATION

General Assumptions :

Annual Precipitation =	275 mm	Runoff Coefficient =	0.11	Proportions of Total Precipitation :	
Drainage Area above Water Storage Dam =	31,000,000 m^2	Mean Runoff =	30 mm	Rainfall =	0.62
Waste Rock Dump Area =	816,000 m^2			Snowmelt =	0.38
Water Storage Pond Area =	82,000 m^2 (@ El. 654 m)				
Max. Water Storage Pond Volume =	380,000 m^3				

YEAR 1

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DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	54.7	39.0	26.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	13.5	34.4	171
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.2	31.4	0.0	105
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow for system (excluding pond and dump)	181,225	129,285	86,378	9,033	-	-	-	-	-	242,216	148,407	114,042	910,586
Direct Precipitation on Pond	4,488	3,202	2,139	224	-	-	-	-	-	5,998	3,675	2,824	22,550
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	35,728	25,488	17,029	1,781	-	-	-	-	-	47,752	29,258	22,483	179,520
Road watering	5,890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	15/68	13/58	1/32	-	-	-	-	-	-	15/74	3/14	11/47	1/34
Freshwater make-up for the Heap Leach Pad	-	-	15,166	32,724	34,180	19,530	19,530	19,530	19,530	-	-	-	160,194
Reduction in flows (%)	3.08%	4.32%	20.93%	-	-	-	-	-	-	0.22%	0.39%	4.87%	17.73%
Overflow Spill	206,751	145,581	81,315	-	-	-	-	-	-	295,306	173,033	124,133	888,124

YEAR 4

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	54.7	39.0	26.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	13.5	34.4	171
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.2	31.4	0.0	105
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow for system (excluding pond and dump)	181,225	129,285	86,378	9,033	-	-	-	-	-	242,216	148,407	114,042	910,586
Direct Precipitation on Pond	4,488	3,202	2,139	224	-	-	-	-	-	5,998	3,675	2,824	22,550
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	35,728	25,488	17,029	1,781	-	-	-	-	-	47,752	29,258	22,483	179,520
Road watering	5,890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	8/37	11/63	4/39	-	-	-	-	-	-	15/74	3/14	7/30	1/20
Freshwater make-up for the Heap Leach Pad	878	6,833	10,380	20,052	21,538	21,538	21,538	21,538	21,538	-	-	106	145,932
Reduction in flows (%)	3.49%	8.81%	16.28%	-	-	-	-	-	-	0.22%	0.39%	4.95%	16.41%
Overflow Spill	205,873	138,748	86,101	-	-	-	-	-	-	295,306	173,033	124,027	902,386

YEAR 9

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	54.7	39.0	26.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	13.5	34.4	171
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.2	31.4	0.0	105
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow for system (excluding pond and dump)	181,225	129,285	86,378	9,033	-	-	-	-	-	242,216	148,407	114,042	910,586
Direct Precipitation on Pond	4,488	3,202	2,139	224	-	-	-	-	-	5,998	3,675	2,824	22,550
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	35,728	25,488	17,029	1,781	-	-	-	-	-	47,752	29,258	22,483	179,520
Road watering	5,890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	15/68	17/80	3/20	-	-	-	-	-	-	15/74	3/14	11/47	5/54
Freshwater make-up for the Heap Leach Pad	-	1,699	6,751	15,500	17,974	17,974	17,974	17,974	17,974	-	-	-	113,821
Reduction in flows (%)	3.08%	5.44%	12.75%	-	-	-	-	-	-	0.22%	0.39%	4.87%	13.43%
Overflow Spill	206,751	143,882	89,730	-	-	-	-	-	-	295,306	173,033	124,133	934,497

Notes: *1) For details of General Assumptions see Knight Piesold's report "Western Copper Holdings Limited, Carmacks Copper Project, Report on Preliminary Design Ref. No. 1783/1) Volume I of II - Main Report", May, 1995.*

2) Calculations assume that the pond is full at the beginning of each year.

3) Freshwater make-up values assumed to be equal to 90th percentile in Figure 4.3, Report 1783/1.

4) Waste rock runoff dilution is calculated by the ratio of waste rock runoff to the net outflow (not including the waste rock runoff).

TABLE - 4.3

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT

MONTHLY WATER BALANCE FOR WATER STORAGE POND - 10 YEAR WET PRECIPITATION

General Assumptions :

Annual Precipitation = 465 mm
Drainage Area above Water Storage Dam = 31,000,000 m^2
Waste Rock Dump Area = 816,000 m^2
Water Storage Pond Area = 82,000 m^2 (@ El. 654 m)
Max. Water Storage Pond Volume = 380,000 m^3

Runoff Coefficient = 0.17
Mean Runoff = 79 mm

Proportions of Total Precipitation :
Rainfall = 0.62
Snowmelt = 0.38

YEAR 1

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DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	92.5	66.0	44.1	4.6	0.0	0.0	0.0	0.0	0.0	0.0	22.8	58.2	288
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.7	53.0	0.0	177
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow for system (excluding pond and dump)	473,581	337,850	225,725	23,605	-	-	-	-	-	632,964	387,821	298,016	2,379,563
Direct Precipitation on Pond	7,589	5,414	3,617	378	-	-	-	-	-	10,143	6,214	4,775	38,130
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	60,413	43,098	28,795	3,011	-	-	-	-	-	80,745	49,473	38,017	303,552
Road watering	5890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	2/15	7/52	2/23	-	-	-	-	-	-	10/77	11/83	3/22	4/47
Freshwater make-up for the Heap Leach Pad	-	-	11,322	24,430	25,516	14,580	14,580	14,580	14,580	-	-	-	119,590
Reduction in flows (%)	1.23%	1.73%	6.92%	93.02%	-	-	-	-	-	0.09%	0.16%	1.92%	5.61%
Overflow Spill	526,892	373,968	237,749	1,883	-	-	-	-	-	723,191	435,201	325,593	2,537,317

YEAR 4

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	92.5	66.0	44.1	4.6	0.0	0.0	0.0	0.0	0.0	0.0	22.8	58.2	288
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.7	53.0	0.0	177
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow (excluding pond and dump)	473,581	337,850	225,725	23,605	-	-	-	-	-	632,964	387,821	298,016	2,379,563
Direct Precipitation on Pond	7,589	5,414	3,617	378	-	-	-	-	-	10,143	6,214	4,775	38,130
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	60,413	43,098	28,795	3,011	-	-	-	-	-	80,745	49,473	38,017	303,552
Road watering	5890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	11/83	8/67	1/10	-	-	-	-	-	-	10/77	11/83	3/22	3/35
Freshwater make-up for the Heap Leach Pad	715	5,566	8,455	16,334	17,544	17,544	17,544	17,544	17,544	-	-	86	118,872
Reduction in flows (%)	1.37%	3.19%	5.80%	63.03%	-	-	-	-	-	0.09%	0.16%	1.94%	5.58%
Overflow Spill	526,177	368,402	240,616	9,979	-	-	-	-	-	723,191	435,201	325,507	2,538,035

YEAR 9

DESCRIPTION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Rainfall Distribution (mm/month)	92.5	66.0	44.1	4.6	0.0	0.0	0.0	0.0	0.0	0.0	22.8	58.2	288
Snowmelt Distribution (mm/month)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.7	53.0	0.0	177
Mean Monthly Lake Evaporation (mm/month)	99	71	33	0	0	0	0	0	0	0	93	108	404
WATER IN SYSTEM (m^3)													
Runoff inflow (excluding pond and dump)	473,581	337,850	225,725	23,605	-	-	-	-	-	632,964	387,821	298,016	2,379,563
Direct Precipitation on Pond	7,589	5,414	3,617	378	-	-	-	-	-	10,143	6,214	4,775	38,130
Evaporation	8,118	5,822	2,706	-	-	-	-	-	-	-	7,626	8,856	33,128
Waste rock dump runoff	60,413	43,098	28,795	3,011	-	-	-	-	-	80,745	49,473	38,017	303,552
Road watering	5890	5,890	5,700	-	-	-	-	-	-	-	-	5,700	23,180
Potable water	682	682	660	682	660	682	682	616	682	660	682	660	8,030
Waste rock runoff dilution at overflow spill (ratio)	2/15	3/23	9/82	-	-	-	-	-	-	10/77	11/83	3/22	5/54
Freshwater make-up for the Heap Leach Pad	-	1,530	6,079	13,958	16,186	16,186	16,186	16,186	16,186	-	-	-	102,497
Reduction in flows (%)	2.71%	3.60%	5.87%	54.23%	-	-	-	-	-	0.09%	1.87%	4.46%	6.13%
Overflow Spill	526,892	372,438	242,992	12,355	-	-	-	-	-	723,191	435,201	325,593	2,554,410

Notes:

1) For details of General Assumptions see Knight Piesold's report "Western Copper Holdings Limited, Carmacks Copper Project, Report on Preliminary Design Ref. No. 1783/1) Volume I of II - Main Report", May, 1995.

2) Calculations assume that the pond is full at the beginning of each year.

3) Freshwater make-up values assumed to be equal to 10th percentile in Figure 4.3, Report 1783/1.

4) Waste rock runoff dilution is calculated by the ratio of waste rock runoff to the net outflow (not including the waste rock runoff).

Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.4
Waste Rock Mineralogy

Sample #	Description	Mineralogy		
		Primary	Secondary	Supergene
TS 21 – 178'	Light grey to pink rock with medium grained matrix	Plagioclase – 40% (an 8 or 33) K–feldspar – 15% Hornblende – 6% Biotite – 0.5% Sphene – 1% Quartz – 13% Epidote – 1% Chlorite – 5% Opaques – 0.5%		Clay – 16% (montmorillonite type) Epidote – 1% Pore space – 0.5%
TS 38 – 187'	Light grey, fine to medium grained, rock with granitoid texture	Plagioclase – 70% (An 12 or 29) Quartz – 17% Biotite – 2% Sphene – 0.5% Apatite – 0.5% Magnetite – 1.5%	Montmorillonite – 5.5% Hydrobiotite – 2% Epidote – 0.3% Sericite – 0.1% Carbonate – 0.1%	
TS 40 – 33'	Light grey, medium grained rock with granitoid texture and approximately 25% mafic minerals	Plagioclase – 67% (An 11 or 30) Hornblende – 20% Biotite – 5% Sphene – 2% Apatite – 0.8% Magnetite – 0.7%	Hydrobiotite – 2% Epidote – 0.2% Magnetite – 0.2% Carbonate – 0.3%	Montmorillonite – 2% Limonite – 0.1% Pore space – $\leq$0.1%

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WESTERN COPPER HOLDINGS LTD.
Carmacks Copper Project

Table 4.5
Waste Rock Quality Test Results (ICP)

Parameter	DDH1-25 10-12	DDH1-25 180-182	DDH1-33 50-52	DDH1-33 150-152	DDH1-33 250-252	DDH1-33 350-352	DDH1-37 50-52	DDH1-37 150-152	DDH1-37 25-252	DDH1-37 349-351	DDH1-53 50-52	DDH1-53 150-152
Aluminum (%)	1.20	1.51	0.87	0.57	0.48	0.71	0.64	0.80	0.45	1.62	0.86	0.70
Arsenic (ppm)	22.00	25.00	17.00	19.00	10.00	11.00	14.00	10.00	6.00	25.00	14.00	15.00
Barium (ppm)	479.00	157.00	114.00	110.00	126.00	84.00	113.00	66.00	100.00	414.00	125.00	169.00
Beryllium (ppm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bismuth (ppm)	1.00	2.00	1.00	1.00	1.00	9.00	7.00	6.00	6.00	1.00	2.00	5.00
Boron (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cadmium (ppm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Calcium (%)	1.28	2.08	1.14	0.62	0.32	0.51	0.82	0.88	0.39	1.27	0.88	0.84
Chromium (ppm)	22.00	16.00	16.00	23.00	23.00	28.00	26.00	23.00	30.00	22.00	25.00	26.00
Cobalt (ppm)	7.00	5.00	4.00	3.00	2.00	3.00	3.00	3.00	2.00	8.00	4.00	3.00
Copper (ppm)	1382.00	62.00	12.00	7.00	8.00	193.00	12.00	7.00	164.00	17.00	11.00	19.00
Gold (ppm)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron (%)	2.81	2.06	1.71	1.24	1.00	1.68	1.60	1.36	1.22	3.09	1.90	1.34
Lanthanum (ppm)	3.00	3.00	3.00	1.00	1.00	5.00	2.00	2.00	2.00	10.00	2.00	1.00
Lead (ppm)	13.00	13.00	11.00	10.00	1.00	3.00	9.00	6.00	4.00	9.00	7.00	9.00
Magnesium (%)	0.85	0.56	0.63	0.32	0.33	0.43	0.34	0.43	0.28	1.29	0.47	0.40
Manganese (ppm)	500.00	393.00	322.00	197.00	179.00	268.00	179.00	179.00	197.00	715.00	286.00	179.00
Mercury (ppm)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Molybdenum (ppm)	3.00	7.00	2.00	1.00	2.00	2.00	1.00	2.00	3.00	3.00	1.00	1.00
Nickel (ppm)	2.00	1.00	1.00	1.00	2.00	4.00	3.00	2.00	5.00	7.00	5.00	4.00
Phophorous (%)	0.12	0.15	0.16	0.11	0.06	0.10	0.14	0.15	0.08	0.16	0.16	0.17
Silicon (%)	0.02	0.33	0.04	0.11	0.02	0.04	0.09	0.11	0.02	0.15	0.19	0.10
Silver (ppm)	1.10	0.40	0.20	0.10	0.10	0.20	0.10	0.10	0.10	0.50	0.10	0.10
Sodium (%)	0.04	0.07	0.06	0.07	0.04	0.05	0.07	0.10	0.04	0.08	0.12	0.12
Strontium (ppm)	20.00	59.00	45.00	32.00	14.00	24.00	40.00	39.00	20.00	71.00	60.00	68.00
Sulphur (ppm)	1.00	4.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Titanium (%)	0.07	0.09	0.06	0.07	0.08	0.10	0.06	0.11	0.06	0.18	0.10	0.10
Tungsten (ppm)	1.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uranium (ppm)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Vanadium (ppm)	56.00	43.00	31.00	28.00	21.00	35.00	39.00	33.00	27.00	71.00	42.00	31.00
Zinc (ppm)	60.00	45.00	36.00	20.00	22.00	37.00	30.00	25.00	24.00	73.00	39.00	30.00

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① DH 125 ② DH 133 ③ DH 137 ④ DH 153

WESTERN COPPER HOLDINGS LTD.
Carmacks Copper Project

(4 cont) DH153 (5) DH156 (6) DH157 comp #14 table 4.9

Table 4.5
Waste Rock Quality Test Results (ICP)

Parameter	DDH1-53 250-252	DDH1-53 350-352	DDH1-53 450-452	DDH1-53 680-682	DDH1-56 50-52	DDH1-56 150-152	DDH1-56 220-222	DDH1-57 50-52	DDH1-57 150-152	DDH1-57 300-302	DDH1-57 350-352	AVERAGE
Aluminum (%)	0.27	0.88	1.64	1.86	1.08	0.72	0.87	1.24	0.70	1.33	1.75	0.91
Arsenic (ppm)	9.00	14.00	32.00	28.00	23.00	13.00	13.00	32.00	12.00	31.00	15.00	16.40
Barium (ppm)	99.00	220.00	391.00	359.00	118.00	100.00	94.00	203.00	198.00	450.00	635.00	196.96
Beryllium (ppm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92
Bismuth (ppm)	1.00	1.00	3.00	10.00	10.00	4.00	4.00	8.00	10.00	9.00	1.00	4.12
Boron (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cadmium (ppm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92
Calcium (%)	0.19	0.98	2.72	2.43	1.41	0.64	0.65	3.97	0.52	2.69	0.64	1.11
Chromium (ppm)	34.00	32.00	10.00	13.00	25.00	39.00	35.00	19.00	32.00	29.00	34.00	23.28
Cobalt (ppm)	1.00	4.00	5.00	7.00	5.00	3.00	4.00	7.00	4.00	3.00	7.00	3.88
Copper (ppm)	18.00	9.00	27.00	9.00	9.00	10.00	8.00	18.00	71.00	10.00	2344.00	177.08
Gold (ppm)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron (%)	0.60	1.90	2.72	2.72	2.58	1.61	1.63	2.57	1.28	1.73	3.41	1.75
Lanthanum (ppm)	1.00	2.00	6.00	2.00	9.00	3.00	4.00	7.00	2.00	8.00	2.00	3.24
Lead (ppm)	3.00	5.00	21.00	21.00	15.00	6.00	4.00	20.00	4.00	21.00	1.00	8.64
Magnesium (%)	0.17	0.51	1.03	0.87	0.75	0.48	0.47	0.74	0.45	0.34	1.23	0.53
Manganese (ppm)	71.00	250.00	518.00	500.00	483.00	322.00	268.00	608.00	286.00	340.00	661.00	316.04
Mercury (ppm)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Molybdenum (ppm)	2.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	7.00	2.00	1.96
Nickel (ppm)	1.00	4.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	2.12
Phophorous (%)	0.02	0.14	0.14	0.18	0.17	0.10	0.10	0.13	0.07	0.09	0.11	0.11
Silicon (%)	0.02	0.18	0.29	0.33	0.09	0.04	0.13	0.04	0.03	0.32	0.08	0.11
Silver (ppm)	0.10	0.20	0.60	0.60	0.60	0.20	0.20	0.60	0.20	0.90	1.50	0.35
Sodium (%)	0.04	0.14	0.06	0.06	0.09	0.07	0.07	0.04	0.06	0.06	0.09	0.07
Strontium (ppm)	19.00	60.00	47.00	87.00	34.00	36.00	39.00	9.00	23.00	55.00	23.00	36.96
Sulphur (ppm)	1.00	4.00	1.00	3.00	10.00	1.00	3.00	9.00	1.00	7.00	1.00	2.28
Titanium (%)	0.05	0.10	0.11	0.16	0.14	0.08	0.06	0.05	0.09	0.01	0.29	0.09
Tungsten (ppm)	1.00	1.00	6.00	5.00	4.00	11.00	1.00	7.00	1.00	3.00	1.00	2.20
Uranium (ppm)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.60
Vanadium (ppm)	14.00	43.00	59.00	55.00	56.00	32.00	30.00	51.00	27.00	27.00	95.00	37.84
Zinc (ppm)	12.00	39.00	59.00	71.00	52.00	36.00	34.00	51.00	31.00	48.00	93.00	38.68

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT

Table 4.6a
Acid – Base Accounting

comp in table 4.9

Sample #	Sample Type	Total Sulphur (%)	Paste pH	Neutralizing Potential (NP)	Max Potential Acidity (AP)	Net Neutralizing Potential	NP/AP
	Pilot Plant Trench Samples						
	Comp 1	0.10	8.1	8.20	3.13	5.1	2.62
	Comp 2	0.12	8.0	13.3	3.75	9.6	3.55
	Comp 3	0.03	8.1	13.2	0.94	12.3	14.04
	Drill Core*						
	Comp 1 +27L*	0.14	8.4	27.2	4.38	22.8	6.21
	Comp 2 +27H	0.08	8.6	15.5	2.50	13.0	6.2
	Comp 3 25–27L	0.01	8.9	31.4	0.31	31.1	101.3
	Comp 4 25–27H	0.08	8.4	12.7	2.50	10.2	5.08
	Comp 5 23–25L	0.04	8.9	21.0	1.25	19.8	16.8
	Comp 6 23–25H	0.03	8.2	12.0	0.94	11.1	12.8
	Comp 7 SE	0.06	8.4	13.4	1.88	11.5	7.1
	Waste Rock Samples						
1	DDH 1–25/10–12	0.01	8.2	37.1	0.31	36.8	119.7
(1) 2	DDH 1–25/180–182	0.01	8.2	34.5	0.31	34.2	111.3
3	DDH 1–33/50–52	0.01	8.5	24.5	0.31	24.2	79.0
4	DDH 1–33/150–152	0.01	8.6	11.9	0.31	11.6	38
(2) 5	DDH 1–33/250–252	0.01	8.6	12.6	0.31	12.3	40.6
6	DDH 1–33/350–352	0.01	8.4	14.5	0.31	14.2	46.8
7	DDH 1–37/50–52	0.01	8.7	12.6	0.31	12.3	40.6
8	DDH 1–37/150–152	0.01	8.8	14.0	0.31	13.7	45.2
(3) 9	DDH 1–37/250–252	0.01	8.5	11.3	0.31	11.0	36.5
10	DDH 1–37/349–351	0.01	8.5	37.8	0.31	37.5	121.9
11	DDH 1–53/150–152	0.01	8.7	15.3	0.31	15.0	49.4
12	DDH 1–53/250–252	0.01	8.0	10.1	0.31	9.8	32.6
(4) 13	DDH 1–53/350–352	0.01	8.7	15.0	0.31	14.7	48.4
14	DDH 1–53/450–452	0.02	8.3	62.9	0.63	62.3	99.8
15	DDH 1–53/680–682	0.01	8.2	48.3	0.31	48.0	155.8
16	DDH 1–53/50–052	0.01	8.5	16.6	0.31	16.3	53.5
17	DDH 1–56/50–52	0.01	8.6	31.4	0.31	31.1	101.3
(5) 18	DDH 1–56/150–152	0.01	8.8	14.0	0.31	13.7	45.2
19	DDH 1–56/220–222	0.01	8.5	33.7	0.31	33.3	108.7
20	DDH 1–57/50–52	0.01	8.1	89.8	0.31	89.5	289.7
21	DDH 1–57/150–152	0.01	8.2	12.9	0.31	12.6	41.6
(6) 22	DDH 1–57/300–302	0.01	8.0	55.6	0.31	55.3	179.4
23	DDH 1–57/350–352	0.01	8.3	17.9	0.31	17.6	57.7

* L = low grade ore, H = high grade ore; See Table 3.2b for composite intervals.
(\H1811\acid–base.wk3)

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT

Table 4.6b
Metallurgical Drill Core Composites

Sample #	DDH #	From	To	Length (feet)	Weight (lbs)
-27L	25	18	101	83	235
	26	10	86	76	215
	31	102	167	65	185
				224	635
-27H	25	101	176	75	213
	26	86	146	60	170
	31	32	102	70	199
				205	582
25-27L	23	122	241	119	338
	29	252	291	39	110
	33	323.5	334	10.5	30
	51	88.3	174.9	86.6	246
				255.1	724
25-27H	23	241	336	95	270
	29	164	252	88	250
	33	275	323.5	48.5	138
				231.5	658
23-25L	24	384.5	428	43.5	124
	45	436.2	480	43.8	124
	52	406	440	34	97
	52	555	580	25	71
	53	470.8	539.1	68.3	194
				214.6	610
23-25H	24	428	553	125	355
	45	480	524.3	44.3	126
	52	440	555	115	326
				284.3	807
SE	34	73.5	153.5	80	227
	37	181	245.5	64.5	183
	48	10	68	58	165
	54	160	197.2	37.2	106
				239.7	681

Grand total 4697 lbs

Table 4.7
SWEP Leachate Quality Standards

Contaminant	Concentration in Waste Extract (mg/L)
Aldicarb	0.9
Aldrin + Dieldrin	0.07
Arsenic	5.0
Barium	100.0
Benzene	0.5
Boron	500.0
Cadmium	0.5
Carbaryl/1-Naphthyl-N-methyl carbamate	9.0
Carbon tetrachloride	0.5
Chlordane	0.7
Chromium	5.0
Copper	100.0
Cyanide (free)	20.0
Diazinon	2.0
DDT	3.0
2,4-D	10.0
Ethylbenzene	0.24
Fluorides	150.0
Heptachlor + Heptachlor epoxide	0.3
Lead	5.0
Lindane	0.4
Mercury	0.1
Methoxychlor	90.0
Nitrate + Nitrite	1000.0
Nitrilotriacetic acid (NTA)	5.0
Pathion	5.0
Pentachlorophenol	3.0
Selenium	1.0
Silver	5.0
Tetrachlorophenol, 2,3,4,6-	0.1
Toluene	2.4
Trichlorophenoxyacetic acid, 2,4,5-(2,4,5-T)	28.0
Trihalomethanes	35.0
Uranium	10.0
Xylenes	30.0
Zinc	500.0

(B.C. Reg. 132/92, s.36(e))

WESTERN COPPER HOLDINGS LTD.
Carmacks Copper Project

Table 4.8
Analyses of Ore and Pregnant Leach Solutions (PLS)

Parameter	Ore Composite No. 1 (SWEP)	Ore Composite No. 2 (SWEP)	Ore Composite No. 3 (SWEP)	Head PLS (ICP)	Neutralized PLS Filtrate (ICP)	Neutralized PLS Precipitate (SWEP)
Ag	<0.01	<0.01	<0.01	<0.5	<0.1	<0.1
Al	1.39	0.5	<0.01	7487	<0.1	7.6
As	<0.02	<0.02	<0.02	1	<0.1	<0.1
Au	<0.01	<0.01	<0.01	<1	<0.1	<0.1
B	0.02	0.09	<0.01	370	<0.1	5.9
Ba	1.12	0.62	2.06	6	0.8	0.55
Be	<0.005	<0.005	<0.005	0.5	0.03	0.04
Bi	<0.02	<0.02	<0.02	<2	<0.1	<0.1
Ca	47.8	48.8	102.2	570	496.4	1411
Cd	0.005	<0.005	<0.005	0.7	<0.01	0.14
Co	0.01	0.02	0.07	22	0.3	1.2
Cr	<0.01	<0.01	<0.01	2	<0.1	<0.1
Cu	97.17	78.98	74.68	8935	0.8	261.5
Fe	2.68	2.43	2.3	7220	0.2	10.9
Hg	<1	<1	<1	<3	<1	<1
La	<0.01	<0.01	<0.01	1	<0.1	<0.1
Mg	8.2	9.3	13	6527	5445	572
Mn	2	2.86	4.1	816	138.4	134.6
Mo	<0.01	<0.01	<0.01	<1	<0.1	<0.1
Na	6	6	3	150	112	15
Ni	0.03	<0.01	<0.01	12	<0.1	0.3
P	<0.1	<0.1	<0.1	147	<0.1	0.4
Pb	<0.02	0.02	0.05	1	<0.1	<0.1
Sb	<0.02	<0.02	<0.02	<2	<0.1	<0.1
Si	7.62	8.09	11.13	120	9.2	9
Sr	0.31	0.27	0.35	1.1	5	5.3
Ti	<0.01	<0.01	<0.01	4	<0.1	<0.1
V	<0.01	<0.01	<0.01	9	<0.1	<0.1
W	<0.02	<0.02	<0.02	<2	<0.1	<0.1
Zn	0.87	0.72	0.72	31	0.1	7

* All parameter levels expressed in mg/L

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Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.9
SWEP Testing of Waste Rock

Element (ppm)	Comp 1 hole 1-25	Comp 2 hole 1-33	Comp 3 hole 1-37	Comp 4 hole 1-53	Comp 5 hole 1-56	Comp 6 hole 1-57	Average
Ag	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	**0.01**
Cu	5.387	0.04	0.037	0.039	<0.010	6.784	**2.0495**
Pb	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	**0.04**
Zn	0.255	0.097	0.087	0.099	0.092	0.127	**0.1262**
As	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	**0.03**
Sb	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	**0.04**
Hg	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	**0.02**
Mo	0.009	<0.005	<0.005	0.006	<0.005	0.008	**0.0063**
Tl	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	**0.08**
Bi	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	**0.07**
Cd	0.004	0.002	<0.002	0.003	<0.002	0.005	**0.003**
Co	0.029	0.016	0.016	0.02	0.016	0.032	**0.0215**
Ni	0.012	<0.010	<0.010	0.016	0.015	<0.010	**0.0122**
Ba	4.878	0.865	1.854	3.887	1.3	4.704	**2.9147**
W	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	**0.008**
Cr	<0.008	<0.008	<0.008	0.014	<0.008	<0.008	**0.009**
V	0.006	0.006	<0.006	<0.006	<0.006	<0.006	**0.006**
Mn	6.878	1.968	2.329	3.028	3.231	8.187	**4.2702**
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**
Sr	0.977	0.508	0.69	1.026	0.518	0.922	**0.7735**
B	0.069	0.076	0.064	0.077	0.057	<0.010	**0.0588**
Se	<0.040	<0.040	<0.040	<0.040	<0.040	0.043	**0.0405**
Ti	0.072	0.004	0.006	0.017	0.004	0.025	**0.0213**
Al	3.113	0.823	5.837	3.348	1.264	3.2	**2.9308**
Ca	546.073	104.578	144.194	417.824	175.848	744.569	**355.51**
Fe	3.926	4.552	3.89	5.99	9.143	9.759	**6.21**
Mg	9.031	8.513	11.82	10.683	11.291	12.242	**10.597**
K	17.483	7.834	6.939	6.108	8.088	20.956	**11.235**
Li	0.011	0.011	0.013	<0.010	<0.010	0.018	**0.0122**
P	<0.060	<0.060	<0.060	0.093	<0.060	<0.060	**0.0655**
Si	14.53	11.316	12.684	12.236	12.561	13.916	**12.874**
Sn	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	**0.02**
Na	12.606	13.47	12.353	12.644	14.368	10.183	**12.604**

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Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.10
Sequential Extraction of Waste Rock Composite

	Al (mg/kg)	Sb (mg/kg)	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Bi (mg/kg)	B (mg/kg)	Cd (mg/kg)	Ca (mg/kg)	Cr (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)
Leach 1	9.55	< 0.040	< 0.030	83.35	< 0.002	1.86	< 0.01	< 0.002	1307.50	< 0.008	< 0.002	1.48	< 0.010	< 0.040
Leach 2	118.76	< 0.0005	0.36	82.22	< 0.001	< 0.001	0.80	2.36	3031.70	< 0.008	0.18	43.62	142.76	5.80
Leach 3	4286.00	< 0.04	< 0.030	31.29	0.06	< 0.07	< 0.010	< 0.002	3590.30	27.87	2.22	114.93	6035.10	2.37
Leach 4	599.00	< 0.04	< 0.030	18.02	< 0.001	< 0.07	< 0.010	< 0.002	448.21	< 0.006	0.59	5.28	1050.90	< 0.040
Leach 5	55284.00	< 5	8.59	947.98	0.79	< 5	395.90	0.14	18626.00	18.616	7.16	10.74	12586.00	8.59

	Mg (mg/kg)	Mn (mg/kg)	Hg (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	K (mg/kg)	Se (mg/kg)	Si (mg/kg)	Ag (mg/kg)	Na (mg/kg)	Sr (mg/kg)	Ti (mg/kg)	V (mg/kg)	Zn (mg/kg)
Leach 1	< 0.050	14.93	< 0.20	< 0.005	2.28	< 1.0	< 0.040	21.34	0.08	171.05	8.29	< 0.002	< 0.006	59.68
Leach 2	265.12	73.54	0.004	< 0.005	0.48	< 1.0	< 0.040	185.66	< 0.001	< 0.07	5.88	< 0.002	< 0.003	2.78
Leach 3	2131.80	103.89	< 0.20	0.03	1.65	314.16	1.08	4203.00	0.18	433.95	21.27	69.00	9.45	29.43
Leach 4	424.25	20.66	< 0.20	< 0.005	< 0.01	247.30	< 0.040	1086.40	< 0.01	129.76	2.31	183.28	2.64	13.33
Leach 5	4163.50	267.07	< 3	< 1	2.15	7638.30	3.58	4318.90	< 1	31860.00	748.29	1981.20	53.70	194.75

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Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.11

Projected Fate of Nitrogen Losses from Blasting Residues

Location (Powder Factor 0.2 kg/t)	Type of Explosive	Explosives Losses (t/a)	Nitrogen Losses (tN/a)	Reporting to Mill	Reporting to Waste Dump	Reporting to Mine Water
Ore Production $1.76x10^6$t/a Total Explosives $0.35x10^6$kg/a	AN/FO (83%) 292 t/a Slurry (17%) 60 t/a	AN/FO (1%) 2.92 Slurry (6%) 3.6	AN/FO (33%) 0.96 Slurry (25%) 0.90	(85%) 0.82 (85%) 0.77	--	(15%) 0.14 (15%) 0.13
Waste Production $7.50x10^6$t/a Total Explosives $1.50x10^6$kg/a	AN/FO (83%) 1245 t/a Slurry (17%) 255 t/a	AN/FO (1%) 12.45 Slurry (6%) 15.30	AN/FO (33%) 4.11 Slurry (25%) 3.83	--	(85%) 3.49 (85%) 3.26	(15%) 0.62 (15%) 0.57
Total Production $9.26x10^6$t/a Total Explosives $1.85x10^6$t/a	AN/FO (83%) 1537 t/a Slurry (17%) 315 t/a	AN/FO (1%) 15.37 Slurry (6%) 18.9	AN/FO (33%) 5.07 Slurry (25%) 4.73	1.59	6.75	1.46

Western Copper Holdings Ltd.
Williams Creek Project

Table 4.12
ICP Analysis of Raffinate and Neutralized Raffinate

Parameter ppm	Raffinate	Neutralized+ Raffinate	% Reduction in Metals*
Aluminum	574.00	0.22	99.96%
Antimony	0.49	0.05	89.80%
Arsenic	0.12	0.02	83.33%
Barium	0.17	0.09	45.03%
Beryllium	0.13	0.00	99.25%
Boron	<0.05	0.05	0.00%
Cadmium	0.12	0.02	87.70%
Calcium	458.20	529.50	−15.56%
Chromium	0.26	0.01	96.59%
Cobalt	0.96	0.01	99.17%
Copper	1.79	0.04	97.93%
Iron	1274.00	2.92	99.77%
Lead	0.07	<0.02	71.43%
Magnesium	350.50	374.20	−6.76%
Manganese	4.32	2.02	53.24%
Mercury	<0.02	<0.02	0.00%
Molybdenum	0.07	0.02	70.27%
Nickel	0.74	0.02	97.31%
Phosphorous	52.51	8.46	83.89%
Silicon	340.00	0.79	99.77%
Silver	0.02	0.01	61.90%
Sodium	32.00	34.00	−6.25%
Strontium	2.11	0.94	55.47%
Titanium	0.11	0.03	73.45%
Tungsten	0.03	<0.02	33.33%
Vanadium	3.11	0.01	99.74%
Zinc	8.95	0.13	98.51%

*values of < are = for % reduction calculations

+raffinate at pH 1.8 was neutralized with slurried lime under aerated conditions to pH 7.0

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Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.13
SWEP Testing of Neutralized Raffinate Precipitate

Element (ppm)	FH NR
Ag	0.013
Cu	<0.010
Pb	<0.04
Zn	0.094
As	<0.030
Sb	<0.04
Hg	<0.020
Mo	0.02
Tl	<0.080
Bi	<0.070
Cd	0.049
Co	0.025
Ni	0.079
Ba	0.018
W	<0.080
Cr	<0.008
V	<0.006
Mn	26.257
Be	<0.001
Sr	3.527
B	<0.010
Se	0.08
Ti	0.019
Al	10.466
Ca	761.589
Fe	0.029
Mg	536.902
K	6.939
Li	0.035
P	0.066
Si	5.85
Sn	<0.020
Na	13.004

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Western Copper Holdings Ltd.
Carmacks Copper Project

Table 4.14
Sequential Extraction of Neutralized Raffinate Precipitate

	Al (mg/kg)	Sb (mg/kg)	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Bi (mg/kg)	B (mg/kg)	Cd (mg/kg)	Ca (mg/kg)	Cr (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)
Leach 1	63.81	< 0.040	< 0.030	0.26	< 0.001	< 0.07	< 0.01	< 0.002	20877.00	< 0.008	< 0.002	< 0.01	< 0.010	< 0.040
Leach 2	12182.00	< 0.0005	0.20	< 0.002	< 0.001	< 0.0005	< 0.005	2.42	11763.00	< 0.008	10.66	< 0.01	2750.60	< 0.04
Leach 3	35583.00	< 0.04	6.84	< 0.002	0.66	< 0.07	< 0.010	2.31	714.15	13.98	25.68	22.95	32896.00	3.09
Leach 4	14.60	< 0.04	< 0.030	0.16	< 0.001	< 0.07	< 0.010	< 0.002	43.16	< 0.006	< 0.002	1.28	6.36	< 0.04
Leach 5	38.15	< 5	< 3	< 1	< 0.1	< 5	0.55	0.01	17.02	0.15	0.02	0.64	15.61	0.96

	Mg (mg/kg)	Mn (mg/kg)	Hg (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	K (mg/kg)	Se (mg/kg)	Si (mg/kg)	Ag (mg/kg)	Na (mg/kg)	Sr (mg/kg)	Ti (mg/kg)	V (mg/kg)	Zn (mg/kg)
Leach 1	< 0.050	203.65	5.820	< 0.005	< 0.01	< 1.000	< 0.040	< 0.03	0.02	245.04	87.30	0.55	< 0.006	0.002
Leach 2	3109.50	319.12	0.004	< 0.005	8.80	< 1	< 0.0005	416.70	< 0.001	< 0.07	27.86	< 0.002	< 0.003	87.32
Leach 3	1077.70	331.80	< 0.02	1.47	14.70	< 1	6.75	1119.70	< 0.01	104.25	6.09	107.46	129.48	283.35
Leach 4	1.00	0.28	< 0.02	< 0.005	< 0.01	< 1	< 0.04	27.80	< 0.010	22.24	0.24	1.92	< 0.006	1.64
Leach 5	2.92	0.15	< 3	< 1	0.26	4.92	0.08	< 10	< 1	5.02	0.34	1.61	0.05	72.80

(\H1811\addend\rafseq.wk3)

WESTERN COPPER HOLDINGS LTD.
Carmacks Copper Project

Table 4.15
Acid Base Accounting of Foundation Area in the Vicinity of the Heap Leach Pad and Events Pond

Sample Identification	% Sulphur	NP/AP Ratio
DH-C 60-65'	0.02	25.3
DH-C 65-85'	0.02	28.3
DH-E 29'	0.02	61.3
DH-E 40-50'	0.02	38.1
DH-F till 36'	0.02	133.9
TR till 5-2'	0.03	40.6
TR 5-30' bedrock	0.02	27.9
RC 92-01, 0-10	0.02	18.9
RC 92-01, 50-60	0.02	25.1
RC 92-01, 100-110	0.03	18.7
RC 92-01, 150-160	0.02	28.3
RC 92-01, 205-210	0.02	18.1
RC 92-01, 255-265	0.02	27.2
RC 92-09, 55-65	0.02	20.2
RC 92-09, 105-115	0.02	20.8
RC 92-09, 155-165	0.02	29.1
RC 92-09, 205-215	0.02	19.5
RC 92-09, 255-265	0.02	19.2
RC 92-09, 305-315	0.02	27.6
RC 92-09, 305-315 (dup)	0.02	28.7

(\H1811\addend\LPABA.WK3)

WESTERN COPPER HOLDINGS LTD.
Carmacks Copper Project

Table 4.16
Till Layer ICP Analysis After Acid Leaching

TOTAL METALS	DH-F-TILL.36'	TR-5-2-TILL
AL	<0.20	<0.20
Sb	<0.20	<0.20
As	<0.20	<0.20
Ba	0.254	0.162
Be	<0.005	<0.005
Bi	<0.10	<0.10
B	<0.10	<0.10
Cd	<0.010	<0.010
Ca	325	342
Cr	<0.015	<0.015
Co	<0.015	<0.015
Cu	0.058	0.163
Fe	<0.030	<0.030
Pb	<0.050	<0.050
Li	<0.015	<0.038
Mg	13.4	8.72
Mn	0.204	0.422
Mo	<0.030	<0.030
Ni	<0.020	<1.12
P	<0.30	<0.30
K	8.9	6.2
Se	<0.20	<0.20
Si	6.53	6.58
Ag	<0.015	<0.015
Na	18.2	16.8
Sr	0.979	0.788
Tl	<0.10	<0.10
Sn	<0.30	<0.30
Ti	<0.010	<0.010
W	<0.10	<0.49
V	0.030	0.030
Zn	0.084	11.6

(\H1811\Addend\Tbl-Till.doc)

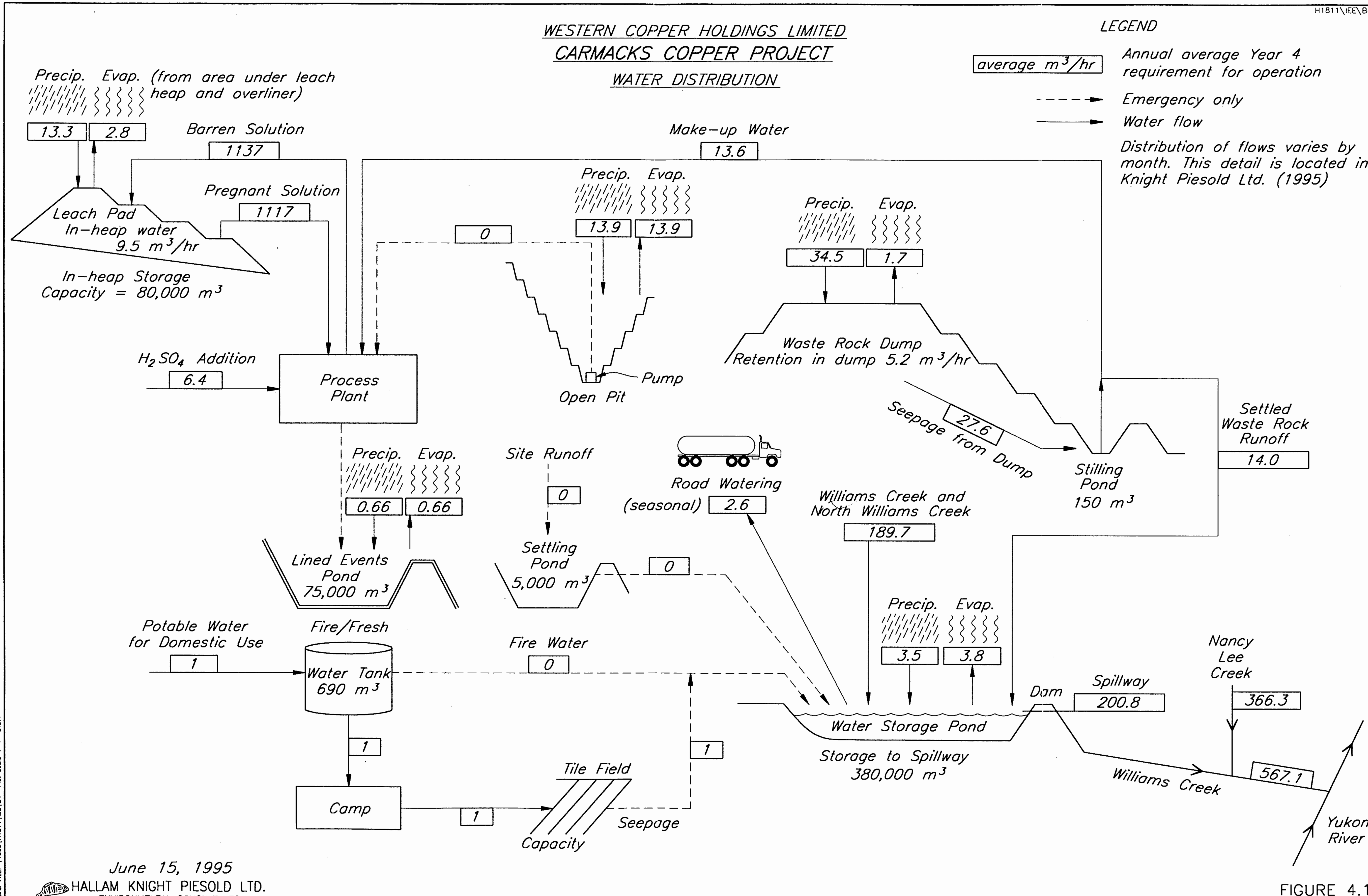
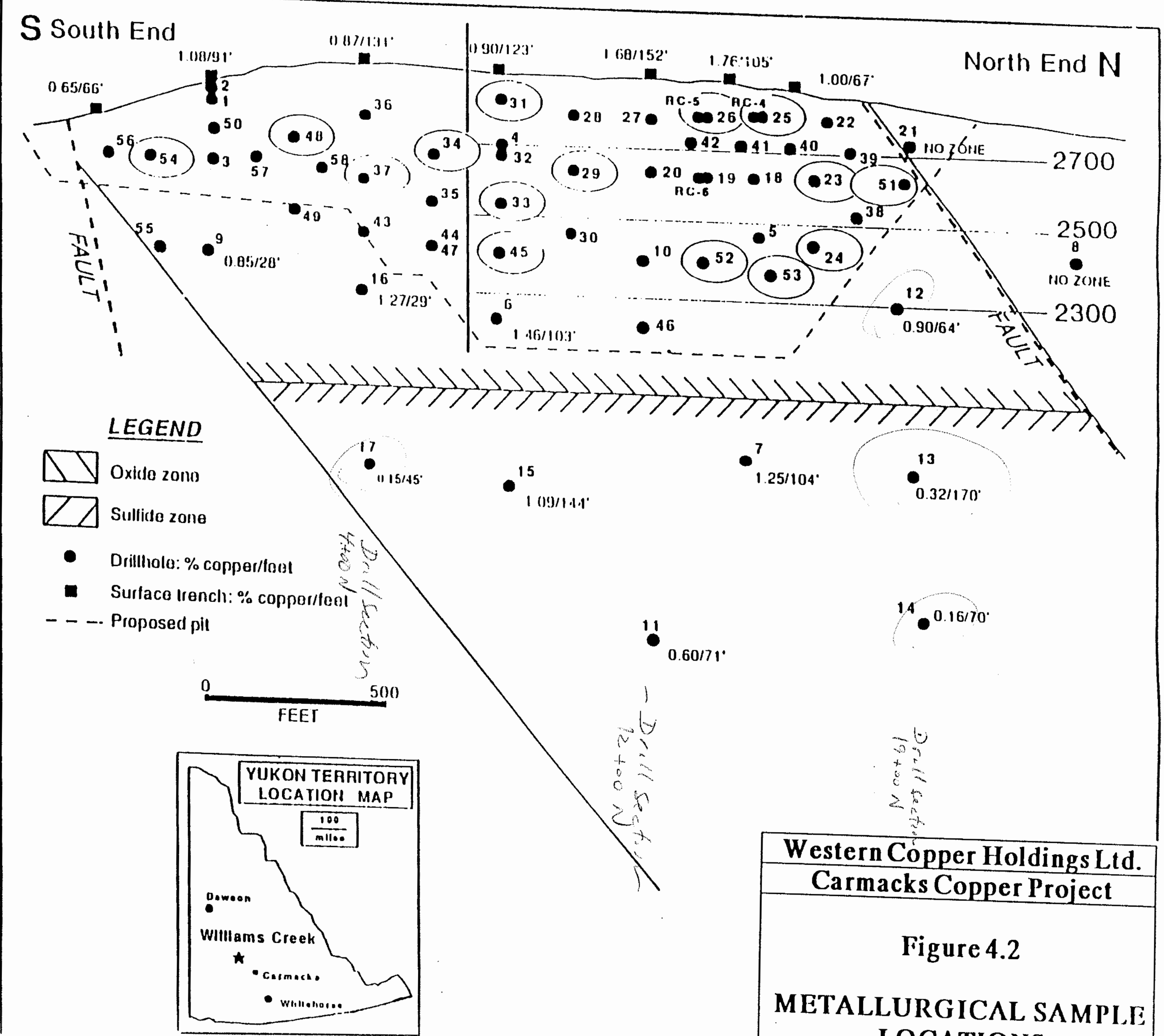

H1811\IEE\B4
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
WATER DISTRIBUTION
LEGEND
average m³/hr
Annual average Year 4 requirement for operation
Emergency only
Water flow
Distribution of flows varies by month. This detail is located in Knight Piesold Ltd. (1995)
Precip. Evap. (from area under leach heap and overliner)
13.3
2.8
Barren Solution
1137
Make-up Water
13.6
Pregnant Solution
1117
Leach Pad
In-heap water
9.5 m³/hr
In-heap Storage
Capacity = 80,000 m³
0
Precip. Evap.
13.9
13.9
Precip. Evap.
34.5
1.7
Waste Rock Dump
Retention in dump 5.2 m³/hr
H₂SO₄ Addition
6.4
Process Plant
Pump
Open Pit
Seepage from Dump
27.6
Settled Waste Rock Runoff
14.0
Stilling Pond
150 m³
Precip. Evap.
0.66
0.66
Site Runoff
0
Road Watering
(seasonal) 2.6
Williams Creek and North Williams Creek
189.7
Lined Events Pond
75,000 m³
Settling Pond
5,000 m³
0
Precip. Evap.
3.5
3.8
Potable Water for Domestic Use
1
Fire/Fresh
Water Tank
690 m³
Fire Water
0
Dam
Spillway
200.8
Nancy Lee Creek
366.3
Water Storage Pond
Storage to Spillway
380,000 m³
1
1
Camp
1
Tile Field
Capacity
Seepage
Williams Creek
567.1
Yukon River
June 15, 1995
HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 4.1

HOLE	INTERVAL TRUE WIDTH	% Cu
1	80'	1.26
2	40'	0.45
3	40'	1.50
4	66'	0.69
5	190'	1.34
10	105'	1.30
18	160'	1.61
19	139'	0.96
20	124'	1.55
22	127'	1.19
23	203'	1.82
24	160'	1.14
25	130'	1.36
26	129'	0.83
27	136'	1.53
28	123'	0.98
29	121'	1.06
30	99'	1.51
31	112'	0.94
32	90'	1.07
33	56'	1.10
34	76'	1.45
35	57'	1.08
36	69'	0.76
37	61'	0.84
38	166'	0.55
39	83'	0.54
40	110'	1.36
41	155'	1.22
42	137	1.11
43	131'	1.09
45	84'	0.99
46	174'	1.31
47	116'	1.39
48	55'	1.32
49	70'	0.78
50	127	0.84
51	82'	0.31
52	165'	1.3
53	183'	1.17
54	35'	1.18
55	1.2'	1.39
56	30'	1.42
57	75'	1.16
58	121'	1.15
RC-4	118'	1.39
RC-5	130'	1.06
RC 6	126'	1.13



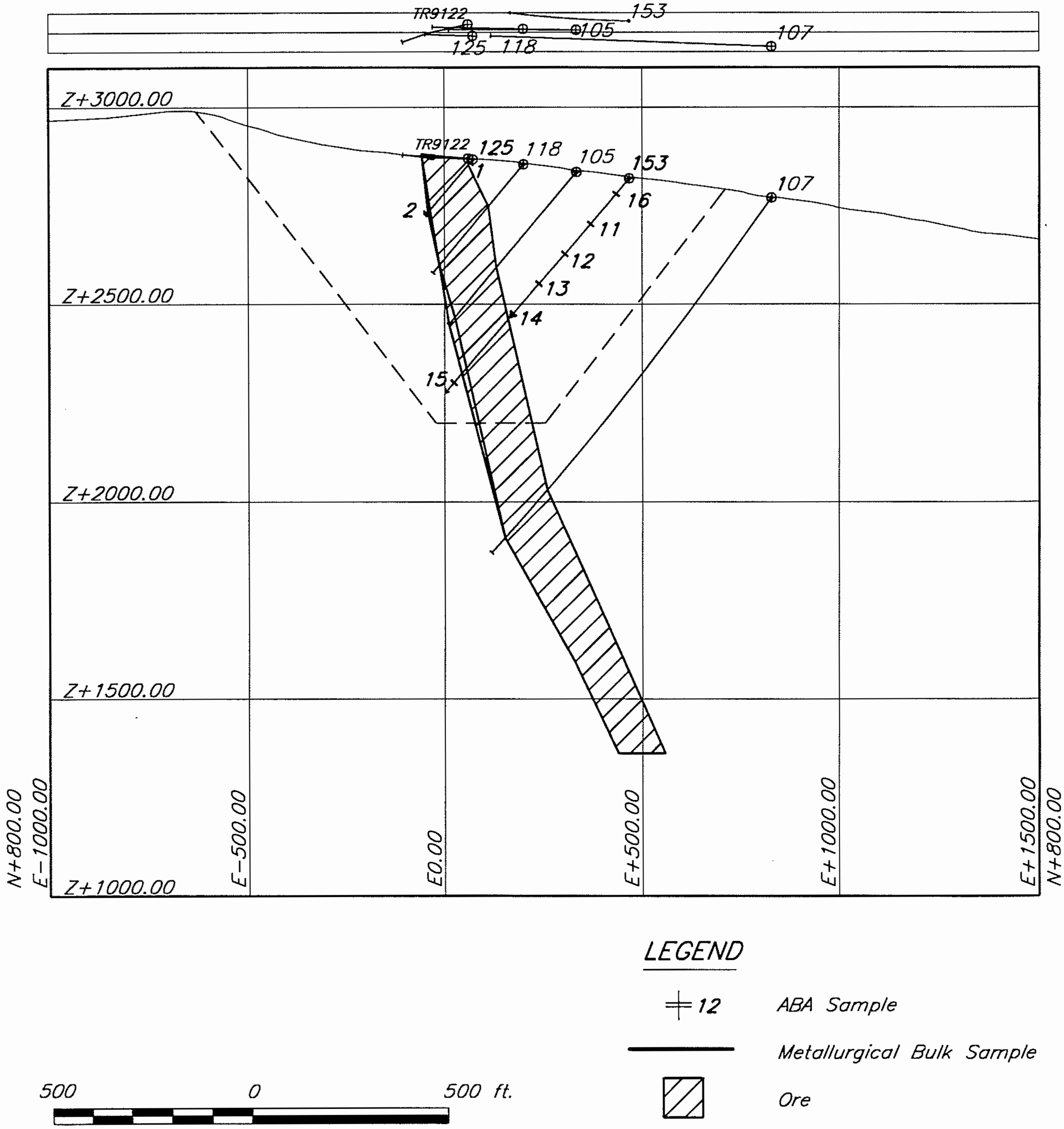
Western Copper Holdings Ltd.
Carmacks Copper Project

Figure 4.2

METALLURGICAL SAMPLE LOCATIONS

H1811\IEE\A5

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT
ACID BASE ACCOUNTING SAMPLE SITES
SECTION 1500N



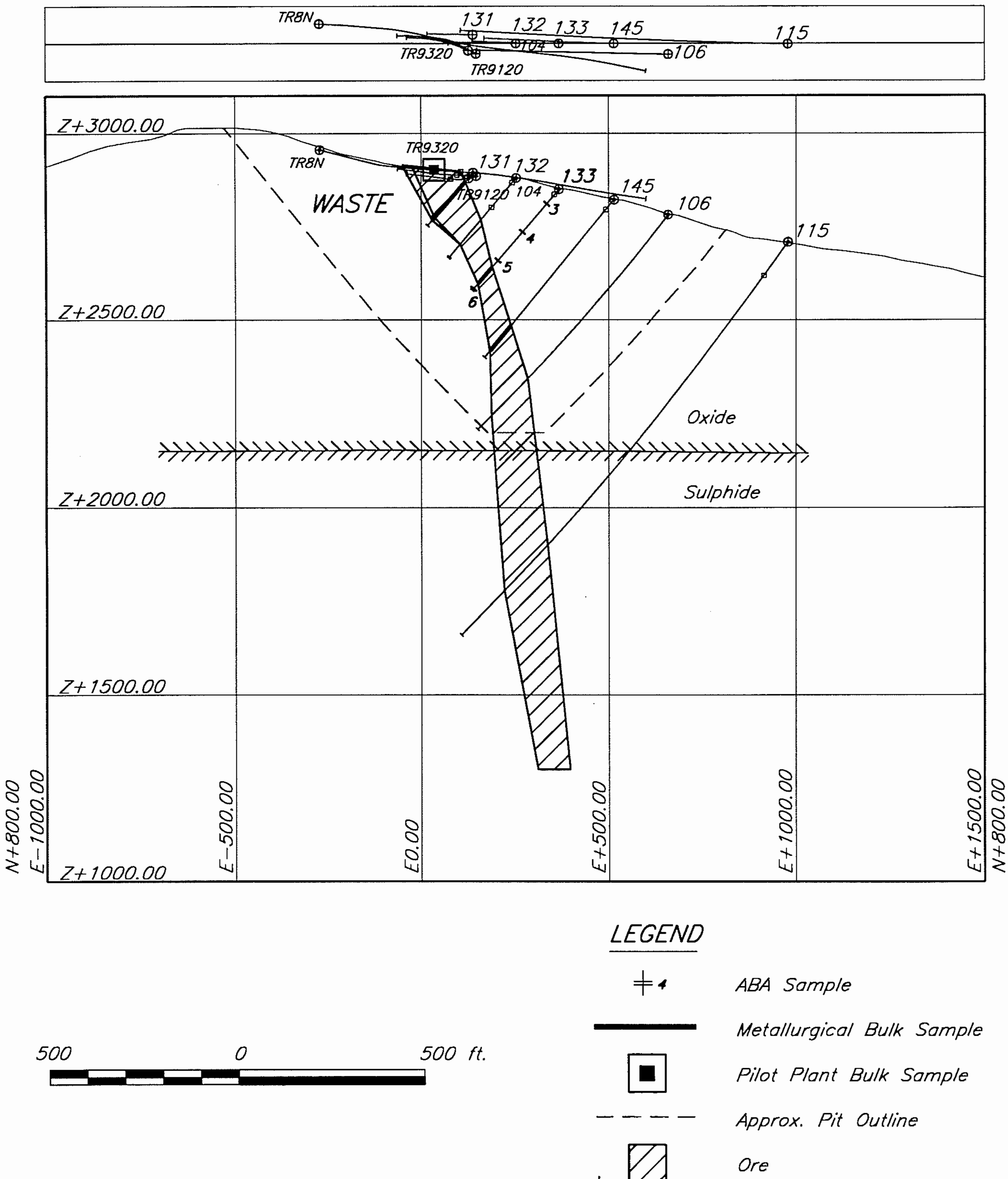
CAD FILE: \1000\H1811\IEE\A5 Plot 1=15

June 16, 1994

HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 4.3

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT
ACID BASE ACCOUNTING SAMPLE SITES
SECTION 800N



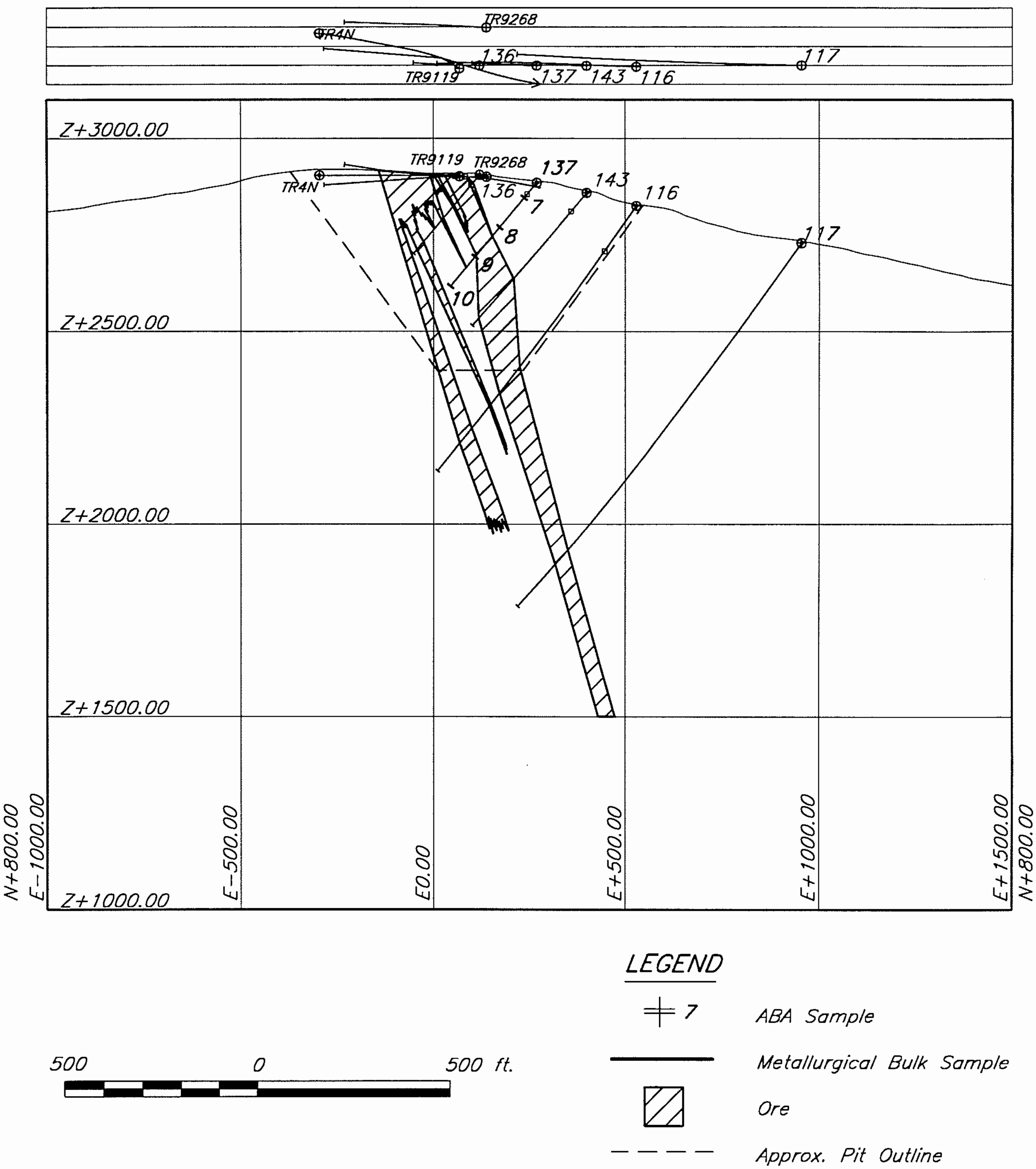
CAD FILE: \1000\H1811\IEE\A6 Plot 1=15

August 18, 1994

HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 4.4

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT
ACID BASE ACCOUNTING SAMPLE SITES
SECTION 400N



CAD FILE: \1000\H1811\IEE\A7 Plot 1=15

August 18, 1994

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FIGURE 4.5

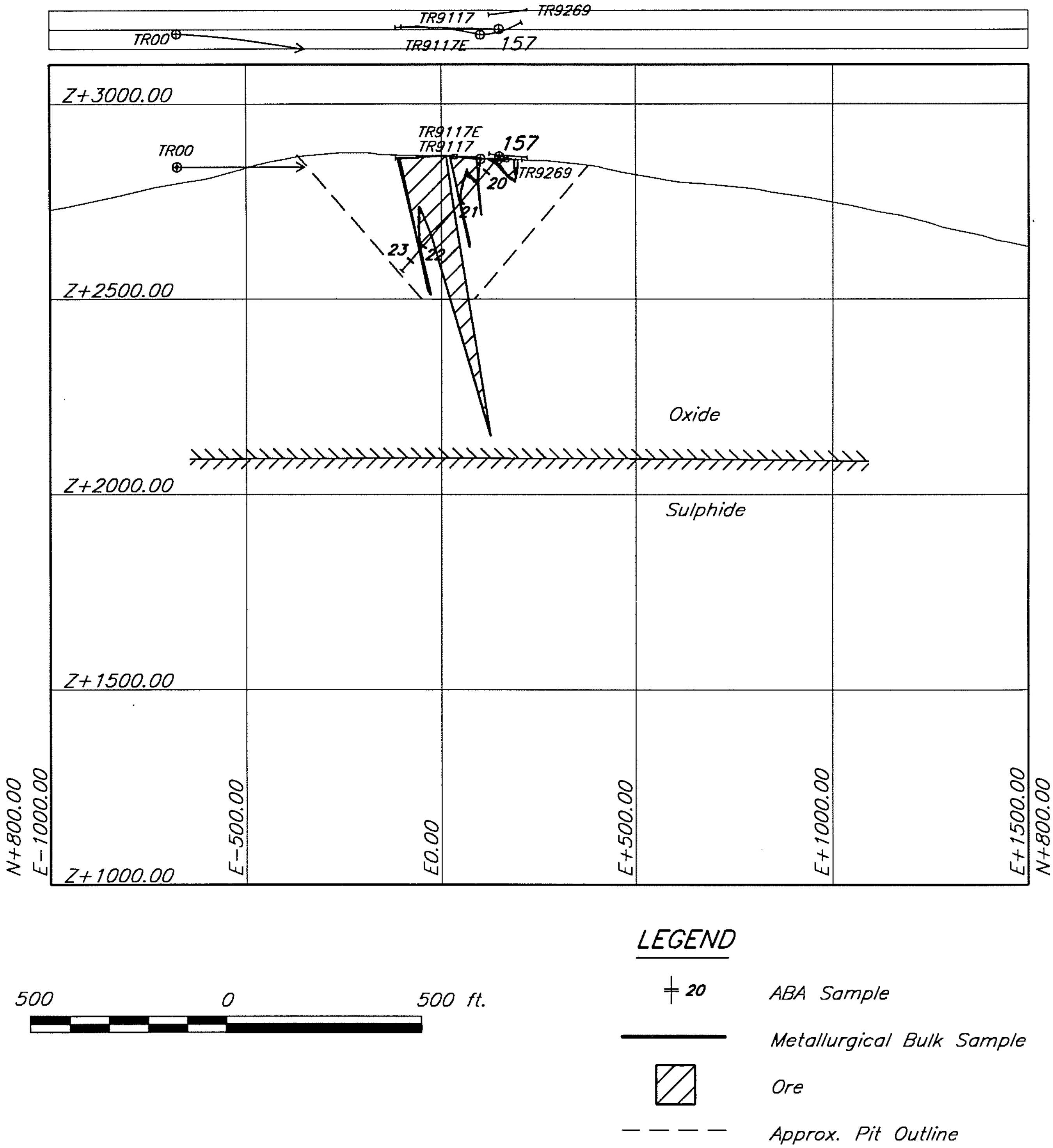
H1811\IEE\AB

WESTERN COPPER HOLDINGS LTD.

CARMACKS COPPER PROJECT

ACID BASE ACCOUNTING SAMPLE SITES

SECTION 100N



CAD FILE: \1000\H1811\IEE\AB Plot 1=15

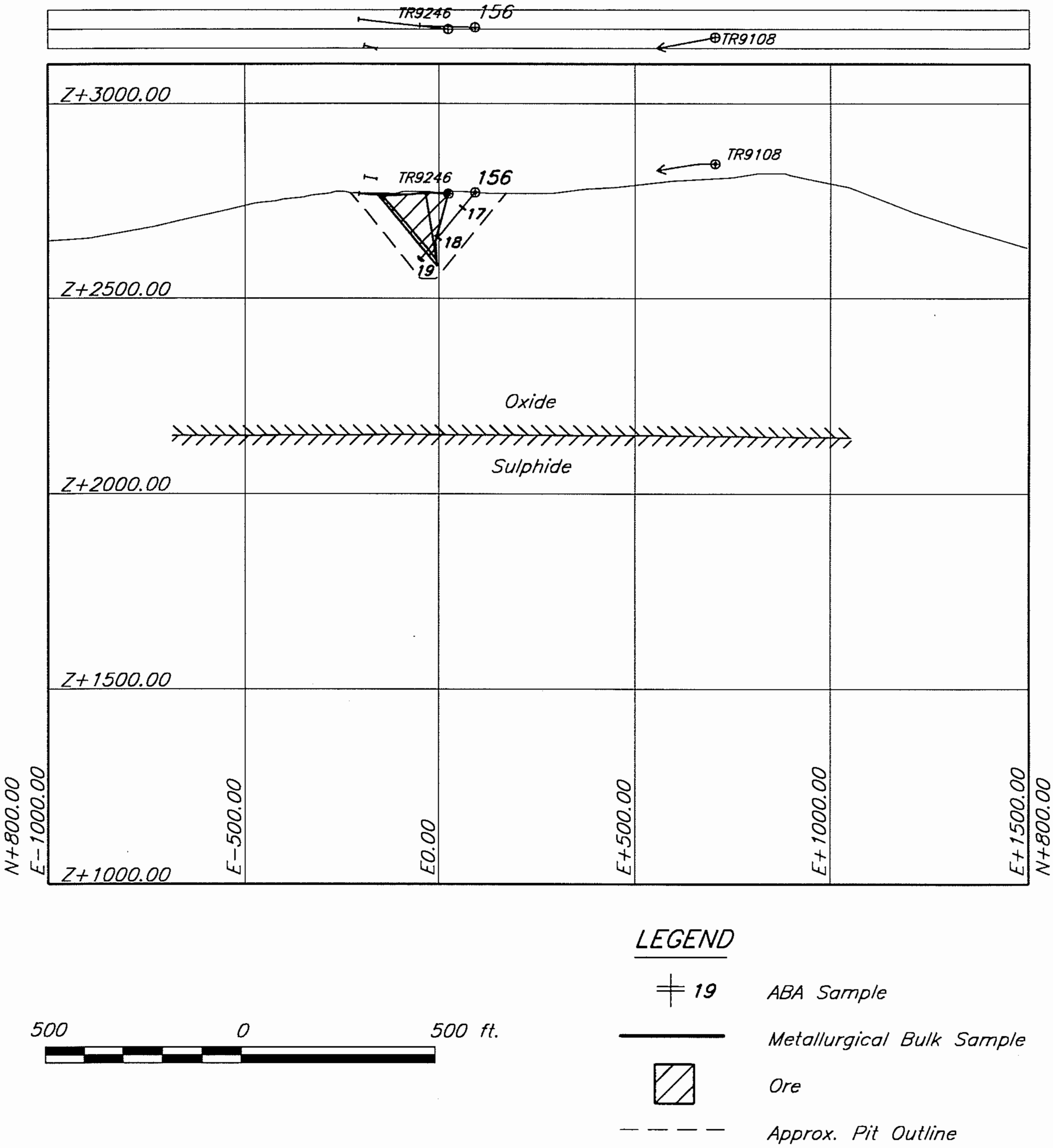
August 18, 1994

HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 4.6

H1811\IEE\A9

WESTERN COPPER HOLDINGS LTD.
CARMACKS COPPER PROJECT
ACID BASE ACCOUNTING SAMPLE SITES
SECTION 300S



CAD FILE: \1000\H1811\IEE\A9 Plot 1=15

August 18, 1994

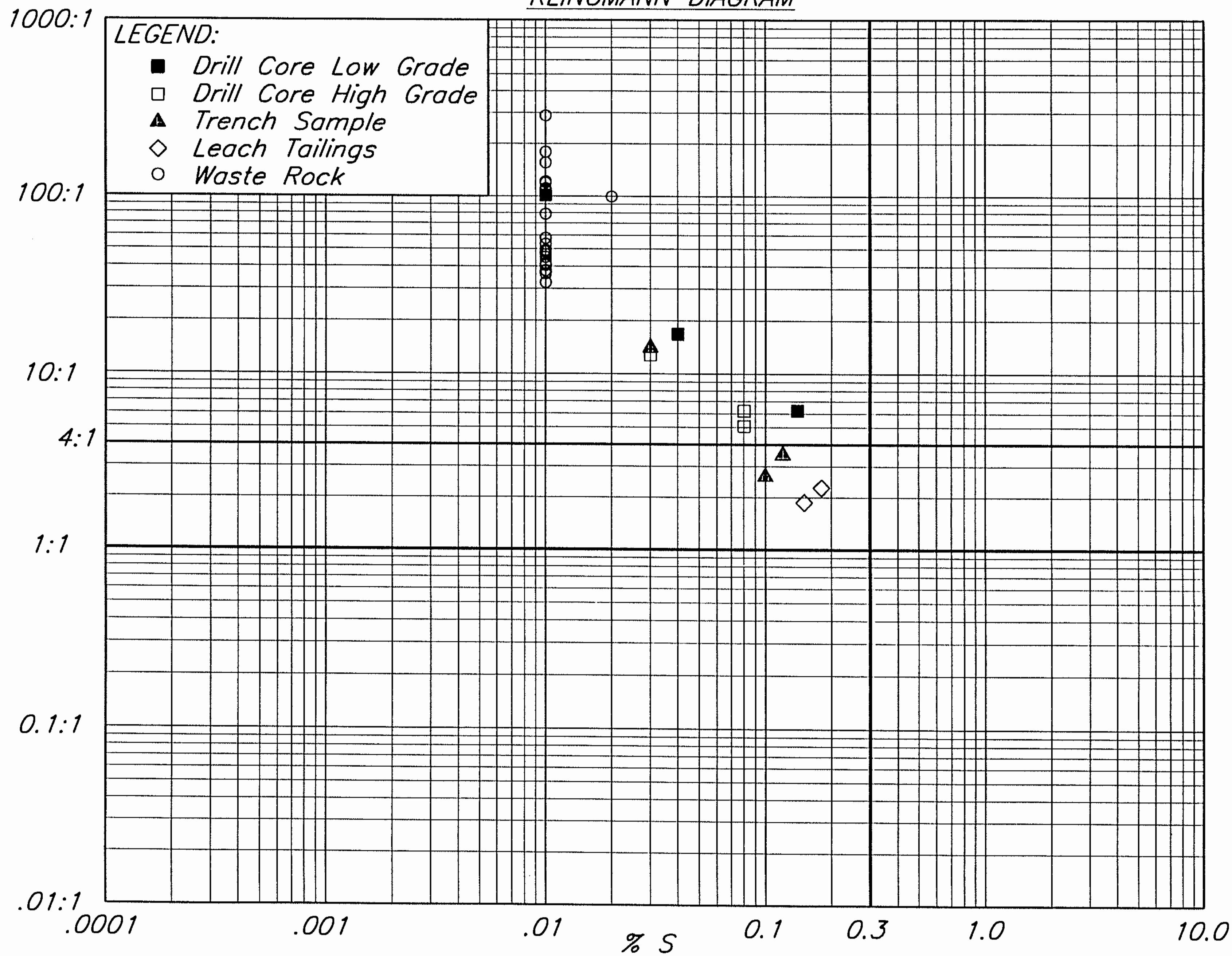
HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 4.7

WESTERN COPPER HOLDINGS LTD.

WILLIAMS CREEK COPPER OXIDE PROJECT

KLINGMANN DIAGRAM



Jan. 27, 1995
HALLAM KNIGHT PIESOLD LTD.
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FIGURE 4.8

SECTION 5.0 - REVISED ENVIRONMENTAL IMPACT ASSESSMENT

5.1 INTRODUCTION

Changes in the mine plan made in early 1995 have resulted in a number of changes to the projected impacts on the receiving environment. Based on the project overview presented in Section 1 and the 1995 Knight Piesold Ltd. report, the revised impact assessment is presented in the sections that follow. This supersedes the impact assessment presented in Volume IV of the IEE.

5.2 PHYSIOGRAPHY, SOILS AND NATURAL HAZARDS

5.2.1 Topography

The Carmacks Copper Project is located within the Klondike Plateau physiographic subdivision which is characterized by rolling till plains forming the dominant glacial landform. The Williams Creek Valley is broad with rounded ridge crests. Relief ranges from 480 to 900 m. The project lies in the Williams Creek watershed which flows into the Yukon River 7 km downstream of the deposit.

The study area lies within the discontinuous permafrost subzone. During field examination, ground ice was encountered at depths of 40 to 50 cm on most north facing slopes where glacial till or medium textured colluvium is present. Ground ice is widespread in the main Williams Creek floodplain as well as the north facing tributary gullies.

Mining operations will result in four permanent changes to local topographical features:

- an open pit covering an area of approximately 32.8 ha and a maximum depth of 230 m;

- a waste rock storage area covering an area of approximately 81.6 ha and a maximum height of 140 m;
- a heap leach pad covering an area of approximately 37.0 ha and a maximum height of 150 m; and
- a fresh water storage pond covering approximately 14.3 ha with a dam reaching a maximum height of 14 m.

Based on data compiled during the drilling program it is expected that negligible groundwater will be encountered during the excavation of the open pit. The waste rock and heap leach pad located north and southwest of the open pit, respectively, will be contoured to a slope less than the angle of repose and the crests on each lift rolled in order to integrate the dumps into the surrounding terrain. The top of the waste rock storage area will be recontoured to avoid concentration of runoff and, in part, to imitate a gently rolling plateau. The surface will be covered with a layer of overburden salvaged from stripping the open pit, waste rock dump and water storage pond, and revegetated.

Other minor changes to the local topography will result from the construction of diversion channels, drainage ditches and road ways, most of which will be restored to their original configuration on closure and reclamation. All disturbed areas such as the waste rock dump, open pit perimeter and heap leach pad will be revegetated on mine closure. A more detailed description of the revegetation plans for each Reclamation Unit is presented in Section 7.0.

5.2.2 Soils

On the basis of regional mapping and site test pitting, soils in the mine site area are dominated by Eutric Brunisols originating from dissected colluvial parent material. Soil texture is gravelly sandy loam (Agriculture Canada 1992, Knight Piesold Ltd. 1993).

According to dominant morphological features and vegetation, well drained soils on south facing slopes are gravelly sandy loam and are expected to be moderately alkaline and have moderate to high organic matter content and nutrients. Areas with moderate to poor drainage, dominated by lodgepole pine and black spruce, respectively, are expected to be more acidic with low to very low nutrient content. Lodgepole pine areas are expected to have much lower quantities of organic matter than the poorer drained areas of black spruce stands (Kennedy 1993).

The disturbance of soils due to mining activity will occur at a number of areas including:

- the open pit;
- waste rock dump;
- the process plant and ancillary facilities;
- the heap leach pad (including events pond and sediment control pond);
- the fresh water storage pond;
- along powerline and road corridors; and
- borrow areas.

During construction, soils will be stripped from areas of development and stored for reclamation purposes on mine closure. Prior to construction, soil quality will be tested to confirm regional mapping and determine if the soils have sufficient nutrients and organic matter to support plant growth. Although soils and overburden material provide valuable growth medium, supplementation with fertilizer and other soil amendments will be required for successful revegetation.

5.2.3 Permafrost

The Carmacks Copper Project lies in an area of discontinuous permafrost which corresponds to an area between the 0°C and -10°C mean annual temperature isotherms. The site mean annual air temperature was calculated from the estimated annual freeze and thaw indices. The mean annual air temperature was calculated as -5°C for an elevation of 850 m at the Williams Creek Site. Thermistor strings Th-1 and Th-2 were installed on a north and south facing slope respectively to measure the temperature as a function of depth. These thermistors have been measured intermittently since 1992 with the results tabulated on Table 5.1a. Thermistor Th-3 was installed in 1995 with two readings taken to date. The measurements are presented in Table 5.1b. The temperature measurements to date indicate that the permafrost temperatures are near 0°C generally ranging between -0.1° and -0.3°C which is classified as "warm" permafrost.

Areas of permafrost occur in the Williams Creek valley in the vicinity of the creek itself and in the north aspect tributaries. Permafrost areas are subject to mass wasting when vegetation is cleared and vehicle disturbance occurs. Ice layers begin to melt from increased heat absorption on bare ground resulting in mud sliding downhill and exposing more ice. As a result, roads in particular become unfit for travel and difficult to stabilize and reclaim.

Road alignments will be chosen carefully and constructed in a manner which avoids road cuts and therefore does not expose permafrost. Gravel roads will be engineered and constructed to maintain permafrost conditions (i.e., the -5°C isotherm) under and surrounding the road. Typically, this involves construction of a gravel road base up to approximately 3 m thick directly on top of existing soils with no pre-construction stripping of organic material. If necessary, other design considerations (such as mixing insulating material with gravel and installation of thermal siphons to vent off heat) may be used to prevent permafrost degradation. The road will be maintained by installation of cross-drains and waterbars. Equipment movement over roads will be minimized and equipment that exerts low ground pressure will be selected. Similar design considerations will be included in construction of diversion ditches, heap leach pads, waste rock piles, and process and ancillary facilities to minimize the potential for permafrost degradation.

5.2.4 Seismic Risk

A review of historical information on seismicity for the mine site was obtained from the Earth Physics Branch of Energy Mines and Resources Canada, Pacific Geoscience Centre at Sidney, B.C. A record of the experienced shock intensity for the proposed mine site (62.37°N, 136.67°W) in terms of ground acceleration as percentage of gravity was obtained from their computer program.

A method of expressing an estimate of earthquake probability, the Cornell-McGuire method, has been introduced in terms of exceeding peak horizontal ground velocity and acceleration on an annual basis and within a 50 year period (Basham et al, 1982, 1985; and Heidebrecht et al, 1983). This method replaces the 1970 zoning map of the National Building Code (NRCC, 1985). The acceleration and velocity mapping provides for seven zones (as opposed to four zones), and a change in the probability of exceedence from 0.01 per annum on the 1970 map to 10% in 50 years, which is mathematically equivalent to a probability of exceedence of 0.0021 per annum as compared to the previous value of 0.01. Acceleration and velocity zone maps are shown in Figure 5.1 and probabilities for the mine site are given in Table 5.2.

For the Carmacks Copper Project, a ground motion of 0.083 G[1] and 0.196 m/s would have a 10% probability of being exceeded in 50 years. Such a probability places the site within Acceleration Zone 3 and Velocity Zone 4 (Table 5.3). In cases where calculated values place a site within an Acceleration Zone and a Velocity Zone that has greater than a difference of one, the acceleration zone is increased by one, however, this is not necessary for this site. The mine site is regarded as having a moderate to low probability of experiencing a major earthquake.

The values of acceleration listed for the proposed mine site are for firm soils or the soil-bedrock interface. The physical effect on overburden soil would be an amplification of motion from rock to the overlying ground surface. For soft soils, a factor of 1.5 and 2.0 are generally used for design values.

5.2.5 Terrain Hazards

Terrain analyses of the Carmacks Copper property conducted by Westland Resources Group (Figure 5.2) indicated that the potential for flooding is high at the Williams Creek confluence with the Yukon River, and within the creek valley to approximately 4 km upstream. Flooding potential for Nancy Lee Creek is also high. All developments are upstream of these potential flood areas.

Areas with evidence of active landsliding were observed on south facing steeply sloping scarps adjacent to Nancy Lee Creek and North Williams Creek (Figure 5.2).

[1] G=gravity, 32 feet/sec/sec

5.3 AIR EMISSIONS AND DUST CONTROL

Overall atmospheric emissions from mining operations at the Carmacks Copper Project are not considered to be a significant environmental concern and will be primarily limited to fugitive dust from open pit mining, hauling and crushing operations, and will be typical of most mine sites. As there will be no roasting or smelting operations, gaseous emissions will be limited to ventilation of the reagent area, the process plant (solvent extraction and electrowinning areas) and the fume hoods in the assay laboratory. Therefore, no source of significant chemical air emissions would require special treatment or control.

Point sources of particulates will be equipped with baghouses, wet scrubbers or filters. Fugitive dust from blasting and hauling will be controlled to the maximum extent possible employing normal dust control procedures such as watering main haul roads. Ore transported from the crusher to the heap leach pile via conveyors is not expected to produce significant dust since the freshly crushed ore contains 1 to 2% moisture.

Vehicle combustion products from the burning of diesel fuel and heating emissions are not expected to significantly impact air quality.

Detailed engineering is currently in progress to ensure compliance with all territorial requirements. Methods of control and detailed design specifications will be provided as required in application for operating permits covering the following:

- the assay laboratory;
- the administration and accommodation heating;
- process plant, maintenance shop, dry and crusher buildings; and
- miscellaneous vents, fume hoods and exhaust fans.

The nature of the air emission sources and their associated controls are presented in the following subsections.

5.3.1 Pit Fugitive Dust

The pit operations will generate dust from general mining activities and the primary sources of dust will be vehicle traffic, drilling and blasting. The standard method used in the industry to control road dust is by watering roads with designated water trucks. This practice has been demonstrated to be effective and is the preferred strategy for controlling road dust during frost-free periods.

There will be sufficient excess water for this purpose which will be available at the water storage pond. Road watering will take place in June, July, August and September. This will help to ensure that actively used roads receive regular watering for dust suppression.

5.3.2 Coarse Ore Stockpile

The ore trucked from the mine area will be stockpiled in a live stockpile adjacent to the crusher for primary feed. Although some fugitive dust loss will occur from this stockpile, exposure to the elements will result in some attenuation of these losses by precipitation. Water sprays can be used for dust control, if necessary, when weather conditions permit. The ore also contains some natural moisture which will reduce losses. The overall fugitive dust losses are expected to be similar to typical stockpile losses experienced throughout the industry, and are not expected to have significant impacts on the adjacent area.

5.3.3 Crushing

The dust generated from the crushing and screening will be vented off. Agglomerated ore from the acid storage tank and the undersize conveyor will be transported via portable conveyors to the leach pad. Because this is a wet system, dust emissions are expected to be minimal. Water sprays will be used, if necessary, during frost-free periods to reduce fugitive dust in the area.

5.3.4 Reagent Mixing and SX/EW Plant

Within the solvent extraction building the primary source of vapour will be from Solvent 160 (kerosene). The plant will be equipped with a ventilation system to exhaust general vapours from the working environment to the atmosphere. A similar system will be installed in the electrowinning building to eliminate the acid mist. As these sources are generally small compared to stack emissions and other industrial sources, there will be minimal environmental impact, if any, and no treatment will be required. Primary concerns with vapour control within the process plant will be worker health, safety and fire prevention.

5.4 GROUNDWATER HYDROLOGY AND WATER QUALITY

5.4.1 Groundwater Hydrology

Investigations to date indicate that the distribution of groundwater at the site is limited to the active layer, small perched water tables above the discontinuous permafrost and at considerable depths along the main drainage courses as subpermafrost groundwater. Investigations at the site have intersected groundwater in the active layer during test pit excavations. Groundwater was encountered in only two drillholes DH-C and RC-92-01. The depth to groundwater in DH-C, in the proposed leach pad area, was 6.8 metres as a shallow perched water table above the permafrost. The depth of groundwater in RC-92-01, south of the events pond adjacent to Williams Creek, has been monitored since 1992 at 15.5 metres.

5.4.1.1 Open Pit

Development of the open pit will result in a cone of depression in the groundwater table radiating from the floor of the pit outwards. This water which normally migrates to North Williams and Williams Creeks as groundwater will be collected in the pit and pumped to the process plant as make-up water.

On mine closure the pit will be allowed to accumulate water; however, the currently available data indicates that the groundwater table may not be intercepted in the vicinity of the open pit. Although the exact pre-production conditions will be altered by the loss of water to the open pit the resulting flow conditions in Williams Creek will not be significantly altered.

5.4.1.2 Waste Rock Storage Area

The accumulation of material in the waste rock storage area could potentially raise the permafrost level under the pile, as it would be sufficiently deep to insulate the ground from surface warming. This may result in a permafrost mounding under and within the lower layers of the waste rock dump which would partially divert, but not significantly impact near-surface groundwater. The area of mounding would be limited to the area covered by the waste rock storage pile.

5.4.1.3 Heap Leach Pad

During construction, the leach pad area will be lined with a 60 mil HDPE liner and a soil liner varying in thickness from 500 mm thick beneath the in-heap storage to 300 mm thick beneath the remainder of the pad (Knight Piésold Ltd. 1995) in order to prevent leakage to groundwater. Consequently, surface recharge to the groundwater table in the area of the heap leach pad will not occur over an area of approximately 37 ha ($\sim$0.4% of the 88 km^2 watershed). There is the potential for the permafrost levels to lower under the heap leach pad due to heat losses from leach solutions into the ground possibly melting the permafrost. This could partially divert near-surface groundwater flows within this area.

5.4.1.4 Fresh Water Storage

Construction of an embankment on Williams Creek will create a freshwater storage pond (Figures 1.1 and 1.9). The storage basin and the upstream face of the embankment will be lined with a single 60 mil HDPE geomembrane to prevent leakage. This structure will raise the water table in this localized area.

5.4.2 Groundwater Quality

Extensive control measures have been included in the design of the Carmacks Copper Project to ensure that the impacts to groundwater are eliminated entirely. The measures include, maximizing recycle of process streams, inclusion of primary and secondary liner systems, containment berms, seepage detection systems and groundwater monitoring systems.

The heap leach pad will be equipped with an impermeable liner overlying a secondary low permeability soil liner, therefore, minimal contamination to the groundwater is expected. Foundation drains beneath the pad will serve as a leak detection system. The events pond will be lined with two 60 mil HDPE geomembranes with a geonet between them.

Waste rock storage facilities will not be lined, but analyses of the waste (acid-base accounting) indicates that waste rock is overwhelmingly acid consuming. The waste rock storage area will be equipped with a stilling basin and a foundation drainage system to collect waste rock dump seepage, both lined with 8 oz. non-woven geotextile. The waste rock dump will also be equipped with perimeter drainage ditches to intercept and collect surface runoff. The stilling basin will allow for the settling out of larger particles in the runoff before it enters the water storage pond.

Although impacts to groundwater quality are projected to be negligible, a comprehensive groundwater monitoring program has been initiated and will be ongoing through construction and operation. Twelve groundwater piezometers have been installed in the vicinity of the heap leach pad and downslope of all facilities and will be sampled to ensure a monitoring system that could detect potential losses from the site during operations. Preliminary baseline groundwater quality data from RC-92-01 is presented in Appendix 3.

Initial results indicate that groundwater is neutral to slightly basic (pH 7.8), alkaline (113 mg/L $CaCO_3$), moderately high suspended and dissolved solids (80 mg/L and 384 mg/L, respectively in March 1995). Anion analysis resulted in 2.4 mg/L chloride, <2 mg/L fluoride, and 168 mg/L sulphate. Total metals were detectable in March and April 1995 for many metals and relatively high for aluminum (3.4 and 1.44 mg/L, respectively), copper (0.157 and 0.038 mg/L), iron (4.09 and 1.71 mg/L), manganese (0.215 and 0.146 mg/L), and molybdenum (0.059 and 0.061 mg/L).

Dissolved metals were below detection for many metals and detectable for aluminum (0.04 mg/L in March), barium (0.190 and 0.169 mg/L in March and April, respectively), copper (0.031 and 0.007 mg/L), iron (1.07 and 0.009 mg/L), manganese (0.037 and 0.082 mg/L), molybdenum (0.053 and 0.060 mg/L), strontium (0.79 and 0.74 mg/L), vanadium (0.004 and 0.003 mg/L), and zinc (0.010 and 0.006 mg/L).

The revised liner system proposed by Knight Piésold Ltd. (1995) includes a composite of 60 mil High Density Polyethylene and a soil liner 500 mm thick beneath the in-heap storage and 300 mm beneath the rest of the pad. A high level of QA/QC will be employed during liner placement as discussed in Section 7 of "Carmacks Copper Project, Report on Preliminary Design (Ref. No. 1783/1)" (Knight Piésold Ltd. 1995).

The groundwater monitoring program includes five wells installed in 1992:

RC-92-01 — south west of the leach pad and ancillary facilities, adjacent to Williams Creek

RC-92-04, -05, -06 — vicinity of the open pit

RC-92-09 — vicinity of the leach pad

and 10 wells installed in 1995:

DH-A, -B (2 wells), -C, -D, -E, -F, -G (2 wells), vicinity of the leach pad

DH-1, -2 (2 wells) — vicinity of the water storage dam

In addition, 3 thermistor strings were installed to monitor ground temperature. Thermistor readings are presented in Tables 5.1a and 5.1b.

5.5 SURFACE WATER HYDROLOGY AND WATER QUALITY

5.5.1 Surface Water Hydrology

Mean annual flows in Williams Creek at the point of the water storage reservoir are estimated to be 0.06 m^3/s below the water storage dam and 0.16 m^3/s at the confluence with the Yukon River. Freshet is typically flashy depending on the amount of snowpack and temperatures. Peak freshet flows occur in late April.

The proposed operations will result in a slight modification to the mean annual distribution in runoff and an overall reduction in mean annual flows in Williams Creek at the water storage reservoir and to a lesser extent, below Nancy Lee Creek near the confluence with the Yukon River, as a result of:

- filling of the fresh water storage reservoir, and
- during operations to satisfy the deficit in process water requirements.

The proposed water storage pond will have a total capacity of 380,000 m^3. Filling of the dam during freshet would require 25 days or 73 days at mean annual flow to fill the water storage pond to its maximum capacity. During the filling flows in Williams Creek will reduced to zero below the dam and to 65% of normal flows at the creek mouth.

As all operations are located above the water storage reservoir and all process streams are designed to operate at 100% recycle, the only impact on the flows in Williams Creek will be the net difference in water pumped from the water storage pond to meet process deficits and the volume of water returned to Williams Creek from the spillway.

Based on average year precipitation estimates (Table 4.1) annual average reductions in flows immediately below the water storage reservoir range from 7.00% or 0.005 m^3/s in Year 9 (0.061 m^3/s to 0.056 m^3/s) to 8.62% or 0.006 m^3/s in Year 1 (0.061 m^3/s to 0.055 m^3/s). The corresponding reductions in flows at the mouth of Williams Creek are 2.6% in Year 9 (0.162 to 0.158 m^3/s) and 3.2% in Year 1 (0.162 to 0.157 m^3/s).

The "worst case" scenario was calculated for the estimated 10-year dry precipitation water balance (Year 1). The reduction in flows was estimated at 17.73%% or 0.006 m^3/s (0.034 m^3/s to 0.028 m^3/s). Corresponding 10-year dry reductions in flow at the creek mouth would be 6.8% (0.088 m^3/s to 0.082 m^3/s).

Daily and seasonal variations in flow as a result of spring freshet or isolated rainstorm events will have little or no impact on the proportion of the projected reduction. However, because of the retention provided by the waste rock dump and the waste rock dump stilling basin there may be a slight modification to the distribution of runoff.

Although the reduction in mean annual flows are insignificant and well within variations in annual runoff, the impact on low flow periods would be somewhat more pronounced. Low flows in the fall months (October) will result in 100% reduction in flows, as in Year 1, 10-year dry precipitation, to 54.23% (0.01 m^3/s to 0.0046 m^3/s), as in Year 9, 10-year wet precipitation. Corresponding reduction in flows at the creek mouth have been estimated at 39.5% (0.01 m^3/s to 0.006 m^3/s) to 22.2% (0.027 m^3/s to 0.021 m^3/s).

5.5.2 Surface Water Quality

Since the proposed operations will operate at a deficit and on the basis of 100% recycle of process streams, there will be no release of effluent to the receiving environment. The only releases to the Williams Creek watershed will originate from the water storage pond. Although these releases will vary in accordance with runoff and precipitation events during the year, the flows will be more-or-less in direct proportion to flows in Williams Creek.

Flows to the water storage pond include:

- flows from Williams Creek and North Williams Creek; and
- runoff and groundwater seepage from the waste rock dump.

Any mine water encountered will be pumped out of the open pit and used as process water. Site drainage and wash water will be directed to the sediment control pond and will filter through the dam and back into Williams Creek below the ancillary facilities.

Results from acid-base accounting work on waste rock and ore, presented in Section 3.2.3, indicates that runoff from these sources would be neutral to basic in pH. Site runoff, on most occasions, is expected to carry a heavy suspended solids load during periods of high precipitation. These flows will be routed to the water storage pond before release.

Flows calculated in the water balance (Section 4 of this Addendum) were used to project impacts on water quality at downstream stations using an arithmetic model which theoretically superimposes effluent quality on natural background concentrations to determine a resulting downstream concentration as follows:

$$Rc = \frac{[(Bc \times Bq) + (Ec \times Eq)]}{Rq}$$

Where:
Bc = Background Concentration (mg/L)
Bq = Background Flow (m^3/s)
Ec = Effluent Concentration (mg/L)
Eq = Effluent Flow (m^3/s)
Rc = Resulting Concentration (mg/L)
Rq = Resulting Flow (Bq+Eq) (m^3/s)

Receiving water quality input to the model were based on mean, maximum and minimum background water quality data generated during baseline studies presented in Volume I (P.A. Harder and Associates, 1994). As a conservative measure, detection limits were used wherever background concentrations were less than the detection limit. It should be noted that detection limits varied a great deal in baseline water quality which tend to skew the results for antimony, arsenic, cadmium, lead, silver, and nitrogen. Projected effluent quality input to the model were based on results from waste rock SWEP testing and low level analyses of waste rock leachate (5.5 to 6.5 pH fraction) (Western Copper Holdings Ltd, 1995). The quantity of waste rock runoff used in the model was calculated assuming that make-up water will be pumped from the waste rock runoff to the process plant rather than from the water storage pond which would result in an average annual release of 14.0 m^3/hr from the waste rock dump.

Estimates of nitrogen loadings were based on calculated estimates of nitrogen losses from blasting as discussed in Section 4.2.5 and from experience at other mines. There is no accurate means at this time to determine the relative composition of nitrogen. However, on the basis of extensive studies carried out at Fording Coal, the composition of total inorganic nitrogen in effluent and receiving water is generally comprised of the following:

10 parts total inorganic nitrogen = 9.0 parts NO_3-N : 0.4 parts NO_2-N : 0.6 parts NH_3+NH_4-N

Obviously on any particular day there are enormous variations on this theme, but generally speaking nitrate-nitrogen (NO_3-N) is always the primary component. For example, under aerobic conditions NH_4-N, NH_3-N, NO-N, NO_2-N, and N_2O-N are oxidized to NO_3-N. Nitrification and denitrification causes shifts from NH_3-N to NO_2-N and NO_3-N through volatilization, and depends on temperature, pH, and ambient alkalinity. Consequently, no one can be precise in stipulating nitrogen species composition since the chemistry is relatively complex and transitional. Of the ammonia-nitrogen (NH_3-N+NH_4-N) the un-ionized ammonia is regarded as the most toxic to aquatic life. The amount of un-ionized ammonia is however, dependent on ambient temperature and pH.

For modelling purposes, the losses to waste rock which would be discharged as waste rock runoff were estimated to be 27.95 mg/L. This would be broken down as discussed above to comprise 90% NO_3-N, 4% NO_2-N, and 6% NH_3+NH_4-N. In addition, ammonia was analytically measured in waste rock SWEP tests to be 0.61 mg/L which was subsequently added to the estimated NH_3-N from explosives and entered as a total 2.287 mg/L NH_3-N effluent concentration into the model.

Resulting water quality in Williams Creek for a point immediately below the water storage reservoir and at the mouth are compared to federal "CCME Canadian Water Quality Guidelines" for protection of aquatic life at ambient pH, hardness, alkalinity and conductivity in Tables 5.4 to

5.7. Under "average conditions" the water quality below the water storage dam and at the mouth of Williams Creek could exceed CCME Guidelines for aluminum, cadmium, chromium, copper, iron, lead and zinc. However, this is not exclusively attributable to the proposed mine operations. The background water quality also exceeds the CCME Guidelines in concentrations of these same seven metals.

Background water quality immediately below the dam at W4 occurs at concentrations above CCME Guidelines for the protection of aquatic life for aluminum, arsenic, chromium, copper, iron, lead, silver, and zinc. Based on the modelling in Table 5.4 mean metal concentrations are projected to increase as a result of waste rock runoff as follows:

- aluminum increase of 0.21 mg/L
- barium increase of 0.185 mg/L
- cadmium increase of 0.0002 mg/L
- calcium increase of 11 mg/L
- chromium increase of 0.0002 mg/L
- cobalt increase of 0.001 mg/L
- copper increase of 0.133 mg/L
- iron increase of 0.2 mg/L
- lead increase of 0.002 mg/L
- manganese increase of 0.271 mg/L
- silver increase of 0.001 mg/L
- zinc increase of 0.006 mg/L

Many metal concentrations at W4 will stay the same or decrease including antimony, arsenic, beryllium, magnesium, molybdenum, nickel, strontium, and vanadium. Concentrations of nitrogen were projected to increase by 1.642 mg/L NO_3-N, by 0.073 mg/L NO_2-N, and by 0.146 mg/L NH_3-N immediately downstream of the dam, W4.

Downstream on Williams Creek below the confluence with Nancy Lee Creek, background metals once again exceed CCME Guidelines for aluminum, arsenic, copper, lead, and zinc. Mean concentrations are projected to increase for a number of metals as follows (Table 5.5):

- aluminum increase of 0.066 mg/L
- barium increase of 0.069 mg/L
- cadmium increase of 0.0001 mg/L
- calcium increase of 7.66 mg/L
- copper increase of 0.049 mg/L
- iron increase of 0.142 mg/L
- manganese increase of 0.103 mg/L
- zinc increase of 0.002 mg/L

Most metals are projected to decrease or stay the same including antimony, arsenic, beryllium, chromium, cobalt, magnesium, molybdenum, nickel, silver, strontium, and vanadium. Nitrogen concentrations were estimated to increase by 0.605 mg/L NO_3-N, 0.03 mg/L NO_2-N, and 0.054 mg/L NH_3-N at W10, but concentrations are projected to be well within the guidelines for protection of aquatic life.

High projected loadings and therefore concentrations are a result of the assumption that 85% of precipitation falling on the waste dump moves through the dump, leaches out metals, and seeps out at a quality equivalent to results from the SWEP or the leach 2 tests. Once operations commence, systems should be in place to treat waste rock runoff if monitoring results require action.

Results from the fisheries sampling from 1991 to 1992 indicated that fish only utilize the bottom portion of Williams Creek, downstream of the Nancy Lee Creek confluence. It is therefore assumed that this is the point of compliance for water quality criteria to meet CCME guidelines for the protection of aquatic life.

Based on worst case modelling results and background concentrations, the proponent proposes that water treatment would be triggered if four consecutive weeks of water quality indicate that metal levels are:

- 20% above background at the spillway, and
- 10% above background at W10 on Williams Creek downstream of Nancy Lee Creek.

Parameters for this permit monitoring may include cadmium, copper, iron and/or zinc.

In order to reduce the potential for contamination of receiving waters based on this modelling, mitigation should include the elimination of the 14 m^3/hr of waste rock runoff currently routed to the water storage dam. This could be achieved by one of the following measures:

- recirculation of waste rock runoff onto the dump to enhance evaporation;
- installation of an evaporation pond;
- treatment with lime to precipitate out heavy metals;
- decrease the cutoff grade to reduce the quantity of mineralized rock in the dump.

5.6 FISHERIES AND AQUATIC RESOURCES

5.6.1 Fisheries

5.6.1.1 Overview

Williams Creek drains the Carmacks Copper Project area and combines with flows from Nancy Lee Creek before flowing into the Yukon River. The Yukon River then flows north and west before discharging to Norton Sound on the west coast of Alaska. Fisheries studies including biophysical inventory, electrofishing, minnow traps, and spawning surveys were completed for three periods between August 1991 and August 1992 (P.A. Harder and Associates, 1994).

Fisheries results indicate that fish inhabit the lower section of Williams Creek to the confluence with Nancy Lee Creek. Species in lower Williams Creek include juvenile chinook salmon (*Oncorhynchus tshawytscha*), arctic grayling (*Thymallus arcticus*), slimy sculpin (*Cottus cognatus*), longnose sucker (*Catostomus catostomus*), burbot (*Lota lota*), and northern pike (*Esox lucius*) (P.A. Harder and Associates 1994).

No fish were observed or captured in Williams Creek above the Nancy Lee Creek confluence. Spawning was not observed in the Yukon River near the Williams Creek confluence during the October 1991 survey and no spawning in Williams Creek has been observed by local residents.

5.6.1.2 Water Quality Effects

Based on modelling presented in Section 5.5, fisheries could potentially be affected by changes to metal concentrations. Metals which may occur at elevated levels include aluminum, copper, and iron. Maximum recycle of waste rock runoff will take place during operations to avoid high metal loadings in the receiving environment. Downstream water quality will be monitored to determine if the projected metal levels occur and whether treatment is required.

Increased sediment loads caused by construction and erosion of fine particles disturbed by mine operations result in scouring attached algae from the stream substrate and a reduction in habitat for benthic macroinvertebrates, both resulting in a reduction in the fisheries food source. Increased sediment loads in the water column can also cause abrasion of fish gills. Fine particles abrade the gill surface reducing the capacity for gas exchange potentially resulting in suffocation and rendering the fish more susceptible to infection and gill parasites.

In order to minimize and mitigate this potential impact, strict construction guidelines will be adhered to and monitored. Construction guidelines will include the following items:

- ditch construction along roadways will incorporate settling ponds and baffles to reduce erosion and to settle-out sediments;
- diversion ditches and settling ponds will be constructed around waste piles and leach pads;
- creek disturbance will be minimized by building well engineered bridges or properly installing culverts and prohibition on fording;
- construction during heavy rainfall or snowfall events will be minimized; and

- construction will be minimized around streams during critical spawning periods in August and September for salmon and for May and June for grayling.

5.6.1.3 Habitat Loss

Construction of the water storage dam below the confluence of North Williams Creek and the mainstem will result in reduced flows during initial filling of the 380,000 m^3 reservoir and during operations when a portion of the water is withdrawn (ranging from 0 to 30 m^3/hr) for process make-up. However, the resulting impact on flows in Williams Creek during operations are relatively small and well within the normal variation in annual runoff. Consequently, it is unlikely that there will be any loss of fish habitat as a result of reduced flows.

Fisheries habitat being used appears to be restricted to the lower portion of Williams Creek between the confluence with Nancy Lee Creek and the Yukon River. Lower Williams Creek habitat consists of a 4-m wide channel flowing on a slope of 1.5% with a northeast aspect. In August 1991, maximum riffle depth was 0.3 m and maximum pool depth was 1.0 m with a distribution of 30% pool, 40% riffle and 30% run. Bed material consists of 25% fines, 40% gravels and 35% larges with undercut banks and a 15% debris cover.

Filling of the water storage reservoir will take approximately 25 days during April following construction assuming mean annual flows. This will result in a 100% loss of flows in Williams Creek immediately below the water storage reservoir spillway and a 35% reduction in flows in Williams Creek downstream of Nancy Lee Creek during this period. This will result in reduced habitat available for grayling spawning for this first year if spawning occurs; however, it is not likely that this reduction will preclude spawning.

During Year 1 operations, based on the revised water balance presented in Section 3 of this Addendum, water withdrawals from the water storage pond would result in a reduction of flows immediately below the water storage reservoir spillway and Nancy Lee Creek of approximately 8.5% in an average year, 18% in a 1-in-10 dry year and 6% in a 1-in-10 wet year. This would equate to a reduction in Williams Creek below Nancy Lee Creek of 3%, 6%, and 2%, respectively. The majority of make-up water is required during winter. The most significant reductions occur in October when there is a 50% to 100% reduction in baseline flows immediately below the reservoir spillway due to process requirements. As a result of the channel configuration in lower Williams Creek, reductions in flow, with the exception of October, will not greatly affect the quantity of cover available for fish. Flow reductions of 6% (i.e. during a dry year below Nancy Lee Creek) result in a reduction of between 0.01 to 0.03 m in water depth which when combined with undercut banks will only minimally reduce the wetted perimeter (available habitat). Chinook spawning occurs mainly in August, although it is not known whether spawning occurs in lower Williams Creek. If spawning does occur, it is likely to be immediately adjacent to the Yukon River with sufficient depth to ensure water coverage during winter incubation.

Due to the potential elimination of flow contributions from upper Williams Creek resulting from drawdown in the freshwater storage pond, additional fisheries studies are required. An overwintering fish study must be completed prior to operation in order to determine whether fish overwinter in lower Williams Creek. Winter water sampling (March 1995) indicates that flows in lower Williams Creek (W10) are approximately 0.35 m^3/s (J. Gibson, pers.comm.). Flows detected in the Williams Creek mainstem above the Nancy Lee Creek confluence were negligible. It is expected that approximately 70% of the winter flows in lower Williams Creek are from Nancy Lee Creek (J. Gibson, pers.comm.). Therefore, it is expected that the presence of the water storage dam will not affect any potential overwintering habitat to fish in the Williams Creek watershed.

The Department of Fisheries & Oceans policy with respect to fish habitat is "no-net-loss" of productive capacity of habitats in response to Section 31 under the Fisheries Act which legislates that no person shall destroy fisheries habitat. Due to the variability associated with mine water management, it is conservatively assumed that there will be a small overall reduction in fish habitat over the lower 1500 m of Williams Creek. Since this will be a reduction in flows rather than a destruction of habitat, Western Copper Holdings Limited proposes to compensate for flow reductions by employing habitat enhancement methods in this lower 1500 m of the creek.

Fish habitat enhancement will be carried out under the direct supervision of a fisheries biologist and may include the following methods:

- removal of barriers to fish migration;
- securing of large organic debris cover at the surface of the creek;
- enhancement of rearing habitat by strategically excavating deep pools; and
- addition of large boulders for instream cover.

Enhancement plans will be further detailed and then reviewed by the Department of Fisheries and Oceans prior to habitat enhancement. Typical pool-riffle-glide sequence enhancement features are illustrated in Figure 5.3. Enhancement design and construction guidelines will follow those laid out in "Fish Habitat Enhancement, A Manual for Freshwater, Estuarine and Marine Habitats" (Department of Fisheries & Oceans, 1990).

In addition, to prevent potentially detrimental effects, mine water use will be managed in such a way as to achieve the following goals:

- adequate flows during critical spawning periods in spring for arctic grayling, longnose suckers, slimy sculpins and northern pike, and in August for chinook salmon if adults are present in the creek;

- adequate flows for fry rearing.

5.6.2 Benthic Macroinvertebrates

Benthic macroinvertebrates are an important component of the ecological network and are useful in assessing environmental impacts from mining activity. They are efficient indicators of water and habitat quality in streams because the majority of their life cycle is intimately linked to the aquatic environment. Therefore, they reflect any disturbance to surrounding vegetation or changes in water quality. Juvenile and adult stages of important fisheries species, particularly salmon and other insectivorous species, depend on the availability of benthic macroinvertebrates as a food source.

Benthic macroinvertebrates may typically be adversely affected by in-stream construction, removal of overstorey cover, increased heavy metals, sediment and nutrient loadings, acid rock drainage or reduction or loss of flows. Increased sediment loads abrade the gill membranes of macroinvertebrates, scour algal growth from rock surfaces which reduces the food source, and fill interstitial pore spaces of substrate which reduces habitat availability. These have a direct effect on benthic organisms, their food resources and their habitat, respectively. Under extreme conditions, increased nutrients such as nitrates and phosphates (from blasting) may have a direct toxic effect or may result in excessive eutrophication which reduces available habitat and oxygen. Moderate increases in nutrient levels causes community stress and increased algal growth which may, for example, result in a shift to a community dominated by herbivorous species. High concentrations of chemicals and heavy metals have the potential to be acutely toxic to benthic macroinvertebrates, or chronically toxic if they are bioaccumulated and interfere with normal physiology.

Baseline benthic macroinvertebrate communities were sampled in 1991 and 1992 on both the control (Nancy Lee Creek) and immediately above and below the confluence with Nancy Lee Creek on Williams Creek. Species composition was dominated by the stonefly Nemouridae and sub-dominated by the Chironomid Orthocladiinae. Between 14 and 19 taxa were represented at these three sites with between 751 and 910 individuals collected in three basket samplers (250 to 303 individuals per basket). In comparison to regional creeks, Williams Creek had comparable number of taxa but lower number of individuals. This was attributed to differences in elevation and different stream flow and substrate conditions.

During October low flows benthic communities immediately downstream of the dam may be affected by creek desiccation prior to freezing. Impacts to benthic communities in the Carmacks Copper Project area will be minimized by:

- maximizing the recycle of process water;
- maximizing the collection and settlement of runoff from disturbed areas to the greatest extent possible;
- minimizing instream construction;
- maintaining buffer zones of vegetation adjacent to streams;
- monitoring seepages from the waste rock dump, open pit and leach pad; and
- taking precautions during blasting to reduce nutrient losses to receiving waters.

5.7 VEGETATION

The proposed Carmacks Copper operations area will comprise an open pit mine, waste rock storage area, heap leach pad, water and process stream management systems, water storage pond, processing facilities and camp accommodations. The amount of existing and proposed clearing will total approximately 198.4 ha as follows:

- the ultimate open pit mine configuration will encompass approximately 32.8 ha on an area presently dominated by lodgepole pine, white and black spruce and aspen;
- waste rock storage to the north of the open pit adjacent to North Williams Creek will require that approximately 81.6 ha of land be cleared of predominantly lodgepole pine, aspen and black spruce;
- construction and operation camp facilities, maintenance shop, warehouse, process plant, and ore conveyors are dominated by lodgepole pine, aspen and black spruce. Approximately 3.57 ha of land will need to be cleared for these facilities;
- the leach pad facilities, sediment control pond and events pond will encompass approximately 37.6 ha of land dominated by aspen, lodgepole pine and grasses.
- main access roads and the powerline will encompass approximately 26 ha;
- access roads and pipeline right-of-ways from the freshwater storage pond to the process plant will encompass approximately 7.3 ha through a zone of white spruce, birch, willow, sedge, moss zone along Williams Creek and climb through black spruce, willow and moss into lodgepole pine, aspen and black spruce leading to the open pit and process plant; and
- the proposed fresh water storage pond and dam covers an area of approximately 14.3 ha comprising areas of white spruce, birch, willow, sedge and moss with south facing slopes mainly carrying aspen and grasses.

Removal of vegetation will result in the loss of wildlife habitat and, if acceptable procedures are not employed, may also result in spread of forest infestation, increased fire hazard, increased runoff and increased erosion.

No unique or endangered vegetation is known to occur in the mine site area. The amount of merchantable timber removed for site preparation will be extremely low, as climate and elevation near the mine site limit forest productivity. Clearing and recovering merchantable timber from approximately 198.4 ha will be contracted out during construction. Efforts will be made to stockpile suitable logs for various requirements such as temporary bridges, retaining walls and guard rails. Slash will be burned or buried as necessary, or stockpiled for use as cord wood for the local community.

Impacts will be minimized by incorporating engineered standards of construction where clearing and earthworks are required; the size of such areas will be kept to a minimum and vegetated buffer strips will remain adjacent to streams. Reclamation and revegetation of existing disturbed areas such as the exploration camp, old drill pads, and road side margins will be initiated immediately after construction, wherever feasible, and monitored to determine if additional seeding and fertilizing are required. Areas to be reclaimed after mine closure are presented in Section 7.0.

Prior to flooding in the fresh water storage pond, vegetation will be removed to reduce the potential for mercury methylation. As documented in many cases in Canada, flooding reservoirs may result in a bacterial process which makes metals such as mercury bioavailable to aquatic organisms. As a result, harmful metals previously unavailable, become readily available to organisms living in the water. However, as a minimum, trees and large organic debris will be cleared prior to flooding.

5.8 WILDLIFE

5.8.1 Species Concerns

No significant impacts to wildlife are foreseen. This interpretation is based on information obtained in the wildlife surveys to date, whereby a basic knowledge of the broad patterns of distribution and seasonal movement of key species is presented. From 1991 and 1992 surveys and wildlife logs, very little ungulate, furbearer, or other mammal activity was noted. Historically, caribou herd migration extended into this area, however, this does not presently occur and no ungulates appear to have filled this abandoned niche. A field survey conducted in July 1994 indicated that the steep sloping south scarps may provide habitat for mule deer, but this area will not be impacted. Waterfowl were not observed, likely due to the absence of productive wetland habitat. Although raptor nests were observed, only the American kestrel was sighted. Key summer nesting habitat is recognized to occur northeast of the project in the Nancy Lee and Hoochekoo creeks watersheds.

One possible explanation for the apparent limited wildlife use of the area is a cyclic low in the different species cycles, analogous to the lynx and hare 10-year lynx population low, which occurred in 1991 according to territorial government information.

Impacts to wildlife habitat are discussed in the following generalized categories which are typically recognized for similar construction projects in remote and undeveloped regions.

5.8.2 Direct Habitat Effects

Open pit development will result in permanent loss of approximately 32.8 ha of low capability conifer dominant upland habitat. The heap leach pad, process plant and camp facilities will result in a temporary loss of 41.2 ha of moderate habitat capability land in aspen dominant uplands. Waste rock storage will cover approximately 81.6 ha of moderate capability conifer dominant wetlands. The water storage pond will result in the permanent loss of 14.3 ha of high potential willow dominant wetlands and moderate potential spruce dominant wetlands. Spruce dominant wetlands have moderate habitat potential for moose, moderate to high potential for hare and its predators and moderate potential for black bears, red squirrels, and spruce grouse. Willow dominant wetlands provide good habitat for moose and snowshoe hare, and their predators, and moderate habitat for black bears (summer forage) and songbirds. Aspen dominant uplands have moderate potential for moose, snowshoe hare, black bears and ruffed grouse. Conifer dominant uplands have high potential for red squirrel and spruce grouse, low to moderate potential for hare and its predators, and very low moose habitat potential.

Access roads will transect similar habitat to the mine facilities including low capability conifer dominant uplands and moderate capability conifer dominant wetlands. The fresh water storage facility will however result in the temporary loss of approximately 14.3 ha of mainly high capability willow dominant wetlands and some moderate capability aspen dominant uplands, but will result in an increase in available wetlands.

5.8.3 Indirect Habitat Effects

Habitat loss also occurs where some form of disturbance prevents a species from using an area or reduces the frequency of use, even though no physical loss of habitat occurs. This may involve avoidance by animals to normal feeding activities in the vicinity of a road or through blocking access to traditional habitats used seasonally. This also includes avoidance by species due to machine noise and operational activity.

It is difficult to predict or estimate the actual area of wildlife habitat lost by avoidance behaviour. McLellan and Shackleton (1988) provide the best comparative data for grizzly bears, in which a seven year study in southeastern B.C. showed most bears used habitats within 100 m of roads less frequently than expected. Avoidance of roads was independent of traffic volume, which suggested that even limited vehicle use can displace bears.

It is expected that there will be some effect on wildlife from mine construction and operation. Some degree of habituation is expected with ungulates as noted at many mining projects. Since the project does not cut through any major migration routes and from field surveys does not lie in critical habitat, the project is expected to cause minimal indirect habitat loss for caribou.

Some disturbance to wolf, black bear and grizzly bear is expected due to mine operations, however, due to the relatively low abundance of these species in the mine site area, little indirect impact is expected.

To prevent injury to wildlife Western Copper Holdings Ltd. proposes to encompass the heap leach pad, open pit and waste rock dump with fencing to prevent entrance into these areas. The design specifics for the proposed fencing is outlined in Appendix 5. Bird netting is not expected to be necessary as the pregnant leach solution will be stored in-heap and the events pond will remain empty. If bird netting is required for the facilities its installation will follow the design specifics outlined in Appendix 5.

5.9 LAND CAPABILITY AND HISTORIC USE

5.9.1 Mining

The proposed Carmacks Copper Project will be an open pit mine expected to process **6,300** t/d ore over 200 days per year with a heap leach/solvent extraction/electrowinning process to produce copper cathode at approximately 38 t/d. The Carmacks Copper Mine is projected to operate for 9 years based on the present ore reserves.

Carmacks Copper will produce approximately 115,000 tonnes of copper cathode over the mine life, contributing to Yukon mineral production, and providing an operating mine in the Yukon. Placer mining, which occurs only seasonally, has been the only mining activities in the Yukon since closure of the Faro Mine in 1993.

5.9.2 Forestry

White and black spruce are the common conifer tree stands in the Williams Creek drainage, with some lodgepole pine occupying old burn areas. Due the very low potential for commercial harvest in this watershed, it is not expected that clearing of the required areas for mine facilities will have any impact on commercial forestry.

Reclamation plans will be implemented in the early stages of mine operation to recreate sustainable forests on the affected areas. Reclamation plans will include seeding cleared land with a mixture of indigenous plant species to reduce erosion and promote forest regeneration.

5.9.3 Fish and Wildlife Resource Use

The Williams Creek watershed is trapped more than once a year during most years by Mr. J. Sam who holds the registered trapline covering the project area. No records are kept, however, lynx, coyote, wolverine and mink are expected to be the key furbearers caught.

The area is within the traditional hunting grounds of the Little Salmon Carmacks First Nation, although no hunting has occurred in the Williams Creek watershed in recent years.

Since key areas for most furbearers and ungulates are in the vicinity of the Williams Creek - Yukon River confluence it is unlikely that mining activities will detrimentally impact these resources.

Fisheries resources mainly occur in the Yukon River mainstem with some activity in lower Williams Creek below Nancy Lee Creek. Provided that seepages are monitored to maintain water quality and that the fresh water storage is managed properly, no negative effects resulting from mine activities are expected on the fisheries resources.

5.9.4 Recreation

Summer canoeing between Whitehorse or Carmacks and Dawson City is very popular, with 693 users registered during 1992. In addition, the annual Yukon Quest Dog Sled race parallels the Yukon River and crosses lower Williams Creek. Since mining activities will be limited to the upper portion of the Williams Creek watershed, it is not expected that the mine will negatively impact these activities. Precautions will have to be taken to ensure the safety of canoeists venturing off track to the mine site.

The Project is not likely to have a significant impact on the aesthetic beauty of the area for the mine life. In relation to the size of the region as a whole, the visual impact is point source and the mine may even be seen as a point of interest. Detrimental impacts will be mitigated for the most part following mine closure with the implementation of a comprehensive reclamation plan.

5.9.5 Power Generation

Electrical power required for the process plant will be brought in from connections with the powergrid in Carmacks. Operations will require approximately 65,000 kW per day. Power generation on site is not practical due to low precipitation and the high cost of diesel power generation.

Installation and operation of the powerline will affect some wildlife habitat due to right-of-way clearing of vegetation. Proper construction guidelines including minimizing instream activity and avoiding fish spawning periods will be necessary for the Yukon River crossing and other small stream crossings. The complete impact assessment and construction guidelines for the powerline will be the responsibility of the Yukon Energy Corporation. Further details are discussed in Section 6 of this report.

5.9.6 Archaeology and Heritage Resources

Three archaeological sites were identified by Antiquus Archaeological Consultants Ltd. in August 1992 in the area surrounding the Carmacks Copper Project. One site consists of an old mine adit on upper Williams Creek and is associated with a log cabin and remains from mining activity from the 1930s or 1940s which is located approximately 400 m away. An old horse trail leads from this cabin to a cabin on the banks of the Yukon River which was probably used as an ore transfer station for river transport. More details on these sites and study may be found in "An Archaeological Impact Assessment for the Proposed Carmacks Copper Project, Williams Creek

Valley, Near Carmacks, Yukon Territory" (Antiquus Archaeological Consultants Ltd. 1992 Volume 3).

It was determined that no archaeological impacts are expected from development of the open pit, heap leach pad or waste rock facility. Additionally, if access roads into these areas are required they will avoid land-altering activity at these sites. If it is necessary to disturb these sites then a systematic data recovery program will be carried out by a qualified archaeologist (Antiquus Archaeological Consultants Ltd. 1992).

TABLE 5.1a

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

SUMMARY OF TEMPERATURE MEASUREMENTS

THERMISTORS TH-1 AND TH-2

Thermistor Th-1 North Facing Slope										
Temperature Readings										
Location on String	0'	7'	9'	11'	13'	17'	20'	25'	45'	65'
True Depth	0'	7'	9'	11'	13'	17'	20'	25'	45'	65'
Date:										
April 29, 1993	0.0	0.0	-0.0	0.1	-0.0	0.0	-0.1	-0.2	-0.3	-0.3
August 2, 1993	4.7	3.1	2.0	1.3	0.3	0.0	-0.1	-0.2	-0.3	-0.3
September 2, 1993	5.0	3.8	2.9	2.1	0.7	0.0	-0.1	-0.2	-0.3	-0.3
Octobre 29, 1993	2.0	2.0	1.9	1.7	0.7	0.1	-0.1	-0.2	-0.3	-0.3
April 15, 1994	-0.0	-0.0	-0.0	0.1	-0.0	0.0	-0.1	-0.2	-0.3	-0.3
March 28, 1995	-0.1	-0.1	-0.0	0.1	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3
April 21, 1995	-0.2	-0.1	-0.0	0.1	-0.0	0.0	-0.1	-0.2	-0.3	-0.3

Thermistor Th-2 South Facing Slope										
Temperature Readings										
Location on String	0'	7'	9'	11'	13'	17'	20'	25'	45'	65'
True Depth	0'	5.3'	6.9'	8.4'	10.0'	13.0'	15.3'	19.2'	34.4'	49.9'
Date:										
April 29, 1993	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2
August 2, 1993	6.3	2.9	-0.0	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2
September 2, 1993	5.8	3.7	1.7	-0.1	-0.3	-0.3	-0.3	-0.3	-0.2	-0.3
Octobre 29, 1993	1.2	1.0	0.6	0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.3
April 15, 1994	0.0	-0.0	-0.1	-0.0	-0.1	-0.2	-0.2	-0.3	-0.2	-0.3
March 28, 1995	-0.1	-0.1	-0.1	-0.1	-0.0	-0.1	-0.2	-0.3	-0.2	-0.4
April 21, 1995	-0.4	-0.1	-0.1	-0.1	-0.0	-0.1	-0.2	-0.3	-0.2	-0.4

TABLE 5.1b

WESTERN COPPER HOLDINGS LIMITED

CARMACKS COPPER PROJECT

SUMMARY OF TEMPERATURE MEASUREMENTS

THERMISTOR TH-3

Temperature Readings										
True Depth (ft)	0	5	15	30	45	60	75	90	95	100
March 28, 1995	-0.4	0.0	-0.1	-0.2	-0.2	-0.1	-0.2	-0.1	-0.7	0.2
April 21, 1995	2.4	-0.1	-0.1	-0.2	-0.2	-0.1	-0.2	-0.1	-0.1	0.1

Western Copper Holdings Ltd.
Carmacks Copper Project

Table 5.2

Probabilistic Ground Motion

Probability of Exceedence per Annum	0.010	0.005	0.0021	0.001
Probability of Exceedence in 50 years	40%	22%	10%	5%
Peak Horizontal Ground Acceleration (g)	0.050	0.064	0.083	0.101
Peak Horizontal Ground Velocity (m/s)	0.114	0.145	0.196	0.235

Western Copper Holdings Ltd.
Carmacks Copper Project

Table 5.3

Seismic Zones for a Probability of 10 percent in 50 Years

Acceleration of Velocity Seismic Zone Z_a, Z_v	Range of Peak Horizontal Acceleration (G) or Peak Horizontal Velocity (m/s) For Probability of 10% in 50 Years		Zonal Acceleration and Velocity (Z_a, Z_v)
	Equal to	Less than	
0	0.00	0.04	0.00
1	0.04	0.08	0.05
2	0.08	0.11	0.10
3	0.11	0.16	0.15
4	0.16	0.23	0.20
5	0.23	0.32	0.30
6*	0.32 or greater	-	0.40

* Zone 6: Nominal Value of 0.40; Site specific studies suggested for important projects

** For NBCC applications, when $Z_v=0$ and $Z_a>0$, the values of Z_v and v should be taken as Zone 1 and 0.05, respectively.

Table 5.4

Impact of Effluent (Waste Rock SWEP analysis) on the Water Quality of Williams Creek at Station W4

Parameter	Station W4 Bc Max (mg/L)	Bc Min (mg/L)	Bc Mean (mg/L)	Bq (m^3/s)	Ec dissolved (mg/L)	Eq (m^3/s)	Rq (m^3/s)	Rc Max (mg/L)	Rc Min (mg/L)	Rc Mean (mg/L)	Federal CCME Guideline (mg/L)
NO_3-N	0.5	0.02	0.022	0.0558	25.155	0.0039	0.0597	2.111	1.662	1.664	–
NO_2-N	5	0.0003	0.0003	0.0558	1.118	0.0039	0.0597	4.746	0.073	0.073	0.06
NH_3-N	0.06	0.05	0.052	0.0558	2.287	0.0039	0.0597	0.205	0.196	0.198	2.2*
Aluminum	3.89	0.005	1.142	0.0558	2.931	0.0039	0.0597	3.827	0.196	1.259	0.1
Antimony	0.05	0.005	0.05	0.0558	0.04	0.0039	0.0597	0.049	0.007	0.049	–
Arsenic	0.12	0.02	0.053	0.0558	0.03	0.0039	0.0597	0.114	0.021	0.051	0.05
Barium	0.175	0.031	0.083	0.0558	2.915	0.0039	0.0597	0.354	0.219	0.268	–
Beryllium	0.0005	0.0001	0.0005	0.0558	0.001	0.0039	0.0597	0.0005	0.0002	0.0005	–
Cadmium	0.0004	0.0003	0.0004	0.0558	0.003	0.0039	0.0597	0.0006	0.0005	0.0006	0.0008
Calcium	63.4	15.6	37.717	0.0558	355.51	0.0039	0.0597	82.5	37.8	58.5	–
Chromium	0.012	0.0002	0.005	0.0558	0.009	0.0039	0.0597	0.0118	0.0008	0.0053	0.002
Cobalt	0.003	0.0005	0.002	0.0558	0.0215	0.0039	0.0597	0.0042	0.0019	0.0033	–
Copper	0.014	0.0005	0.006	0.0558	2.05	0.0039	0.0597	0.1470	0.1344	0.1395	0.002
Iron	6.6	0.349	2.161	0.0558	6.21	0.0039	0.0597	6.575	0.732	2.426	0.3
Lead	0.005	0.002	0.004	0.0558	0.04	0.0039	0.0597	0.007	0.004	0.006	0.002
Magnesium	16.1	5.20	10.195	0.0558	10.60	0.0039	0.0597	15.74	5.55	10.22	–
Manganese	0.191	0.058	0.121	0.0558	4.2702	0.0039	0.0597	0.457	0.333	0.392	–
Molybdenum	0.01	0.001	0.004	0.0558	0.0063	0.0039	0.0597	0.010	0.001	0.004	–
Nickel	0.014	0.001	0.005	0.0558	0.0122	0.0039	0.0597	0.014	0.002	0.005	0.065
Silver	0.002	0.001	0.002	0.0558	0.01	0.0039	0.0597	0.003	0.002	0.003	0.001
Strontium	0.42	0.142	0.306	0.0558	0.774	0.0039	0.0597	0.443	0.183	0.337	–
Vanadium	0.016	0.0002	0.005	0.0558	0.006	0.0039	0.0597	0.0153	0.0006	0.0051	–
Zinc	0.0578	0.001	0.018	0.0558	0.126	0.0039	0.0597	0.062	0.009	0.025	0.03

Ambient Conditions: pH 7.4 to 8.1
Conductivity 98 to 465 umhos/cm
Hardness 82.5 to 224 mg/L CaCO3
Alkalinity 28 to 169 mg/L CaCO3

(shaded) Below detection level

(boxed) Mean concentration above CCME Guideline

* Ammonia CCME guideline at pH 7.75 and temperature 5°C

(H1811\VOL4\WQIMP4.WK3)

Table 5.5

Impact of Effluent (Waste Rock SWEP analysis) on the Water Quality of Williams Creek at Station W10

Parameter	Station W10 Bc Max (mg/L)	Bc Min (mg/L)	Bc Mean (mg/L)	Bq (m^3/s)	Ec dissolved (mg/L)	Eq (m^3/s)	Rq (m^3/s)	Rc Max (mg/L)	Rc Min (mg/L)	Rc Mean (mg/L)	Federal CCME Guideline (mg/L)
NO_3-N	0.2	0.08	0.106	0.1575	25.155	0.0039	0.1614	0.803	0.686	0.711	–
NO_2-N	2	0.003	0.003	0.1575	1.118	0.0039	0.1614	1.979	0.030	0.030	0.06
NH_3-N	0.05	0.05	0.05	0.1575	2.287	0.0039	0.1614	0.104	0.104	0.104	2.2*
Aluminum	0.463	0.005	0.181	0.1575	2.931	0.0039	0.1614	0.523	0.076	0.247	0.1
Antimony	0.05	0.02	0.05	0.1575	0.04	0.0039	0.1614	0.050	0.020	0.050	–
Arsenic	0.08	0.04	0.052	0.1575	0.03	0.0039	0.1614	0.079	0.040	0.051	0.05
Barium	0.146	0.026	0.057	0.1575	2.915	0.0039	0.1614	0.213	0.096	0.126	–
Beryllium	0.0005	0.0002	0.0005	0.1575	0.001	0.0039	0.1614	0.0005	0.0002	0.0005	–
Cadmium	0.0004	0.0003	0.0004	0.1575	0.003	0.0039	0.1614	0.0005	0.0004	0.0005	0.0008
Calcium	59	16.3	37.04	0.1575	355.51	0.0039	0.1614	66.2	24.5	44.7	–
Chromium	0.009	0.001	0.003	0.1575	0.009	0.0039	0.1614	0.009	0.001	0.003	0.002
Cobalt	0.002	0.001	0.002	0.1575	0.0215	0.0039	0.1614	0.002	0.001	0.002	–
Copper	0.005	0.001	0.003	0.1575	2.05	0.0039	0.1614	0.054	0.051	0.052	0.002
Iron	0.824	0.070	0.354	0.1575	6.21	0.0039	0.1614	0.954	0.218	0.496	0.3
Lead	0.005	0.004	0.005	0.1575	0.04	0.0039	0.1614	0.006	0.005	0.006	0.002
Magnesium	12	4.53	7.728	0.1575	10.60	0.0039	0.1614	11.97	4.68	7.80	–
Manganese	0.034	0.004	0.021	0.1575	4.2702	0.0039	0.1614	0.136	0.107	0.124	–
Molybdenum	0.005	0.003	0.005	0.1575	0.0063	0.0039	0.1614	0.005	0.003	0.005	–
Nickel	0.006	0.001	0.004	0.1575	0.0122	0.0039	0.1614	0.006	0.001	0.004	0.065
Silver	0.001	0.001	0.001	0.1575	0.01	0.0039	0.1614	0.001	0.001	0.001	0.001
Strontium	0.47	0.132	0.26	0.1575	0.774	0.0039	0.1614	0.477	0.148	0.272	–
Vanadium	0.01	0.0005	0.003	0.1575	0.006	0.0039	0.1614	0.0099	0.0006	0.0031	–
Zinc	0.195	0.003	0.045	0.1575	0.126	0.0039	0.1614	0.193	0.006	0.047	0.03

Ambient Conditions: pH 7.6 to 8.1
Conductivity 97 to 355 umhos/cm
Hardness 62.5 to 183 mg/L CaCO3
Alkalinity 59 to 166 mg/L CaCO3

[shaded] Below detection level

[boxed] Mean concentration above CCME Guideline

* Ammonia CCME guideline at pH 7.75 and temperature 5°C

(H1811\VOL4\WQIMP4.WK3)

Table 5.6

Impact of Effluent (Waste Rock Leach 2) on the Water Quality of Williams Creek at Station W4

Parameter	Station W4 Bc Max (mg/L)	Bc Min (mg/L)	Bc Mean (mg/L)	Bq (m^3/s)	Ec (mg/L)	Eq (m^3/s)	Rq (m^3/s)	Rc Max (mg/L)	Rc Min (mg/L)	Rc Mean (mg/L)	Federal CCME Guideline (mg/L)
NO_3-N	0.5	0.02	0.022	0.0558	25.155	0.0039	0.0597	2.111	1.662	1.664	–
NO_2-N	5	0.0003	0.0003	0.0558	1.118	0.0039	0.0597	4.746	0.073	0.073	0.06
NH_3-N	0.06	0.05	0.052	0.0558	2.287	0.0039	0.0597	0.205	0.196	0.198	2.2*
Aluminum	3.89	0.005	1.142	0.0558	118.76	0.0039	0.0597	11.394	7.763	8.826	0.1
Antimony	0.05	0.005	0.05	0.0558	0.0005	0.0039	0.0597	0.047	0.005	0.047	–
Arsenic	0.12	0.02	0.053	0.0558	0.362	0.0039	0.0597	0.136	0.042	0.073	0.05
Barium	0.175	0.031	0.083	0.0558	82.22	0.0039	0.0597	5.535	5.400	5.449	–
Beryllium	0.0005	0.0001	0.0005	0.0558	0.001	0.0039	0.0597	0.0005	0.0002	0.0005	–
Cadmium	0.0004	0.0003	0.0004	0.0558	2.36	0.0039	0.0597	0.1545	0.1545	0.1545	0.0008
Calcium	63.4	15.6	37.717	0.0558	3031.7	0.0039	0.0597	257.3	212.6	233.3	–
Chromium	0.012	0.0002	0.005	0.0558	0.008	0.0039	0.0597	0.0117	0.0007	0.0052	0.002
Cobalt	0.003	0.0005	0.002	0.0558	0.18	0.0039	0.0597	0.0146	0.0122	0.0136	–
Copper	0.014	0.0005	0.006	0.0558	43.62	0.0039	0.0597	2.8626	2.8500	2.8552	0.002
Iron	6.6	0.349	2.161	0.0558	142.76	0.0039	0.0597	15.495	9.652	11.346	0.3
Lead	0.005	0.002	0.004	0.0558	5.8	0.0039	0.0597	0.384	0.381	0.383	0.002
Magnesium	16.1	5.20	10.195	0.0558	265.12	0.0039	0.0597	32.37	22.18	26.85	–
Manganese	0.191	0.058	0.121	0.0558	73.54	0.0039	0.0597	4.983	4.858	4.917	–
Molybdenum	0.01	0.001	0.004	0.0558	0.005	0.0039	0.0597	0.010	0.001	0.004	–
Nickel	0.014	0.001	0.005	0.0558	0.48	0.0039	0.0597	0.044	0.032	0.036	0.065
Silver	0.002	0.001	0.002	0.0558	0.001	0.0039	0.0597	0.002	0.001	0.002	0.001
Strontium	0.42	0.142	0.306	0.0558	5.880	0.0039	0.0597	0.777	0.517	0.670	–
Vanadium	0.016	0.0002	0.005	0.0558	0.003	0.0039	0.0597	0.0152	0.0004	0.0049	–
Zinc	0.0578	0.001	0.018	0.0558	2.780	0.0039	0.0597	0.236	0.183	0.198	0.03

Ambient Conditions: pH 7.4 to 8.1
Conductivity 98 to 465 umhos/cm
Hardness 82.5 to 224 mg/L CaCO3
Alkalinity 28 to 169 mg/L CaCO3

[shaded] Below detection level

[boxed] Mean concentration above CCME Guideline

* Ammonia CCME guideline at pH 7.75 and temperature 5°C

(H1811\VOL4\WQIMP2.WK3)

Table 5.7

Impact of Effluent (Waste Rock Leach 2) on the Water Quality of Williams Creek at Station W10

Parameter	Station W10 Bc Max (mg/L)	Bc Min (mg/L)	Bc Mean (mg/L)	Bq (m^3/s)	Ec (mg/L)	Eq (m^3/s)	Rq (m^3/s)	Rc Max (mg/L)	Rc Min (mg/L)	Rc Mean (mg/L)	Federal CCME Guideline (mg/L)
NO_3-N	0.2	0.08	0.106	0.1575	25.155	0.0039	0.1614	0.803	0.686	0.711	–
NO_2-N	2	0.003	0.003	0.1575	1.118	0.0039	0.1614	1.979	0.030	0.030	0.06
NH_3-N	0.05	0.05	0.05	0.1575	2.287	0.0039	0.1614	0.104	0.104	0.104	2.2*
Aluminum	0.463	0.005	0.181	0.1575	118.76	0.0039	0.1614	3.321	2.875	3.046	0.1
Antimony	0.05	0.02	0.05	0.1575	0.0005	0.0039	0.1614	0.049	0.020	0.049	–
Arsenic	0.08	0.04	0.052	0.1575	0.362	0.0039	0.1614	0.087	0.048	0.059	0.05
Barium	0.146	0.026	0.057	0.1575	82.22	0.0039	0.1614	2.129	2.012	2.042	–
Beryllium	0.0005	0.0002	0.0005	0.1575	0.001	0.0039	0.1614	0.0005	0.0002	0.0005	–
Cadmium	0.0004	0.0003	0.0004	0.1575	2.36	0.0039	0.1614	0.0574	0.0573	0.0574	0.0008
Calcium	59	16.3	37.04	0.1575	3031.7	0.0039	0.1614	130.8	89.2	109.4	–
Chromium	0.009	0.001	0.003	0.1575	0.008	0.0039	0.1614	0.009	0.001	0.003	0.002
Cobalt	0.002	0.001	0.002	0.1575	0.18	0.0039	0.1614	0.006	0.005	0.006	–
Copper	0.005	0.001	0.003	0.1575	43.62	0.0039	0.1614	1.059	1.055	1.057	0.002
Iron	0.824	0.070	0.354	0.1575	142.76	0.0039	0.1614	4.254	3.518	3.795	0.3
Lead	0.005	0.004	0.005	0.1575	5.8	0.0039	0.1614	0.145	0.144	0.145	0.002
Magnesium	12	4.53	7.728	0.1575	265.12	0.0039	0.1614	18.12	10.83	13.95	–
Manganese	0.034	0.004	0.021	0.1575	73.54	0.0039	0.1614	1.810	1.781	1.797	–
Molybdenum	0.005	0.003	0.005	0.1575	0.005	0.0039	0.1614	0.005	0.003	0.005	–
Nickel	0.006	0.001	0.004	0.1575	0.48	0.0039	0.1614	0.017	0.013	0.016	0.065
Silver	0.001	0.001	0.001	0.1575	0.001	0.0039	0.1614	0.001	0.001	0.001	0.001
Strontium	0.47	0.132	0.26	0.1575	5.880	0.0039	0.1614	0.601	0.271	0.396	–
Vanadium	0.01	0.0005	0.003	0.1575	0.003	0.0039	0.1614	0.0098	0.0006	0.0030	–
Zinc	0.195	0.003	0.045	0.1575	2.780	0.0039	0.1614	0.257	0.070	0.111	0.03

Ambient Conditions: pH 7.6 to 8.1
Conditivity 97 to 355 umhos/cm
Hardness 62.5 to 183 mg/L CaCO3
Alkalinity 59 to 166 mg/L CaCO3

* Ammonia CCME guideline at pH 7.75 and temperature 5°C

(Shaded) Below detection level

(Boxed) Mean concentration above CCME Guideline

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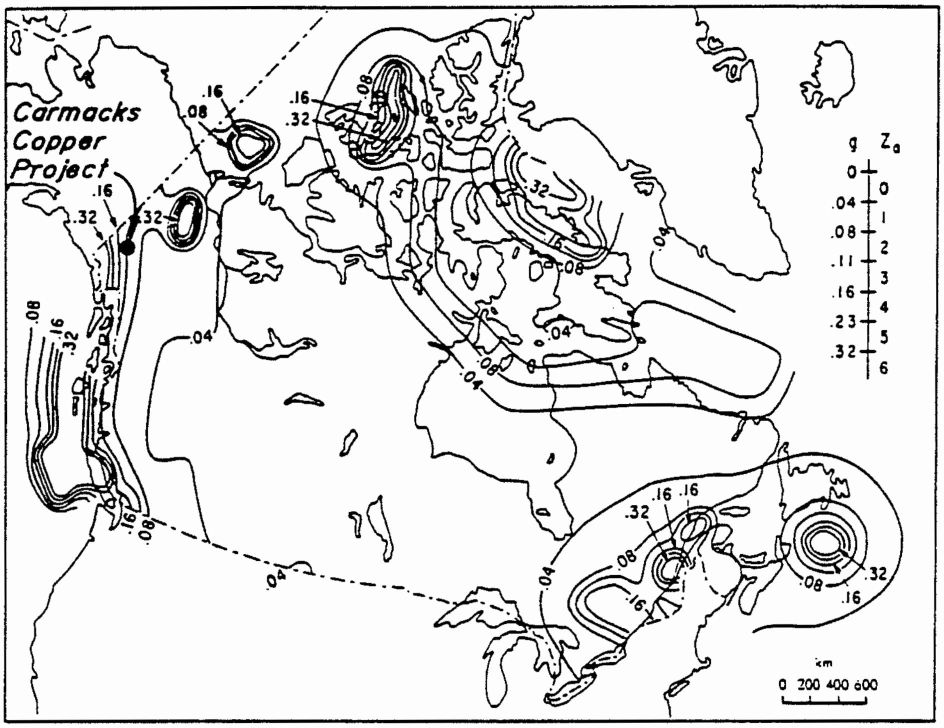
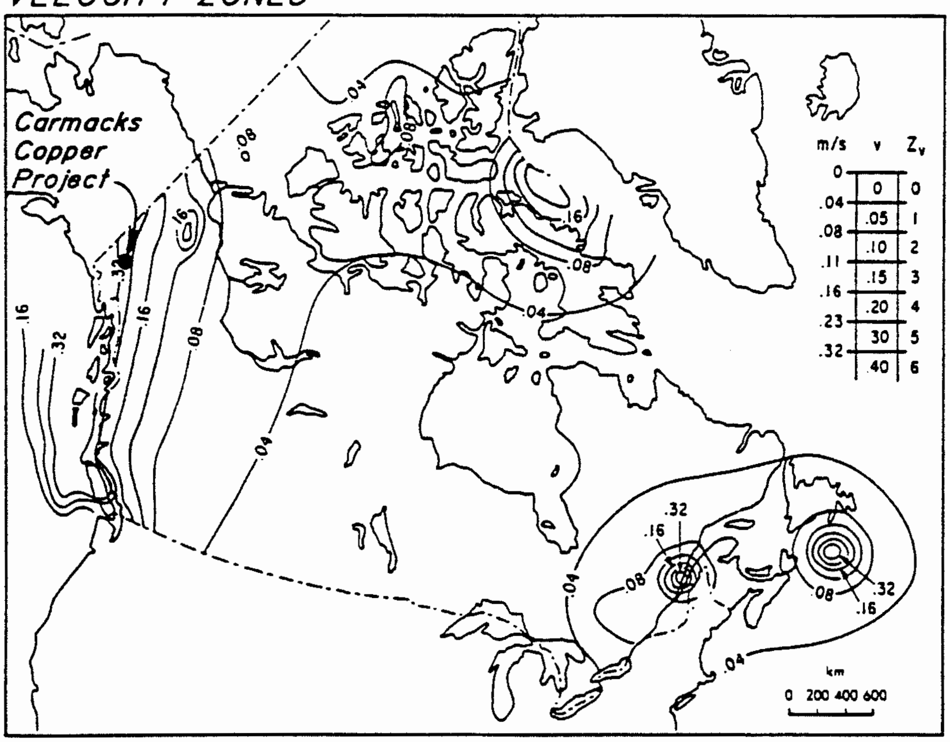
SEISMICITY

ACCELERATION ZONES



VELOCITY ZONES



June 28, 1994

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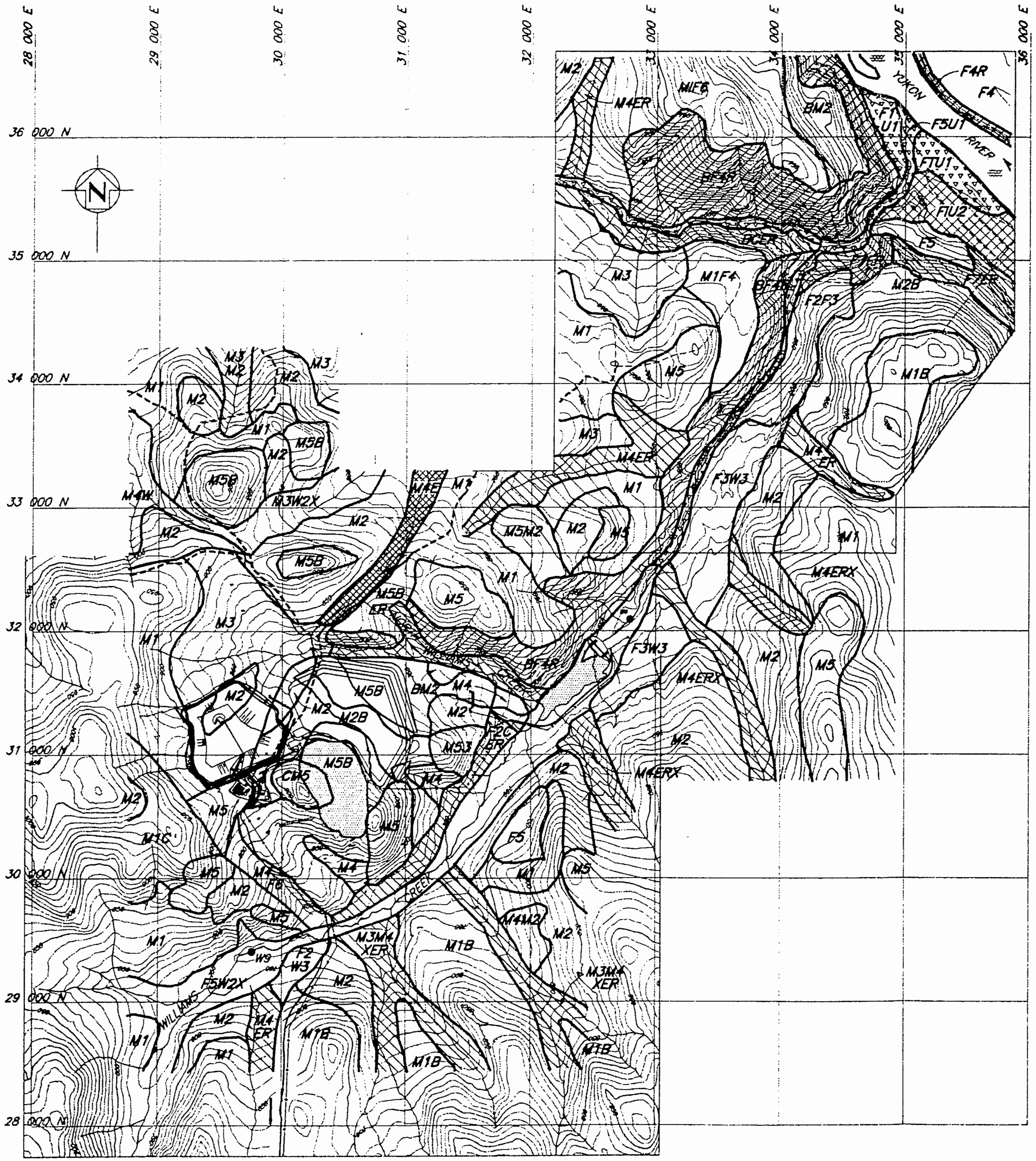
FIGURE 5.1

CAD FILE: \PROJECT\1000\H1811\FIG\ABterrp Plot scale 1=1



LEGEND
TERRAIN INTERPRETIVE MAP
Geotechnical and Environmental Considerations

LANDFORMS and MATERIALS	COMMON VEGETATION TYPE
Morainal Landforms – valley bottom and lower slope glacial till: mainly a dense sandy silty matrix, but may be closer and looser in upper valleys.	
M1 mainly thick subdued till landforms; average depths exceed 2m and slopes are usually less than 25%; in places there may be a thin veneer of silt and gravel.	Aspen, Kinnikinnick, minor Lodgepole Pine
M2 sloping till blanket overlying bedrock; depths range from 1–3m; slopes are mainly less than 40%.	Lodgepole Pine, Aspen, Black Spruce
M3 wet, subdued to moderately sloping till; features poor drainage, seepage, and/or shallow organic capping on slopes usually less than 30%.	Black Spruce, Willow, Labrador Tea
M4 Gullied till on valley sides; may contain fluvial and/or colluvial deposits; usually incised into bedrock.	Black Spruce, Willow, moss
M5 Shallow deposits of till overlying besrock; dominantly south and east facing slopes; slopes greater than 40%.	Aspen, Lodgepole Pine, grass
Colluvial Landforms – lower slope, gravity transported debris derived from bedrock.	
C accumulation of deep colluvial fans, cones and aprons (1–3m); blocky and rubbly debris may provide a source of coarse aggregate or ballast.	Black Spruce, Willow, moss
Bedrock Landforms	
B areas of bedrock outcrop and shallow colluvium	Open stands of Lodgepole Pine, Aspen and grasses.
Fluvial–Glaciofluvial Landforms – valley–bottom and lower–slope granular material; texturally variable from clean, coarse sand and gravels to dirty, silty gravels with variable interlayers; in places, may be capped with thin veneer of silt or minor wet areas may occur; potential sources of aggregate depending on thicknes of deposit and texture.	
F1 level to gently subdued surface, thick deposits	White and Black Spruce, Willow, moss
F2 subdued to moderately sloping (15–30%), thick deposits	White and Black Spruce, Willow, moss
F3 hummocky and ridged, moderately to moderately steeply sloping (30–65%), thick deposits.	Aspen, Kinnikinnick, grass
F4 steeply sloping scarps (greater than 65%), thick deposits, south facing.	Aspen and grasses
F5 subdued fluvial fans and low lying terraces; high water table and occassional floodeing may occur near channels and in depressions.	White Spruce, Birch, Willow, moss
F6 variable thickness (.5–2m) of sand and gravel overlying subdued to moderately sloping till surface; well–drained.	Lodgepole Pine, Willow, Labrador Tea
F7 steeply sloping scarps (65%)	Black Spruce, Willow, moss
Wetlands – valley–bottom and depressional areas which are wet for most of the year; inundation from high water table or flooding is the main constraint, but soft compressible soils are also common.	
W1 dominantly organic materials greater than 1m thick.	Black Spruce, Labrador Tea, Willow
W2 variable extent and thickness of organics (40–150cm) overlying wet floorplain sediments.	Willow, sedge, moss
W3 thin organics (less than 1m) and poorly drained mineral soil on floodplains and in large depressions; overbank silts and fine sands occur on floodplain lacustrine silts and till usually underlie depressions.	Black Spruce, Labrador Tea, moss

GEOMORPHIC CONDITIONS AND PROCESSES

Permafrost – perenial frozen ground.

X areas of potential ground ice occur on poorly–drained till slopes and floodplain areas where organic soils predominate.

Terrain Hazard Units

- R slopes which show evidence of active landsliding; mass movement and erosion hazard.
- ER slopes which have the potential for mass movement and/or have high erosion potential.
- E slopes which have moderate erosion potential.
- D toe–slope areas actively receiving deposition from upslope landslides or on–going erosion.
- U1 areas highly susceptible to flooding, channel shifting, or inundation by high water table.
- U2 areas potentially susceptible to flooding, channel shifting, or inundation by high water table.

NOTE:
Map units are defined by one or more symbols representing the occurence of significance terrain features and conditions and/or geomorphic hazards which may have a beneficial or constraining effect on mine–facility and access–road development.

LEGEND

- Index Contour
- Intermediate Contour
- Depression Contour
- Stream
- Intermittant Stream
- Indefinite Stream
- Single Tree
- Brush / Scrub
- Swamp
- Paved Road
- Dirt Road
- Water Quality Monitoring Station

Seed Mix (kg/ha)

1) Yukon wheatgrass (3), Violet wheatgrass(6), Northern fescue(4), Artic lupine(1), Yellow locoweed(1), Glaucous bluegrass(3).
2) Meadow foxtail(5), Tufted hairgrass(4), Polargrass(1), Bluejoint reedgrass(1), Altai fescue(6).
3) Meadow foxtail(3), Tufted hairgrass(4), Bluejoint reedgrass(1), Fowl bluegrass(8).
4) Yukon wheatgrass (3), Violet wheatgrass(8), Northern fescue(3), Artic lupine(2), Glaucous bluegrass(3), Sheep fescue(3), Snowy locoweed(1).

Scale 1000 500 0 1000 2000 Metres

DRG. NO.	DESCRIPTION	REV.	DATE	DESCRIPTION	APPROVED	REV.	DATE	DESCRIPTION	APPROVED
REFERENCE DRAWINGS		REVISIONS				REVISIONS			

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DRAWN VY
CHECKED
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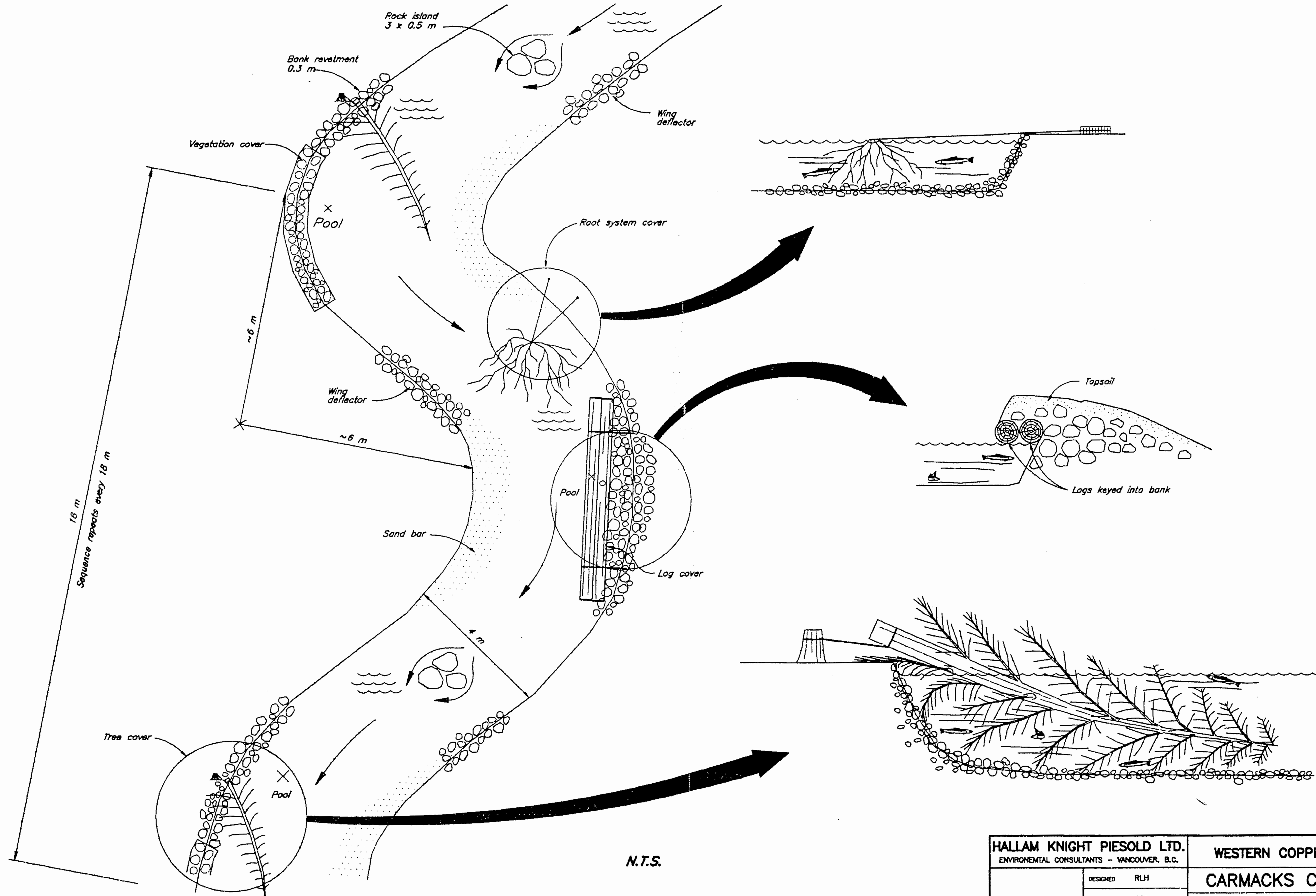
TERRAIN HAZARDS
FIGURE 5.2

DATE AUG. 17, 1994 | SCALE AS SHOWN | DRG. NO. H1811 | REV. –



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DESIGNED RLH	CARMACKS COPPER PROJECT
DRAWN VY	FISH HABITAT ENHANCEMENT PLAN AND SECTIONS FIGURE 5.3
CHECKED DJR	
APPROVED	
DATE JUNE 7, 1994	SCALE AS SHOWN / DRG. NO. H1811 / REV. –

DRG. NO.	DESCRIPTION	REV.	DATE	DESCRIPTION	APPROVED	REV.	DATE	DESCRIPTION	APPROVED
REFERENCE DRAWINGS		REVISIONS				REVISIONS			

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SECTION 6.0 - REVISED OPERATIONAL MONITORING PROGRAM

6.1 OPERATIONAL MONITORING PROGRAM

An ongoing monitoring program will be required during the full life of the operations to:

- ensure that all waste management facilities, such as dump pads, settling ponds, solution pumps, leach pad liners and septic tanks are operating efficiently;
- ensure that environmental protection systems such as fuel storage berms and the fire water tank are functioning as required; and
- ensure that water quality protection programs, such as regular sampling and treatment, are maintained.

The open pit mine activities will run from March to December which will require ongoing routine maintenance as well as monitoring similar to the commissioning stage at the beginning of each mining season. Maintenance, including scheduled shutdowns, will be carried out by operating personnel, using contract services when required, and will include, for example, sediment removal from waste rock dump settling ponds, access road maintenance, cleaning of intake screens, repairs to electrical controls, and major repairs due to damage from cold weather. In addition to regular scheduled inspections and testing of the entire system, all systems will be equipped with comprehensive monitoring devices for continuous automated operation. All automatic remote monitoring systems will be linked by dedicated data communication lines to a centrally located control room equipped with alarms and print-out devices.

The heap leach facility will comprise an area of 310,000 m^2 divided into 2 cells. A perimeter berm 2 metres high will extend from the crest of the retaining structure around the perimeter of the leach pad. A soil liner comprising processed glacial till will be prepared on the inside face of the perimeter bers and the confining embankment, and in the basin of the leach pad facility.

A network of foundation drains will be excavated and constructed to minimize seepage forces on the engineered liner system. The leach pad liner (permeability 1×10^{-9} m/s) consists of a composite of 60 mil High Density Polyethylene and a soil liner. Beneath the composite liner, the foundation drains will serve as the main leak detection system. The estimated leakage of 0.26 m^3/day would be intercepted by the foundation drains which comprise the leak detection system.

Most modern milling operations are now equipped with automatic control systems such as mechanically linked deflectors, hydraulic breaks, temperature controls, overload switches, overspeed and no-flow shutoffs, plugged chute alarms, etc., which will act internally to disengage individual systems instantaneously to protect primary pieces of equipment. The electrical systems will be equipped with protective relaying to both recognize electrical faults and abnormal system conditions. The powerline to site will also be equipped with the necessary devices prescribed to protect the territorial grid system.

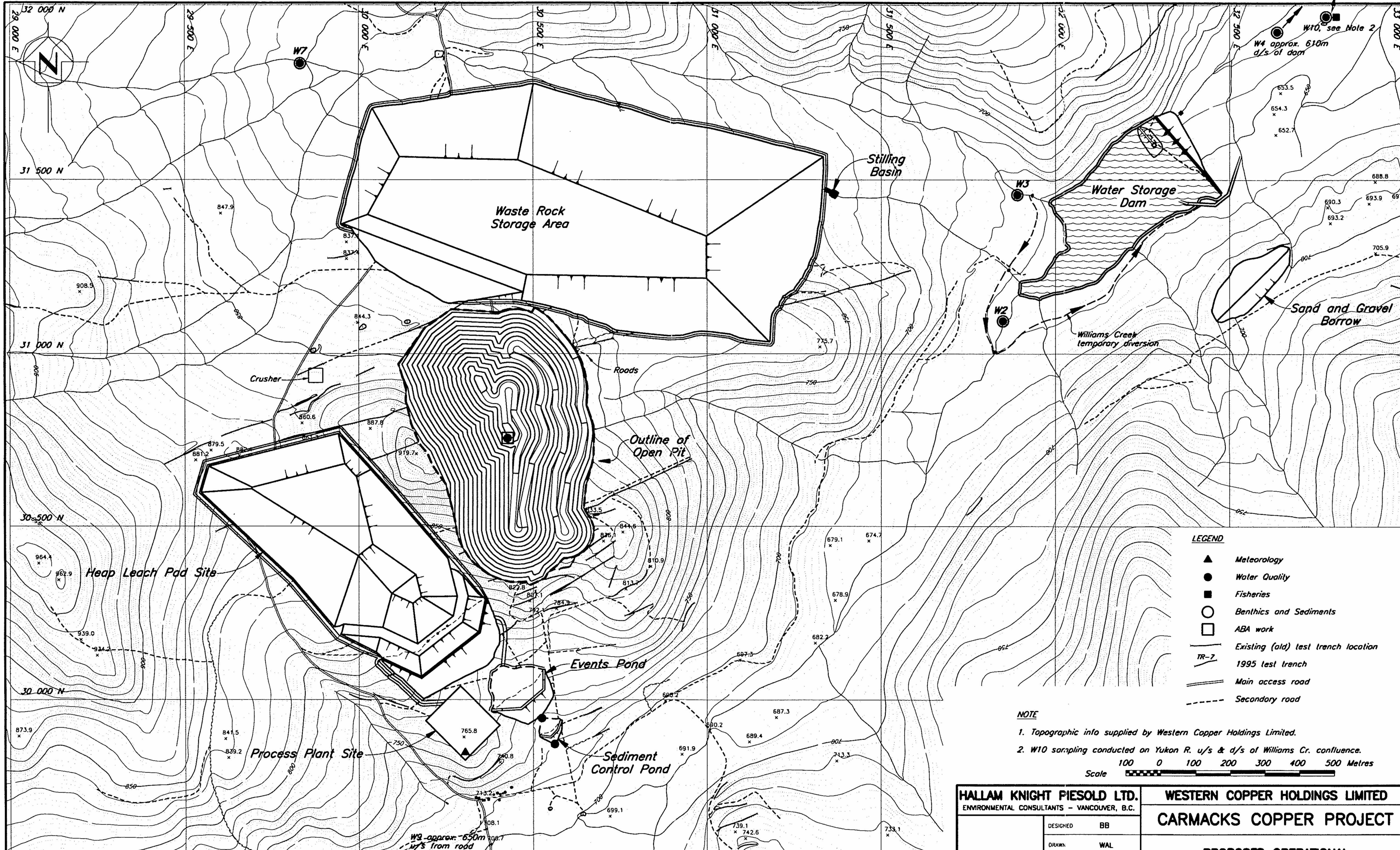
Apart from internal controls, a recommended monitoring program will be established to include effluents and the receiving environment as outlined in Table 6.1 and presented in Figure 6.1.

In addition to monitoring by the Environmental Manager, an environmental education program will be employed. This education program will be designed to instill environmental awareness in the employees of the mine. Education will include scheduled seminars and poster boards providing information on the environmental effects of construction and operation and how to best reduce these effects, and monitoring activities. All employees at the mine will be responsible for recognizing potential problems which may otherwise be overlooked and reporting to the environmental supervisor so that the problem may be ameliorated.

Table 6.1

Recommended Environmental Monitoring Program

Area	Source/ Location	Analyses	Material	Frequency
Sources (Effluents and Emissions)				
Open Pit	Waste Rock	Acid-Base Accounting	Blasthole Cuttings	By Bench
	Low Grade Ore	Acid-Base Accounting	Blasthole Cuttings	By Bench
	Wall Rock	Acid-Base Accounting	Panels/Leachate	Monthly
	Mine Water	Heavy Metals/Physical Sulphates/Nitrogen/pH	Mine Water	Monthly
Waste Rock Dump	Seepage	Heavy Metals/Physical	Stilling Basin	Monthly
Heap Leach Pad	Seepage	Heavy Metals/Physical	Leak Detection System	Ongoing
		Flow	Leak Detection System	Ongoing
Receiving Environment				
Williams Creek	Stations W2,W9	Physical/Heavy Metals	As Per Baseline	Monthly, QA/QC
	W7, W3	Sulphates/Nitrates/pH	Water Quality	Monthly, QA/QC
	W4, W10	Benthic Macroinvertebrates	Population Characteristics	Annually, Replicated
		Sediments	Heavy Metals/LOI	Annually, Replicated
	Station W10	Fish Tissue	Heavy Metals/MIMS	Annually, Replicated
Yukon River	Above and Below	Water Quality	Physical/Heavy Metals	Annual (Freq. increased if contamination noted in W4, W10)
Heap Leach Pad Events Pond	Below	"	"	Monthly
Sediment Control Pond	Below	"	"	Monthly
Mine Site	Climate	Temp/Precip/Snow/Wind	Meteorology	Daily
Reclamation	Reclamation Plots	Soil Characteristics	Reclamation	On-going
	Reclamation Trials	Soil Amendments	Research Program	"
	Reclaimed Areas	Vegetation Species	Growth/Productivity	"
		Wildlife Use	Periodic	"
		Browse/Pellet Groups	Observations	"



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DRAWN WAL	PROPOSED OPERATIONAL
CHECKED	ENVIRONMENTAL MONITORING PROGRAM
APPROVED	

REV.	DATE	DESCRIPTION	APPROVED
0	05/01/1995	ISSUED FOR PRELIMINARY DESIGN	

DRG. NO. | DESCRIPTION — REFERENCE DRAWINGS

REVISIONS

DATE MAY 8, 1995 | SCALE AS SHOWN | DRG. NO. FIGURE 6.1 | REV. 0

SECTION 7.0 - REVISED CONCEPTUAL RECLAMATION AND CLOSURE PLAN

The objective of the conceptual reclamation and closure plan is to provide a systematic approach to decommissioning the mine and returning all disturbed lands to a habitat capability equitable to pre-mining conditions. The following goals are implicit in achieving this primary objective:

- the long-term preservation of water quality within and downstream of decommissioned operations;
- the long-term stability of engineered structures including the waste rock dumps, heap leach, water storage dam, and open pit;
- the removal and proper disposal of all access roads, structures and equipment not required beyond the end-of-mine-life;
- the long-term stabilization of all exposed erodible materials;
- the natural integration of disturbed lands into surrounding landscape, and restoration of the natural appearance of the area after mining ceases, to the greatest possible extent; and
- the establishment of a self-sustaining vegetative cover consistent with existing wildlife needs.

As an overall approach to achieving this objective, the Reclamation Plan must be sufficiently flexible to allow for future changes in the mine plan and to take advantage of information obtained from ongoing reclamation research. This conceptual reclamation plan forms the basis for the Reclamation Permit required by the Territorial Land Use Regulations governed by DIAND.

Presently, the mine site and facilities lie on an area dominated by white spruce on well drained slopes, black spruce on poorly drained slopes and lodgepole pine in seral areas of previously burned vegetation. Stands are interspersed with paper birch, trembling aspen and poplar.

Feathermoss dominates the understorey in dense black spruce stands, with willows and ericaceous shrubs in more open stands. Sedge and sphagnum tussocks are common in poorly drained areas. Ground cover on south facing slopes consists of sagewort; grasses and forbs occur in gulleys and draws containing trembling aspen.

The following sections address each component of the project and the necessary closure and reclamation procedures for the areas of disturbance as presented in Table 7.1. Although each component delineates a specific area of influence, the total area affected through mine operations including temporary haul roads and material storage is estimated to be 378 ha. This estimate includes the area of influence surrounding the actual disturbed area of 198.4 ha presented in Table 7.1 and includes temporary storage piles and areas that may be temporarily disturbed during operations. Revegetation of the areas discussed in the following sections will follow "Guidelines for Reclamation/Revegetation in the Yukon" (Kennedy 1993) and "Mine Reclamation in Northwest Territories and Yukon (Steffen, Robertson and Kirsten (B.C.) Inc. 1992). Reclamation plans are presented in Figure 7.1.

7.1 RECLAMATION RESEARCH PROGRAM

An important component of the Reclamation Plan is an ongoing reclamation research program with the objective of establishing the necessary methods and materials required to implement a successful abandonment plan that will meet with the stated objectives of returning all disturbed lands to pre-mining use and capability, when the operations are closed. The program will be administered by the site Environmental Manager in co-ordination with mine surface crews using mine equipment.

Although some reclamation research work was initiated during the baseline studies program and indigenous species of plants have been catalogued, characterizing available soils in various biogeoclimatic and vegetation zones will be required. At the completion of mining, it is expected that the reclamation research program will have fostered the development of local knowledge and experience required to develop an effective reclamation abandonment plan. Expertise developed from on-site research will be supplemented, where necessary, with information developed by the Department of Mines, Department of Environment, Department of Indian and Northern Affairs and studies completed by other operations, associations with University faculties, consultants with agronomic expertise and commercial nurseries.

The Reclamation Research Program will initially consist of three primary elements:

- detailed characterization of soils in the mine site area;
- establishing a series of test plots on various disturbed materials; and
- documenting natural recolonization successes.

While there are some baseline data on soils in the mine site area, they are limited. More detailed soils mapping and soil chemistry is required. These data are necessary to assess the available soils in the area, possible nutrient deficiencies and candidate species for reclamation. Further testing of overburden removed from the open pit will also be required since it will form the largest component of growth medium on the property.

As soon as mining commences, test plots will be established for purposes of evaluating potential impediments that may be encountered in reclaiming specific units. Test plots will be designed to test such variables as soil chemistry, soil amendments (fertilizers, sand, wood chips, peat, lime), site preparation, seeding times, seed mixtures and adaptability of tree seedlings. Successes and failures will provide natural direction to the research, such that the outcome of the selected approach for reclaiming each unit will be predictable.

A number of seed mixtures will be grown on test plots during operation in order to optimize the species composition. As fertilizers will be necessary over most of the mine area due to naturally low soil nutrients these will also be tested. Due to the xeric (dry) conditions at the Carmacks Copper Project, snow seeding will be completed when there is less than 10 cm of snow cover using the seed mixtures presented in Table 7.2.

Recontouring of the various aspects of the project, including the waste dump, freshwater storage dam and the heap leach pad, will take into consideration slope stability and erodability. In areas with steep slopes, stabilization measures using synthetic materials or a step configuration will be employed. Rip rap will be layed down in areas adjacent to streams or where stability is required.

Since test plot information is normally based on small scale optimum conditions, the information acquired from test plots must be applied successfully on a successively larger scale before they can be deemed applicable. These scale-ups are termed reclamation trials and are normally applied to areas of 1 to 2 ha in size. A series of reclamation trials will be implemented before mine closure on areas that have been finalized, for example, completed portions of the waste rock dump, unused exploration roads, and margins of diversion channels. Information obtained from reclamation trials can then be scaled-up to reclaim areas as they become available on an on-going basis. In this manner, the company will be able to optimize species composition and ensure self-sustaining vegetation communities for closure.

7.2 OPEN PIT

Based on precipitation alone since groundwater contributions to mine water are expected to be nil, preliminary calculations estimate that it will take over 300 years for the open pit to flood if there are no losses to groundwater. Results from acid-base accounting indicate that the waste rock and open pit wall material are overwhelmingly acid consuming. Potential open pit effluents are expected to have a neutral pH but may contain elevated levels of some metals. Mine water after closure may seep out as groundwater; however, the quantities are not expected to be great enough to contaminate groundwater or surface waters.

Due to the steepness of the pit walls (54°), the open pit will be fenced off and locked at mine closure to limit access to the persons using the area for hunting, trapping or recreation. Areas along the top perimeter of the open pit, which were disturbed during initial stripping, will be seeded during mine operation to reduce erosion.

7.3 WASTE ROCK DUMP

Dump crests will be dozed or rolled over to a final design gradient of 2.5:1. Large boulders will be left in place to break up the planar surface of the dump. The surfaces will be scarified and surfaced with overburden (approximately 15 cm in depth) which was stockpiled during the stripping of the dump and open pit area. The surface will be revegetated with indigenous plant species (preferable) or agricultural equivalents which are compatible with regional vegetation types.

Once the dump is decommissioned and vegetation has taken hold, the wildlife fence will be removed to allow wildlife use of the dump. The diversion channels and stilling pond at the base of the dump will remain in place to serve as a primary settling pond to remove large sediments while the dump is returned to a stable state.

Seed selection for reclamation purposes will be determined from test plots to optimize mixtures for best growth and longevity. Two mixtures will be tested first for the waste rock dump. Lodgepole pine on south and east facing slopes and white spruce on north and west facing slopes. Both mixtures comprise a native seed mixture of Yukon wheatgrass, violet wheatgrass, northern fescue, arctic lupine, yellow locoweed and glaucous bluegrass. Both seed mixtures have been determined to be acceptable for the Yukon in areas of the Pelly River vegetation zone. Nutrient amendments will be added as necessary.

Longevity may be a problem with these two mixtures due to altitude, at which point a high elevation subalpine mixture will be tested if necessary. This seed mixture consists of Yukon wheatgrass, violet wheatgrass, tufted hairgrass, northern fescue, ticklegrass, arctic lupine, yellow locoweed and glaucous bluegrass in different proportions to the two previous mixes. Revegetation using these mixes will be carried out with the aid of "Guidelines for Reclamation/Revegetation in the Yukon" (Kennedy 1993).

7.4 HEAP LEACH PAD AND EVENTS POND

Benchscale testwork is currently in progress in order to project the time and process required to neutralize the leach pad. Columns of leached material from the pilot plant were established and leached at a known rate. A slurried milk-of-lime solution was then used to assist the neutralizing process. Although testwork is not complete, preliminary estimates indicate that the leach pad will be fully neutralized in approximately two years following closure.

Once the leach pad is neutralized, a till layer will be applied to reduce water inflow. To provide a medium for plant growth, the till will be topped with approximately 15 cm of overburden from stripping the pad and open pit during construction. This measure will preclude the necessity of active long-term post-closure monitoring and treatment.

The pad will be revegetated with seed mixtures compatible with the mixed deciduous/coniferous vegetation areas. Native plant species in this association will include Yukon wheatgrass, northern fescue, violet wheatgrass, sheep fescue, glaucous bluegrass, sweetgrass, and arctic lupine. This will be optimized based on test plots containing leached and neutralized material from the pad.

It is expected that a layer of sediment will have accumulated on the bottom of the events pond over the mine life. Following closure, the pond will be drained, the double liner folded back on itself to contain the sediments and permanently buried. An overburden layer will be placed over top and vegetated with a black spruce community ground cover seed mix. The sediment control pond downstream of the events pond will be similarly decommissioned.

The wildlife fence surrounding the pad will be removed once water quality is deemed safe, the till and overburden has been placed, and vegetative cover has been established.

7.5 PLANT AND ANCILLARY FACILITIES

The mill and ancillary surface facilities that are not required for future, including the conveyor system and wildlife fence, will be dismantled and equipment will be sold for salvage value. Above ground foundations will be broken down to ground level, covered with local glacial tills and seeded. Recontouring will restore pre-mine drainage patterns and revegetation will follow the seed mixture for mixed deciduous/coniferous forests.

Water treatment facilities will remain intact until the heap leach pad has been neutralized and water quality is appropriate for direct release to Williams Creek. When treatment water meets compliance standards the water treatment facilities will be dismantled and removed from the mine site.

The sand and gravel borrow area south of the water storage dam will be recontoured and seeded with the mixture for a black spruce community association.

7.6 WATER STORAGE POND

The water storage pond will be lined during construction and the dam will ultimately be only 16.5 m high. This dam and pond will remain following closure. Emergent vegetation along the perimeter will be planted to encourage water fowl use. Perimeter areas and access roads in the immediate vicinity will be planted using the suggested seed mixture for willow/sedge community soils. Native species in this mixture include meadow foxtail, tufted hairgrass, bluejoint reedgrass and fowl bluegrass (Kennedy 1993).

7.7 ACCESS ROADS AND POWERLINE

Access roads to the site and facilities will be closed and reclaimed. This will be achieved by removing all culverts, bridges and approaches, scarifying the road, restoring drainage patterns and seeding. To prevent further travel, a number of trees will be felled to create impasses.

As suggested for linear developments, access roads at the project will be tested for revegetation with a seed mixture including a native selection of Yukon wheatgrass, violet wheatgrass, northern fescue, sheep fescue, yellow locoweed, showy locoweed, arctic lupine and glaucous bluegrass. Seed proportions will follow those suggested by Kennedy (1993).

Measures will be taken during design and construction to prevent permafrost degradation along access roads. However, if this occurs, reclamation of affected areas will be completed as necessary. This can usually be accomplished in relatively dry areas with a thin organic layer, such as exist at this location, by stripping the organic layer, replacing it with a sufficient depth of gravel to restore the natural thermal gradient and revegetating the area.

At this stage, it is unknown whether the main powerline will be removed or left in place for regional development. However, in either case ground cover will be well established at mine closure and no further seeding will be required (powerline removal will not significantly disturb established vegetation). For the purposes of preliminary reclamation cost estimates, removal of the powerline has been included.

7.8 RECLAMATION CAPITAL COST ESTIMATE

Table 7.3 outlines a preliminary cost estimate for reclamation of the mine site. These estimates are based on 1995 costs. A more detailed description of site preparation, revegetation and maintenance costs, including estimates of salvage value for equipment from the mine site, is presented in Appendix 4. With a 20% contingency, the total cost for reclamation is estimated to be $2.8 million.

7.9 RECLAMATION SCHEDULE

Reclamation will begin during operations to promote slope stabilization and reduce erosion during the life of the mine. Following closure, equipment and buildings will be removed and resloping and revegetation will occur during open ground periods for the first two years. The monitoring of the heap leach pad will continue until it is deemed safe at which time the treatment facility and settling pond will be removed, recontoured and revegetated. It is difficult at this point in the project to determine how long the neutralization process will take. It is anticipated that one to two seasons of flushing will be required to neutralize the pile.

In the second year after closure, after heavy equipment has been removed from site, the main access road will be scarified and reclaimed. Biomonitoring and geotechnical assessments will occur annually for a minimum of 5 years to ensure that revegetation is successful and that slopes are stable.

7.10 SUSPENDED OPERATIONS, EARLY OR PREMATURE CLOSURE

Reclamation and revegetation will be ongoing so that in the event of suspended operations or a premature closure, revegetation will be well advanced in disturbed areas. In the event of suspended operations, the heap leach will be drained down and no further reclamation will be carried out until operations recommence or a decision is made to proceed with full closure. In the event of a premature closure, a temporary closure plan based on material stability will be instigated. All materials including stockpiles, reagents and stored fuel will be secured and on-site monitoring will take place until mining recommences or full closure occurs.

Table 7.1

Carmacks Copper Project

Projected Area of Disturbance at End-of-Mine Life (Year-9)

Reclamation Unit	Area (ha)
Open Pit (Incl. Diversions, Haul Roads)	32.8
Waste Rock Storage Area (Incl. Diversions, Stilling Basin)	81.6
Heap Leach Pad (Incl. Diversions, Wildlife Fence, Perimeter Berm, Events Pond)	37
Sediment Control Pond	0.6
Plant and Ancillary Facilities (Incl. Mill, Maintenance, Camp)	3.57
Surface Water Storage (Incl. Dam, Pumphouse, Powerline, Haul Roads)	14.3
Sand and Gravel Borrow	2.5
Access Road	26
Total Estimated Disturbed Area	198.4
Total Affected Area	378

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Table 7.2

Carmacks Copper Project

Suggested Seed Mixes For Reclamation Test Plots at Carmacks Copper (Kennedy 1993)

Native Species	Community Association SeedMixture					
	Lodgepole Pine[1] kg/ha	Mixed Decid/Coni kg/ha	Black Spruce[2] kg/ha	Willow/Sedge[3] kg/ha	White Spruce[4] kg/ha	(Linear)[5] kg/ha
Yukon wheatgrass	3	2			5	3
Violet wheatgrass	6	6			5	8
Northern fescue	4	2			2	3
Arctic lupine	1	2			2	2
Yellow locoweed	1				1	1
Glaucous bluegrass	3	2			2	3
Meadow foxtail			5	3		
Tufted hairgrass			4	4		
Polargrass			1			
Bluejoint reedgrass			1	1		
Altai fescue			6			
Fowl bluegrass				8		
Sheep fescue		2				3
Showy locoweed						1
Sweetgrass		1			1	
Total	18	17	17	16	18	24

Agronomic Species	Community Association Seed Mixture					
	Lodgepole Pine[1] kg/ha	Mixed Decid/Coni kg/ha	Black Spruce[2] kg/ha	Willow/Sedge[3] kg/ha	White Spruce[4] kg/ha	(Linear)[5] kg/ha
Streambank wheatgrass	6	6			6	5
Slender wheatgrass	6	6			8	8
Creeping red fescue	2	4			2	8
Sheep fescue	8	4			4	9
Alfalfa	4				2	6
Canada bluegrass	6					4
Meadow foxtail			8	10		
Tufted hairgrass			8	8		
Reed canarygrass			8	8		
Timothy			6	6		
Fowl bluegrass		6			4	
Kentucky bluegrass		2			2	
Alsike clover		2			2	
Total	32	30	30	32	30	40

Native species may be substituted with agronomic species, however, native species are recommended and require approximately one half the weight in seed as the agronomic species.

[1] suggested for waste dump south and east slopes
[2] suggested for mill, ancillary facilities and heap leach pad
[3] suggested for the fresh water storage area
[4] suggested for the waste dump north and west slopes
[5] suggested for access roads

TABLE 7.3

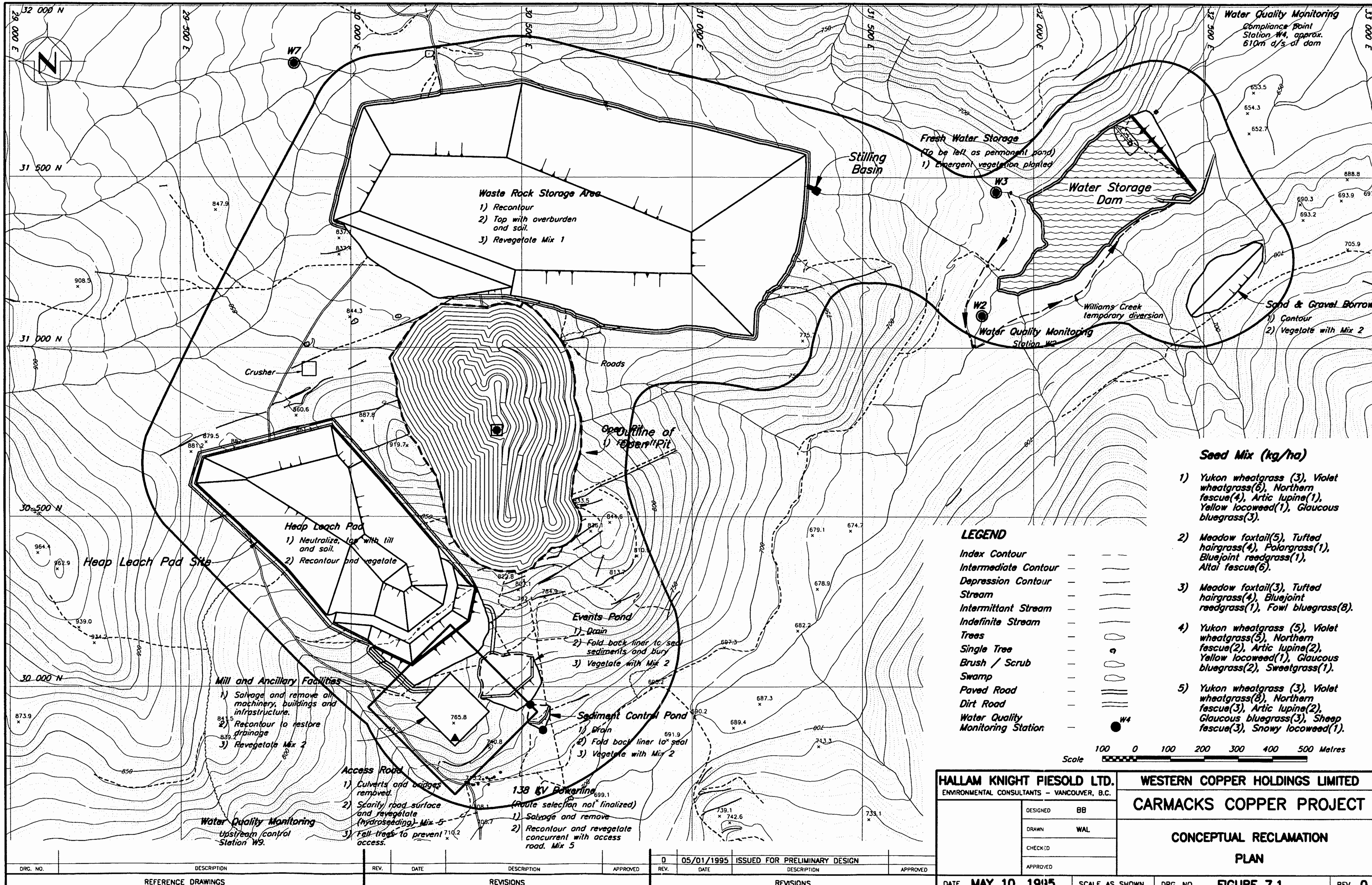
Carmacks Copper Project

Reclamation Costs

Facility	Land Use	Area Reclaimed (ha)	Site Preparation	Revegetation	Maintenance	Cost
Research Program	Revegetation Research	1.25	$118,500	$0	$100,000	$218,500
Open Pit	Rock Cliff	32.8	$6,100	$0	$0	$6,100
Waste Rock Dump	Wildlife/Lodgepole	48	$147,984	$145,697	$0	$293,681
Waste Rock Dump	Wildlife/Whitespruce	33.1	$102,047	$101,285	$0	$203,332
Heap Leach	Wildlife/Mixed	37.4	$324,454	$109,609	$0	$434,063
Events Pond	Wildlife/Mixed	2.4	$5,000	$7,034	$0	$12,034
Plant and Ancillary	Wildlife/Mixed	3.6	$190,800	$10,551	$0	$201,351
Water Storage Pond	Waterfowl/Riparian	14.3	$0	$17,349	$0	$17,349
Borrow Pit	Wildlife/Blackspruce	2.5	$0	$7,501	$0	$7,501
Road/Powerline	Wildlife	26	$139,150	$79,811	$0	$218,961
Subtotal		201.35	$1,034,035	$478,837	$100,000	$1,612,872

Lump Sum Items	
Erosion Mats where necessary	$250,000
Placement of Erosion Mats	$6,000
Post-closure reclamation monitoring and administration.	$90,000
Monitoring - 5years Water quality Benthics Vegetation	$300,000
Engineering	$100,000

Total cost without contingency =	$2,358,871.88
Contingency (20%)=	$471,774
Total cost with contingency =	$2,830,646



Water Quality Monitoring
Compliance Point Station W4, approx. 610m d/s of dam
W7
Waste Rock Storage Area
1) Recontour
2) Top with overburden and soil.
3) Revegetate Mix 1
Stilling Basin
Fresh Water Storage
(To be left as permanent pond)
1) Emergent vegetation planted
W3
Water Storage Dam
W2
Williams Creek temporary diversion
Water Quality Monitoring Station W2
Sand & Gravel Borrow
1) Contour
2) Vegetate with Mix 2
Crusher
Roads
Outline of Open Pit
Heap Leach Pad
1) Neutralize, top with till and soil.
2) Recontour and vegetate
Heap Leach Pad Site
Events Pond
1) Drain
2) Fold back liner to seal sediments and bury
3) Vegetate with Mix 2
Mill and Ancillary Facilities
1) Salvage and remove all machinery, buildings and infrastructure.
2) Recontour to restore drainage
3) Revegetate Mix 2
Sediment Control Pond
1) Drain
2) Fold back liner to seal
3) Vegetate with Mix 2
Access Road
1) Culverts and bridges removed.
2) Scarify road surface and revegetate (hydroseeding) Mix 5
3) Fell trees to prevent access.
138 KV Powerline
(Route selection not finalized)
1) Salvage and remove
2) Recontour and revegetate concurrent with access road. Mix 5
Water Quality Monitoring
Upstream control Station W9.
Seed Mix (kg/ha)
1) Yukon wheatgrass (3), Violet wheatgrass(6), Northern fescue(4), Artic lupine(1), Yellow locoweed(1), Glaucous bluegrass(3).
2) Meadow foxtail(5), Tufted hairgrass(4), Polargrass(1), Bluejoint reedgrass(1), Altai fescue(6).
3) Meadow foxtail(3), Tufted hairgrass(4), Bluejoint reedgrass(1), Fowl bluegrass(8).
4) Yukon wheatgrass (5), Violet wheatgrass(5), Northern fescue(2), Artic lupine(2), Yellow locoweed(1), Glaucous bluegrass(2), Sweetgrass(1).
5) Yukon wheatgrass (3), Violet wheatgrass(8), Northern fescue(3), Artic lupine(2), Glaucous bluegrass(3), Sheep fescue(3), Snowy locoweed(1).
LEGEND
Index Contour
Intermediate Contour
Depression Contour
Stream
Intermittant Stream
Indefinite Stream
Trees
Single Tree
Brush / Scrub
Swamp
Paved Road
Dirt Road
Water Quality Monitoring Station
W4
Scale
100 0 100 200 300 400 500 Metres
HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS - VANCOUVER, B.C.
DESIGNED BB
DRAWN WAL
CHECKED
APPROVED
WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
CONCEPTUAL RECLAMATION PLAN
DATE MAY 10, 1995
SCALE AS SHOWN
DRG. NO. FIGURE 7.1
REV. 0
0 05/01/1995 ISSUED FOR PRELIMINARY DESIGN
DRG. NO. DESCRIPTION
REFERENCE DRAWINGS
REV. DATE DESCRIPTION APPROVED
REVISIONS
REV. DATE DESCRIPTION APPROVED
REVISIONS

SECTION 8.0 - RESPONSE TO REVIEW COMMENTS

8.1 Manfred Hoefs, Supervisor, Habitat Management, Yukon Renewable Resources

" Table I, which lists individual plant species..... *Vaccinium sp*...... should be referred to as *Oxycoccus microcarpus*. They should have their collections verified and possibly write a note on range extensions."

Plant species lists presented in the Volume 1 Addendum were compiled from ground survey transects located in eight vegetation zones from the Volume 1 mapping from air photographs. The range of these species in the project area is presented in Figure 1 of the Volume 1 Addendum. Further range assessment was not completed at this stage, since the purpose of the study was simply to ground-truth the vegetation mapping. The consultants concur that the species seen was *Oxycoccus microcarpus* as a result of range distribution; however, MacKinnon, Pojar and Coupé (1992) mention that both names may be used.

8.2 Benoit Godin, Environmental Protection, Yukon Region, Environment Canada

Volume IV Comments

• *Section 1.2, p. 1-2*, "... Are the settlement ponds integral to waste rock dump drainage water quality, and if so can the proponent explain the apparent loss of protection to the N/NE dump component? ....discrepancy between plan and flowsheet..."

The latest design incorporates drainage ditches around the perimeter, drains under the dump, and a stilling pond at the outflow that captures all waters and provide a primary settling system to remove large sediments. The latest water balance and design incorporate these components. Further details are presented in Knight Piésold Ltd. (1995).

• *Section 1.4.3, p. 1-5*, "is expected to reduce flow by 1.8% per month or 5.4% annually. These estimates are derived at the lower portion of Williams Creek which includes Nancy Lee Creek, its tributary. Will the upper portion of Williams Creek flow be interrupted either during the construction of the dam or during the operation of the dam?"

Williams Creek immediately below the water storage dam and above Nancy Lee Creek is expected to have reduced flows of 100% during initial filling which will take approximately 25 days in April (during freshet). Reductions in flows during operations are expected to range from 9% to 18% annually depending on whether it is a dry, average or wet year. Section 5.5 of this Addendum discusses this further.

• *Section 1.5, p. 1-10*, "overburden deposits ... do not appear to be extensive in the pit area. Can the proponent provide volumes of material available from pit salvage and will these volumes and materials be sufficient for the proposed reclamation and revegetation program?"

Approximately 0.5m of material will be stripped from the waste rock, the heap leach pad area, water storage pond and open pit and stored for reclamation purposes. This material, which has been calculated to total 862,000 m^3, is expected to provide sufficient quantity of overburden to replace 0.3m over the entire site for revegetation.

• *Section 2.10, p. 2-8*, "... a substantial amount of sulphuric acid will be stored in Skagway, however, section 1.6 does not indicate permitting and licenses to be obtained from the U.S."

The company concurs with this statement and will be obtaining the appropriate permits from the Alaskan and U.S. governments for transportation from Skagway to the Carmacks Copper Project site.

• *Section 3.2.5, p. 3-5*, "... method for determining annual nitrogen loadings from operations after Pommen (1983). The text should contain calculations for this loading, along with an expected range of ammonia nitrogen concentrations at various stations in Williams Creek. From the data supplied, a calculated average annual nitrogen concentration in lower Williams Creek at Yukon River of 1.088 ppm could be suggested"

Please refer to Section 5.5 of this Addendum, water quality modelling, which provides a revised assessment of projected nitrogen concentrations in Williams Creek at stations W4 below the reservoir spillway, and W10 downstream of Nancy Lee Creek.

• *Section 4.4, p. 4-4*, "The groundwater program has apparently not met with much success: ... The proponent needs to better explain the reason for losses of data and data gathering opportunity, the exact nature of problems encountered, and the inherent meaning of the ">" sign in groundwater levels ... does [so much permafrost encountered] shed light upon potential permafrost problems associated with the heap leach pad location and location of other project components?"

Groundwater sampling did not have much success initially because the wells were installed in inclined drill holes creating problems with sampling techniques. The shallow dip of the drill hole made initial bailer operation difficult. A Watera pump was subsequently used to complete groundwater sampling. The "less than" value indicates that water was not reached at the maximum depth that the pump could reach.

A groundwater sample was obtained from RC-92-01 in March and April 1995 following specific procedures that include reducing the contaminant sources and removing three volumes prior to taking the sample for laboratory analysis. Results are presented in Appendix 3. Additional geotechnical studies were completed which more completely identified permafrost distribution. Modifications were then made to the location of the waste rock and leach pad and appropriate engineering design was included to provide stability of all facilities. These details are presented in Section 1 of this Addendum (Knight Piésold Ltd. 1995).

• *Section 5.1.3, p. 5-2*, "describes expected heap leach pad conditions including the foundation, and the potential of permafrost under the pad to melt due to the heat of solution. ... Can the proponent comment upon the design of insulative mechanisms to prevent permafrost melt or ensure none is encountered ... during pad construction? Can the proponent comment on the implications ..."

Further geotechnical studies in February 1995 have resulted in the relocation of the leach pad to an area without permafrost and with extremely low permeability till. The design of this facility includes a synthetic liner, in conjunction with the low permeability till underlying the pad. Projected losses to groundwater are in the order of 0.26 m^3/day. Details of ground conditions and design details are presented in Section 1 of this addendum (Knight Piésold Ltd. 1995).

- "Leach pad stability concerns... Volume I, Appendix I; ... What further geotechnical work has or will be performed in order to address questions of foundation stability...? Can the proponent speak of the suitability of the present program to provide adequate coverage and data?"

Further geotechnical studies in February 1995 have resulted in the relocation and redesign of a number of facilities. The leach pad has been moved to an area without permafrost and with very low permeability till. Stability analysis has been completed on the waste dump, leach pad, and water storage dam and the design has incorporated these results to ensure longterm stability. Please refer to "Carmacks Copper Project, Report on Preliminary Design (Ref.No. 1783/1)" (Knight Piésold Ltd. 1995) summarized in Section 1 of this Addendum for additional information on the ground conditions.

- "... characteristics of materials underlying the heap pad area? Are these materials acid consuming? What are these materials' abilities to attenuate for loss of pregnant leachate solution?"

The area under the leach pad presently consists of an organic/ash layer 0.3 to 1 m thick, discontinuous well sorted glaciofluvial/glaciolacustrine deposits, well graded glacial till from 2 to 30 m deep, weathered/decomposed bedrock 0.3 to 4 m thick, and granodiorite bedrock. Materials under the leach pad lie in a discontinuous permafrost area, therefore detailed design to minimize differential settlement is required. The proposed engineered liner system will consist of a composite of 60 mil High Density Polyethylene and a soil liner 500 mm thick beneath the in-heap storage and 300 mm beneath the rest of the pad. Complete data is presented in "Carmacks Copper Project, Report on Preliminary Design (Ref.No. 1783/1)" (Knight Piésold Ltd. 1995) summarized in Section 1 of this Addendum. Static acid-base accounting was conducted on samples from the proposed leach pad area including the till layer which will be used as a soil liner. This work indicates that the samples have a net neutralizing potential of 8.9 to 41.5, % sulphur of 0.02 to 0.03 and NP/AP ratios of 18.1 to 133.9. In addition, two till samples were tested for metal leaching. The samples were adjusted to pH 2.0 with H_2SO_4, leached for 24 hours and filtered. An ICP analysis was completed on the filtered supernatant. Results are presented in Table 4.16. Levels of metals released from the till layer are low.

• "The inundation area of the leach pad is sized for a 12 hour contingency capacity under the given draindown and rainfall event conditions. Is this design criteria also sufficient to handle expected snowmelt surges? ... Can the proponent review contingency requirements possibly required to accommodate a potential snowmelt surge and compare this to the present contingency situation? What is the draindown volume of the heap?"

Specifics for the design of all facilities assume that 70% of snowmelt occurs in April (the expected snowmelt surge) and that the majority of rain falls in May. The leach pad as per the Knight Piésold Ltd. design will accommodate the 1 in 10-year, 24-hour rainfall event in-heap storage and the events pond will accommodate the 1 in 100-year, 24-hour rainfall event with complete draindown of the heap. Draindown volume of the heap is 57,000 m^3 with an in-heap leachate storage capacity of 80,000 m^3. Details of this design are presented in "Carmacks Copper Project, Report on Preliminary Design (Ref.No. 1783/1)" (Knight Piésold Ltd. 1995).

• *Section 2.7, p. 2-6*, "The proponent earlier details the future possiblity of "wasting" raffinate..., however does not specify... the reasoning behind which raffinate would need to be "wasted." Can the proponent comment upon this? The Feasibility Study (p. 8-12) suggests raffinate neutralization during times of excess precipitation or snowmelt. What capacity event can the raffinate treatment system respond to?"

The revised leach pad design has a neutral to negative water balance which provides for complete recycle between the process plant and the leach pad. Therefore, raffinate would be recycled back to the leach pad and there would be no need for raffinate wasting during operations. Storm events are included in the design of the leach pad and an events pond with size specifications outlined in

Section 1.3 of this Addendum for a 1-in-100 year, 24-hour rainstorm event with complete active leach pad draindown and emergency freeboard.

Raffinate would not have to be wasted until leach pad closure, if at all necessary. In earlier reports, the location of raffinate waste disposal has not been specified. Based on the Knight Piésold Ltd. design, any treated raffinate solids may be disposed of in the double-lined events pond where metal hydroxides would precipitate to the bottom. Once operations cease, the liner will be double-backed onto itself to contain all precipitates, sealed, buried and reclaimed.

• *Section 3.3, p. 3-6*, "What is the chemical nature and stability of precipitates generated from neutralisation of raffinate? Is it a special waste?... What are the potential impacts of the precipitate to receiving environment water quality under the storage options forwarded? After neutralization, are trace organics carried over to the supernatant? Given the circuitous route supernatant takes before final release to Williams Creek (with dilution), what water quality is expected at Williams Creek before confluence with Nancy Lee Creek?"

The stability of precipitates from neutralized raffinate have been tested using sequential extraction and SWEP tests to determine their stability and whether it constitutes a special waste. Trace organics (Solvent 160 - petroleum solvent) were also tested at this time to determine the presence of reagent organics in the leach pad and the raffinate. Total Extractable Hydrocarbons (TEH) in neutralized raffinate precipitate (NRP) were below detection limits (<1200mg/L). SWEP testing indicates that the Neutralized Raffinate Precipitate is not a special waste. Details on sequential extraction testing are outlined in Section 4.

• *Section 3.1, p.3-1*, "...no discharge of process effluent to Williams Creek. This is misleading given the statement soon following that where necessaray ... treated raffinate would be directed to the waste rock dump settling pond.... [that] drains to North Williams Creek."

This comment is misleading, raffinate will not be directed to the waste rock dump settling pond (which has been replaced by a stilling basin in the current mine layout design). Raffinate will be kept in the process circuit with solids landfilled as necessary in a lined facility (the decommissioned events pond).

• *Section 3.1, p. 3-1,* " From October through April, the freshwater reservoir will be drawn down. Will there be no discharge from the pond during this period? How would this affect downstream flows and downstream water quality (esp. at confluence with Nancy Lee Creek)? Is there overwintering of juvenile chinook or other fish spp. above and below the confluence of Nancy Lee Creek which could be adversely impacted by this [flow modification]? [A commitment to maintaining flows] should be firmed up ..."

Based on the water balances presented in Section 4 of this Addendum, there will be no discharge from the water storage dam during the winter months from October to March in most years. Based on observations by J. Gibson during winter hydrology surveys, Williams Creek above Nancy Lee Creek freezes solid, but there are still flows in Nancy Lee Creek and flows were measured to be 0.006 m^3/s in Williams Creek at the mouth in March 1995 (J. Gibson pers.comm. 1995). As discussed in Section 5.5, fish overwintering habitat will not be affected by elimination of flows from the upper Williams Creek watershed during this period.

• *Section 3.2.2, p. 3-2,* "Mineralogy of the waste rock would be worthwhile -- especially a mineralogic accounting of arsenic oxides and other oxide species."

The proponent concurs that the mineralogy of the waste rock would be worthwhile. Mineralogy and petrography were completed during exploration and are discussed in Section 4 of this Addendum.

• *Section 3.2.2, p. 3-2,* "The text refers to monitoring waste rock dump catchment ponds... This will be difficult to do in the present configuration depicted in Figure 2.1 since the North/North-East part of the dump does not appear to report to a settlement pond... Can the proponent rectify this?"

The proponent concurs that Figure 2.1 did not clearly illustrate the limits of the waste rock dump catchment pond. The latest design and location of the waste rock dump completed by Knight Piésold Ltd. clearly depicts the stilling pond and diversions around the waste rock area. Please refer to Drawing 1783.300 in Section 1 of the Knight Piesold Ltd. (1995) report.

• *Section 3.2.3, p. 3-2*, "The text states that Acid-Base Accounting (ABA) testing was undertaken... to determine leachability... ABA would not provide light on leachability of oxide minerals. The proponent should persue a rock testing program which better fits characterization of oxides. An extraction testing program would likely suffice."

The proponent concurs that leachability cannot be determined from Static Acid-Base Accounting testing. A sequential extraction test has been completed on 6 composite waste rock samples. Please refer to Section 4 of this Addendum for results.

• *Section 3.2.4, p. 3-5*, "The proponent discounts columns or humidity cell testing based on ICP and ABA analysis... column leach testing or other extraction test methodologies can provide valuable data about the chemical stability of ore, spent ore, and waste rock which the proponent should approach."

Additional characterization of waste rock was completed including SWEP testing and sequential extraction testing. Please see Section 4 for details.

• *Section 3.2.4, p.3-5*, "SWEP testing was conducted upon ore samples used for the pilot program. How does the information presented relate to the field release of metal species indicated, and especially in relation to MMLER and to CCME?"

The SWEP data is not an actual indication of metals released to the environment. The purpose of the program was to determine the leachability of the ore for leaching. Once operations are complete the characteristics of spent-ore runoff will be significantly different from the initial SWEP tests. Based on the present leach pad design and water balance, there will not be a discharge to be regulated under MMLER except in year 10.

• *Section 3.1, p. 3-1*, "The drainage from the temporary ore stockpile is not indicated... it would be located near the crusher... Can the proponent clarify this? Where do diversion ditch waters report to?"

The temporary ore stockpile will be located adjacent to the crusher. During the detailed design, the appropriate diversions to capture all runoff from the stockpile will be included.

• *Section 5.3.2, p.5-7*, "... How would the company monitor the inundated area under the crushed ore? Is the inundated leach area instrumented with pneumatic piezometers to monitor the water level?"

The heap leach design outlined in the Feasability Report (Kilborn 1994) has been modified. Current design details are presented in the Knight Piesold Ltd. report (1995).

In the current design, a network of foundation drains will be part of the liner system under the leach pad and will serve to monitor and collect leaks in the liner.

• *Section 5.4.2, p.5-9*, "... the proponent cannot discount the possibility of a release to the subsurface environment, given the possibility of losses discussed above in exothermic process - permafrost - foundation - tearing."

The proponent concurs with this statement. Detailed design will work to minimize differential settlement and will employ a high level of QA/QC during construction to ensure the liner integrity.

• *Section 5.4.2, p.5-10*, "Water quality projections are based upon the assumption that dump pond water quality is equivalent to treated raffinate. This assumption may or may not be conservative given that waste rock has not been fully characterized for stability. Again, additional rock testing would shed light upon the validity of the assumption, and thus provide for a more meaningful estimate of resultant downstream water quality."

Upon analyses of waste rock SWEP and Leach 2 fractions of Sequential Extraction testing water quality modelling below the water storage dam and in lower Williams Creek has been determined. Water quality modelling is presented in Section 5 of this addendum.

• *Section 5.4.2, p.5-9*, "... states that high and low flows from dumps would fluctuate in direct proportion to flows in Williams Creek ... is clearly inconsistent with... Impacts to Surface Water

Hydrology where the proponent states that retention provided by in-pit settling pond, waste rock dump, and dump settling pond results in probable lag times of 7 to 15 days... The proponent should revisit this section of the text and re-think the scenario presented."

Due to the re-routing of pit water and 50% of waste rock runoff to the process circuit and the high runoff coefficient of the waste rock dump (85%) very little lag time is expected in the current mine layout scenario. See Section 5 of this Addendum for projected surface hydrology impacts.

• *Section 5.4.2, p. 5-11*, "... net contributions of metals ... should also be undertaken at Williams Creek at confluence with Nancy Lee Creek and under the lag scenario presented above. New rock testing and inclusion of other concerns listed within this evaluation may refine the model and thus numbers presented."

The revised water quality impact section is presented in section 5.4 of this Addendum and takes these comments into account.

• *Section 5.4.2, p. 5-10*, "... Data indicates that background concentrations are at times exceeding these values. It is important that criteria are in place to trigger actions from the company should the water quality data indicate degradation. The company should propose metal concentration objectives for W4, which would provide a safeguard for the downstream aquatic resources."

Revised water quality impacts and proposed mitigation strategies are presented in Section 5.

• *Section 7.3, p. 7-3*, "... a low permeability soil layer acts as secondary containment for the heap pad area. Can the proponent state the design permeability of this layer?"

The design permeability of the liner described in Knight Piésold Ltd. (1995) is 1×10^{-9}. The expected leakage for the system is approximately 0.26 m^3/day.

• *Section 7.3, p. 7-3*, "A 12 hour contingency retention design with 1 m freeboard is incorporated into the PLS collection pond design. Is this sufficient available contingency volume? What systems are in place to ensure recovery of the system within the 12 hour window?... snowmelt surge volumes also apply here."

Based on the present design (Knight Piésold Ltd. 1995), in heap storage is sized for a 24 hr, 1 in 10 year storm event, 24-hour operating volume, and the 95th percentile in-heap stored water volume during operations. An events pond is located below the leach pad and process plant and has been sized for the difference between the 24-hour, 1 in 100 year storm event and the 24-hour, 1 in 10 year storm event, millsite solutions, complete active leach area draindown, and an emergency freeboard. The 1 in 100 year storm event was calculated based on 80% snowmelt occurring in April and April's precipitation using risk assessment (@RISK) with 1500 iterations. This extreme condition provides a realistic design criteria. The pump system for recovering this water to the leach pad will be sized accordingly.

• *Section 7.3, p.7-3*, "... In order to differentiate effects from the north Williams Creek and Williams Creek mainstem before reaching W4, another station at W2 should be included in the program. QA/QC should be provided not only for the water quality program but also for other components such as fish tissue, sediment, and benthic invertebrates."

The monitoring program has been modified to include station W2 as presented in Section 6 of this Addendum. Sediment and benthic invertebrate analysis will be completed at this site as well as W9 and W4. Fish tissue will only be sampled at site W10 where fish occur. Quality assurance and quality control will be maintained throughout the environmental monitoring program.

• *Section 7.4, p.7-4*, "What are the triggers for reducing, increasing or ending monitoring during post-closure?"

During post-closure monitoring, the monitoring program will be reduced to only a few key stations after one year of monitoring shows no change. Monitoring will increase in frequency if large changes are observed in the data collected. Monitoring will end after approximately three years of data showing no change, an environmental audit results in the recommendation to end monitoring, and the proponent has DIAND's approval.

• *Section 8.3, p.8-4,* "The spill response should include the immediate reporting of the spill to government agencies and the supply of information about the incident..."

The detailed spill response and contingency plan will include this reporting procedure.

• *Section 9.10, p.9-11,* "The company states that in case of suspension of operation no further reclamation will be carried out until operations recommence. How long will the operations be suspended before it can be considered closed and therefore reclamation activities resume?"

The period of operation suspension before reclamation activities resume will depend on the economic and market situation of the company at that time in conjunction with government agency consultation. This will also depend on the cause of operation suspension. However, during suspension an annual review of site conditions will take place to ensure the integrity of environmental protection.

Feasibility Study

• *p. 7-32, & Appendix F, p.9,* "Thermal modelling conducted by Brown & Root Braun ... The perimeter may thus become unstable when temperatures increase (spring/summer) resulting in possible sloughing of the heap perimeter. Has the proponent considered this aspect...?"

The preliminary analysis has completed a stability analysis of the leach pad design as presented by Knight Piésold Ltd. (1995).

• *P. 8-6,* "What will be the size criteria for management of rocks which may be encountered during foundation preparation? Could rocks exposed at, or brought to the surface or near surface puncture the liner during the operational life...?"

Please see Knight Piesold Ltd. (1995) report, Section 7.1.4 on soil liner surface preparation.

• *p. 8-6,* "...protective cover layer of crushed ore... over the liner... differs from other statements... and from design indicated in drawing 400-35-F04(b)... Can the proponent clarify this apparent disagreement? ... will seams be welded closed or will the liner be overlapped? When will the actual cross section of the pad be finalized (p. 5-14)?"

Modifications to heap leach design, including liner type, are presented in the Knight Piesold Ltd. report (1995). Details on liner system design are presented in Section 4.6 and a cross section of the pad is presented in Drawing 1783.220.

8.3 Dan Cornett, Water Resources, Government of Canada

a. "The proponent provides design and detailed supporting documentation for review. This will permit evaluation that various project components can be constructed as planned and whether any mitigation proposed is also technically feasible. This is particularly critical for the heap leach pad, event ponds, water storage reservoir and all waste rock dumps and pits. Of particular concern is that the company must address the environmental risk associated with the newly selected heap leach pad from start-up to site closure. Designs should address any changes in the ore as a result of leaching that could adversely affect permeability, phreatic surfaces and stability. It appears that the company has not taken a risk based approach to selection of the new pad site. See K. McNaughton memo to K. Simpson dated February 23/95 regarding Leach Pad - Site Selection Criteria."

The permeability, porosity and stability of the leached ore was investigated. Results are presented in the Knight Piésold Ltd. (1995) report. The assessment evaluated both static and pseudostatic (earthquake) conditions for the ultimate slope configuration. Details of the testing are presented in Appendix C of that report.

b. "Detailed engineered design plans are provided for the heap leach pad and event ponds, water storage reservoir and all waste rock dumps and pits. Detailed design criteria and operational plans are required to understand how these components will be constructed. We expect to review a Design Report and operational plans for construction of the heap leach pad (Construction Quality Assurance and Quality Control Program). Provision of these plans will ensure that these project components can be constructed as designed."

c. "The proponent must show that they are prepared to establish a mechanism to adequately supervise the construction of all engineered project components and submit detailed reports on the construction of each component. This mechanism would ensure that alterations in designs or construction methods is monitored and any mitigation of problems encountered during construction is documented. We expect to have detailed Design Reports and Construction Quality Assurance and Quality Control plans for the water licence application process."

Construction Specifications and Quality Assurance are presented in Sections 7.0 and 8.0, respectively, of the Knight Piesold Ltd. report (1995).

Section 1.2 - Water & Waste Management

> "Additional information and design is needed for the centralized settling facility which would collect and provide treatment for waste dump seepage, mine runoff and treated raffinate. Treatment details are not given.
>
> The water balance analysis is not adequate to support the statements that the entire mining process will operate on the basis of 100% recycle, slight overall water deficit and zero discharge of process streams to the environment."

Additional tests for determining waste rock runoff quality have been completed. Based on the results, it will be necessary to re-route approximately 50% of waste rock runoff to the process circuit as make-up water. Further treatment will be required; one of the following techniques will be used: recirculation of waste rock runoff onto the dump to enhance evaporation, installation of an evaporation pond, treatment with lime to precipitate out heavy metals or decrease the cutoff grade to reduce the quantity of mineralized rock in the dump.

Raffinate will be treated with lime to raise the pH and precipitate metals. SWEP tests performed on precipitate show that it is not a special waste and therefore will be buried at the end of operations in the events pond liner.

Engineering completed by Knight Piésold Ltd. in 1995 used the @RISK computer model to determine the maximum in-heap water storage volume, and the annual fresh make-up water requirements. Based on this analysis, no discharge would occur except in the 10th year at closure. In Year 9 rinsing of the heap would commence followed by treatment of the process water. Upon successful rinsing and neutralization of the heap the remaining water would be treated to acceptable levels as per specified by MLER guidelines prior to release.

Section 1.4.4.2 - Groundwater Quality Effects

> "A double liner is proposed below those areas of the pad that are inundated. A single liner will be placed under the remaining area if required. What is the criteria for this liner placement? Where is the location for the lined, low permeability land fill storage site proposed for process raffinate solids? The comprehensive groundwater monitoring program must be outlined in detailed."

The revised liner system proposed by Knight Piésold Ltd. (1995) includes a composite of 60 mil High Density Polyethylene and a soil liner 500 mm thick beneath the in-heap storage and 300 mm beneath the rest of the pad. A high level of QA/QC will be employed during liner placement as discussed in Section 7 of "Carmacks Copper Project, Report on Preliminary Design (Ref. No. 1783/1)" (Knight Piésold Ltd. 1995).

The groundwater monitoring program includes five wells installed in 1992:

RC-92-01	south west of the leach pad and ancillary facilities, adjacent to Williams Creek
RC-92-04, -05, -06	vicinity of the open pit
RC-92-09	vicinity of the leach pad and 10 wells installed in 1995:

DH-A, -B (2 wells), -C, -D, -E, -F, -G (2 wells), -H	vicinity of the leach pad

DH-1, -2 (2 wells) vicinity of the water storage dam

In addition, 3 thermistor strings were installed to monitor ground temperature. Thermistor readings are presented in Tables 5.1a and 5.1b.

Section 2.1.2 - Property Geology

"Remaining 13 ore zones should be outlined with locations and reserves."

The location of the remaining 13 ore zones are presented in Figure 8.1 of this addendum. Exploration in these zones was not extensive enough to determine reserves. These reserves will not be affected by the proposed project components.

Section 2.4 - Mine Operation

"Where will salvaged top soil from the pit and waste dumps be stored. Does the previous statement imply that waste rock dump sites will be stripped of overburden prior to dumping?"

Salvaged topsoil will be placed in piles strategically placed around the perimeter of the waste rock dump area to minimize materials handling during reclamation.

Section 2.9 - Road Access

"Information on mine access road stream crossings is required for Merrice Creek. If the Nordenskiold River and Crossing Creek bridges are to be replaced, water licences may be required. Who would be responsible for bridge replacement? Stream crossing characteristics and bridge designs are required."

Details on road crossings and bridge and culvert installation will be outlined in the Water Licence Application.

Section 3.1 - Water Balance

> "How are mine water effluents, wash water effluents, site runoff effluent being conveyed to the waste dump settling ponds?"

Based on the revised water balance, mine water will be pumped to the process plant for use as make-up water, wash water effluents will be treated in the tile field with seepages ultimately reporting to the water storage pond, site runoff will flow by gravity via diversions and will be filtered through the settling pond adjacent to the events pond. The waste dump stilling pond will only be responsible for removing silts and sands from waste rock runoff. Please refer to the revised design completed by Knight Piésold Ltd. (1995).

Section 3.2.2 - Whole Rock Analysis

> "Results indicate that waste rock may contain high As, Cd, Cu, Ag. Were leachate tests or SWEP tests performed to determine the mobility of these metals in waste rock dumps? Monitoring of waste dumps for metals is proposed. A commitment to treat waste dump leachate is also required should elevated metals levels be detected. What are the companies contingencies should ammonia levels in the waste dump settling ponds become elevated? What is the downstream impacts associated with a 10.3 t/a nitrogen load into North Williams Creek?"

Leachate tests on waste rock runoff were conducted to determine whether treatment of runoff is necessary. The revised water quality modelling predicts that waste rock runoff may contain approximately 2.287 mg/L ammonia which would translate to 0.198 mg/L ammonia at station W4, and 0.104 mg/L ammonia at W10, well below CCME guidelines of 2.2 mg/L NH_3. Please see Section 4.0 for further details concernin nitrogen loading of waste rock, and Section 5.0 for water quality modelling and details on proposed water treatment options.

Section 3.3 - Water Treatment

> "What events within the solution management system would require the need to bleed raffinate from the heap? Provide results of bench scale tests currently underway to optimize the neutralization process for heap detoxification at closure."

The proponent's primary objective is to prevent discharge of raffinate into the Williams Creek watershed. The first option would be to maintain the entire raffinate volume in in-heap storage. If this is not possible, raffinate would be pumped to the events pond. The third option would be to recirculate the raffinate onto the heap without adding make-up water, resulting in evaporation.

Laboratory pilot studies are currently underway to optimize heap detoxification. Details will be provided when the data becomes available.

Section 3.4 - Fuel Storage and Handling

> "The location of the fuel and acid tanks should be provided. The liner type for the acid containment berms should be specified."

The final details on ancillary facilities layout are in progress. Details on location of fuel and acid storage tanks will be provided when this information is available.

Section 8.0 - Spill contingencies and Emergency Response Strategies

> "The company's comprehensive plan for Spill Contingency and Emergency Response should be contained in the water licence application."

A comprehensive Spill Contingency and Emergency Response will be included in the water licence application.

Section 9.8 - Reclamation Capital Cost Estimates

> "The company has stated that a more detailed cost estimate will be prepared using the reclamation cost Estimate Model. This information should be provided at this stage of the review and assessed. The company should ensure that unit cost estimates are provided. A closure expenditure schedule and yearly closure liability for all project components should be prepared. The company should outline any proposed closure fund strategy."

Please refer to the revised conceptual reclamation plan in Section 7 of this Addendum. A more extensive cost estimate model incorporating unit costs is included. Costs of reclamation will defined on an annual basis and funds will be accrued into a reclamation account.

8.4 Les F. Sawatsky, AGRA Earth & Environment

1. "We question the rationale for selecting the new leach pad site. We believe the selection should be based on a fair comparison of each potential site. We note that the ground slopes of the new site are about double that of the previous site. Will this affect the stability of the pad? We believe the selection of the new site, based on minimum field investigation of permafrost conditions at each site, is weak. Instead, we recommend site selection be based on a field investigation which properly characterizes each site for this level of assessment."

Slope stability has been addressed in Section 4.7 of the Knight Piesold Ltd. (1995) report. Selection of the new leach pad site was based on a review of the available information and selection of an area with the least frost susceptible foundation soils. The proponent agrees that the slopes for the new site are steeper than the previous site; the stability has been addressed in the above mentioned report. The new site was characterized by 8 geotechnical drill holes and by 8 trenches which determined the material types and foundation conditions for the site. A thermistor was installed in one of the drill holes to measure ground temperature with depth. Thaw settlement of the foundation was addressed by determining the frozen properties of the glacial till. Carrying out field investigations at each site was considered uneconomic when it was known that the other sites had unfavourable ground conditions.

2. "The proposed drilling program involves seven drill holes over an area of about 500,000 m^2. This might be sufficient to characterize bedrock and hydrogeologic conditions; however, we believe the seven drill holes are not sufficient to provide a reliable characterization of surface soil conditions. We believe a reliable characterization of surficial soils is required for two reasons. Firstly, surface soil conditions may govern the design and technical feasibility of the leach pad, especially if there is a risk of ice rich permafrost conditions. Secondly, the proposal to use this existing surficial soils in a composite soil liner requires field evidence that the surficial soils have low permeabilities, less than 10^{-6} cm/s. If the site characterization proves that the soils are more pervious, then the proponent will need to recommend alternative measures. Therefore, we would recommend additional investigations of surficial soils, possibly by test pitting."

This comment does not acknowledge the 8 trenches across the site that were excavated, mapped and sampled as part of the characterization of foundation soils. The surface soil conditions were characterized and addressed in the design of the leach pad.

3. "A total of three permeability tests of fine grained soils are planned. This seems to be insufficient if the proponent plans to use the surficial soils in a composite liner where the permeability of the soil shall be less than 10^{-6} cm/s."

Laboratory testing on 2 samples of proposed soil liner returned permeabilities several order of magnitudes lower than the design permeability of 1 x 10^{-7} cm/s. The particle size grading of the material along with the Atterberg Limit results when compared to materials exhibitting similar properties also yielded permeabilities lower than the design permeability of 1 x 10^{-7} cm/s, which would make additional testing superfluous.

8.5 John Hough, Land Resources - Government of Canada

"It appears that all activities will be conducted on claims but it is in no way certain. Information pertaining to land tenure is basic and the requirement for such should be included in the IEE information guidelines.

All activities conducted off claims will require a Land Resources authorization of some kind. A new access and road upgrade will require a land use permit. Land use permits are valid for a maximum of three years only. Utilization of a new access road will require land tenure such as a lease or a licence of occupation. The process of obtaining a lease or a land use permit is time consuming and the earlier the process is started the better it is for the company. The specific information required for application is not in an IEE nor should it; however, the company should be advised of the requirements for Land Resources authorization and be encouraged to contact Land Resources as soon as possible and practical in the planning process. The most expeditious approach would be to provide my name and number to Western Copper's representative and I can arrange a meeting with the Supervisor of Lands and/or the Head, Land Use."

The company appreciates these comments and will be applying for the appropriate land use permits as soon as possible.

8.6 Mark Zrum, Head, Land Use - Land Resources, Government of Canada

1. "The selection of the facilities locations is based on a number of criteria of which the most weight should be placed on the geotechnical suitability of a site to support the proposed function. In the case of the leach pad location it was chosen more for economic reasons rather than sound geotechnical information. The pad area itself has only had 3 test pits dug which is not a sufficient number to draw a conclusive information from let alone site a heap leach pad. This does not allow enough information to begin designing the pad or ancillary structures. The stability of the site could be seriously called into question."

The geotechnical suitability and stability of the site have been addressed in the Knight Piesold Ltd. (1995) report.

2. "Another area of concern is the amount of baseline data that has been collected and the period of time that it was collected over. The proponent has made some very large assumptions based on fairly thin information. To calculate water balance based on 1 season's climatic readings and extrapolation of readings and long term information from distant sites is somewhat presumptuous."

The amount of site baseline meteorlogical and hydrological data is limited. Temperature and precipitation records are available for periods in 1992, 1994 and 1995. Streamflow records are available for Williams Creek during the summer months of 1992 to 1994. It is recognized that this data base, alone, is not sufficient for adequate assessment of the site meteorology and hydrology. Therefore, regional data from a number of weather and streamflow stations operated by AES, WSC and DIAND were utilized, in conjunction with the site data, to develop estimates of the site conditions. Please refer to Knight Piesold Ltd.'s "Report on Preliminary Design, 1783/1, May 1, 1995" for the most recent assessment of site meteorology and hydrology.

3. "The company has committed to reclamation planning, however they have the impression that the reclamation plan is a requirement of the TLUR and that a reclamation permit will be issued. This is not possible under the TLUR. Further to this the company has stated that they will apply for a lease for their access road, it should be clarified that a licence of occupation is the tenure that is required."

A conceptual reclamation plan has been included in order to present a full impact assessment and to determine a final time frame upon which temporary effects would occur. Full detail for a reclamation permit will be provided in the appropriate application report.

The company appreciates the comment on land tenure. An application for a licence of occupation rather than a lease will be applied for.

4. "The information supplied in this IEE does not provide the details for the engineering in the construction of the leach pad or mine facilities. There are no detailed drawings or specifications. I understand that there is information available in the feasibility study, however, it is still vague. It is important to compare the engineering and sense of a project to ensure that it is supportable and the processes will work as described."

The revised engineering design provided by Knight Piésold (1995) includes additional detail which when combined with the revised sections presented in this Addendum should provide enough information to determine whether the project may go ahead.

8.7 Gail Faulkner, Department of Fisheries & Oceans, Yukon

"As indicated in Volume IV of the IEE, the design and long term maintenance of the tailings pond must incorporate the potential for release of water into Williams Creek. It is stated in the IEE that information regarding the potential use of the downstream area by overwintering fish has not been completed. Therefore, the timing of filling and the potential necessity for residual flows downstream of the dam are still unresolved. However, the dam design should allow for the maintenance of the residual flows if the further data collection indicates that this is necessary.

DFO had expressed the concern that total removal of the tailings dam would have resulted in unacceptable deposition of sediment into the fish habitat in lower Williams Creek. This concern has been addressed to our satisfaction in the IEE.

We agree with the concept of a bridge crossing at Merrice Creek and will be providing advice later in the process."

Please refer to the revised mine information and impact assessment provided in this Addendum. For clarification, the "tailings pond" mentioned in your comments is more accurately a water storage dam and does not carry the characteristics associated with tailings deposition. In addition, the revised conceptual closure maintains that the water storage dam remain in place at closure.

8.8 W.P. (Wally) Hidinger, Yukon Government Department of Community & Transportation Services, Transportation Division

1. "Upgrading of the Freegold Road will involve the construction of a BST surface as it is estimated that this will result in the minimum level of costs over the long term. Inherent in this design decision is the implementation of load restrictions during the spring breakup period each year. Mine traffic will be subject to axle weight restrictions of up to 50% of the legal maximum during spring breakup - mine resupply operations should be planned accordingly."

As part of the operational strategy, the proponent will ensure that sufficient bulk supplies (fuel, sulphuric acid, and reagents) are on site in order to maintain effective operations with minimal restocking during spring breakup when regulations require axle weight restrictions of up to 50% of the legal maximum. Copper transportation will likely be via a lowbed truck to Carmacks during this period in order to comply with weight restrictions.

2. "Any construction work planned for the access road from the Freegold Road to the mine site will require a permit for work within a right of way from this agency. Depending on the scheme proposed by the company for daily transportation of personnel from Carmacks to the mine site the standard of road proposed in the IEE may or may not be adequate. We suggest that the company discuss the details of the road design standard with the Transportation Division as soon as possible so that a determination can be made on whether or not the standard proposed is adequate and the conditions which will be attached to any construction permit."

The proponent will cooperate will all regulatory agencies to obtain the required permits and will develop the most effective design for the project and the community. The company appreciates these comments and will be in contact with the Transportation Division to discuss this further.

3. "It was also mentioned by Carmacks Copper during both of their meetings with RERC that they may reroute the access road from the Freegold Road to the mine site. The final decision on this matter is very important as it determines whether or not the upgrading of approximately five kilometres of the Freegold Road will be required. The company should advise us as soon as possible of their decision in this matter."

The proponent has not made a decision on the access road rerouting, but does prefer the new route. The company will advise all agencies involved prior to construction and upgrading of the Freegold Road.

> "Section 9.1 of the feasibility study discusses all season road access. Although there are three distinct and vastly different classes of road between Whitehorse and the mine site (the Klondike Highway, the Freegold Road and the mine access road) the study makes no distinction between them. The comments on river crossings are accurate only for the Freegold and mine access roads. It would be highly unusual for loads to be routed across river ice because of their weight on the Klondike Highway. It is also doubtful that 40 tonne loads would be allowed on the Bailey bridge across the Nordenskiold River at Carmacks. The final point is that the allowable loads on the three roads will vary, depending on the structural capability of each. Spring weight restrictions below 100% of legal axle loads have never occurred on the Klondike Highway while even an upgraded version of the Freegold Road will require such restrictions, perhaps as low as 50% of legal axle limits. There also seems to be no awareness that substantial upgrading is being planned for both the Freegold Road and the mine access road even though the IEE addresses this. Section 9.1 of the study makes no mention of the effect of seasonal weight restrictions even though such restrictions could have a substantial effect on the cost of operating the mine. In general, the short length of this section of the report and the omission of some of the crucial facts regarding access to the mine site from Whitehorse seems to indicate that a very superficial level of analysis was carried out."

See comments to question 1 above.

> "Section 9.3 of the report discusses fuel and acid supply to the mine. The second paragraph of the section titled "Fuel" indicates that the main supplier of fuel in the area is Petro Canada and that they have a virtual monopoly on fuel distribution in the Yukon. This is nonsense. There are at least six different fuel distributors in the Yukon varying in size from quite large (Petro Canada and White Pass) to quite small (Totem and Tessoro). Any of these distributors would, I'm quite sure, be more than pleased to provide bulk fuel to the mine."

A preliminary survey indicated that Petro Canada could provide fuel at the lowest price. All contracts will go to competetive bid.

> "Section 9.4 of the feasibility study addresses personnel transportation. Statements are made that local employees will be engaged on the basis that they provide their own transportation from the mine to their home base, both during mine construction and during mine operation. This is completely contrary to the statements regarding crew transportation in IEE Volume II Section 4.3. For the Department's purposes I have mentioned that staff transportation issue in our response to RERC, a copy of which was forwarded to you yesterday. For your own purposes, it would seem to me that mine operating costs will differ depending on how crew transportation is handled and that the accuracy of the feasibility determination could be affected by the choice made."

The company will encourage and may subsidize a local bus system, but it is the proponents experience that due to the close proximity of the mine site to the community of Carmacks, many workers will prefer to provide their own transportation. If traffic on the Freegold Road becomes a problem the company will set a policy for bus transportation to the mine site.

8.9 Karen Larson, Environmental Health Officer, Occupational and Environmental Health Services, Yukon

1. Page 3-7 outlines disposal method for precipitations. States "if required precipitates would be disposed of as landfill in a lined storage facility in the vicinity of the process plant."

   "Is a plan for disposal of industrial/chemical waste required?"

Disposal of small quantities of laboratory chemicals will be required; however, no special wastes will be generated on site from general mine operations.

2. "Pages 3-2. Location of waste rock storage dump. Distance to creek. Acid Rock Drainage concerns ? Waste rock contains high amounts of arsenic and cadmium. IEE states that the waste rock dump runoff settling pond should be monitored for arsenic, cadmium, and copper.

   Will it be monitored?"

Yes, as part of the compliance monitoring and environmental monitoring, these elements will be monitored regularly.

3. "Surface water chemical characteristics were monitored over a short time span.

   More data is required."

At least one years worth of water quality data has been collected which provides adequate information for the initial review. Additional data will be collected during construction and operation as part of the permit requirements.

8.10 Ken Kiemale, Environmental Assessment Analyst, Renewable Resources - Yukon Government

"Volume IV goes into considerable detail on how the leach pad will be monitored to detect leaks that could result in sulphuric acid entering the water system. However, the proponent does not discuss what kind of emergency measures would be undertaken to repair the leak, if one is detected. The proponent should provide information about the technology available to repair damaged membranes, appropriate methods and, if possible, the criteria to decide whether to repair the leak or not. Should the heap leach system fail, effects on fish and wildlife may be significant. We request the opportunity to review the conclusions of the technical experts regarding the soundness of the system. Please send this material to my attention as it becomes available."

Based on in-heap storage area and leach pad area calculations, Knight Piesold Ltd. has estimated a leakage rate of 0.26 m^3/day, which would be intercepted by the foundation drains which acts as a leach detection system. If water quality monitoring of the leach pad area indicates that a substantial leak has occurred the application of leach solution will cease, the heap will be allowed to drain down and all PLS will be pumped from the in-heap storage. Leaching in the cell where the leak has been detected will be discontinued until the extent of the liner damage is determined.

"The IEE does not provide information on whether the leachate ponds, containment dykes or channels will effect water fowl and other animals that might visit these sites, although this matter was identified in the IEE Guidelines. Volume IV states that there is limited waterfowl habitat in the project areas, and that, where necessary, access of wildlife to the mine and process facilities will be restricted by fences and bird nets (page 1-9). What facilities will be protected initially by fencing or netting, and what type of fencing or netting will be used."

Wildlife fences will be constructed around the leach pad, open pit and waste rock dump. As storage of the PLS in in-heap, the need for bird netting over the leach pad is not anticipated. The water storage dam will contain clean water for waterfowl use and will likely be preferred over the leach pad since there is no open water on the pad.

WESTERN COPPER HOLDINGS LIMITED
CARMACKS COPPER PROJECT
GEOLOGICAL RESERVES

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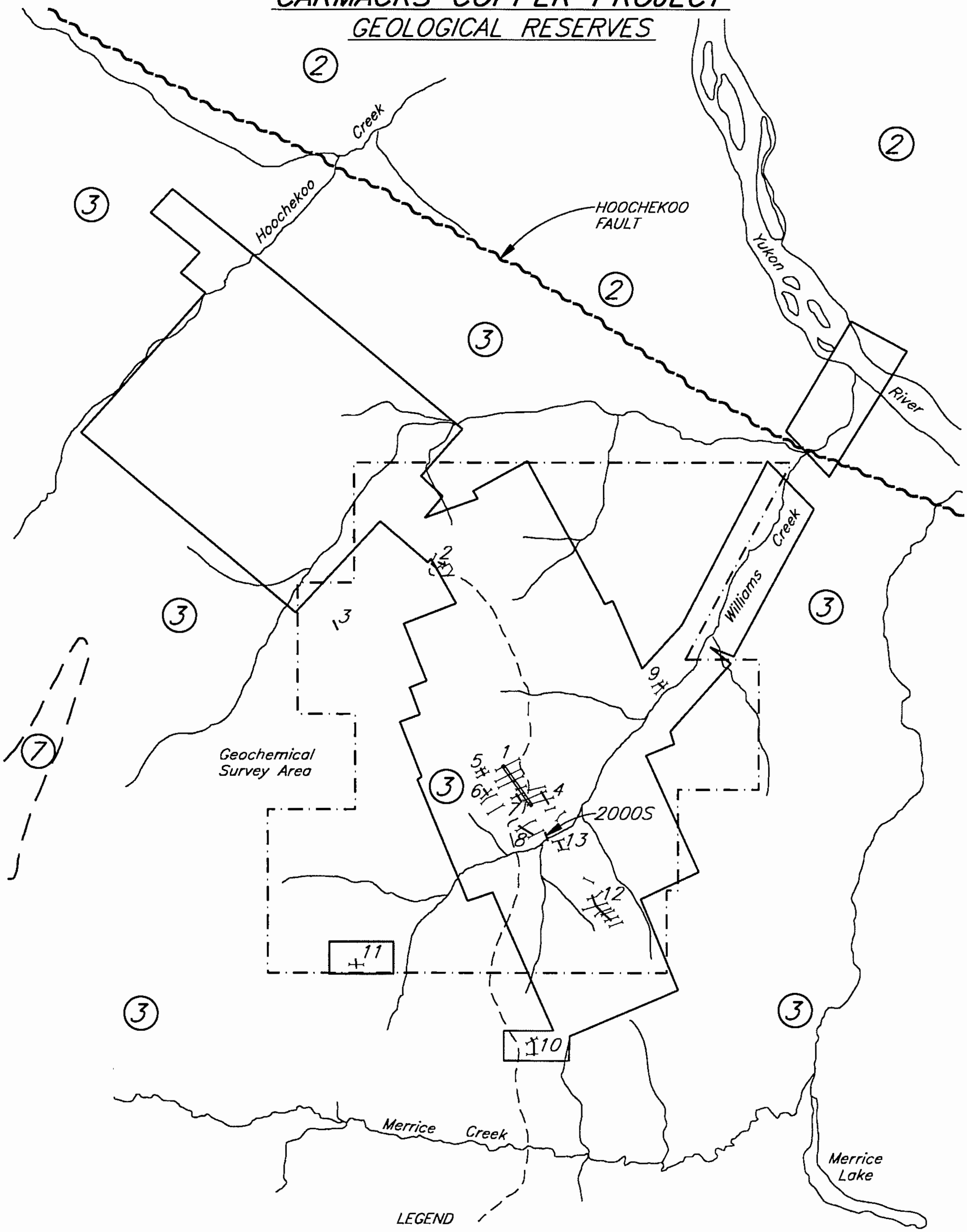

LEGEND

⑦ Carmacks Group – toff & andesitic basalt flows
③ Granite Mountain Batholith – biotite hornblende granodiorite with feldspar hornblende biotite gneiss
② Povoas Fm. – andesitic basalt, volcanic breccia, tuff & conglomerate
Zone
No. 1 Deposit
Trench
Geophysical survey area
Property outline

NOTE: No reserve figures available for zones other thon No. 1 zone.

May 16, 1995

HALLAM KNIGHT PIESOLD LTD.
ENVIRONMENTAL CONSULTANTS

FIGURE 8.1

CAD FILE: \1000\H1811\IEE\A1 Plot scale 1=1

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APPENDIX 1

List of Petrographic Samples (Table A1-1), and Vancouver Petrographics Ltd. "W1002 Project - Petrographic Report" dated January 21, 1995

APPENDIX 1
WESTERN COPPER HOLDINGS
CARMACKS COPPER PROJECT

Table A1-1
Petrographic Samples

Sample #	Rock Type	
40-131	1a (type sample)	ORE
40-113	1b (type sample)	ORE
40-158	1c (type sample)	ORE
31-151	1d (type sample)	ORE
26-98.7	1e (type sample)	ORE
36-242	1f (type sample)	ORE
36-237	1g (type sample)	ORE
40-33	2c (type sample)	WASTE ROCK
21-178	2d (type sample)	WASTE ROCK
38-187	2e (type sample)	WASTE ROCK
24-433	1a to 1c	ORE
23-298.5	1a	ORE
23-241.5	1b (1c or 1e)	ORE
25-146	1c	ORE
32-195	1c	ORE
42-216	1c	ORE
53-649	1c	ORE
26-129.5	1c (to 1e)	ORE
28-91	1c next to 3 - Kfeldspar altered by 3	ORE
28-96	1c (1e)	ORE
27-133.5	1f (or 1c)	ORE

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Vancouver Petrographics Ltd.

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Report for: **Ken McNaughton**
Western Copper Holdings Ltd.
900, 850 West Hastings St.
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January 21, 1992

Project: **W1002 Project - Petrographic Report**

Polished Thin Sections:
PTS 23-241.5' & 298.5'
PTS 24-433'
PTS 25-146'
PTS 26-129.5'
PTS 27-133.5'
PTS 28-91' & 96'
PTS 32-195'
PTS 42-216'
PTS 53-649'

Thin sections:
TS 21-178'
TS 26-98.7'
TS 31-151'
TS 36-237' & 242'
TS 38-187'
TS 40-33', 113', 131' & 158'

Summary:

This report covers a suite of 21 specimens from the same deposit area. There are 18 igneous and three mafic volcanic rocks. The igneous rocks have medium grain size and only samples 21-178 and 32-195 are distinctly porphyritic. Only two of the rocks had primary quartz, and they are classed as granodiorite and tonalite (quartz diorite). Although three rocks contain significant amounts of secondary quartz, the other 16 igneous rocks were originally silica undersaturated with compositions in the diorite range. Compared to typical diorites, most are relatively low in mafic mineral content, and in some cases might warrant specialized names such as "leucodiorite" or "syenodiorite". Biotite is the dominant mafic mineral in most samples, however, in five samples hornblende is dominant.

Texturally, the rocks show minor compositional variations and in several rocks irregular concentrations of hornblende are interpreted as partially assimilated mafic or ultramafic rock fragments. Foliation is generally very weak or absent. Some specimens show weak shearing and a passive brecciation that disaggregates the larger plagioclase grains, with the other minerals and mineralization filling in around. Sample 40-113 has pockets of microbreccia that appear to have been emplaced by a miniature event of gas streaming such as produces diatremes. This was noted on an even smaller scale in sample 40-131.

Three rocks in the suite are andesitic mafic volcanics, two of which bear hornblende phenocrysts. There are no other nonigneous rocks.

Secondary veins are not common in the rock suite. Vein quartz was noted in core specimen 32-195. A 1 mm gypsum vein occurs in 53-649, and smaller veinlets of gypsum and carbonate occur in 40-113.

All the polished thin sections bear supergene mineralization primarily as malachite but most have no primary mineralization. Primary bornite, chalcopyrite and minor magnetite occur in a few specimens. These rocks, as with many of the others, contain no hydrothermal alteration products. The copper sulphides are magmatic, having crystallized from the silicate magma. Magmatic sulphides rarely occur in igneous rocks of these compositions, so the copper sulphides are interpreted to have developed through assimilation of copper-bearing country rocks. These precursor rocks must have been devoid of iron sulphide or else pyrrhotite would now accompany the bornite and chalcopyrite. Minor amounts of molybdenite, bismuthinite, native bismuth and arsenopyrite are also interpreted as primary.

Hydrothermal alteration affects some of the rocks, and clearly two distinct types of solutions were involved. In a few specimens, there has been major silicification. This is accompanied by degradation of biotite, initially to a nonpleochroic hydrobiotite and finally to chlorite with minor amounts of associated magnetite, rutile and epidote. These solutions have little or no affect on hornblende and sphene in the rocks. The second type of alteration, which must involve a markedly different type of hydrothermal solution, introduces K-feldspar. Here hornblende and sphene are totally destroyed and biotite remains stable. No mineralization accompanied the hydrothermal events except minor gold, as noted below.

The supergene mineralization in all the specimens is attributed to the weathering cycle, as is weak to moderate montmorillonitic clay alteration of the feldspars. This has resulted in partial oxidation, to specular hematite, of the sparse magmatic magnetite crystals, and of magnetite formed by the hydrothermal breakdown of sphene. Some cuprite has formed around copper sulphides. Leaching yielded cavities sometimes lined with goethite and in-filled with limonite and malachite. A protracted supergene process gave rise to limonite and malachite that appear to be both early and late. Very late malachite veinlets 0.02-0.1 mm wide occur in several specimens. The introduction of secondary copper and gold into these rocks represents supergene enrichment. All specimens retain a few percent pore space and should be reasonably permeable.

Gold grains, seldom larger than the 0.1-3 micrometre (µm) range, mostly occur in limonite and other supergene settings. As with the supergene copper, these gold grains clearly have been transported into the specimens by the supergene weathering solutions. Only two larger gold grains of 15 and 25 µm size were observed in specimen 28-91. These lie in quartz and must have been introduced by the hydrothermal solutions. As shown in the photographs, the gold grains are a rich golden color. No silver minerals were found, and the silver in these rocks must occur as colloidal particles in the limonites. This should be confirmed by electron probe analyses.

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Summaries of Individual Petrographic Descriptions

Sample PTS 23-241.5'

The rock is a silica undersaturated biotite leucodiorite that is now moderately to strongly sericitized. It is in sheared contact with the mineralized part of the specimen which is a mineralized breccia. Initial mineralization was magnetite and chalcopyrite with minor amounts of bornite, molybdenite and native bismuth. Limited hydrothermal alteration caused minor silicification. During a late, presumably meteoric water oxidation stage, most of the original magnetite was oxidized to specular hematite. Limonites and minor cuprite and covellite were also produced. The final supergene event was partial filling of open spaces by malachite. About 7 percent porosity remains in the rock.

Sample PTS 23-298.5'

There is K-feldspar interpreted as original in this silica undersaturated biotite-horblende syenodiorite, and if there is a greater proportion than estimated here, the rock would then classify as a monzonite. The relatively large mafic mineral content for a syenodiorite appears to be due to almost complete assimilation of bits of mafic or ultramafic rock. Other than the primary magnetite that has undergone later partial oxidation to specular hematite, there is no primary mineralization. Hydrothermal alteration is limited to sparse alteration of biotite to chlorite. A lot of limonites and porosity are attributed to late stage, probably a weathering cycle. No malachite or gold were observed.

Sample PTS 24-433'

This is a silica undersaturated igneous rock of intermediated composition interpreted to be mineralized biotite-hornblende diorite. Some of the untwinned and altered feldspar may be nepheline that has gone unrecognized. The feldspars are variably altered, sometimes intensely, to clays, epidote and sericite, but the hornblende and biotite remain fresh. The rock is strongly mineralized with primary magnetite, bornite and chalcopyrite. The magnetite is partly altered to specular hematite by the supergene alteration stage. The copper sulphides are slightly altered by this late alteration. Most of the secondary iron and copper is interpreted to have been introduced from outside the specimen, so this represents a supergene enrichment. One of the gold occurrences is in the specular hematite, the other two in limonite. Therefore the gold was transported into the specimen during the very late stage alteration. This is interpreted as a weathering cycle and "standard wisdom" is that gold does not move very much during weathering of mineralized rock. However this, and other specimens to follow, are evidence to the contrary.

Sample PTS 25-146'

This silica undersaturated, mineralized biotite syenodiorite is not hydrothermally altered and is only weakly weathered. The biotite appears to be unusually rich in both ferrous and ferric iron - a lepidomelane variety. The bornite, chalcopyrite, bismuthinite and native bismuth appear to be in equilibrium with the rock and show no evidence of post magmatic introduction. The absence of primary iron oxides and of iron sulphides is also striking. Although not intensely weathered, the rock has been leached. There is at least three percent pore space, and the malachite (3 %) and limonites (2%) are also open space fillings. The largest gold grain at 5 x 9 micrometres (μm) occurs isolated in plagioclase, but the other much smaller ones occur in malachite so they have been introduced, or at least remobilized, at a very late stage.

Sample PTS 26-129.5'

Although this silica undersaturated biotite svenodiorite is relatively homogeneous in thin section, biotite is somewhat more concentrated along one 5-7 mm band. However, limonite and pore spaces are more uniformly distributed in cavities and along relatively open, cross-cutting fractures at about 5-10 mm spacing. Gold, in grains less than 8 µm, occurs late with the limonite as does the specular hematite which in one place occurs in a vein with limonite that cuts earlier formed crystalline malachite.

Sample PTS 27-133.5'

This mineralized biotite syenodiorite is a breccia of rounded plagioclase crystals "floating" in a matrix of biotite, malachite, and limonite. Biotite flakes show some deformation and crudely wrap around the plagioclase grains. Also a rounded 10 mm fragment preserves some of the primary rock texture. Malachite, with lesser limonite, cuprite and goethite, fills open spaces as well as crude vein-like masses crossing the rock and surrounding some of the plagioclase fragments. Limited pore space remains. A large number of gold grains can be found, ranging in size from 3 to <0.1 µm. They all occur entirely within, or closely associated with, limonite. They are more common with the minor amounts of limonite between the intergranular breccia grains than in the large limonite areas that have filled open spaces.

Sample PTS 28-91'

This altered rock is interpreted as diorite based on the plagioclase composition. It has been extensively metasomatized with additions of quartz and K-feldspar, as well as alteration of all sphene and part of the biotite. Supergene weathering has caused partial clay plus sericite alteration of the plagioclase. Malachite and the limonites have been introduced as there are no relict sites for primary copper minerals. The two largest gold grains encountered in this suite of rocks, at 15 and 25 µm plus a 2 µm grain, occur in the secondary quartz. A 3 µm grain occurs in plagioclase and a 1 µm grain in limonite. In most of the other rocks, the very fine, limonite-hosted gold is supergene, but most of the gold in 28-91 is hydrothermal.

Sample PTS 28-96'

This altered syenodiorite is similar to others in the suite except that it is hydrothermally altered, as in 28-91, whereas the others were only weathered. It has more than 10 percent quartz distributed throughout the rock, whereas the metasomatic K-feldspar is restricted to one end of the slide, presumably near a channelway not included in the specimen. However, sphene relict outlines, which occur throughout the slide, are all hydrothermally destroyed. It is interpreted that the same solution altered the sphene and caused silicification of the originally silica undersaturated rock. There is no primary mineralization. All the malachite and the limonites, have been introduced.

Sample PTS 32-195'

In this silica undersaturated biotite leucodiorite porphyry, limited silicification has accompanied K-feldspar introduction, but the original rock has no primary quartz. Sphene was not observed unlike similar rocks in this suite. In addition to the hydothermal alteration, there is clay alteration of the plagioclase which is interpreted as weathering. There are minor relicts of chalcopyrite but most is replaced by supergene cuprite and magnetite is partially altered to specular hematite. Open spaces are filled by goethite followed by limonite and malachite. Several percent porosity remaining in the rock suggests it should have good permeability. No gold was observed.

Sample PTS 42-216'

This silica undersaturated rock marginal in composition between diorite and syenodiorite is termed biotite-hornblende diorite. There is more biotite and hornblende than other rocks in the suite. Other than minor magnetite, there is no evidence of precursor mineralization in this rock. Abundant limonites, malachite and minor specular hematite have been introduced at a late stage, probably related to weathering. The gold grains, all less than 3 µm, were introduced at this stage. Porosity, and presumably permeability, remains in the rock.

Sample PTS 53-649'

This silica undersaturated altered syenodiorite is compositionally similar to other rocks in the suite, but it differs in that all the original mafic mineral content has been hydrothermally altered to chlorite. Also there is a gypsum vein and more K-feldspar introduction near the vein than in other samples, together with increased sericitization and clay alteration of the plagioclase near the vein. Minor original chalcopyrite remains along with minor arsenopyrite and a trace of magnetite. Supergene alteration has converted most of the chalcopyrite to cuprite in some cases and to limonite in others. The nine gold grains which are all less than or equal 5 µm were all observed in chlorite or in plagioclase, sometimes near K-feldspar. This differs from other samples where gold was mostly in the limonite, and indicates transport during the hydrothermal alteration stage in this rock as opposed to the weathering stage in other rocks.

THIN SECTIONS

Sample TS 21-178'

Assuming that the K-feldspar phenocrysts are primary, there is still insufficient K-spar to classify as monzonite, hence it is a diorite. The rock is highly silicified, and originally was probably undersaturated in silica. The silica flooding was accompanied by secondary epidote and almost complete chloritization of biotite, although hornblende and sphene remain fresh. In other rocks of this suite which have had K-feldspar metasomatism, sphene and hornblende were totally destroyed but biotite remains. Clearly, the two types of hydrothermal solutions are quite different.

Sample TS 26-98.7'

The K-feldspar and most of the quartz are interpreted to be primary. Based on the mineralogy, the rock does not easily fit some igneous rock classifications because of the high quartz and low K-feldspar contents. However, for most criteria, it most easily fits the pigeon hole for granodiorite on the American Geological Institute data sheet for Descriptive Modal Classification of Igneous Rocks by Donald W. Peterson, although the low mafic mineral content is anomalous. There is clearly far too much quartz to be a syenite or leucodiorite. A broader examination of outcrops or drill core might clarify classification. Partial alteration of biotite is evidence of a weak hydrothermal event which may have added quartz, but there is no clear evidence of such silicification. Minor limonite and clay are the only evidences of weathering. There is no mineralization, the carbonate not being malachite.

Sample TS 31-151'

This silica undersaturated rock is termed hornblende porphyritic basalt. This places heavy emphasis on the anorthite determination in plagioclase, and the color index (mafic mineral content) is more in the andesite composition range. Based on field or other petrographic data, it may become apparent which volcanic rock name is preferable (see also TS 36-237' and 36-242'). Weak hydrothermal alteration has introduced minor carbonate, pyrite and chalcopyrite. Weak montmorillonitic clay weathering has variably affected the plagioclase.

Sample TS 36-237'

Although considerably more hydrothermally altered than TS 31-151, the primary mineralogy would have been similar. In this case, the slightly lower anorthite content of the plagioclase makes it an andesite porphyry, but there is little doubt that this rock plus 31-151 and 36-242 are all from the same series of volcanic flows. A portion of this slide has been intensely bleached of mafics and hydrothermally altered, while these effects are weak in the rest of the slide. The intense alteration has quantitatively removed hornblende and altered biotite, produced some epidote and added several percent chalcopyrite and lesser magnetite. The plagioclase shows considerable clay alteration as a result of either hydrothermal effects or of weathering. There are minor malachite, goethite, limonite and pore spaces all attributed to supergene weathering.

Sample TS 36-242'

Coincidentally, the plagioclase composition lies on the boundary separating the basalt and andesite pigeon holes, but based on the low color index, this rock is classed as andesite, again a silica undersaturated variety. Sparse irregular concentrations of hornblende, as noted in both specimen and thin section, do not occur uniformly through the rock and may reflect partially assimilated possibly ultramafic rock fragments. The effects of moderate hydrothermal alteration are irregularly distributed. Magnetite is the principal, and possibly sole, opaque mineral with local concentrations to >10 %. Biotite is partially altered to hydrobiotite plus chlorite and plagioclase has undergone moderately strong montmorillonite alteration. A supergene stage of alteration has given rise to small amounts of limonite and malachite.

Sample TS 38-187'

Because this faintly porphyritic, rather felsic rock has no K-feldspar, it is a tonalite, for which the field name "quartz diorite" is often employed. Relatively weak hydrothermal alteration is shown by partial biotite breakdown with development of some epidote and chlorite. The magnetite is interpreted as a primary magmatic phase.

Sample TS 40-33'

This is a silica undersaturated hornblende diorite. There is weak hydrothermal alteration of biotite and weak supergene montmorillonite alteration. Minor limonite indicates possible slight permeability. The large range in grain sizes shows a tendency for the rock to be porphyritic in both plagioclase and hornblende. There is less than one percent magmatic magnetite and a small additional amount derived from partial alteration of sphene to carbonate plus magnetite and/or rutile.

Sample TS 40-113'

This is a silica undersaturated hornblende-biotite diorite which has an increased mafic minerals content due to assimilation of possibly ultramafic material. Hydrothermal alteration is relatively weak, but pockets of microbreccia appear to be due to high pressure gas streaming such as in a diatreme but on a micro scale. There are only traces of supergene alteration, aside from weak clay alteration of plagioclase which may by hydrothermal or supergene.

Sample TS 40-131'

This a silica undersaturated biotite diorite with low mafic content relative to "normal" diorites. The irregular distribution of biotite, magnetite, apatite and sphene in the rock are attributable to assimilation that has gone nearly to completion. Hydrothermal alteration is almost nonexistent. Weathering has caused minor clay alteration of plagioclase and given rise to very minor limonite and pore spaces.

Sample TS 40-158'

With only about 20 % mafic minerals, this silica undersaturated biotite diorite probably should be termed leucodiorite. There is moderate hydrothermal alteration of plagioclase, biotite and total destruction of the sphene. As noted with other rocks in this suite, there have been two distinct hydrothermal solutions. One caused silicification with limited other effects, while the second, which affected this rock, caused alteration of biotite and sphene and introduction of K-feldspar. Supergene solutions have developed some limonte and a trace of gypsum in the rock plus minor pore space.

Sample PTS 23-241.5' **Silica Undersaturated Biotite Leucodiorite with Mineralized Breccia**

Specimen: This core has some fine to medium grained felsic igneous rock in contact with 5-10 mm of relatively massive hematite-magnetite followed by 10-15 mm of massive chalcopyrite. The rock contact is moderately sheared and altered over a width of 3-5 mm and within the section, this contact is also offset 8-10 mm by a small fault and a second smaller one. Rock fragments also occur in the sulphide-oxide mass. Both the rock, and especially the iron oxide-rich marginal part of the mineralization are porous with 0.5-1 mm holes, and there is minor oxidation due to leaching. This porosity (5-7 %) should be considered in any ore reserve calculations.

Mineralogy:

A. Rock portion of PTS:

Plagioclase (An 40-45%)	72. %
Biotite	10
Sericite	10
Epidote	3
Chlorite	1
K-feldspar	<1
Quartz	0.3
Apatite	0.1
Pore space	3

B. Mineralized portion of PTS:

Primary:	
Magnetite	2. %
Chalcopyrite	14
Bornite	1
Molybdenite	0.5
Bismuth	0.1
Supergene:	
Specular hematite	21
Goethite	6
Limonite	7
Cuprite	0.5
Covellite	0.5
Malachite	1
Quartz	12
Clay (montmorillonite type)	28
Pore space	7

A. Plagioclase in grains up to 5 mm is weakly to almost totally replaced by mostly sericite (or illite) plus 10-15 % epidote and minor chlorite. Most of the larger grains are untwinned and resemble nepheline but they are biaxial +ve so must be plagioclase. Rounded fragments of highly altered rock up to 3 mm occur in the mineralized part of the slide.

Biotite occurs typically in ragged bladed grains 0.15 x 0.8 mm. Often there is some brown cryptocrystalline material interlaminated that may be another form of biotite or an Fe-rich clay like montmorillonite. Biotite is much more concentrated in the 3-4 mm sheared zone adjacent to the mineralized rock.

Sericite occurs as a very fine grained alteration of the plagioclase and may replace only a few percent or nearly 100 % of some grains. This is also the occurrence of epidote, some chlorite and minor K-feldspar. It occasionally occurs as slightly coarser grains as an incipient alteration of some biotite grains.

Ther is no primary quartz. It only occurs as thin films around some cavities or rarely at the edge of an altered plagioclase grain.

B. Mineral percentage estimates in the mineralized portion do not include 3 or 4 rounded rock fragments, probably breccia fragments, that are 1-2.5 mm across and consist mostly of altered plagioclase.

The specular hematite is interpreted as an early supergene pseudomorphous replacement of original magnetite grains, little of which remain. The hematite is fractured and cut by patterns of quartz, goethite and limonite. (In specimen PTS 26-129.5', the specular hematite is clearly a very late supergene phase.)

Chalcopyrite occurs as massive patches several mm accross with minor inclusions and fringes of bornite. It is cut by occasional limonite veinlets which may have an extremely thin intervening layer of covellite.

Molybdenite grains are sparse but up to 0.5 x 1 mm in size, either rounded or ragged and occasionally intergrown with bismuth. They are usually found along the most sheared zone separating the rock and ore parts of the slide.

Goethite and limonite occur as colloform space fillings, veins and other irregular masses throughout the mineralized area with the minor cuprite associated near areas of copper sulphides.

There is a few percent malachite in one area and none elsewhere. It occurs as tiny fibrous crystals radiating into open spaces and post-dates all other minerals.

Quartz in fine 0.03 mm crystals fills in around the other minerals as a late silicification. The cryptocrystalline brown clay must be a montmorillonite variety that occupies large irregular areas several mm across mostly near the sheared zone between the two parts of the specimen.

No gold grains were observed.

PTS 23-298.5' Silica Undersaturated Hornblende-Biotite Syenodiorite

Specimen: The rock is medium to coarse grained, mottled dark green and creamy white with approx. 8 % porosity where some soft red oxide has been plucked out by the diamond saw. About 35-40 % of dark green mafic minerals occur disseminated and occasionally more concentrated in 5 x 20 mm patches (schlieren?) that give the rock a very faint banded appearance, but there is little or no foliation of the minerals. The remaining 50-60 % of the rock is feldspar with plagioclase and K-feldspar but no apparent quartz.

Mineralogy:

Plagioclase	27. %	Sericite	2. %
K-feldspar	7	Clay (montmorillonite type)	6
Hornblende	15	Quartz	0.1
Biotite	28	Magnetite	0.2
Sphene	1	Specular hematite	0.2
Apatite	0.2	Goethite	5
Chlorite	0.5	Limonite	3
		Pore space	5

Plagioclase, with around 16-26 % anorthite, occurs as anhedral 0.5-2.5 mm grains that are variably altered from relatively fresh to locally patches of advanced alteration to a little sericite (or illite) and major brown clay of the montmorillonite group plus limonite staining. Nepheline may be present but was not recognized as such. K-feldspar occurs throughout the rock as slightly smaller primary grains that have been subjected to the same clay alteration which may relate to the weathering cycle rather than to hydrothermal alteration.

Hornblende in grains up to 3 mm and biotite up to 0.8 x 3 mm are both fresh and unweathered. Biotite shows a weak foliation. Rarely a biotite grain is almost completely replaced by chlorite, a probable hydrothermal affect. Very minor quartz occurs as a late stage space filler.

Euhedral magnetite grains up to 0.6 mm are partly to amost completely pseudomorphed by specular hematite, which is interpreted as an early supergene alteration. Some <0.05 mm hematite grains have probably been completely oxidized from magnetite.

The porosity plus the goethite and limonite all occur in irregular areas up to 1.5 mm and 0.5 x 2 mm. The oxides occur as colloform areas that partially or completely fill the various cavities. No cuprite could be distinguished, and no malachite or gold were observed.

<u>Sample PTS 24-433'</u> Mineralized, Silica Undersaturated, Hornblende-Biotite Diorite

<u>Specimen</u>: This large diameter core piece of medium grained, medium grey, felsic to intermediate composition igneous rock is cross-cut by a replacement, not a vein, of relatively concentrated copper sulphides, malachite and at least 5 % porosity. In addition to about 15 % mafic minerals, the rock has plagioclase, some K-feldspar and no apparent quartz.

<u>Mineralogy</u>:

Mineral	%	Primary mineralization:	%
Plagioclase (An 35)	40. %	Magnetite	3. %
K-feldspar	4	Bornite	4
Biotite	7	Chalcopyrite	0.5
Hornblende	5	Molybdenite	0.5
Sphene	1	<u>Supergene mineralization</u>:	
Apatite	0.5	Specular hematite	1
Sericite	2	Gold	Trace
Epidote	5	Digenite	0.5
Clay (montmorillonite type)	5	Covellite	<0.1
Chlorite	0.2	Malachite	10
		Cuprite	1
		Goethite	3
		Limonite	4
		Pore space	3

Plagioclase occurs as anhedral grains up to 2 mm. An unusual dark clay (?) alteration along one set of albite twin lamellae and not the other in many grains, makes extinction angles difficult to determine. Untwinned grains interpreted as K-feldspar are less than 1 mm in size. Alteration of both feldspars is very patchy in distribution varying from almost nil to 100 % in a few grains. In some cases, it contains ≥15 % sericite (or illite). More commonly sericite is <5 %, and the alteration consists of epidote, chlorite and probably montmorillonite-type clay in an assemblage too fine grained to resolve microscopically. There is <u>no quartz</u>.

Hornblende occurs in rounded and irregular grains up to 2.5 mm and biotite in ragged books up to 0.5 x 2 mm. The hornblende is pleochroic in light tan, dark bluish green, and dark brownish green. The biotite is light tan to medium brown to very dark brown. Occasionally biotite shows incipient alteration to chlorite or montmorillonite.

Magnetite occurs as subhedral grains up to 3 mm that is replaced from 5 to 50 % by hematite, around the edges and along fractures and crystallographic planes (the latter may be exsolutions).

Bornite occurs as irregular massive areas up to 6 mm across with occasional chalcopyrite areas within it. Chalcopyrite also occurs as almost submicroscopic exsolution lamellae in the bornite. Digenite occurs as smooth, continuous 15 micrometre (μm) rims around bornite and as more irregular replacements along widely spaced fractures cutting the bornite. In the first instance, it looks primary but the veinlets indicate that it is more likely a supergene phase. A trace of very late covellite occurs along some fractures.

Molybdenite occurs mostly as bundles of very fine curved needles (presumably plates in the third dimension) outside the edges of some magnetite and bornite/chalcopyrite areas, but rarely these needles protrude into bornite as a minor replacement indicating a slightly later stage of crystallization. More rarely molybdenite also occurs as isolated rounded tabular grains up to 0.1 x 0.3 mm.

One gold grain 1.6 x 5 µm is encased in a 3 µm film of limonite surrounding a bornite grain with digenite rim adjacent to a plagioclase inclusion in the bornite area. At a second location 20 gold grains ranging in size from 0.1 to 3 µm lie entirely within the high temperature hematite that has replaced part of a magnetite grain. A third occurrence appears to be a plate or film in the third dimension that is about 2-5 µm thick and 20-25 µm across. It is entirely encased in limonite near a plagioclase grain.

The secondary iron oxides are classed as goethite and limonite. They are intimately intergrown as colloform bands in open space fillings, and color variations suggest the presence of as many as four phases, some of which may not even be crystalline. Cuprite is only distinguished from goethite by a slightly bluer color in reflected light, as both are shades of red in transmitted light, and their relative proportions may be in error. Malachite is the latest open space filling. It occurs as clusters of radiating fine needles that coalesce to fill the available spaces. Especially in the limonitic areas, open pore spaces are most abundant and should make the rock relatively permeable.

Sample PTS 25-146'   Mineralized, Silica Undersaturated, Biotite Syenodiorite

Specimen: Light buff to grey, mostly fine to medium grained but variable with some irregular feldspar clots giving a coarser texture in some patches or indistinct bands. Aside from an oxidized 10 mm band across one end of the core, the rock has 5-10 % copper sulphides disseminated throughout with about 2 % malachite and 3 % porosity. There are 10-15 % mafic minerals, nonfoliated, and the rest of the rock is plagioclase. There is some irregular cobaltinitrate staining perhaps reflecting some sericite.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 10-30)	70. %	Bornite	7. %
Biotite	6	Chalcopyrite	3
Sphene	1	Bismuthinite	1
Zircon	0.6	Bismuth	0.3
Apatite	0.4	Gold	Trace
Sericite	1	Supergene mineralization:	
Clay (montmorillonite type)	1	Digenite	0.3
Chlorite	0.2	Djurleite	0.2
		Limonite	2
		Geothite	0.1
		Malachite	3
		Pore space	3

The anhedral, mostly relatively equidimensional plagioclase grains show a complete range of sizes from 0.15 to 4 mm. About half is untwinned, but it is biaxial +ve so is not nepheline. There is minor sericite alteration and local patches of limonitic montmorillonite alteration but most is quite fresh.

Biotite in irregular books up to 1x1.5 mm in size is pleochroic from light tan to dark brownish green to dark brown approaching black. This reflects the lepidomelane variety that is unusually rich in both ferrous and ferric iron. There is rare alteration to chlorite. In addition to the minor sericitic alteration of plagioclase, there is an occasional 15 µm rim of sericite around some of the bornite areas.

Bornite and chalcopyrite occur in very irregualr massive areas up to 5 mm across in between the plagioclase grains in apparent equilibrium as though they were magmatic sulphides. Digenite and a second isotropic sulphide (hence not chalcocite) is probably djurleite. These form 15 µm rims around bornite and tiny veinlets cutting through chalcopyrite. Bornite commonly has very fine chalcopyrite exsolution lamellae.

Bismuthinite and native bismuth are intergrown and occur inone larger 0.5 x 0.8 mm area attached to a chalcopyrite/bornite area. Bismuthinite also occurs in many parts of the slide as small individual grains and larger ones up to 0.25 mm with or without associated bismuth. Mostly these occurrences are isolated in plagioclase areas.

One 5 x 9 µm gold grain occurs isolated in plagioclase with a second at 1 µm size near an adjacent 15 µm bornite grain. Another cluster of many small gold grains from 2 µm size down to submicroscopic (about 0.1 µm) is enclosed entirely in a cluster of radiating malachite crystals.

Malachite occurs as subhedral crystals up to 0.15 mm as well as exceptionally fine grained polycrystalline masses. These are open space fillings in both cases but reflect two generations of supergene solutions.

Sample PTS 26-129.5' **Silica Undersaturated Biotite Syenodiorite**

Specimen: It is a mottled light to medium buff to grey, igneous-looking rock. It appears that the PTS is cut parallel to an indistinct 12 mm wide slightly more felsic band that crosses this small piece of drill core at approx. 60° to the core axis. Near one side of this felsic band leaching of 0.5-3 mm holes has created 5-10 % porosity locally. There is ≤10 % mafic mineral content that is very weakly foliated. Only minor K-feldspar occurs and widespread faint cobaltinitrate yellow staining reflects mica or clay alteration. No quartz is apparent.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 17-24)	83. %	Arsenopyrite	<0.1 %
K-feldspar	0.2	Supergene mineralization:	
Biotite	9	Gold	Trace
Hornblende	0.5	Specular hematite	0.3
Sphene	0.3	Goethite	0.5
Chlorite	0.1	Limonite	3
Quartz	0.1	Malachite	1
		Pore space	2

Anhedral plagioclase grains, mostly in the 0.5-1.5 mm size range, vary from fresh to 50 % altered to a very fine grained assemblage interpreted as mostly montmorillonitic clay with minor sericite. This alteration often occurs in relatively intense 0.2-0.5 mm patches with no apparent control. There is minor silicification and K-feldspar introduced around some areas of minor porosity.

Hornblende occurs as very irregular, poikilitic 0.5-1.5 mm grains with pleochroism from very pale green to dark green and dark brownish green. It is fresh as is the biotite in 0.2-1 mm grains. Rarely, biotite is hydrothermally altered to chlorite and sometimes minor limonite is interleaved.

Arsenopyrite occurs as two grains, one 0.04 mm wedge-shaped grain and a second is 0.05 x 0.2 mm. The latter grain occurs adjacent to a similar sized mass of very fine "wormy" specular hematite grains. Specular hematite occurs as very fine ragged grains around the margins of some plagioclase grains and as radiating needles or plates within some large limonite areas and along veinlets.

One rounded gold grain 6 x 8 µm in size lies in a small mass of limonite at the edge of a large pore space and 15 µm from one of the above arsenopyrite grains. Two 0.2 and 1 µm gold grains were observed in a second limonite area. At a third location, a round 4 µm gold grain occurs at the contact of a limonite-malachite area with plagioclase.

Goethite occurs as 5-10 µm linings of fracture walls later filled with limonite. Occasionally some specular hematite also occurs along such a fracture and as partial linings of some limonite-filled cavities in place of goethite. In the only large 2 x 3 mm patch of malachite, that partially fills a large cavity, the relatively well crystallized malachite is cut by a vein of limonite with specular hematite at the centre indicating that, at least in this instance, hematite is the latest alteration phase.

Sample PTS 27-133.5' **Mineralized Breccia of Silica Undersaturated, Biotite Syenodiorite**

Specimen: Medium grey, medium grained igneous-looking rock. Some rounded feldspars up to 2 mm gives a faint porphyritic appearance. The texture is relatively massive but some faint felsic banding may be due to feldspathization along shears? Some of the rock has about 25 % mafic minerals. Much of the rock is very altered and the whole matrix for the feldspar grains is now a mineral mixture rich in malachite. The specimen also has ≥5 % of irregular 1-4 mm lumps of relatively dense iron oxide, maybe goethite, but unfortunately little or none of this red mineral was caught in the PTS. These are interpreted as oxidized remnants of former chalcopyrite or bornite clots and rarely specks of chalcopyrite can still be observed within the red oxide. There is ≥5 % porosity. The indecisive cobaltinitrate stain reflects clay alteration but no K-feldspar.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 6 or 35?)	61. %	Digenite	<0.1 %
Biotite	18	Supergene mineralization:	
Epidote	0.5	Gold	Trace
Sphene	2	Cuprite	3
Apatite	0.3	Limonite	5
Clay (montmorillonite type)	2	Malachite	15
Sericite	0.5	Goethite	1
		Pore space	2

Plagioclase occurs mostly in grains of 0.2 to 2 mm size. The crystals are disaggregated and "float" in a matrix of biotite, malachite, limonite, etc. One rounded 10 mm area preserves some of the original rock texture. This may be termed as a breccia, but it was a nonviolent disaggregation by solutions rather than tectonism. Alteration of plagioclase to clays and a little sericite is a bit less intense than in other rocks of this suite.

Biotite mostly in the 0.05-0.2 mm size range is finer than in other rocks of this suite. The grains are very ragged, sometimes folded and reoriented to form crude alignments encircling the plagioclase grains. There has been some mechanical comminution of the biotite but little or no alteration.

Epidote occurs as rounded fine grained polycrystalline aggregates that have been fractured from original 0.2 to 0.3 mm crystals. If these arise by alteration, there is no evidence of the precursor.

Wedge-shaped grains of sphene up to 0.1 x 0.25 mm are commonly associated with biotite.

One 0.15 x 0.6 mm grain of possible digenite is the only copper sulphide in the section.

Cuprite occurs with limonite as irregular, colloform masses up to 0.2 x 1 mm. They may be isolated or occur along larger vein-like intergranular masses of malachite. Some areas appear to be exclusively cuprite, many are all limonite. Some limonite areas have a 10-15 µm goethite rim.

With diligent search under high magnification, numerous gold grains in the range 3 to <0.1 µm can be found usually in or near limonite areas.

Sample PTS 28-91' **Metasomatically Altered Diorite**

Secimen: Light pink, medium grained granitoid rock with only about 2 % mafic minerals. K-feldspar alteration is major. There is a lot of late fracturing both along grain bounderies and cross cutting grains with a few percent malachite along the fractures.

Mineralogy:

		Supergene mineralization:	
Plagiocalse (An 40)	43. %	Specular hematite	0.1 %
K-feldspar	20	Gold	Trace
Biotite	2	Goethite	0.5
Chlorite	3	Limonite	1
Epidote	0.3	Malachite	4
Apatite	0.3	Pore space	1
Quartz	18		
Sericite	2		
Clay (montmorillonite type)	4		
Leucoxene	0.5		
Magnetite	0.2		

Plagioclase grains range from 0.2 to 4 mm size and are moderately "peppered" with sericite and heavily clouded with clay. K-feldspar occurs throughout in 0.1-1.5 mm untwinned grains which show only very faint clay weathering effects. Quartz shows a similar size range of complex interlocking grains.

Biotite is more than 50 % altered to chlorite and minor epidote.

Malachite is entirely distributed in 0.05-0.2 mm late, cross-cutting veinlets. Goethite and limonite occur both in cavities and in veinlets to a lesser extent.

As in PTS 28-96, opaque areas interpreted as relict sphene sites, contain "leucoxene" and minor magnetite formed by the hydrothermal breakdown of the sphene. At some sites, the magnetite has been oxidized to supergene specular hematite.

In one area of quartz, there are two "large" gold grains 15 and 25 µm in size plus one at 2 µm in the quartz, one at 1 µm in a limonitic fracture, and one at 3 µm in plagioclase.

Sample PTS 28-96 **Metasomatically altered Syenodiorite**

Specimen: Mottled light buff and grey, medium grained granitoid rock with approximately 10 % mafic minerals. There is no K-feldspar except for a 5 mm band across one end of the PTS with 60-70 % K-feldspar. There is ≥2 % malachite as hairline veinlets and some dissemination; it is slightly more concentrated where the K-feldspar is localized. There is 2-3 % porosity.

Mineralogy:

Plagioclase (An 13 or 28)	53. %
K-feldspar	6
Biotite	10
Epidote	0.1
Apatite	2
Quartz	15
Sericite	2
Clay (montmorillonite type)	2
Leucoxene	1

Supergene mineralization:	
Specular hematite	0.5 %
Goethite	1
Limonite	2
Malachite	3
Gold	Trace
Pore space	2

Irregular plagioclase grains mostly lie in 0.3-2.5 mm size range. The grains are relatively weakly altered to sericite and clay, but these alterations often completely replace the narrowest albite twin lamellae. K-feldspar is concentrated near one end of the specimen in 0.3-0.8 mm irregular grains. It is only distinguished from plagioclase with difficulty as much of the plagioclase is untwinned.

Quartz varies from very fine to 0.5 mm grains. It always lies interstitial to the plagioclase, but it is relatively uniformly distributed throughout the slide. It is interpreted as secondary but introduced with a different solution pulse than the K-feldspar, as it pervades the rock rather than being restricted in occurrence. One 0.8 x 3 mm area of quartz is clearly a vein.

The biotite is not altered to chlorite, but it is a bit ragged with incipient bleaching, probably reflecting some potassium leaching and degradation to hydrobiotite. Sparse epidote crystals occur in the biotite. This rock has much more apatite than the others in the suite. The relict outlines of 1-2 % sphene remain, but it is now entirely altered to a semiopaque mass including some specular hematite and minor rutile. Sphene was fresh in rocks that were only weathered, so this is a hydrothermal alteration effect.

In this rock, most of the malachite occurs in very fine grained ropey veinlets 0.02-0.1 mm wide, which sometimes follow cleavages through biotite-rich areas. By contrast, the limonite occupies 0.3-1 mm cavities having goethite rims and limonite in the center along with pore spaces. The small amount of specular hematite occurs mostly around the sites of altered sphene grains.

One 8 µm gold grain grain occurs in contact with plagioclase at the margin of a limonite-filled cavity.

Sample PTS 32-195' **Silica Undersaturated Biotite Leucodiorite Porphyry**

Specimen: Approximately 65 % is dark greenish grey matrix mottled with pale cream colored feldspar phenocrysts up to 6 x 10 mm and rounded masses of vein-type quartz up to 2 cm (not included in the PTS). 8-10 % K-feldspar is irregularly distributed. About 12 % mafic minerals include about 3 % magnetite disseminated in equant grains up to 1 mm. There is 3-5 % porosity, about 3 % disseminated malachite and one very irregular 4 x 8 mm area of iron oxide has remnants of chalcopyrite in it but little of this appears in the PTS.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 40)	63. %	Magnetite	3. %
K-feldspar	8	Chalcopyrite	<0.1
Biotite	9	Supergene mineralization:	
Chlorite	0.3	Specular hematite	0.1
Apatite	0.1	Cuprite	0.5
Quartz	0.5	Goethite	0.5
Clay (montmorillonite type)	4	Limonite	5
Sericite	1	Malachite	2
		Pore space	3

Plagioclase occurs in rounded, mostly untwinned biaxial +ve grains in the matrix and as phenocrysts up to 4 x 8 mm. Alteration, interpreted as a product of weathering, mainly to limonitic montmorillonite and minor sericite (or illite) is moderate and patchy but is especially pronounced along alternating albite twin lamellae.

Biotite is pleochroic from pale tan to medium greenish brown to dark brown and occurs in grains up to 0.5 x 1.3 mm. There is very minor alteration to chlorite.

Quartz occurs as irregular grains, generally about 0.1 mm. This silicification occupies about 25% of the rock in one 4 x 7 mm area of high porosity and is absent elsewhere. The K-feldspar, which occurs in rounded 0.15 mm grains, is also concentrated in this area and similar areas of increased porosity in the slide.

Magnetite occurs in rounded to subhedral grains up to 1 x 2.5 mm but mostly about 0.15 mm. They are highly fractured, segmented, and infilled by limonite, but there is only a couple percent of alteration to specular hematite.

Chalcopyrite may have occupied an area up to 6 mm across, but it is almost totally replaced by cuprite with later malchite and limonite, the largest remnant grain being 0.1 mm.

Limonite occurs both as small pore fillings and as large areas up to 4 x 6 mm. The latter area has traces of remnant chalcopyrite which have largely been replaced by cuprite with the surrounding open space filled by zones of limonite and malachite. Some cavity fillings have an initial liner of goethite then infilled with limonite and malachite.

Sample PTS 42-216' **Silica Undersaturated, Biotite-Hornblende Diorite**

Specimen: Medium to dark grey, fine to medium grained rock. About 35 % mafic minerals with faint foliation at approx. 30° to core axis as a result of weak shearing or microbrecciation. Approximately 5 % porosity, ≥5 % malachite and ~7 % limonite.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 11 or 31)	43. %	Magnetite	0.2 %
Biotite	25	Molybdenite	Trace
Hornblende	8	Supergene mineralization:	
Epidote	0.5	Specular hematite	1
Sphene	1	Gold	Trace
Quartz	1	Goethite	1
Clay (montmorillonite type)	2	Limonite	9
Sericite	0.3	Malachite	5
		Pore space	3

Plagioclase grains mostly fall in the 0.2-2 mm size range with only minor alteration to clays which rarely comprise upto 15 % of a plagioclase crystal. No K-feldspar was observed, and minor secondary quartz occurs around areas of solution transport.

Biotite is mostly fresh with some breakdown to a semi-opaque mixture of montmorillonite(?) and goethite(?) along some areas of solution flow. Primary epidote occurs as unusual tabular and lenticular crystals interleaved in the biotite books.

Hornblende, in grains up to 1.5 x 3 mm, is pleochroic from pale yellowish tan to medium bluish green to dark olive green.

Primary magnetite in 0.1-0.3 mm grains is 40-100 % replaced by specular hematite.

Most of the limonite fills open spaces and is the latest mineral in the rock. Some cavities have a rim of malachite and a later in-filling of limonite. A less abundant earlier stage of oxidation produced semi-opaque goethite alone or mixed with limonite and montmorillonitic clay along poorly defined shears or zones of weak brecciation.

In addition to partial fillings of larger openings together with limonite, malachite often occurs filling 0.2-0.5 mm cavities that have a 10-15 µm lining of cryptocrystalline silica, or sometimes a partial 5 µm lining of specular hematite.

Eight 1-3 µm gold grains were observed in the following settings: three are in plagioclase near a limonitic fracture, three within limonite areas, one in a goethite-clay mixture, and one in limonitized biotite.

Sample PTS 53-649' **Chloritized, Silica Undersaturated Syenodiorite**

Specimen: Medium grained, medium to dark grey, with an irregular limonitic wash. There are 15-20 % mafic minerals and ≤10 % K-feldspar which is more concentrated within 5-10 mm of a 1 mm gypsum vein which is offset by other minor fractures. There is about 2 % disseminated limonite, 1 % malachite and 3 % porosity.

Mineralogy:

		Primary mineralization:	
Plagioclase (An 9 or 31)	58. %	Magnetite	<0.1 %
K-feldspar	6	Arsenopyrite	0.2
Biotite	1	Chalcopyrite	0.2
Chlorite	14	Supergene mineralization:	
Epidote	1	Specular hematite	0.8
Sphene	1	Cuprite	0.4
Apatite	0.5	Malachite	1
Clay (montmorillonite type)	5	Goethite	0.3
Sericite	3	Limonite	2
		Gypsum	3
		Pore space	3

Plagioclase occurs in irregular and tabular grains from 0.2 to 2 x 6 mm. K-feldspar forms clusters of 0.02-0.1 mm rounded grains along boundaries between the plagioclase crystals and as sparse, discontinuous 0.1 mm veinlets.

Fine grained sericite (or illite) may occupy up to 25 % of plagioclase grains within about 8 mm of the gypsum vein but only 1-5 % elsewhere. Similarly, montmorillonite in a more patchy distribution varies from nil to 50 % locally, affecting any parts of the plagioclase grains whereas sericite is concentrated in the cores.

One sphene grain at 0.4 x 0.8 mm, and bearing plagioclase inclusions, is much larger than grains typical for this suite of rocks, but sphene is not abundant in this specimen.

Anomalous blue penninite variety of chlorite forms irregular, ragged patches and anastamosing areas like crude veins. It is interpreted as a product of hydrothermal alteration. There are rare remnants of biotite, so it is believed to be the precursor mineral. Ironically, the K-metasomatism, that has developed K-spar and some sericite, has also affected the chlorite. Thin layers of almost microlite-size feathery rows of biotite crystals are growing along various minor shear surfaces that cut all the chlorite areas. Some of this very fine grained material is also interpreted as epidote and sparse larger crystals of epidote also occur in the chlorite areas.

Remnants of chalcopyrite in 15-60 µm sizes are now enveloped in goethite and limonite. At two places cuprite envelopes the chalcopyrite and limonite surrounds the cuprite.

Arsenopyrite in grains up to 0.2 mm may be highly fractured and have some fringing very fine specular hematite, but the arsenopyrite is not altered. One grain has a tiny inclusion of chalcopyrite.

A 0.5-1 mm wide gypsum vein traverses the slide, and there are one or two minor subsidiary veinlets. The K-feldspar, sericite and clay alterations are more pronounced with 8 mm of this vein.

Nine gold grains less than 5 µm in size occur: five in chlorite, two in plagioclase, and two in plagioclase/K-feldspar contact areas.

Sample TS 21-178' **Silicified Diorite Porphyry**

Specimen:

The rock is light grey to pink with medium grained matrix and 5-10 % of K-feldspar phenocrysts up to 15 mm which tend to cluster rather than be uniformly distributed. There is 10-15 percent each of quartz and of mafic minerals, rather irregularly distributed. The rock looks fresh but contains sparse <1 mm holes that belie some fluid movement.

Mineralogy:

Plagioclase (An 8 or 33)	40. %
K-feldspar	15
Hornblende	6
Biotite	0.5
Sphene	1
Quartz	13
Epidote	1
Chlorite	5
Opaques	0.5

Supergene minerals:

Clay (montmorillonite type)	16. %
Epidote	1
Pore space	0.5

Plagioclase grains 0.2 to 4 mm in size range from weakly altered to totally replaced by the very fine grained mixture interpreted to be mostly montmorillonitic clay together with small amounts of epidote.

K-feldspar occurs in two large phenocrysts 6 x 15 and 4 x 10 mm plus a couple in the 2-4 mm size range. They are Carlsbad twinned, are only faintly weathered, and bear small inclusions of hornblende, sphene and highly clay-altered plagioclase. Based on the size and shape of these grains, they are interpreted as primary phenocrysts even though the rock is highly metasomatized.

Quartz occurs in large irregular patches up to 3 x 5 mm and grain sizes from <0.1-1 mm. Most, and probably all, of the quartz is clearly introduced by an intense metasomatism.

Hornblende, in grains ranging from 0.2 to 1 x 2 mm, is poikilitic and fresh with only a trace of chloritization.

Sphene is common in larger than usual grains up to 0.5 x 1 mm. It is also totally unaltered, in spite of the intense silica flooding. This is in contrast to other specimens which had suffered K-feldspar metasomatism and the sphene was totally destroyed.

Biotite is almost totally replaced by chlorite.

Epidote occurs in three modes. There are clear, fresh 0.2-1 mm irregular to subhedral grains that may in part have replaced biotite and are interpreted as coeval with the silicification. There are also very fine, poorly crystallized grains interleaved in the secondary chlorite. Finally, the supergene alteration of plagioclase appears to contain some epidote.

Sparse opaque grains up to 0.5 mm may be magnetite, based on their subhedral shapes.

Sample TS 26-98.7' **Granodiorite**

Specimen:

The rock is a light to medium pinkish grey, somewhat mottled, medium grained, felsic igneous rock with very indistinct banding, but not foliation, of some of the mafic minerals. There are some 0.5 mm leach zones along sparse fractures and sparse 0.5 mm quartz veinlets. A small percent- age of K-feldspar is irregularly distributed. There is about seven percent disseminated mafic minerals. The rock is nonporous other than the sparse fractures.

Minerlogy:

		Secondary minerals:	
Plagioclase (An 8 or 32)	60. %	Carbonate	0.5 %
K-feldspar	11	Biotite-chlorite mixed layer mica	3
Biotite	3	Chlorite	0.2
Quartz	20	Clay (montmorillonite type)	1
Sphene	0.5	Opaques (magnetite)	0.2
Apatite	0.2	Goethite & limonite	0.1

Plagioclase is generally in the 0.2-1 mm size range, and there are occasional 3mm phenocrysts. Additionally, there are occasional 0.1 mm rounded spots of myrmekitic plagioclase-quartz intergrowth. There is a slight dusting of clay alteration on most grains and also on K-feldspar grains to a minor extent. There is minor montmorillonite alteration of the plagioclase.

K-feldspar occurs as irregular 0.3-1 mm grains that are almost unaltered.

Quartz in 0.1-0.5 mm size range dominates the rock and is intimately mixed with the two feldspars.

The smaller books of biotite remain relatively unaltered. Large crystals up to 1.3 mm are hydrothermally altered to a relatively coarse mixture of carbonate and brown nonpleochroic biotite-chlorite mixed layer mica grains with lesser amounts of chlorite, sericite, and opaques presumably magnetite. Some of the original strongly pleochroic biotite may be preserved as a partial rim. About 60 % of the grains are degraded to the mixed-layer chloritic mica but only a very few of the largest grains show the most advanced alteration.

The only opaques are the presumed magetite derived from biotite alteration.

One 0.8 mm cavity is filled with goethite and lesser limonite.

One 0.2 mm vein of quartz plus carbonate curves across the slide.

Sample TS 31-151' **Hornblende Porphyritic Basalt**

Specimen: Dark grey, very fine grained matrix studded with 15-20 % of 1-5 mm black hornblende phenocrysts. There is an almost imperceptible flow(?) layering at about 65 ° to the core axis. The rock appears to be fresh but does contain a few tenths of one percent pyrite disseminated in grains up to 0.5 mm and a lesser amount of chalcopyrite.

Mineralogy:

Primary minerals:		Secondary minerals:		Supergene minerals:	
Plagioclase (An 60)	56. %	Montmorillonite	4. %	Limonite	trace
Hornblende	30	Carbonate	1	Pore space	0.1
Biotite	5	Chlorite	0.2		
Sphene	2	Epidote	0.1		
Apatite	0.3	Opaques	0.8		

Most plagioclase grains fall in the 0.1-0.7 mm size range, rarely up to 1 mm. They are relatively fresh and subjected to variable montmorillonite alteration.

Hornblende is pleochroic in pale yellowish green, dark olive green and dark bluish green and is mildly poikilitic. It occurs in monomineralic patches up to 5 mm but the largest individual crystals are 1.6 mm and grains in the matrix are all sizes down to 0.03 mm. At a few locations, there is some alteration to carbonate and chlorite.

Ragged biotite grains are less than 0.3 x 0.8 mm size. Biotite occurrence is restricted to the plagioclase-rich portions of the rock away from the areas of hornblende agglomeration. It occasionally shows incipient alteration to chlorite and opagues, presumably magnetite.

The opaques occur in irregular 0.01-0.1 mm grains, rarely up to 0.2 mm, often intergrown with carbonate and sometimes with sphene and hornblende. Some can be assumed to be magnetite, however pyrite and minor chalcopyrite were noted in the specimen, which sulphides were apparently introduced with the carbonate.

The carbonate occurs in irregular ≤0.3 mm patches throughout the rock. Minor pore space also occurs in the carbonate areas. Although some alteration may be associated with the carbonate plus opaques areas, there generally is none.

No quartz was observed.

Sample TS 36-237' **Hydrothermally Altered Hornblende Porphyritic Andesite**

Specimen:

Dark grey, fine grained matrix with about 3 % dark green phenocrysts up to 3 mm. In total about 45 % mafic mineral content, except for one end of the core piece that is totally bleached. This area contains about half a percent of disseminated chalcopurite and minor magnetite. Weak cobaltinitrate staining perhaps reflects some sericitic alteration mostly in the bleached area but no K-feldspar. There are rare 1 mm quartz veinlets. Minor porosity increases to ≤5 % in the bleached area.

Mineralogy:

Primary minerals:		Secondary minerals:		Supergene minerals:	
Plagioclase (An 43)	50.%	Montmorillonite	8. %	Limonite & goethite	0.2 %
Hornblende	30	Hydrobiotite	3	Malachite	0.2
Biotite	1	Chlorite	2	Pore space	1
Sphene	2.5	Epidote	1		
Apatite	0.5	Quartz	≤0.1		
		Opaques	1		

Plagioclase grains are mostly in 0.1-0.6 mm size range. Alteration of grains varies from weak to total and is estimated to be ≥15 % of the plagioclase areas. Because of the very fine grain sizes of the clays, they have been interpreted as weathering products in other specimens, however this rock is somewhat more hydrothermally altered, so this may be a more likely alternative explanation at least for this rock. No K-feldspar was observed.

Hornblende occurs in crystals and rounded monomineralic agglomerations up to 2.5 mm and much larger, less dense agglomerations of crystals. It is of very restricted occurrence in the 15 mm wide bleached and mineralized zone at one end of the specimen. Even there it remains unaltered, although large amounts of hornblende must have been removed by the altering solutions.

While some biotite grains remain almost completely fresh, even in the most altered part of the rock, most are either (a) degraded to weakly pleochroic, brown hydrobiotite, or (b) to penninite-type chlorite. In both cases, there is some associated dusty epidote and magnetite along cleavages.

Epidote occurs as clear, irregular grains up to 0.5 mm in the altered area. It undoubtedly reflects some of the former mafic mineral content of this area. Its occurrence is restricted to the bleached zone whereas altered biotite occurs as irregular concentrations throughout the rock.

Sphene is more abundant than in most rocks of the suite in fresh 0.02-0.2 mm grains.

Limonite and goethite occupy sparse cavity-fillings up to 0.3 x 1 mm and may also rim other opaques. Minor pore spaces occur throughout the rock but are larger and more abundant in the bleached zone. A trace of quartz occurs as 10 µm layers around some pores.

Malachite occurs in two 0.2 mm patches associated with pores and with limonites and epidote. It also forms occasional 0.02-0.05 mm rims lining some pores in the bleached zone and sparsely elsewhere.

Opaques occur with cubic outlines up to 0.8 mm across, but most are in the 0.02-0.2 mm size range. They may be disseminated up to 7 % but are generally about 4 % in the bleached area of the thin section and <1 % in the rest of the rock. In the rock, the opaques are shown to be mostly chalcopyrite and magnetite.

Sample TS 36-242' **Altered Andesite**

Specimen:

Mostly uniform, dark grey, fine grained rock with a 10 x 20 mm area at one side of core with equal amounts of quartz, coarse dark green mafic mineral, and ≥10 % magnetite disseminated in this area but no sulphides. There is about 2 % K-feldspar disributed in four patches about the slide, about 5 % porosity and 1-2 % disseminated malchite.

Mineralogy:

Primary minerals:		Secondary minerals:		Supergene minerals:	
Plagioclase (An 50)	56. %	K-feldspar	2. %	Limonite & goethite	1. %
Hornblende	1	Montmorillonite	13	Malachite	0.7
Biotite	15	Hydrobiotite	1	Pore space	3
Sphene	2	Chlorite	1		
Apatite	0.5	Epidote	0.5		
		Opaques	3		

Plagioclase grains are mostly 0.2-1 mm and are moderately to strongly altered to montmorillonite. It may comprise from a few percent to 100 % of some plagioclase grains. This clay is still very fine grained but is coarser than in other rocks with occasional grains up to 50 µm.

Some untwinned 0.5 mm grains are tentatively identified as K-feldspar.

Hornblende grains are sparse but may occur up to 2 x 2.5 mm size.

Biotite is usually in irregular books 0.2 to 1.5 mm long. Throughout most of the rock, it is fresh but within more hydrothermally altered areas it is partially degraded to hydrobiotite which is still brown but almost nonpleochroic, and to chlorite both with tiny epidote grains along cleavages.

In addition to the very fine grained epidote noted, there are irregular 0.1-0.2 mm grains in some of the larger altered biotite sites.

The opaques, presumed to be mostly magnetite, range from cube forms 0.5 mm to 10 µm tiny particles. They are disseminated throughout but amounts vary up to >10 % locally.

Limonite fills, or partially fills, cavities apparently with a 25 µm rim of goethite. Limonite often occurs near a concentration of opaques.

Malachite occurs as fine radiating needles in cavities and also associated with limonite areas.

There is no quartz in the thin section.

Sample TS 38-187' **Tonalite (Quartz Diorite)**

Specimen:

Light grey, fine to medium grained, rock with granitoid texture bearing sparse 2 mm white feldspar phenocrysts and 1-3 % each of disseminated magnetite and biotite along a relatively well developed foliation at approximately 70 ° to core axis. Late fractures spaced 10-20 mm are partly open. No sulphides are present.

Mineralogy:

Primary:		Secondary:		Supergene:
Plagioclase (An 12 or 29)	70. %	Montmorillonite	5.5 %	
Quartz	17	Hydrobiotite	2	
Biotite	2	Epidote	0.3	
Sphene	0.5	Sericite	0.1	
Apatite	0.5	Carbonate	0.1	
Magnetite	1.5			

Plagioclase grains show wide size variation from 0.2 to 2.5 x 3.5 mm. There must be significant compositional zoning as grain cores are often partly or 100 % altered to montmorillonite while the outer two thirds is relatively fresh. Alternate twin lamellae are also usually completely altered leaving few useable grains for composition determination. As a consequence, the plagioclase composition may be significantly in error. Plagioclase also occurs in rare 0.05 mm veinlets.

Quartz grains may occur up to 0.8 mm but most are 0.02-0.2 mm. The sutured grains occur mostly along plagioclase intergrain boundaries and occasional larger 1 x 2 mm areas. None is clearly fracture controlled, although some may be old rehealed veins. It is assumed to be mostly primary, in the absense of clear evidence to the contrary.

Ragged biot grains and clusters are generally less than 0.25 x 2 mm size. They often are aligned in a crude foliation along which fractures have developed. It is about 50 % altered to hydrobiotite and lesser chlorite and epidote.

Epidote, in grains up to 0.4 mm, occurs in a crude 1.5 mm long vein. It is pleochroic pale tan, pale yellow and medium brown. Fine epidote is also produced by biotite breakdown.

Sparse sericite grains up to 0.1 mm occur along fractures. As with sericite, sparse carbonate occurs along ill defined fractures or metasomatized zones.

Magnetite occurs widely scattered in 0.1-1 mm, anhedral to euhedral grains. These grains appear to be primary and rarely show a poorly developed possible skeletal intergrowth with plagioclase. It sometimes has partial 10-20 µm rims of sphene.

Unless the montmorillonite alteration in the plagioclase is due to weathering, there are no supergene minerals in this slide, nor any porosity.

Sample TS 40-33' **Hornblende Diorite**

Specimen:

This is a light grey, medium grained rock with granitoid texture and about 25 % mafic minerals. Sparse 5 x 8 mm clots of mafic minerals, with minor associated magnetite, may be partially digested inclusions. There is no K-spar or significant porosity.

Mineralogy:

Primary:		Secondary:		Supergene:	
Plagioclase (An 11 or 30)	67. %	Hydrobiotite	2. %	Montmorillonite	2. %
Hornblende	20	Epidote	0.2	Limonite	0.1
Biotite	5	Magnetite	0.2	Pore space	≤0.1
Sphene	2	Carbonate	0.3		
Apatite	0.8				
Magnetite	0.7				

Anhedral plagioclase occurs in a wide range of grain sizes from 0.2 mm up to 3 x 6 mm. Montmorillonite alteration is generally weak, but local small patches are up to 100 %. As it is very fine grained, it may be supergene in this rock.

Hornblende occurs in irregular grains up to 3 x 5 mm. Sphene and biotite may occur as inclusions.

Biotite, in grains up to 1 mm, is generally finer grained. It shows some alteration to hydrobiotite due to a very weak hydrothermal alteration event.

Magmatic magnetite in irregular and subhedral grains 0.1-0.3 mm may be associated with, or have 10 µm rims of, sphene, as in TS 38-187. Sphene occurs in wedges and irregular grains up to 0.7 mm. Based on size and distribution, some 0.2-0.3 mm patches of carbonate, which are full of very fine grained opaques, may be products of hydrothermal alteration of sphene with minor associated pore space. The opaques would be magnetite and/or rutile.

Sparse epidote grains 0.1-0.3 mm occur intergrown with hydrobiotite and are interpreted as deriving from the same hydrothermal alteration event.

Minor limonite occupies a 0.35 x 0.7 mm cavity.

There is no quartz or K-feldspar.

Sample TS 40-131' **Biotite Diorite**

Specimen:

It is a medium grey, fine to medium grained rock with granitoid texture. The rock is not banded on the scale of a 10 cm core piece, but there is some felsic concentration in one 20 mm zone and sparse, mostly digested remnants of possibly ultramafic rock inclusions are vaguely aligned at approximately 60° to the core axis. There are about 20 % mafic minerals in total, including 3-5 % disseminated magnetite in one end of the core piece (not in the thin section). There is no K-feldspar.

Mineralogy:

Primary:		Secondary:		Supergene:	
Plagioclase (An 40)	77. %	Carbonate	0.2 %	Montmorillonite	2. %
Biotite	17	Sericite	<0.1	Limonite	0.1
Sphene	0.5	Vein material	1	Pore space	0.1
Apatite	1.5				
Magnetite	0.8				

Plagioclase occurs in two size ranges 1-3 mm and a lot of 0.05-0.3 mm intergranular filling. There is patchy weak montmorillonite alteration which may be supergene.

The biotite distribution is irregular comprising 50 % of irregular patches up to 5 x 10 mm. Also the individual grains are coarser than in other rocks being up to 1.5 x 3 mm and generlly in the 0.5-1 mm size range.

Sericite forms rare 0.05 mm grains along healed fractures or grain boundaries.

Magnetite occurs as 0.2-0.8 mm grains associated with the biotite-rich areas where sphene and apatite are also more concentrated.

Carbonate occurs in rare, vein-like patches and as partial filling of rare pores partly still open.

A 0.25-0.6 mm vein crosses the slide. While it contains some recognizable carbonate, it is mostly a very fine grained mush that is largely unrecognizable. There are fine opaque particles and rounded lumps that may be altered plagioclase. It is interpreted as a fine microbreccia in which the individual fragments are now altered beyond recognition. In addition to carbonate, there probably are large amounts of montmorillonite and epidote? The vein contents were not altered insitu, as fragments of biotite and plagioclase from the adjacent vein walls are unaltered.

There is no K-feldspar or quartz.

Sample TS 40-158' **Biotite Diorite**

Specimen:

The rock is fine grained and light to medium grey with a weak limonitic wash and 20 % mafic minerals including ≤1 % magnetite. There is <1 % K-feldspar, minor porosity and a faint foliation at 60° to the core axis.

Mineralogy:

Primary:		Secondary:		Supergene:	
Plagioclase (An 13 or 28)	70. %	K-feldspar	0.5 %	Limonite	1. %
Biotite	14	Montmorillonite	6	Gypsum	trace
Apatite	0.6	Carbonate	1	Pore space	0.5
Magnetite	0.4	Hydrobiotite	5		
		Epidote	0.2		
		Chlorite	<0.1		
		Magnetite + rutile	1		
		Leucoxene	0.4		

Plagioclase, in 0.4-2.5 mm grains, is at least 10 % altered to patchy montmorillonite and lesser carbonate. The alteration products have partly migrated along fractures for short distances.

The minor K-feldspar, indicated by staining, could not be localized in thin section. It is arbitrarily assumed to be secondary.

Biotite, in grains up to 0.5 x 1 mm, vary from fresh to >60 % altered (average ~25 %) to mostly hydrobiotite and very minor chlorite. The altered grains also contain ≥10 % of fine, feathery-looking opaque or semiopaque minerals. These form irregular aggregates that are often elongated in random directions relative to the biotite cleavage and about 5-10 x 50 µm in size. These are assumed to consist of very fine magnetite, rutile and possibly epidote, although none of these minerals can be resolved in transmitted light.

Magnetite forms scattered 0.2-0.5 mm euhedral grains. Opaque grains also form aggregates up to 0.5 mm with associated leucoxene, pore space and occasional limonite. Based on size and distribution, these are interpreted as magnetite and rutile derived from hydrothermal breakdown of sphene.

Limonite fills cavities up to 0.4 x 0.8 mm and a minor amount forms a stain along late fractures.

There is no quartz.

Descriptions of 35 mm Photographs for Project W1002
Western Copper Holdings Ltd.

No.	Sample No.	Width of Field of View, mm	Light Reflected R Transmitted T	Description
1	23-241.5	3	R	Chalcopyrite + bornite + specular hematite cut by quartz & goethite. Geoth fringe on bn + cp
2	23-241.5	1	R	Molybdenite with native bismuth intergrown at lower left, chalcopyrite upper right with limonite around cp & goethite below moly. Pore space at lower right.
3	24-433	1	R	Compound bornite/chalcopyrite grains with moly replacing at edge. Digenite rim around bornite.
4	"	1	R	Bornite with digenite replacement at left, magnetite w specular hematite replacement at right and curvy spec hem "plates" in between.
5	"	0.3	R	1.6 x 5 µm gold grain in limonite film at edge of bn mass with digenite rim adjacent to plag incln in bn
6	"	0.3	R	Approximately 20 gold grains 0.1 to 3 µm size within hematite replacing edge of magnetite grain.
7	"	0.3	R	Plate-like gold grain 2-5 µm thick by 20-25 µm wide enclosed in limonite near a plagioclase grain.
8	"	1	T	Cuprite intergrown with colloform limonite, surrounded by malachite with plagioclase & hornblende.
9	"	3	T	Colloform cuprite & limonite with goethite rims with malachite. Large magnetite grain at top (black).
10	25-146	1	R	Bismuthinite, native bismuth + cp & bn with dig rims (bismuthinite is pleochroic so appears as several diff greys). 3 dk grey tiny grains are unidentif. isotropic.
11	"	0.3	R	5 x 9 µm gold grain in plagioclase. A second 1 µm gold on other side of a 15 µm bornite grain.
12	"	0.3	R	Many gold grains from <0.1 to 2 µm size, all in cluster of radiating malachite crystals.
13	"	3	T	Coarsely crystalline malachite and v fine malachite (almost black at upper right). Rest is plag + bornite.
14	32-195	3	T	Tiny chalcopyrite core in cuprite surrounded by slightly limonitic malachite & geoth. Plag + biot at lft
15	"	3	R	Chalcopyrite in same field as 14, reflected light.
16	"	3	T	Malach + lim in cavity, geoth around edges.

17	26-129.5	0.3	R	6 x 8 µm gold grain in limonite at edge of large pore and 15 µm from an arsenopyrite grain.
18	27-133.5	3	T	Cuprite with lesser limonite in malachite area plus plagioclase and biotite.
19	"	0.3	R	2.5 µm cross sectional end of larger gold grain extending down in limonite. Cuprite & goeth at bottom
20	"	3	T	Malachite/limonite area with plagioclase & biotite.
21	28-91	0.3	R	25 µm gold grain entirely in secondary quartz.
22	42-216	3	T	Geothite filling cavity (black) with later in-filling of malachite & finally limonite. Also plag & biotite.

APPENDIX 2

Sequential Extraction Test Procedures

Appendix 2

Sequential Extraction Test Procedures

LEACH 1: Ion exchangeable metals

Test descriptions

- add 50 mL of 1 M magnesium chloride and 5.0 grams of -325 mesh sample in a 250 mL erlenmeyer flask
- agitate the sample in a orbital shaker for 30 minutes
- micropore filter the sample with 0.45 micron filter paper
- submit filtrate for ICP analysis
- repulp filtered cake with distilled and de-ionized water and filter
- repeat repulping and filtering of the solids
- save solids in a refrigerator for next leaching stage

LEACH 2: Carbonate bound metals

Test descriptions

- add 100 mL of the 1.0 M sodium acetate solution to the **LEACH 1** residue in a 250 mL erlenmeyer flask
- agitate the sample in an orbital shaker for 30 minutes
- micropore filter the sample with 0.45 micron filter paper
- submit filtrate for ICP analysis
- repulp filtered cake with distilled and de-ionized water and filter
- repeat repulping and filtering of the solids
- save solids in a refrigerator for next leaching stage

LEACH 3: Iron and manganese oxides bound metals

Test descriptions

- add 150 mL of the 0.25 M hydroxylamine hydrochloride in 0.25 M hydrochloric acid solution to the **LEACH 2** residue
- agitate in an orbital shaker for 2 hours at 60°C
- micropore filter the sample with 0.45 micron filter paper
- submit filtrate for ICP analysis
- repulp filtered cake with distilled and de-ionized water and filter
- repeat repulping and filtering of the solids
- save solids in a refrigerator for next leaching stage

LEACH 4: Organic matters and sulphide bound metals

<u>Test descriptions</u>

Stage 1

- add 170 mL of 1 M nitric acid to the **LEACH 3** residue
- agitate in an orbital shaker for 4 hours
- micropore filter the sample with 0.45 micron filter paper

Stage 2

- add 100 mL of 0.02 M N_2O_2 in 1 M nitric acid to the Stage 1 residue
- agitate in an orbital shaker for 4 hours
- micropore filter the slurry with 0.45 micron filter paper
- combine filtrate with Stage 1 filtrate for ICP analysis
- repulp filtered cake with distilled and de-ionized water and filter
- repeat repulping and filtering

LEACH 5: Silicate and refractory Fe-oxides bound metals

<u>Test descriptions</u>

- solids from **LEACH 4** are digested with diluted aqua regia solution at 95_0C for 90 minutes
- digested solution is bulked up to a fixed volume with distilled and de-ionized water
- submit filtrate for ICP analysis

APPENDIX 3

Groundwater Quality (RC-92-01) - Preliminary Data

Appendix 3

Western Copper Holdings Ltd.
Carmacks Copper Project

Groundwater Quality (RC-92-01) - Preliminary Data

Parameter		March 1995		April 1995	
Physical tests					
Hydroxide	CaCO3	<5.		<5.	
Carbonate	CaCO3	<5.		<5.	
Bicarb.	CaCO3	113		114	
Total Alk.	CaCO3	113		114	
pH		7.8		7.8	
SOLIDS					
Suspended	105C	80		47	
Dissolved	105C	384		403	
ANIONS BY IEC					
Chloride	Cl	2.4		2.5	
Fluoride	F	<2.		<3.	
Nitrate	NO3-N	0.6		0.7	
Nitrite	NO3-N	<2.		<1.	
Sulfate	SO4	168		187	
Total Cyanide	CN	0.005		0.005	
		Dissolved	Total	Dissolved	Total
Aluminium	Al	0.04	3.4	<0.01	1.44
Antimony	Sb	<0.02	<0.02	<0.02	<0.02
Arsenic	As	<0.02	<0.02	<0.02	<0.02
Barium	Ba	0.190	0.240	0.169	0.194
Beryllium	Be	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	Bi	<0.02	<0.02	<0.02	<0.02
Cadmium	Cd	<0.0005	<0.0005	<0.0005	<0.0005
Calcium	Ca	74.6	76.2	76.0	72.4
Chromium	Cr	0.002	0.005	<0.001	0.003
Cobalt	Co	<0.001	0.002	<0.001	<0.001
Copper	Cu	0.031	0.157	0.007	0.038
Iron	Fe	1.07	4.09	0.009	1.71
Lead	Pb	<0.01	<0.01	<0.01	<0.01
Lithium	Li	<0.002	<0.002	<0.002	<0.002
Magnesium	Mg	19.0	19.4	17.0	17.6
Manganese	Mn	0.037	0.215	0.082	0.146
Mercury CVUV	Hg	–	<0.001	–	<0.001
Molybdenum	Mo	0.053	0.059	0.060	0.061
Nickel	Ni	0.003	0.004	<0.001	<0.001
Phosphorus	P	<0.06	0.13	<0.06	<0.06
Potassium	K	2.4	2.2	1.7	1.8
Selenium	Se	<0.02	<0.02	<0.02	<0.02
Silicon	Si	6.83	14.0	6.18	9.27
Silver	As	<0.001	<0.001	<0.001	<0.001
Sodium	Na	10.4	10.5	12.7	13.3
Strontium	Sr	0.79	0.79	0.74	0.75
Sulfur	S	51	54.2	51.1	51.6
Thorium	Th	<0.01	<0.01	<0.01	<0.01
Tin	Sn	<0.01	<0.01	<0.01	<0.01
Titanium	Ti	0.003	0.128	<0.001	0.004
Uranium	U	<0.07	<0.07	<0.07	0.07
Vanadium	V	0.004	0.011	0.003	0.007
Zinc	Zn	0.010	0.016	0.006	0.009
Zirconium	Zr	<0.001	0.002	<0.001	0.003

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APPENDIX 4

Detailed Estimate of Reclamation Costs and Salvage Values

CARMACKS COPPER

REVEGETATION COSTS

Facility & Land Use	Area (ha)	Item / Service	Cost ($/kg, $/ha)	Application Rate (kg/ha)	Cost
Waste Rock Dump Wildlife/Lodgepole	48	Streambank wheatgrass	$30.80	6	$8,870.40
		Slender wheatgrass	$3.85	6	$1,108.80
		Creeping red fescue	$1.21	2	$116.16
		Sheep fescue	$2.31	8	$887.04
		Alfalfa	$2.97	4	$570.24
		Canada bluegrass	$7.48	6	$2,154.24
		Monammonium Phosphate	$0.54	231	$6,020.78
		Ammonium Sulfate	$0.31	138	$2,033.57
		Mulch	$0.36	3300	$57,024.00
		Tackifier	$6.00	99	$28,512.00
		Hydroseeding	$800.00		$38,400.00
				Total Cost=	$145,697.23
Waste Rock Dump Wildlife/Whitespruce	33.1	Streambank wheatgrass	$30.80	6	$6,116.88
		Slender wheatgrass	$3.85	8	$1,019.48
		Creeping red fescue	$1.21	2	$80.10
		Sheep fescue	$2.31	4	$305.84
		Alfalfa	$2.97	2	$196.61
		Fowl bluegrass	$4.18	4	$553.43
		Kentucky bluegrass	$2.86	2	$189.33
		Alsike clover	$1.32	2	$87.38
		Monammonium Phosphate	$0.54	192	$3,450.87
		Ammonium Sulfate	$0.31	376	$3,820.80
		Mulch	$0.36	3300	$39,322.80
		Tackifier	$6.00	99	$19,661.40
		Hydroseeding	$800.00		$26,480.00
				Total Cost =	$101,284.94
Heap Leach Wildlife/Mixed	37.4	Streambank wheatgrass	$30.80	6	$6,911.52
		Slender wheatgrass	$3.85	6	$863.94
		Creeping red fescue	$1.21	4	$181.02
		Sheep fescue	$2.31	4	$345.58
		Fowl bluegrass	$4.18	6	$937.99
		Kentucky bluegrass	$2.86	2	$213.93
		Alsike clover	$1.32	2	$98.74
		Ammonia Sulfate	$0.31	301	$3,489.79
		Mulch	$0.36	3300	$44,431.20
		Tackifier	$6.00	99	$22,215.60
		Hydroseeding	$800.00		$29,920.00
				Total Cost =	$109,609.30

CARMACKS COPPER

REVEGETATION COSTS

Facility & Land Use	Area (ha)	Item / Service	Cost ($/kg, $/ha)	Application Rate (kg/ha)	Cost
Events Pond Wildlife/Mixed	2.4	Streambank wheatgrass	$30.80	6	$443.52
		Slender wheatgrass	$3.85	6	$55.44
		Creeping red fescue	$1.21	4	$11.62
		Sheep fescue	$2.31	4	$22.18
		Fowl bluegrass	$4.18	6	$60.19
		Kentucky bluegrass	$2.86	2	$13.73
		Alsike clover	$1.32	2	$6.34
		Ammonia Sulfate	$0.31	301	$223.94
		Mulch	$0.36	3300	$2,851.20
		Tackifier	$6.00	99	$1,425.60
		Hydroseeding	$800.00		$1,920.00
				Total Cost =	$7,033.75
Plant & Ancillary Wildlife/Mixed	3.6	Streambank wheatgrass	$30.80	6	$665.28
		Slender wheatgrass	$3.85	6	$83.16
		Creeping red fescue	$1.21	4	$17.42
		Sheep fescue	$2.31	4	$33.26
		Fowl bluegrass	$4.18	6	$90.29
		Kentucky bluegrass	$2.86	2	$20.59
		Alsike clover	$1.32	2	$9.50
		Ammonia Sulfate	$0.31	301	$335.92
		Mulch	$0.36	3300	$4,276.80
		Tackifier	$6.00	99	$2,138.40
		Hydroseeding	$800.00		$2,880.00
				Total Cost =	$10,550.63
Water Storage Pond Waterfowl/Riparian	14.3	Meadow foxtail	$5.85	3	$250.97
		Tufted hairgrass	$38.50	4	$2,202.20
		Reed canarygrass	$7.70	8	$880.88
		Fowl bluegrass	$4.18	8	$478.19
		Monammonium Phosphate	$0.54	192	$1,490.86
		Ammonium Sulfate	$0.31	138	$605.83
		Hydroseeding	$800.00		$11,440.00
				Total Cost =	$17,348.93

CARMACKS COPPER

REVEGETATION COSTS

Facility & Land Use	Area (ha)	Item / Service	Cost ($/kg, $/ha)	Application Rate (kg/ha)	Cost
Borrow Pit Wildlife/Blackspruce	2.5	Meadow foxtail	$5.85	5	$73.13
		Tufted hairgrass	$38.50	4	$385.00
		Reed canarygrass	$7.70	8	$154.00
		Timothy	$0.99	6	$14.85
		Monammonium Phosphate	$0.54	154	$209.06
		Urea	$0.42	137	$142.82
		Potash	$0.27	100	$67.50
		Mulch	$0.36	3300	$2,970.00
		Tackifier	$6.00	99	$1,485.00
		Hydroseeding	$800.00		$2,000.00
				Total Cost =	$7,501.35
Road/Powerline Wildlife	26	Streambank wheatgrass	$30.80	5	$4,004.00
		Slender wheatgrass	$3.85	8	$800.80
		Creeping red fescue	$1.21	8	$251.68
		Sheep fescue	$2.31	3	$180.18
		Alfalfa	$2.97	6	$463.32
		Canada bluegrass	$7.48	4	$777.92
		Monammonium Phosphate	$0.54	231	$3,261.26
		Urea	$0.42	163	$1,767.25
		Potash	$0.27	167	$1,172.34
		Mulch	$0.36	3300	$30,888.00
		Tackifier	$6.00	99	$15,444.00
		Hydroseeding	$800.00		$20,800.00
				Total Cost =	$79,810.74

CARMACKS COPPER
SITE PREPARATION COSTS

	x $1000
1) On-Site Reclamation Research Program and Annual Reclamation Reporting	
a) Materials	
test plots (seeds and fertilizer)	
(5-0.25 ha @ $800/ha)	1
plant propagation facilities	
(seed and cutting beds, greenhouse, equipment)	10
b) Manpower and Services	
consulting (10 years @ $10,000/yr)100	
soils testing and laboratory analyses7.5	
Subtotal	118.5
2) Open Pit and Associated Water Control Systems (~32.8 ha)	
a) Manpower and Services	
removal of pumping system (no resale value)	
(Contract Crew 2 days @ $3050/day)	6.1
Subtotal	6.1
3) Heap Leach Pad (~37.0 ha)	
a) Manpower and Services	
maintenance of neutralization system	
(2 years @ $100,000/year)	200
removal of pump and pipe system	
(Contract crew 3 days @ $3050/day)	9.15
recontouring leach pad	
(Contract crew @ $1233/ha)	46.2
deposition of till layer on leach pad	
(Contract crew @ $1850/ha)	69.2
Subtotal	324.5
4) Waste Rock Storage Area (~81.6 ha)	
a) Manpower and Services	
recontouring waste rock storage area	

(Contract Crew @ $1233/ha)	100
deposition of till layer	
(Contract Crew @ $1850/ha)	150
Subtotal	250

5) Plant and Ancillary Facilities (~3.57 ha)

a) Manpower and Services

drain and secure all fuel storage facilities	
(L.S. $ 5000)	5
special waste and hazardous waste disposal (all facilities)	
(L.S. Contract $10,000)	10
on-site refuse incineration and disposal (all facilities)	
(Contract Crew 30 days @ $3200/day)	96
breaking up foundations (all facilities)	
(Contract Crew 20 days @ $3200/day)	64
filling of septic tank	
(Contract Crew 1 day @ $3200/day)	3.2
equipment and facilities removal (no resale value)	1
scarifying and recontouring exploration camp area and roads	
(Contract Crew 3 days @ $3850/day)	11.6
Subtotal	190.8

6) Access Roads and Powerline Corridor (~26.0 ha)

a) Manpower and Services

removal of culverts and bridges	
(Contract Crew 3 day @ $3050/day)	9.15
removal of powerline and poles	
(Contract Crew 30 days @ $3050/day)	91.5
scarify and recontouring	
(Contract Crew 10 day @ $3850/day)	38.50
Subtotal	139.15

7) Events Pond (2.4 ha)

a) Manpower and Services

draining and liner preparation	0.6
deposition of till layer	
(Contract crew @ 1850/ha)	4.4
Subtotal	5.0

Total cost for Site Preparation 1,034

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SITE MAINTENANCE COSTS

	x $1000
1) Site Erosion Control (Camp, Mill, Conveyor, Crusher, Warehouse Complex, Access Roads, Overburden Stockpiles, etc.)	
a) Materials:	
Erosion mats where necessary (10 ha @ $25000/ha)	250
b) Manpower and Services	
Placement of erosion mats (Contract Crew 5 days @ $1200/day)	6
Subtotal	256
2) Post-Closure Reclamation Monitoring & Administration	
Manpower	
1 person with benefits for 2 years for $45,000/year	90
3) Maintenance of Research Facilities throughout mine life	100
4) Monitoring of benthos, water and vegetation following closure	300
5) Engineering costs	100
Total Cost for Site Maintenance	846

CARMACKS COPPER
SALVAGE VALUE OF EQUIPMENT FROM THE MINE SITE

It was determined in a Placer Dome Inc. reclamation costing study that the salvage value of equipment after dismantling, cleaning, hauling and auction sale was approximately 1% of the original capital cost. Based on this assumption, the following totals were estimated for salvage value:

	x $1000
dismantling SE/EW plant and laboratory facility (after salvage value) (1% of Equipment Capital Cost of $1 million)	(10)
dismantling explosives storage and handling facility (after salvage value) (1% of Equipment Capital Cost of $0.2 million)	(2)
dismantling conveyor line (after salvage value) (1% of Equipment Capital Cost of $5 million)	(50)
dismantling crusher facility (after salvage value) (1% of Equipment Capital Cost of $35 million)	(35)
dismantling mine maintenance-shops-offices complex (after salvage value) (1% of Equipment Capital Cost of $2.5 million)	(25)
dismantling fuel storage facilities (after salvage value) (L.S. $ 5000)	(5)
dismantling potable water systems (after salvage value) (L.S. $ 5000)	(5)
dismantling electrical substations (after salvage value) (1% of Equipment Capital Cost of $7.5 million)	(75)
dismantling electrical distribution system (after salvage value) (1% of Equipment Capital Cost of $1 million)	(10)
dismantling and removal of all housing units together with electrical and propane heating (camp resale value) (1% of Equipment Capital Cost of $3 million)	(30)
Subtotal	(247)

APPENDIX 5

Design Specifics for Perimeter Fencing and Waterfowl Protection Netting

PERIMETER FENCING

The Contractor shall supply all labour, Plant and materials necessary to install the perimeter fences as shown on the Drawings, or required by the Engineer. The perimeter fence shall, unless otherwise specified, conform to the standards of the State of Nevada, Department of Wildlife.

1. Posts

Posts for corner panels and gate panels shall be galvanized, standard weight steel pipe conforming to the requirements of the current Standard Specification for Black and Hot-Dipped Zinc (Galvanized), Welded Seamless Steel Pipe for Ordinary Uses, ASTM A120, except that the hydrostatic test will not be required.

At the Contractor's option, pipe posts conforming to the requirements of AASHTO M181, Grade 2, may be substituted.

Posts and braces shall conform to the following requirements:

Location	Min. Size (inches)	Min. Weight (lbs/ft)
End, Corner and Pull	2.375 O.D.	3.65
Braces	1.660 O.D.	2.27
Line	1.900 O.D.	2.72
Gate - Single to 6 ft or Double to 12 ft	2.375 O.D.	3.65
Gate - Single over 6 ft or Double to 12 ft	4.000 O.D.	9.11

Brace wire shall be eight (8) gauge medium temper, with minimum 55000 psi tensile strength, and shall be galvanized in accordance with the requirements of ASTM A121.

Line posts shall be standard "T" type posts.

2. Gates

Vehicle gate frames shall be two sections 10 ft wide and of the height of the adjacent fence and shall be constructed of not less than one and one-half ($1^1/_2$) inch galvanized standard weight pipe conforming to the dimensions, nominal weights and galvanizing specified in the current ASTM A53 requirements (hydrostatic test not required). Gate frames shall be cross-trimmed with galvanized three-eighth (3/8) inch adjustable truss rods.

The corners of the gate frames shall be fastened together and reinforced with malleable iron fittings designed for the purpose of welding.

Fence fabric as specified for the fence shall be attached to the gate frame by use of stretcher bars and tie wires as specified for fence construction and suitable tension connectors, spaced at approximately one (1) ft intervals.

Walk gates shall be three and one-half ($3^1/_2$) ft wide and of the height corresponding to the adjacent fence. The gate frame shall be constructed of not less than three-fourth (3/4) inch galvanized standard weight pipe conforming to the dimensions, nominal weights and galvanizing specified under current ASTM A53 requirements (hydrostatic test will not be required).

3. Fence Material

The fence material shall be woven wire fabric. The fence shall be 8 ft in height. The bottom 4 feet of fabric shall have a mesh with 2-inch vertical spacing of wire on the bottom 2 feet and a maximum of 4 inch vertical spacing of the top 2 feet. The top 4 feet of fabric shall have a maximum vertical spacing of 4 inches.

The bottom four ft of the fence shall be rodent proof, and the Contractor shall advise the Engineer of the method he proposes to use to achieve this.

The gate frame shall be filled with fabric meeting the requirements for fabric as specified herein.

All gates shall be furnished complete with approved hinges, latches, drop rod, and auxiliary braces as required. The gate hinge shall permit the gate to swing 180 degrees.

4. Installation

Posts shall be placed on maximum 12-ft centers and shall be placed in a vertical position except in unusual locations where, in the opinion of the Engineer, it would be more satisfactory to place the post perpendicular to the slope of the ground.

All lane posts shall be of a total length of not less than the depth of 1 ft 6 inches below ground, plus the 8 ft above ground. Corner and gate brace panel posts shall be not less than 2 ft 6 inches below ground and 8 ft above ground and set in concrete.

Changes in line where the angle of deflection is thirty (30) degrees or more shall be considered as corners and corner posts shall be installed.

End, corner and gate posts shall be braced with galvanized braces used as compression members and galvanized steel truss rods with truss tighteners used as tension members. Line posts, at intervals of five hundred (500) ft shall be braced and trussed in both directions.

The fabric shall be stretched taut and securely fastened to the posts at 12-inch intervals. The top and bottom fabrics shall be fastened together with ties at a minimum of 18-inch intervals.

The bottom of the woven wire fabric shall be placed tight to the ground to prevent animals from securing access under the fence. The Contractor shall level the ground to remove mounds or depressions under the fence.

WATERFOWL PROTECTION NETTING

1. Netting

The netting shall be of medium weight (approximately 6 lbs per 1000 sq ft), fabricated from a single strand polypropylene with UV stabilizers, Wildlife Control Technology No. OB2651 or as approved by the Engineer. Netting roll width is to be 17 ft with approximate grid opening size of 1-$^5/_8$" by 1-$^5/_8$".

2. Cable

The support cables are to be 3/16", 7x19 strand, coated aircraft cable. The approximate breaking strength of the 3/16" cable is to be 4200 lbs.

The setting overlap is to be a minimum of twelve (12) inches and is to be laced together with hog rings on a staggered, six (6) inch spacing.

3. Anchors

The cable support anchors are to be constructed with 4000 psi concrete with all reinforcing materials (including attachment loops) to be fabricated from grade 60 steel. The net anchor rods are to be grade 60 deformed, reinforcing steel supplied to the length as shown on the Drawings.

4. Turnbuckles

The turnbuckles shall be 5/8" x 12" and 1/2" x 12" and meet or exceed federal specification FF-t- 79 lb, Type 1, Form 1. Turn buckles are to be Supabuckle manufactured or as approved by the Engineer.

5. Accessories

Accessories such as cable, clips, sleeves, hog rings and zip ties shall be manufacturers standard. Any zip ties used shall be manufactured from a black, UV stable polypropylene material..

6. Installation

Installation of the netting shall proceed continuously from one end of the pond to the other. The initial support cable shall line up approximately parallel with the edge of the pond liner, however, prior to permanently setting the anchors, the location of all anchors shall be laid out and checked and approved by the Engineer to ensure the complete assembly is reasonably square and interferences with existing installations are avoided. Where interferences with existing installations are encountered, the spacing of the support anchors may need to be adjusted to a lesser width.