A PRELIMINARY APPRAISAL

of the

SURFICIAL GEOLOGY

of the

MT. MILLIGAN MINE SITE

with

SPECIAL REFERENCE

to

TAILINGS IMPOUNDMENT AREA "C"

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for

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SUMMARY

An overview surficial geological map (Scale 1:12,500) of the proposed Site "C" Tailings Impoundment Area, located within the watershed of Limestone Creek valley, has been drawn up. Drill hole and test pit data of the 1990 and 1991 geotechnical reconnaissance programs have been used as the ground truth control points for the photo-geological delineation of the geologic units. Morainal, glacio-fluvial, and subsurface glacio-lacustrine features dominate the Pleistocene geology of the area. The former are found on all topographic domains: ridge top, valley slope, and valley bottom; while the latter two are much more predominant on the lower valley slope and valley bottom domains. Fluvial deposits of the fan and flood plain facies are prevalent on valley bottoms, while colluvial deposits in the form of apron, fan, or nondescript blanket/veneers are found on the valley slope domain.

The stratigraphic assemblage of geologic units is surprisingly complex, featuring about three different successions of glacial advances and recessions—each with morainal, glacio-fluvial, and glacial lake units. Some of the latter two are a product of the proglacial environment, while others are developed during only the stages of ice recession.

Limestone Valley is a fault offsetted open ended drainage basin with: a downstream exit to the Rainbow system, a mid reach "through" corridor which no longer carries discharge water but also connects to the Rainbow, and a headwater low divide which at one time during deglaciation spilled water in the reverse direction into other tributaries of the Nation River. The balance of this basin is enclosed in valley walls of bedrock covered by a more or less uniform layer of till on upper slopes and a thicker complex of surficial geologic units on the lower slopes and valley floor. So, construction of an impoundment is much simplified in this type of topographic/geologic catchment, with only the three exits noted above needing engineering structures to achieve confinement of tailings waste.

For the Main Embankment area, or downstream structure, the surficial geology reveals a coarse till, overlain erratically by glacio-fluvial sands and gravel and colluvium, and underlain by a silty to clay-rich till. Towards the valley floors the underlying geology increases in complexity with the presence of one or two subsurface till layers separated by "over" consolidated thick sequences of glacial lake silts. Immediately under and above the subsurface till layers there are also sand and gravel horizons which are discontinuous. Under the flood plain, which appears to be relatively thin at this location, the two main glacial lake units are separated by a thick, and apparently continuous, layer of sand and gravel which is probably confined by impervious strata throughout the length of the valley floor.

For the mid reach South Embankment area, the valley wall surficial geology is of glacial till covered by a layer of colluvium. On the valley floor, however, there are two layers of till, separated by a pervious buried channel of sand and gravel. A thin glacio-fluvial fan gravel also overlies the upper till; it apparently spilled northward into a glacial lake in Limestone Valley. Recent flood plain deposits superposed on the above succession show a "misfit" valley, indicating that it was once used for copious discharge during deglaciation and perhaps at some older pre-glacial interval.

Between the above noted two embankment areas, a lower swale on the rolling ridge top, marked by Heather Lake, was once a major broad but shallow overflow channel in use during an earlier stage of deglaciation, while stagnating ice lay in Limestone Valley. However, the "spillway" for this channel is of bedrock overlain by till—the channel gravels are downstream of it to the south of Heather Lake.

Upstream of the South Embankment area, the ridges are much higher, and steeper north facing slopes are of till and/or colluvium overlying bedrock. The latter is a coarse blocky material lying along the slopes rising above Limestone Lake. South facing slopes, however, are fronted by a long dissected kame terrace which is blanketed by glacial lake silts. This terrace probably overlies glacial till, but more drilling is needed to define its subsurface characteristics. The valley head (Limestone Lake) is underlain by extensive hummocky glacio-fluvial deposits that also appear to overlie glacial till.

The array of surficial deposits ensures an adequate supply of granular and core materials to construct dams and roads and the terrain is fairly stable at present. However, organic-rich silts of the floodplain and under-consolidated glacial lake sediments are compressible; steeper hillsides of till are potentially prone to debris flow instabilities if stripped of vegetation; groundwater seepage is to be expected at porous zones in rising escarpments of surficial deposits, or at the contact of such deposits to either underlying bedrock, or overlying organic cover; and porous surficial sands and gravels locally occur on the abutments of most embankment structures. Some can be easily removed, while those that underlie the uppermost till will likely have to be left in place.

Drilling has ascertained the millsite to be on a thin layer of glacial till, overlying weathered volcanic bedrock. Removal of the latter would ensure a stable foundation. The conveyor belt corridor which connects to this site extends across a broad till plain, after crossing Rainbow Creek valley on a series of granular fluvial and glacio-fluvial terraces. The corridor is stable.

Further work on the Site C project includes the following suggested tasks:

- drill an infilling set of drill holes along and across the axis of the Main Embankment to confirm the subsurface geology;

- carry out a series of check drill holes along the entire length of the valley being dammed by the South Embankment;

- conduct a detailed drilling and other exploration program on the upstream retention dam sites; data to date is insufficient to make predictions on the subsurface geologic characteristics of upper Limestone Valley;

- define aggregate deposits needed to construct the various works; and

- as roads are constructed into Limestone Valley, carry out surficial geologic mapping to correct the deficiencies that will appear on the Site "C" maps.

As for comparing Site "C" to Site "A" the former is a relatively enclosed system with only complex geology to contend with at three localized areas. Slopes may not be as stable in this area, as far as slides and sloughs are concerned, but the latter is plagued with lengthy inset valleys which have demonstrated porous strata that could easily discharge fluids into Rainbow Creek unless expensive blanket sealing procedures are undertaken.

1.0 INTRODUCTION

1.1 Background and Purpose of Project

Surficial geologic mapping was recently completed for the main mine site and adjacent eastern till plains of the Mt. Milligan project area. The main objective then was to evaluate a proposed tailings impoundment which would have been enclosed by the following: "Esker Lakes" to the north and east, "Meadow Creek" to the southwest, "King Richard Creek", to the southwest, and the two open pit mine areas to the west. While proximity to the mine area made such a tailings impoundment location desirable, it was discovered that the incised creek waterways had exposed potential porous horizons situated below a capping silty till plain which could possibly connect to nearby Rainbow Creek, and thence flow into the Nation River. Consequently it was decided to have a second look at an alternate tailings site in adjacent Limestone Creek valley which lies about 8 km to the northeast of the main mine site area. Initial plans called for the piping of tailings to this impoundment site, but recently a new plan, which looks very favourable, has relocated the main processing mill on a broad ridge (el 1090 m at mill site) which would directly overlook the main embankment of the tailings pond. A conveyor belt would carry mined out ore directly overland to this new mill site.

Limestone Valley is within an enclosed bedrock basin; however, its upstream boundary terminates in a rather low elevated hummocky divide to two other unnamed tributaries of the Nation River system. Furthermore, the southwest or true left bank of Limestone Valley is breached at one point by an "ancient" valley which at one time connected directly, in a short cut route, to Rainbow Creek valley. So, at these two mid and upstream areas, secondary embankments will also be required to develop an enclosed valley which would confine the tailings pondage to only Limestone Valley.

In 1990, Knight and Piésold carried out some preliminary geotechnical investigations in Limestone Creek valley, but no surficial geological mapping of the basin was undertaken. Provincial government geologists, however, did carry out some re-mapping at the 1:50,000 scale in the same field season and have recently released the map. It shows only a slightly modified picture of the surficial geology compiled in previous government surveys during the late 1970's. Drill hole and test pit data were not available for the compilation of either map, although the later survey did have the benefit of some new road cuts to provide much needed ground truth data.

For this project the mapping is at a scale of four-fold finer (1:12,500), and the scale was supported by the use of new 1:20,000 scale aerial photos for geomorphic analysis and the 1990 drill hole and test pit data. A "flood" of new data comprised of test pitting, geotechnical drilling, and some "condemnation" drilling, was received during map preparation to provide more ground truth. From such came the need to re-compile the geology of the main embankment area at a yet finer scale of 1:5,000. Not to undergo less scrutiny, however, were the following areas: the new mill site, a "saddle embankment" on a swale in the ridge crest which is located at adjacent 10 metre deep Heather Lake, the south embankment on the abandoned valley connection to Rainbow Creek valley, and a water "retention" dam to be built near the west end of Limestone Lake. The latter will allow the Limestone Lake area to remain as a source of water, rather than become part of the tailings pondage. As an adjunct to the project, the geology of the conveyor belt corridor was also quickly scanned on a reconnaissance plotting scale of 1:25,000. No field work has been performed on this route, and thus the map should be regarded as "quasi-preliminary".

1.2 Location

Tailings pondage area "C" is located on a first order tributary, locally known as "Limestone Creek", in the Rainbow Valley of the Nation River system. The latter empties into Williston Reservoir, about 35 kilometres to the northeast. The Nation River is also the approximate demarcation between the crystalline rocks of the Omineca Mountains to the north and the volcanics of the Manson Plateau (new physiographic nomenclature) to the south, in which the Mt. Milligan project is situated. The layered sedimentary strata of the northern Canadian Rockies lie to the eastward of the Williston Lake Reservoir, and the latter overlies the linear faults and younger rocks of the Rocky Mountain Trench. The present day access is from the east, off Highway 97, which is provided by forestry access roads. The District Municipality of Mackenzie, a pulp mill centre, (35 km to the NE) is the nearest source of supplies, but new road construction will enable the mine site to be connected to Fort St. James, some 50 km to the south southwest. Prince George, the central focal point to both of those regional centres, lies 100 kilometres to the south southeast of the mine site.

1.3 Local Topography and Geology

Limestone Creek valley lies within and parallel to a series of northwest trending rolling ridges which nearly reach elevation 1400 metres to the north of its headwaters at Limestone Lake. Elevations are lower on the ridges lying southwest of the valley, reaching about 1250 metres. On both sides of the valley elevations diminish to the northwest. At the main embankment and plant site, the maximum elevation is about 1090 metres on the south and 1150 metres on the north, and the local relief from ridge crest to valley floor is only 110-160 metres. The gradient of the valley floor between the proposed site of the Main Embankment and Limestone Lake (elevation 1020 metres) is a low profile of 0.63%. An anomalous feature in the topography is the rhomboid arrangement of the main valleys. The principal northwest trending pattern is "offset" by a secondary east northeast trending pattern which may represent an underlying intersecting system of faults. The drilling in valley floor locations has encountered fault gouge at some sites to add some support to this hypothesis.

The underlying bedrock geology is imperfectly known because the outcrop exposure is very sparse. Using the 1:12,500 scale surficial geology map as a guide, it would appear that the most extensive exposures are on the slopes rising above both sides of Limestone Lake. According to Tipper et al (1979) the south side of the lower valley is underlain by Upper Triassic-Lower Jurassic aged Takla Group volcanics. However, at the south embankment area an intrusive gabbro stock (?) has been found in the drilling. The northeast side of the lower, and both sides of the upper valley are underlain by older Upper Paleozoic-aged volcanics, their greenstone equivalents, and associated shale/argillites and limestones. Faulted "up" into the latter sequence are blocks and slices of granitoid gneisses, schists, amphibolites, and quartzites of the Wolverine Complex. The latter reached a final stage of metamorphism in mid-Tertiary time; the initial age of petrogenic evolution has yet to be sorted out.

The Wolverine Complex, however, is the typical assemblage which underlies the Omineca Mountains, but it definitely extends to some parts of the Manson Plateau, and further drilling will give a better picture of its area of near surface exposure (without overlying cover rocks). Geotechnically, the unit is likely to be the most stable; it might be the major sandy to granular component of the glacial tills encountered in the exploration drilling, whereas the Takla Group is more likely to be the main contributor to the silty and clayey tills that were sampled in shallow test pitting programs.

1.4 Geological Work in the Project Area

The first bedrock geology compilation of the area was undertaken by Muller (1961), but the Geological Survey of Canada and British Columbia Geological Survey Branch have carried out finer scale updates in the area. Surficial geologic mapping was carried out in the mid 1970's by the Resource Analysis Branch (or their ELUC forerunners) at a scale of 1:50,000, but lack of roads in map-area NTS 930/4, at the time, confined the mapping operations to brief aerial reconnaissances which were fortified by much photo interpretation. Since then, the logging road networks have advanced into the area, and the geologists of the B.C. Geological Survey Branch have used Mt. Milligan camp facilities as a base to recompile the surficial geology, as exposed in numerous road cuts, onto a special map which covers the west half of NTS 930/4 and neighbouring east half of NTS 93N/1, and at a scale of 1:50,000. Neither map, however, has the benefit of subsurface drill results or much test pit examination, which was the focus of the 1990 operations carried out by a large portion of the staff of Knight and Piésold Consulting Engineers. This consulting group have been retained by Placer Dome Inc. to carry out a Stage III follow-up field program that was carried out in the winter months of 1991. While much more subsurface definition of the geology has come about from these two excellently run programs, spring break up will cause a delay in implementing a final feasibility study which will be needed to firm up the engineering and environmental requirements to design an efficiently built and safety monitored tailings impoundment.

1.5 Acknowledgement

The writer is indebted to the Placer Dome project development staff, especially Mr. Ross Banner, for the immediate launching of the project once it became clear that the other tailings impoundment project was not suitable. The unrelenting forwarding of new data provided by Knight and Piésold Consulting Engineers has ensured a more accurate map, keeping the compiler busy with modifications with each daily release of data. The drafting and secretarial services provided by Pro Map and Jean Martin, respectively, have ensured delivery of the maps and report at a very busy fiscal year end time. Errors, omissions or delays are the sole responsibility of the author, who was working against such constraints.

2.0 METHODOLOGY AND MATERIALS

2.1 Materials

One 1:12,500 scale map of the entire reservoir area and one 1:5,000 scale map of the main embankment, both with 10 metre contour intervals and provided by Knight and Piésold Consulting Engineers, are the plotting base for the surficial geology. A 1:25,000 scale overview map was used as the plotting base for the geology of the conveyor belt route. Recent air photos used for the geological interpretation are of two scales; three lines of 1:30,000 scale photos (flown 11 July 1990) were reviewed to outline the major geologic units, while five lines of 1:20,000 scale photos (flown 21 July 1990) were analyzed in a more thorough fashion to provide the geologic boundaries shown on the base map. No plotting instruments were used to transfer the lines because there was generally sufficient detail shown on the maps to allow replotting by "dead reckoning". For viewing of the photos a Wild STD4 mirror-reflecting stereoscope with three power magnification oculars was used. Point data in the form of drill and test pit logs, all supplied by Knight and Piésold as previously noted, were transcribed to the working draft maps, but for the sake of elimination of excess clutter were removed from the 1:12,500 and 1:25,000 scale maps. All told, there are 65 test pits, 30 geotechnical bore holes, and a few "condemnation" drill holes that were used to verify the geologic mapping.

The surficial geologic legend shown on the project maps is that currently in use by the provincial government (Howes and Kenk, 1988). It is spelled out in MOE Manual No. 10

(4th edition) which is now used by the geologists of the provincial Ministry of Energy, Mines and Petroleum Resources. The description of the surficial geology in the text that follows is organized according to the definition of geologic units in the provincial terrain classification system.

2.2 Methodology

The usual geologic methods were employed, making deviations to overcome the lack of field observations by the map compiler, as described in the following sequence of tasks:

(1) gather geologic data and review reports;

(2) procure suitable base maps, and build a legend onto them;

(3) obtain and interpret aerial photographs, marking units directly on the photo;

(4) transfer air photo geology to base maps;

(5) plot ground truth data onto the maps;

(6) re-adjust geologic boundaries on the maps to agree with the ground truth (this often required re-examination of the aerial photos);

(7) standardize the map format;

(8) send pencil draft maps out to drafting;

(9) edit the drafting on a check print;

(10) re-draft and final print;

(11) review findings with Placer Dome and project consultants; and

(12) prepare report.

Because the data arrived in "bits and pieces" on an almost daily delivery schedule, steps 5 to 7 were repeated several times, while steps 8 to 10 were repeated twice. Thus the "fast tracking" of the project generated some inefficiencies. Undoubtedly review of the work with Mr. D. Kerr, the provincial geologist who is currently working the area, would also have been of assistance, but for the sake of expediency, this step was omitted.

3.0 MAP UNITS - THEIR DISTRIBUTION AND CHARACTERISTICS

The description of the geologic units defined in the "Terrain Classification System for British Columbia" have already been outlined in the author's previous report. For the uninitiated, pages 14-16, (including Figures 2 and 3), should be reviewed in that report. In order to follow the text of this report it is assumed that readers will have the accompanying 1:12,500 scale surficial geological map on hand for reference.

3.1 Morainal (Glacial) Deposits (Map Code "M")

Ground moraine, or glacial till, is highly variable in texture within the proposed impoundment area. Normally there is a coarse textured (sandy to gravelly) facies in the upper few metres which blends into a siltier or even clay-rich matrixed unit at depth. This is interpreted to be an "ablation moraine" overlying a more dense and tighter basal till. Both are a product of the latest glacial episode; the basal till is deposited beneath the ice while the ablation till represents "fallout" of particles within the ice. In some drill or test pit logs one or the other component may be missing, and on the floor of Limestone Creek valley itself the drill logs appear to indicate the post glacial erosional removal of both facies (Figure 1).

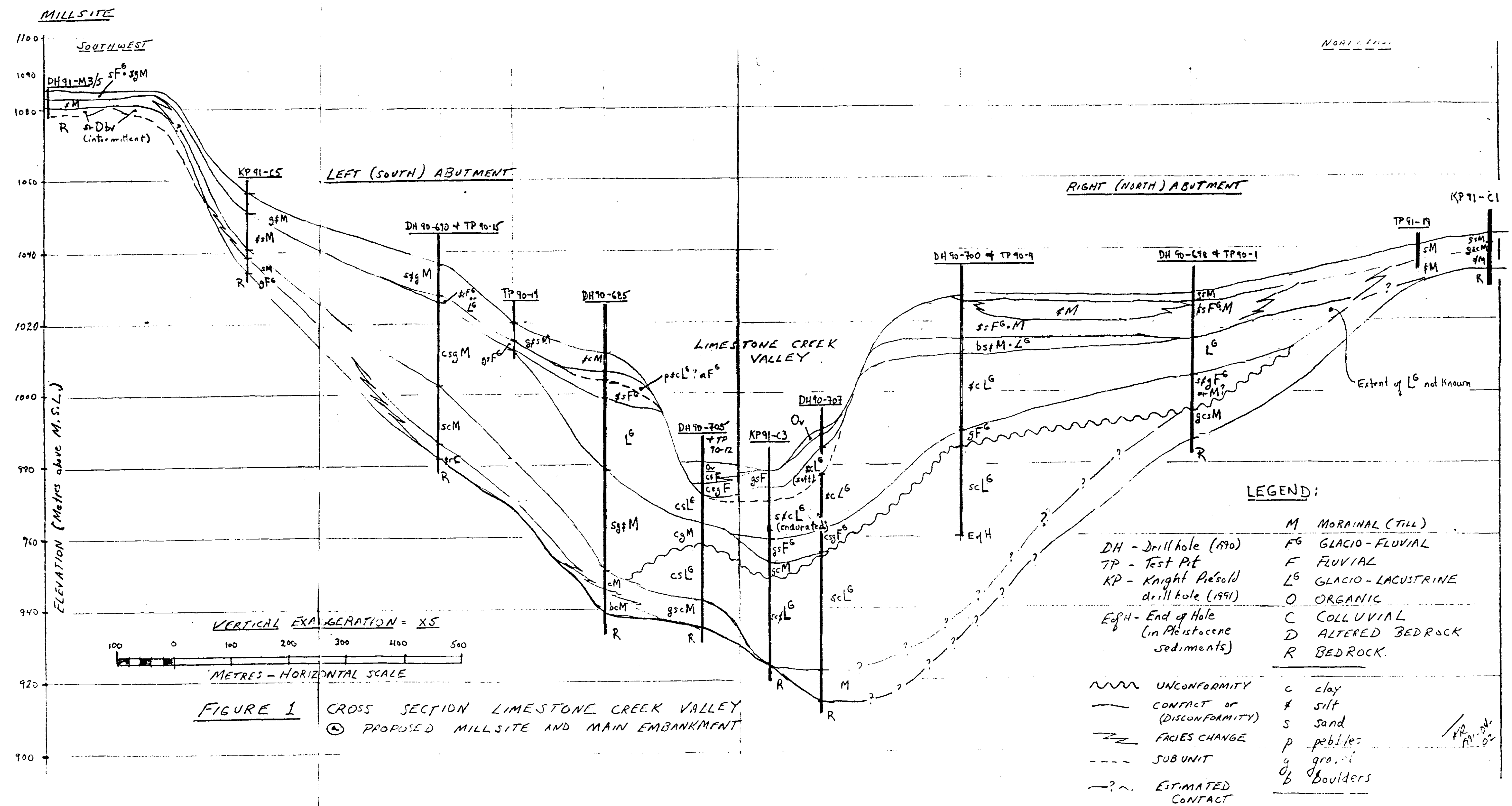

FIGURE 1 CROSS SECTION LIMESTONE CREEK VALLEY @ PROPOSED MILLSITE AND MAIN EMBANKMENT

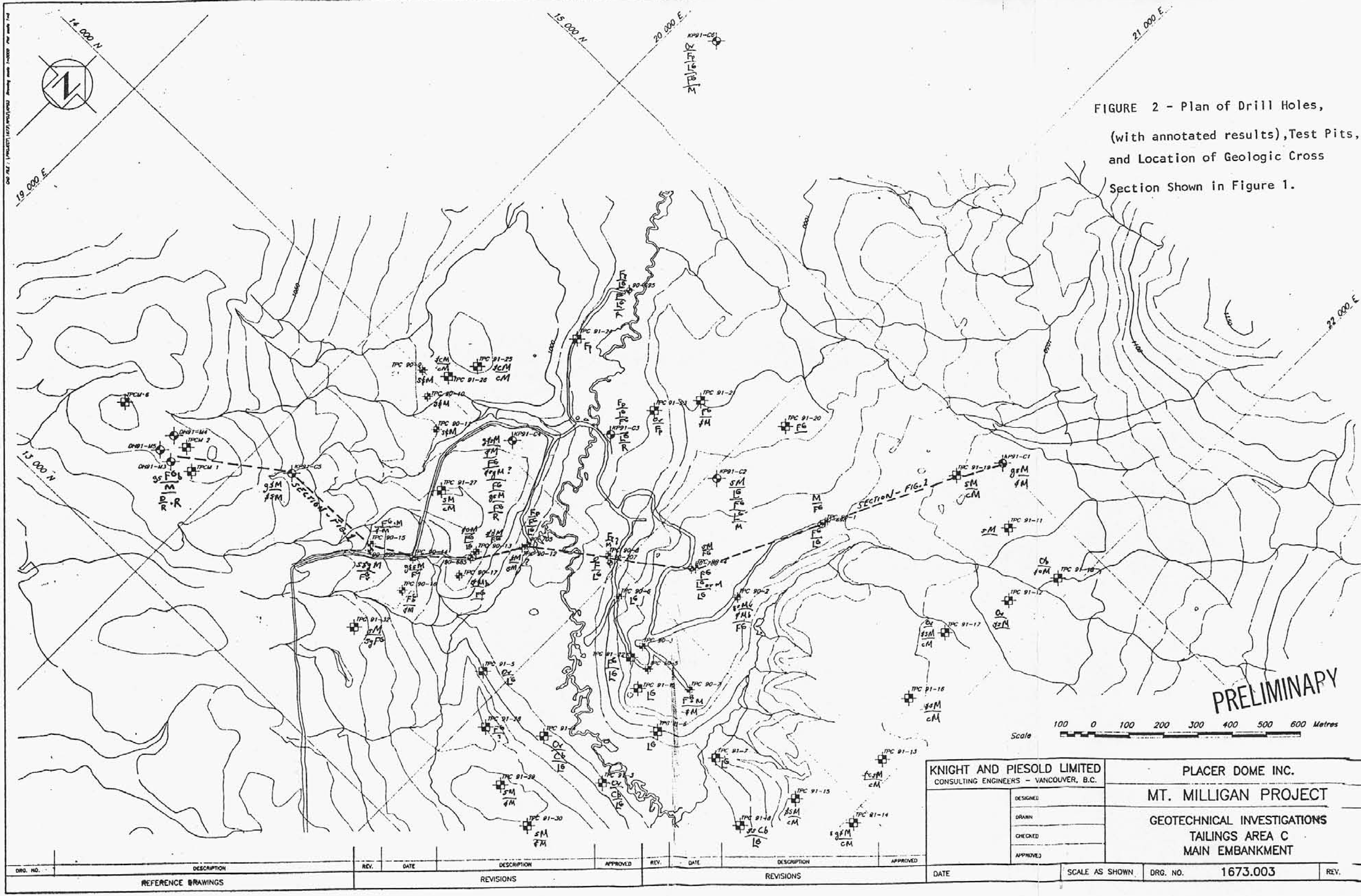

FIGURE 2 - Plan of Drill Holes, (with annotated results), Test Pits, and Location of Geologic Cross Section Shown in Figure 1.

The thickness of the upper (most recent) glacial till is highly variable but tends to be thinner on ridge tops, thickening down slope, until its abrupt disappearance occurs on the valley floor. It should be noted, however, that the "abandoned" valley (South Embankment) connection to Rainbow Creek valley appears to have this till layer, although it is covered by slightly younger outwash fan gravels. The following are typical thicknesses of the upper till sequence encountered in test pits and drill holes:

ridge crest	- 1 to 13 metres
upper slopes	- 8 to 16 metres
lower slopes	- 6 to 8 metres
valley floor (where present)	- 4.5 to 19.0 metres.

The drill logs also indicate an "intermediate" till at depth, and an older basal till which lies on bedrock, or on colluvium which covers the bedrock. The intermediate till is best described as gravelly, with a predominant clay matrix, and is only found on the south side of the valley and under the valley floor in a thinner partially eroded-out unit (Figure 1). Hence thicknesses are variable, reaching up to almost 30 metres. The basal or lowermost till occurs on both valley walls and is a sandy-silty matrixed unit of two to eight metres in thickness. At DH 90-685 it may be thicker by virtue of the accumulation of a basal bouldery facies at the toe of the valley wall, as existed during that older glacial episode.

All facies of till (ablation, basal, etc.) appear to be impervious where tested. Permeability of sandy gravelly tills varies from 1×10^{-4} to 7×10^{-8} cm/sec for those tested in the drill holes, and silty-clayey tills show slightly tighter values over the range of samples tested. It is cautioned, however, that the upper zones of the ablation tills have not been tested (shallow portion of the drill holes), and that increased permeabilities of an erratic nature are to be expected. Laboratory tests on samples taken in test pits and road cuts, however, show yet lower permeabilities of 2 to 4 x 10^{-8} cm/sec for sandy tills and 9 x 10^{-9} to 10^{-10} cm/sec for silty clay tills (all values reported in Knight and Piésold's Phase 2 report for Tailings Impoundment "C"). Other properties of the tills (moisture content, Atterberg Limits, specific gravity, grain size distribution, resistance to penetration) are also recorded in that report.

The land form variation shown by the surface (youngest) tills is quite variable. Along the conveyor belt corridor, between the Rainbow Creek valley wall escarpment and the relocated plant site, the till is on a very smooth plain (Mbp). The plant site area and rolling ridge crests to the southeast show a veneer to blanket (Mv, Mb) of till plastered over hummocky bedrock (Rh). Farther to the southeast the broad ridge crests show parallel drumlinoid features which are aligned on a northeasterly axis. These landforms, which nicely show the direction of ice sheet movement, are probably made up of a thin layer of till (Mbv) plastered over the streamlined bedrock shaped land forms (Rm and Rhm). Within the confines of Limestone Valley, the lower benches near the main embankment are made up of a complex of Pleistocene-aged sediments of which the capping horizon is of relatively smooth ablation moraine at the site of the main embankment, but apparently siltier tills (including "flow tills") on the bench upstream of it on the true right bank (as represented by the line of test pits TPC 91-12 to 91-18). Farther upslope, and upstream, the till blanket is incised by numerous meltwater channels. At the east end of Limestone Lake and ablation till (Mbh -HE) is intermixed with pitted and ridged glacio-fluvial landforms (F^{G}h-HE) deposited around a few distinctive rock hummocks (plastered with till), but again the terrain is much modified by the scouring action of silt ladened meltwater discharge. Surprisingly, a condemnation drill hole in this area uncovered about 6 to 12m of basal till underlying a 6 metre cap of bouldery gravels.

3.2 Glacio-fluvial Deposits (Map Code - "F^{G}")

Meltwater discharge in the presence of downwasting and decaying ice is manifested by two principal types of landforms: erosional features, and features of sediment constructed by particles carried in running water in the presence of ice. Dealing with the former first, the mapping reveals an upland series of narrow sinuous channels etched into glacial till and underlying bedrock. On the north side of Limestone Valley, the overall trend shows meltwater flow to the southeast; that is, contrary to present day drainage direction. On the lower ridges to southwest of Limestone Valley, meltwater discharge was initially directly over the ridge and into Rainbow Creek valley. Broad (400-700m), shallow channels beginning at Heather Lake mark the scouring of the existing till plain, leaving 5 metre and thicker outwash "valley train" deposits on these now oversized channel areas. With further downwasting of ice in Limestone Valley to levels below ridge crest elevations, it would appear that the residual ice divide lay just north of the proposed South Embankment area. That is, there was copious discharge through the valley of the South

Embankment towards Rainbow Valley (with additions of water from flanking tributary valleys) and discharge towards Limestone Lake, and the opposing direction toward the Main Embankment down valley.

At this point in the de-glacial cycle the development of "constructional" glacio-fluvial landforms began. At the Main Embankment area a more or less uniform blanket of sand and gravel outwash was deposited over the till, but on the downstream side of the axis for the proposed structure, the surface deposit is pitted with a few kettle depressions on the right bank. Thicknesses are in the 3 to 5 metre range, but a few test pits and holes show an absence or a thin veneer, while two drill holes on the right bank indicate a mixture of glacio-fluvial and ablation moraine deposits which approach 12 metre thicknesses.

At the South Embankment area, a large glacio-fluvial fan "debouches" from a tributary valley on the southeast side into the main channel floor. The opposing valley wall has a smaller fan developed from upland runoff. Southwest of both fans a large shallow lake appears to be the product of kettle development on a valley fill of outwash and buried ice. Curiously, the dense transect of drill holes to the northeast of this feature, but collared on the forementioned large fan, appear to have intersected surficial glacial till rather than glacio-fluvial deposits in some cases, but in turn this layer (till) overlies a very thick sand and gravel sequence which may or may not have drainage communication to the large kettle deposit to the southwest. A line of check holes on the central axis of this abandoned valley, beginning at Limestone Creek and terminating at Rainbow Creek, a distance of five kilometres, should be drilled to establish the subsurface drainage hydrogeology of this system. The spacing of the holes should be set so that the geological units can be predicted from one hole to the next. If a probe comes up with an unexpected result there is a requirement to drill one or two intervening holes to establish the exact location of the geologic change.

Upstream of the South Embankment area, but west of Limestone Lake, one or two "retention" dams are to be built onto (or into) a kame terrace which appears to be blanketed by glacial lake silts. The terrace, which is bisected by a deep erosional gully running parallel to Limestone Creek, is located on the true right bank, and has a length of 2.6 kilometres and a mean width of about 400 metres. The height is 30 to 40 metres above the existing valley floor, although the northeast end is stepped at two lower levels. Building a dam against and over this feature will obviously require much more drilling to elucidate the apparent composite geologic makeup of this feature. The one drill hole to date (KP91-WSD1) suggests the following sequence (from the top down): 9.5m glacio-lacustrine silts (cap of terrace), 1.2m glacio-fluvial gravel, 3.0m glacio-lacustrine (?) silts, 23.2m glacio-fluvial silty sands with a basal 1.8m basal gravelly facies, 10.0m glacio-fluvial silty sands and either a thin basal till or colluvium at the base which overlies bedrock. The author of this report would be surprised if the entire length of the terrace maintained such a stratigraphy, and indeed a valley wall drill hole nearby (KP91-WSD3), implies that a glacial till could overlie the uppermost glacio-lacustrine unit, but for the time being it is considered to be an intermittently present sub till unit.

Finally, the best display of glacio-fluvial deposits is found at the southeast end of Limestone Lake. A kame terrace deposit on both valley walls is gradually submerged into the lake with an islet marking its approximate terminus. The feature is kettled and intermingled with ablation moraine. The only recognizable esker, 600 metres in length, lies on its surface, indicating meltwater flow to the east. The thickness of this complex deposit is quite variable, but a minimal 6 metres is indicated by the one condemnation drill hole which was collared on the main valley floor; terraces rise up to 30 to 40 metres above this drillsite on adjacent valley walls.

So far there have been no borehole tests on the permeability of the youngest (uppermost)glacio-fluvial deposits. Lab tests on a few samples taken in road cuts and shallow pits show permeabilities of 4×10^{-5} (uniform sand) to 6×10^{-7} cm/sec (silty sands and gravels). Obviously much testing will have to be carried out on the kame terrace and on the surficial outwash at the Main Embankment. As for the buried channels of possible glacio-fluvial origin, several tests at the South and Main Embankments yield a range of permeabilities of 3.5×10^{-3} (decidedly porous) to 8.8×10^{-8} cm/sec.

3.3 Fluvial Deposits (Map Code - "F")

Flood plains of channel gravels and overbank silts, generally covered by organic deposits, are of a low surface gradient (<1%), and hence the active portions are very irregularly sinuous in plan. The flood plain of Limestone Valley as a whole is 100 to 300 metres wide, downstream of the South Embankment area, but towards Limestone Lake the widths are only 50 to 100 metres. At several tributary junctions there are small fans, probably of a silt dominated texture, but nearly conspicuous by their absence are only a few and low valley wall terraces. The lack of the latter simplifies dam construction. The thickness of flood plain deposits has been determined at the Main Embankment and Water Retention dam sites: 4.0 to 6.0 metres at the former and 12.7 metres at the latter. The underlying strata are glacial lake silts and schistose bedrock respectively, while at the South Embankment the modern flood plain is all but lacking, but underlain by fluvial glacial fan deposits or till where recognizable.

3.4 Lacustrine Deposits - (Map Code - "L")

Shallow lakes are remnant channels of Limestone Creek, and are likely floored with organic detritus and silts of fluvial origin. The sediments of much larger Limestone Lake are likely a complex of delta-fan deposits, talus from the valley walls, and remnant glacio-fluvial deposits. There is no reason to suggest that sedimentation of silt or clay is a dominant process on the lake basin floor at present, because the sources of sediment are very limited in their headwater location. As for Heather Lake, organic growth is encroaching on its north and south ends, and this has reduced the area of the lake by about 20% over the last 10,000 - 12,000 years. The depth of Heather Lake is about 10 metres (K & P pers. comm.), whereas the depths on Limestone Lake are unknown. A limnological survey of this basin is now overdue, in view of the pending tailings and water reservoir pondages being planned for this area.

3.5 Glacio-Lacustrine Deposits (Map Code - "L^G")

Surprisingly Limestone Creek valley appears to have been a significant glacial lake basin during two or more glacial episodes. Whether or not a glacial lake was present at the windup of the last glacial event depends on the interpretation of the drill logs at the Main Embankment, and the forementioned enigma concerning the drill results on and adjacent to the kame terrace at the Water Retention Structure near Limestone Lake. Unequivocal recognition of glacial lake silts deposited during this last de-glacial episode are the 1.8 metre thick section at test pit TP91-33, elevation 1050 metres, 300 metres east of Heather Lake. However, this ridge top deposit is indicative of only a small lake ponded between ridge rock and the main valley ice mass, and was obviously a fairly early developed de-glacial feature. On the main valley floor, underneath flood plain drill holes 90-707 and 91-C10 there is an upper silt sequence which does not appear to be over consolidated; that is, blow counts on the hammer penetration tests are low. While there are some drilling and ground water hydrology factors which could yield this condition, the evidence for lack of a lake deposit is not compelling, except that neither drill holes 91-C3 and C6 nor 90-705 and 685, all on flood plain locations, noted any less dense glacial-lake silts. However, the glacial lake silt which caps the kame terrace, as noted in a foregoing discussion, needs further clarification on its stratigraphic position - on a blows/foot basis it is of the last deglacial cycle (KP91-WSD1), whereas the glacial lake silt in adjacent drill hole WSD3 is over consolidated and is a remnant of an earlier deglaciation or pro-glacial feature associated with the advance of the latest glaciation.

A cross section of the Main Embankment area (Figure 1) shows that there are at least two older sequences of glacial lake silts. The upper, which is 10-44 metres thick, is exposed on both valley walls, above the flood plain, and has been intersected by several drill holes, although not at drill hole KP91-C4 which apparently marks a possible deltaic shore edge to the lake basin at that time. The upper elevation of glacial-lake silt deposition during this penultimate episode of glaciation-deglaciation appears to be about 1010 metres above mean sea level, although the younger overlying fluvial and glacial units may have been deposited by cutting into this feature.

The oldest glacial lake silt beds are found in drill holes on the flood plain and on the true right bank. They are separated from the intermediate aged lake beds by till (DH 90-705, 91-C3, 90-707) and fluvial or glacio-fluvial sands and gravels. The unit has obviously been significantly thinned by subsequent erosion, and the highest elevation of silts of the oldest cycle is only 980-990 metres. Unfortunately, the greatest residual thickness is unknown because DH90-700 terminated operations in the unit after having logged 24.4 metres of its sediment.

The glacial lake silt units are a big asset in sealing off the lower valley slopes and valley floor from fluid losses. Several permeability tests generally indicate values of 10^{-7} to 10^{-8} cm/sec with the range being 2.4×10^{-4} to 6×10^{-8} cm/sec. The softer (under consolidated) units will no doubt pose some construction difficulties, which may result in their total removal in the worst case scenario.

3.6 Eolian Deposits (Map Code - "E")

There are no dune-like features which are visible on the aerial photos. However, on-site geologists have recognized eolian silty sands along the access road to the South Embankment area. The source of the deposits is no doubt the glacio-fluvial fan located at the site of much drilling in this area; during deglaciation it was a barren surface ideally exposed to deflation before the colonization of forest cover. Undoubtedly there are other veneers of eolian deposits (eg. Heather Lake area) which have yet to be recognized.

3.7 Colluvial Deposits (Map Code - "C")

Aprons and fans of silty colluvial debris mark the toe of slopes throughout Limestone Valley. Where the source of sediment is bedrock, rather than Pleistocene deposits, rubbly rock fragments are the expected composition of the colluvium. Thicknesses of colluvium are unknown except at a few test pits near the Main Embankment area where 1.5 to 4.0 metre intersections are recorded. While most of these deposits are developed by piecemeal gravitational processes, some minor slide activity is shown on the aerial photos at the South Embankment (left bank) area and near the proposed Water Retention Dam (left bank) site. Stripping of vegetation in the latter area especially could exacerbate the situation.

3.8 Volcanic Deposits (Map Code - "V")

So far, no Pleistocene or recent volcanic strata have been found or recognized in the Limestone Creek watershed.

3.9 Organic Deposits (Map Code - "O")

To date, drilling on the Limestone Creek flood plain has penetrated only a thin (to non-recognizable) covering of organic terrain. At drill hole 90-707 the greatest thickness of 2.1 metres of silty organic material has been logged; elsewhere the thicknesses are less than one metre. However, at Heather Lake, where botanical succession appears to be a rather significant geological process, almost 5 metres of peat was recorded at a drill site (91C-8) location in the middle of a rather broad deposit. Similar thicknesses and expanses of peat may overlie a broad remnant discharge channel located between this deposit and the new site for the ore processing mill. Air photo interpretations suggest expansive veneers of organic cover on the upper valley slopes to the northeast of Limestone Valley. Their existence ensures a low but continual runoff of water into the tailings empoundment area.

3.10 Anthropogenic Deposits (Map Code - "A")

Other than a few drill sites, test pits and access roads there are as yet no significant mappable man-made features in the watershed of Limestone Creek.

3.11 Bedrock and Weathered Bedrock (Map Codes - R and D)

Actual outcrop is sparse, being recognized only in the Limestone Lake area. Weathered volcanic bedrock of the Takla Group is about 1.0 to 2.0 metres thick at the proposed new plant site overlooking the Main Embankment. This condition likely prevails wherever the Takla Group is capped by glacial till, but with other rock units weathering will likely be less and only of significance at fault zones.

3.12 Modifying Processes

Associated with glacio-fluvial sediments are kettled depressions (-H) which are not spectacularly developed anywhere in the Limestone Creek basin. Much better developed features are broad erosional overflow, lengthy sinuous, and narrow lateral meltwater channels (-E). One such line of the latter demarcates the outer edge of a tongue of ice plunging eastward into Limestone Lake. Gullying (-V) is present on most lower valley slopes, but the process appears to be held in check by vegetation. Groundwater seepage to surface (-P) is not readily visible on the aerial photos although the forenoted slope instabilities (-R) may be caused by seepage problems.,

There is no conspicuous evidence of slowly collapsing slopes (-F), avalanching (-A), periglacial activity (-Z), karst activity (-K), or eolian deflation (-D). Permafrost (-X), if present, would have to occur under thick moss matts as small isolated islands on the north sides of shaded slopes. Present day water courses on the flood plain are with irregularly (-I) developed channels rather than of organized meanders (-M), or of the braided network (-B) of "valley train" outwash systems that are typical of ice field areas.

4.0 PLEISTOCENE GEOLOGICAL HISTORY

The author's previous reports on the surficial geology of the Mt. Milligan mine site area discussed the evidence for multiple glaciation, and whether the events spanned a lengthy period during the Pleistocene Epoch. However, it was also cautioned that there were two sources of ice for each glaciation—the distant Coast Mountains and Interior Plateau to the southwest, and the nearby Omineca and Rocky Mountains to the north and east. And, it was noted that ice from the latter passed over resistant quartz-rich lithologies which in turn would likely deposit a granular till before the arrival of ice from the southwest which would likely carry a siltier matrixed till. In addition, glacial lakes could be developed between the two ice sources in a pro-glacial environment (ice advance stage), as well as be developed between stagnating ice masses in the retreatal stage at the conclusion of each glacial episode. These compounding elements of glaciation, therefore, can cause great uncertainties when correlating the stratigraphy in drill logs—especially without absolute age control data and lack of lithologic and mineralogic analysis of the coarse and fine components in each horizon encountered in the drill log.

However, in order to discuss Pleistocene geologic history, which is in part the succession of strata that is the record of each event, some sort of stratigraphic analysis of the drill logs, test pits, and road cuts has to be assembled. From the geotechnical reconnaissance work undertaken to date it is apparent that the Main Embankment area holds the most complete succession of Pleistocene aged strata. Not surprisingly, the overall sequence is much the same as that reported for the Tailings Impoundment "A" area which was located on the broader and lower elevated expanse of Rainbow and Meadow Creek valleys. However, there are slight variations; post glacial terrace development is almost absent in Limestone Creek Valley, and there is an apparent absence of Early (?) Pleistocene age volcanism.

4.1 Composite "Standard" Stratigraphic Succession

Analysis of the drill hole and test pit data shown in a cross section of the valley (Figure 1) provides the framework to suggest a tentative stratigraphic column of events. The sequence begins with the youngest strata (post Pleistocene or Holocene) at the "top", and proceeds down section to the oldest recognized Pleistocene unit as follows:

- organic cover (O) and adjacent active flood plain sedimentation (Fpf) with colluvial (C) mass wasting on valley walls (contemporaneous to older);
- major unconformity;
- glacial lake (L^G) development (extent unknown) and synchronous to older glacio-fluvial (F^G) outwash sedimentation: deglaciation; (1)
- late glacial and early deglacial deposition of ablation moraine (sdM); (2)
- early glacial basal till (M) of the Latest Pleistocene ice advance; (3)
- proglacial advance outwash (F^G) and minor proglacial Lake (L^G) deposition proceeding as a forerunner to latest Pleistocene ice advance*; (4)
- major unconformity;
- major glacial lake (L^G) development following a penultimate ice advance;
- glacial-fluvial deposition ($\not{s}sgF^G$) following a penultimate ice advance*;
- penultimate ice advance (Late Pleistocene or earlier?) (cgM or gcM);
- major unconformity (?);
- pro-glacial or older deglacial glacial lake (L^G) development;
- oldest ice advance (scM or gcsM);
- advance outwash (F^G) and/or colluvial mass wasting (C) on "original" valley slopes of bedrock (R).

Bracketed strata or events (1) to (4) are collectively known as the Late Pleistocene age Fraser Glaciation. The asterisked (*) horizons (the younger on the valley wall and the older under the valley floor), are potential porous subsurface units which require some attention with further delineation and testing in a detailed drill program. The cross section (Figure 1) shows the above array of units to be slightly more complex than shown in Section1/1672.020 of the Phase II Knight and Piésold report. Not to go unnoticed is the author's recognition of the "penultimate" till, which immediately underlies the lower asterisked horizon. Further drilling may either disprove its existence or show a broader areal expanse of it. The lithology of this till should be checked to see if it is of Omineca-Rocky Mountain or of Interior Plateau source. If the former, the stratum may simply indicate an early stadial advance of the Fraser Glaciation (Late Pleistocene), and hence should be denoted (5), which was overridden by the slower-to-arrive ice sheet from the southwest.

The composite section for the South Embankment (abandoned valley) area is much simpler. Nonetheless by compiling surficial mapping data with the drilling log results a somewhat more complex picture of geologic succession of events emerges than what is shown on Section 2/1672.020 in the forementioned Knight and Piésold Phase II report. From top to bottom the sequence appears to be as follows:

- organic cover (O) and adjacent floodplain sedimentation (Fpf) with colluvial (C) mass wasting on valley walls (contemporaneous to older);
- disconformity (?);

- eolian (E) deflation and re-deposition of wind blown materials elsewhere on recently deglaciated surfaces; (1)

- simultaneous glacial lake (L^G) sedimentation to the north and glacio-fluvial (F^G) outwash deposition on and to the south of the axis of the South Embankment area; (2)

- late glacial and early deglacial deposition of ablation moraine (ꞩdM); (3)

- basal till (ꞩM) of latest Pleistocene ice advance; (4)

- unconformity;

- fluvial or glacio-fluvial channel outwash towards (?) Rainbow Creek Valley; (5)

- penultimate (or older) advance of ice (ꞩ and sgM) on floor of bedrock (R) pre-glacially (?) eroded channel.

The above tentative picture could change markedly once a line of drill holes is drilled along the longitudinal axis of the valley. Again, bracketed events (1) to (5) are part of the Fraser Glaciation, and the lowest morainal layer could represent an earlier stadial advance.

Finally, a very tentative section of the upstream Water Retention Dam site area is suggested from results of three drill holes (shown on the 1:12,500 scale map) and the surficial geologic mapping:

- organic cover (O) and adjacent floodplain sedimentation (Fph) with colluvial mass wasting (C) on valley walls (contemporaneous to older);

- fluvial terrace (Ft) downcutting through deglacial sediments;

- unconformity;

- glacial lake deposition (L^G); (1)
- glacio-fluvial deposition (F^G): kame terraces; (2)
- deposition of basal till (s̸cM) (3)
- unconformity;
- deposition of glacial lake sediments following deglaciation of an older (?) ice advance (penultimate?), or proglacial to the younger advance.

Further drilling along the kame terraces will undoubtedly add more geologic units to the above over-simplified sequence. The Fraser Glaciation is marked by bracketed numbers (1) to (3), but may also include the oldest glacial lake event as well as some of the terrace development activity (there are kettles on the upper terraces).

The foregoing three "standard" composite columns tend to indicate an increasing complexity of geologic units in the down valley direction. That is, up valley, evidence of the older events is obliterated by more vigorous erosion between glacial events.

4.2 General Trends of Glaciation - Deglaciation

The direction of flow in the last main advance of the ice sheet (Fraser Glaciation) was southwest to northeast. During downwasting of this ice sheet the ice disappeared first in the higher areas of the headwaters of Limestone Creek valley, and in adjacent Rainbow Creek valley, leaving a lobe of ice over the Main and South Embankment areas which terminated in Limestone Lake. There is no visible evidence to show that this lobe was actively moving towards the lake, but such might be shown in pebble orientation studies of the glacial till on the lower slopes of the valley. However, the capping glacial lake silts on the high kame terrace sequence infers that the Limestone Lake itself was the site of a final "plug" of ice which caused the backing up of the lake to the Main and South Embankment areas. This lake may have drained out through the latter exit in concert with copious meltwater being added to the discharge from several upland basins to the east of the South Embankment area. This may account for the local absence of the upper till in some of the drill holes across the South Embankment—the unit was eroded out during deglaciation. The down valley extent of the glacial lake is imperfectly known. Suggestions of thin lacustrine layers overlying tills on especially the right bank benchland at the Main Embankment area are not conclusive evidence; nor is the apparent geotechnical discontinuity in the glacial lake silts on the valley floor an unequivocal clue; and there are disagreements between the government and consulting geologists as to the existence of a glacial lake in this particular area. Until the writer visits the site first hand, this important issue is left as unresolved.

For the earlier glaciation(s) the direction(s) of ice movement are not locally known; but work outside the area by the Geological Survey of Canada shows the same southwest to northwest movement for such, after an initial northeast to southwest pre-emptive ice advance from the local source. The deglaciation pattern during these earlier events was also probably much the same. The valley of the South Embankment area was likely a major conduit of meltwater into a then already ice-free Rainbow Creek valley. No doubt the Heather Lake overflow channel was also operative in this event as well. Near final ice disappearance, however, it appears that all of Limestone Creek valley was inundated by a glacial lake. Lack of older glacial lake sediments at the South Embankment area, however, suggests that this abandoned valley channel was the major drainage outlet for the lake body. However, this is speculative, and drilling may well confirm that a glacial lake in Rainbow Creek valley was continuously connected to that of the Limestone Creek valley through this South Embankment corridor area.

As for the oldest glaciation, provided that the above noted penultimate ice advance did exist, there is even less data on its direction of movement, style of downwasting, and extent of glacial lakes backed up during its final disappearance.

Post-glacially, Limestone Creek has cut down through 50 or so metres of composite Pleistocene section before reaching an equilibrium base level. This has probably left "over-steepened" slopes which could be mobilized during saturated climatic conditions—especially if exacerbated by forest removal. At present the dominant post-glacial process appears to be expansion of the organic cover, which is covering creek courses and floodplains, and encroaching into lake basins.

5.0 IMPLICATIONS OF THE SURFICIAL GEOLOGY ON THE SITING OF ENGINEERING FACILITIES.

The surficial geology features a fairly stable terrain for the construction of mega-civil engineering projects. The weak horizons are the surficial peat and thinner silty organic cover occurring elsewhere, the overbank silts on the floodplain, the "under" consolidated glacial lake silts, and the silt-rich colluvial aprons/fans along the base of the valley walls. However, there is only minimal evidence of minor slumping and debris flows, and there appears to be an absence of mega landslide features. Absence of permafrost, as manifest by ground ice, is not assured on valley wall aspects that are shaded from the sun. Locally it may be present as isolated islands under thick organic cover or it occurs interstitially within glacial lake silts. On the whole, however, much of the above potential problem strata can be avoided or removed.

Subsurface porous horizons, however, are not so easily circumvented. While this problem proved to be a major obstacle in the case of Tailings Impoundment "A", because of the vast extent of the confining impoundment to be dammed, the problems are relatively local and confined at Site "C" because bedrock valley walls enclose so much of the potential reservoir.

5.1 Tailings Impoundment - Plan "C" (modified)

The impoundment requires the construction of four confining embankments in order to achieve total closure. However, a fifth embankment to isolate the sulphide-rich tailings may also be constructed in order to preclude any possibility of acid mine drainage.

Main Embankment

Figure 1 shows a generalized cross section of the valley at the approximate position of the Main Embankment, while Figure 2 shows the location of the section as well as the array of drill holes and test pits in the general embankment area. The results of the geotechnical investigation show an almost haphazard presence of tight and impervious strata at ground surface, and immediately below the uppermost basal silty or clay-rich till. Thus, in the preparatory phases of dam construction it may well be advantageous to strip the upper surface down to either the basal till, or to the underlying glacial lake silt beds where the till is locally absent. Because the thickness of fluvial deposits on the valley floor flood plain is four to six metres, it may be a more difficult task to remove them despite the relatively narrow 250 metre width at the prime embankment location. Nonetheless, there are about 4 to 7 metres of underlying "soft" or compressible glacial lake silts which also require consideration. At depth within the glacial lake sequence a somewhat porous gravelly horizon appears to be well buried from any potential connection to tailings deposition. Rather, there is a thinner (?) horizon labelled "dense alluvial sands and gravels with some silts" in the Knight and Piésold report which underlies the upper basal till (not well defined by the drilling on the right bank) which could leak tailings fluids downstream. The consulting engineers however, have a system designed to recollect such seepages and thus the Main Embankment site appears to be suitably confined, stable and otherwise with tight strata. It is however cautioned that the cross section compiled by the author must be regarded as tentative and a much closer-spaced series of drill holes will be required to prove up the geology before initiating a final engineering design.

Saddle Embankment

The embankment is needed because of a 10 metre topographic low spot on the left bank near Heather Lake. The original plan to enclose Heather Lake as part of the impoundment was scuttled with an unfavourable drill hole result (KP91-C8) on its south side. Thick peat underlain by porous gravels would have created undue problems in constructing an overlying embankment. However, subsequent test pitting on the north side of the lake has turned up relatively thin impermeable glacial tills, and one "pocket" of glacial lake silt, overlying bedrock, and hence a very suitable substrate for construction of an embankment. In order to do this, the creek which drains Heather Lake will have to be scoured out before construction begins, and thereafter Heather Lake will drain southward through extensive peat lands in an abandoned meltwater channel directly toward Rainbow Creek. Thus the diversion should produce only little if any significant hydrologic or biologic changes to the environment.

South Embankment

The structure will be built on competent till and sand/gravel strata, with abutments on valley walls of bedrock thinly covered by colluvium and/or till. Conceivably the buried channel, underlying the upper till, could have a porous connection with the flood plain deposits within the Limestone Creek corridor, and to the surface-exposed kettled glacio-fluvial deposits to the south west. The forementioned suggested requirement for a new line of drill holes spaced out along the longitudinal axis of the abandoned valley containing the

South Embankment would help resolve this unknown. Possibly the results could suggest a slightly off-setting position for the embankment structure, and an alternate means to collecting any undesirable seepage.

Sulphide Retention Dam

The dam will be located about 1 kilometre west of the Water Retention Dam in upper Limestone Creek Valley. A geotechnical reconnaissance of the site has not yet been undertaken, but surficial geologic mapping suggests the following:

- the left abutment will be against bedrock overlain by a blanket of till;
- the axis will lie on fairly thick flood plain deposits (10 to 15 metres), with a covering veneer of organics; and
- the right abutment will be against a kame terrace capped by glacial lake silts.

The right abutment will need several drill holes to define the exact stratigraphy and degree of permeability of the horizons encountered. At least one drill hole and the test pits will be needed on the left bank to define the character and thickness of the glacial till. Glacial lake silts could underlie the till. The flood plain will need one or two drill holes to check on floodplain thickness and permeability and foundation conditions.

Water Retention Dam

The dam, located near Limestone Lake, is on the north end of the forenoted kame terrace. At this point there are subsidiary terraces at the lower levels "etched" into the feature. Conceivably they could be of porous terrace gravels. Construction of a tight structure will be eased by the local presence of core material (glacial lake silts) capping the terrace. However, much excavation and testing appears to be required to achieve an impermeable dam and a stable foundation.

5.2 Mill Site

The plant site is on a rolling to hummocky ridge crest, underlain by Takla Volcanics. Overlying basal till averages 2 metres thickness and a variable thickness of more granular ablation till caps the sequence. While this is a very competent foundation, the weathering of the upper 1 to 2 metres on the bedrock itself is a cause of concern. Removal of till and weathered rock to achieve a solid foundation can be capitalized upon by using the spoil materials for local road construction.

5.3 Camp Site

Located south of the plant site, the area is on a thicker layer of till and possibly overlain and underlain by thin layers of sand and gravels. Access to the camp will require road construction across some organic filled abandoned channels.

5.4 Conveyor Belt Corridor

The corridor begins on the esker complex on the west side of Rainbow Creek Valley; crosses this valley on granular terraces (thin organic discontinuous veneers on them); and then passes upslope to the plant site on a remarkably smooth till plain which likely overlies a thick sequence of older Pleistocene deposits. Possible spillage of conveyor belt ore onto the floor of Rainbow Valley appears to be only a very minor concern for which there are several rectifying solutions.

6.0 RECOMMENDATIONS

Geotechnical reconnaissance of the Site "C" tailings impoundment is all but complete. The surficial geologic mapping, which was very reliant on these initial investigations, can only be improved upon once more roads are developed in the reservoir area. Meanwhile design engineering will need much more drill hole data in order to effect an efficient set of plans to build and monitor the embankment and foundation structures. At the Main Embankment area, the "line" of drilling has to be spaced such that a reliable prediction of what to expect geologically can be made from one hole to the next. Some holes will only have to penetrate into the "over consolidated" glacial lake silts and then can be halted. The South Embankment is reasonably well explored. However, the concern here is the stratigraphy under the balance of the valley which interconnects between Rainbow and Limestone Creek valleys. Again, the holes should be spaced on a longitudinal axis arrangement so that a reliable prediction can be made as to what is expected in the adjacent hole. The upstream valley dams will abut on a kame terrace of complex "micro" stratigraphy. A thorough geotechnical reconnaissance along the length, as well as across the width, of the feature may reveal a zone where the capping glacial lake silts are thin (as opposed to 9.5 metres) and the underlying strata is consistently tighter. To date, this area is the weak link in the exploration of the reservoir area. Undoubtedly as more drilling proceeds, the mapping and section which accompany this report will need revision.

The geology as it now stands appears to be reasonably suited to the further development of the Impoundment "C" concept, and follow up studies and mapping should keep pace with the development of the reservoir through the design and construction phases.

7.0 REFERENCES

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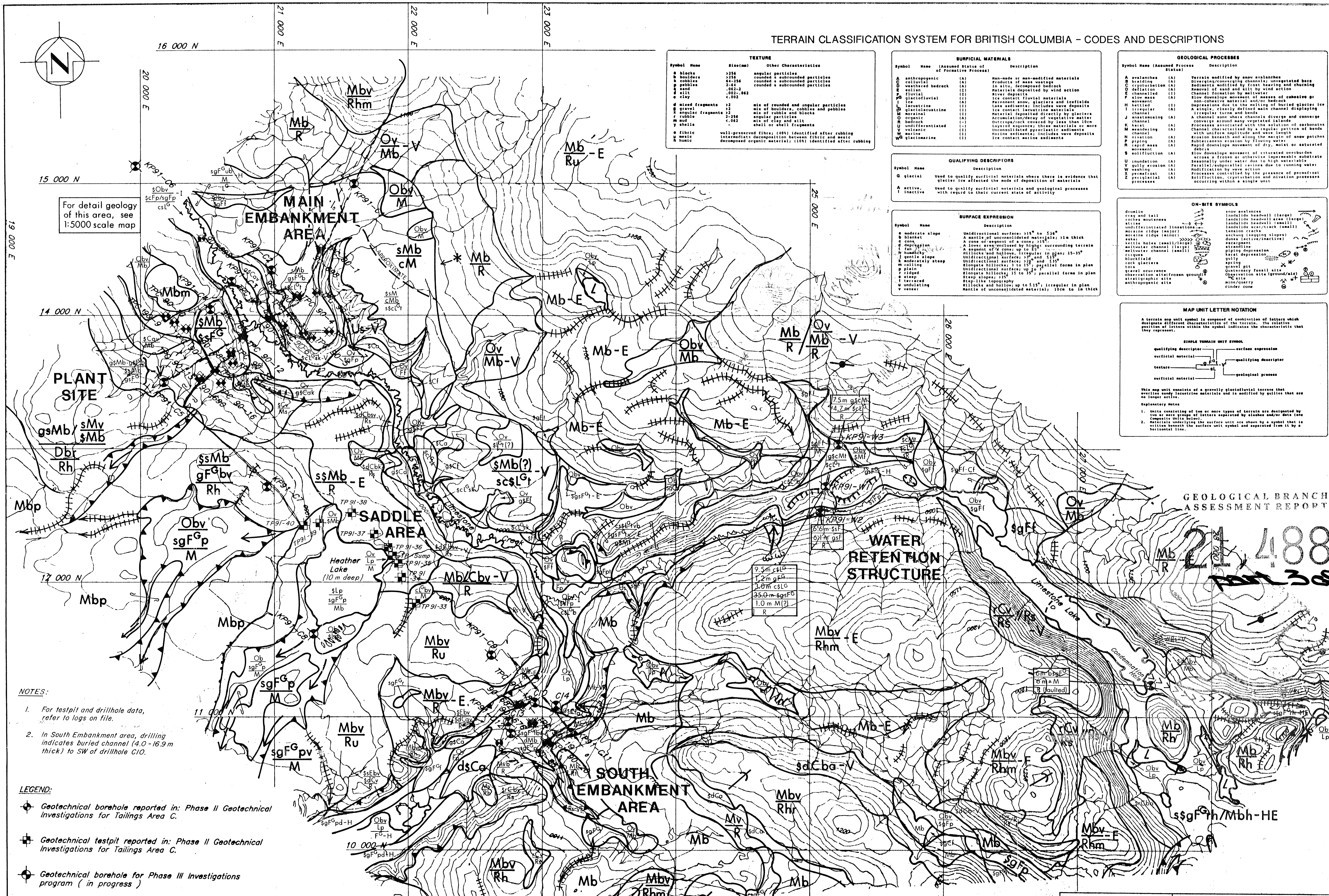
SITE "C" AREA

STATEMENT OF EXPENDITURES
See 1 - 27 Claims

Karl E. Ricker

March/April 1991 Surficial Analysis and mapping Area C 70%	$3,913.53
Supplies and Services Mapping Services 70%	$1,689.36
TOTAL KARL E. RICKER:	**$5,602.89**

Compiled by: R.H. Banner, P. Eng.



Scale 200 0 400 800 1200 1600 2000 Metres

CAD FILE : \PROJECT\1673\002 Drawing scale 1=12500 Plot scale 1=12.5

No	DESCRIPTION	DATE	BY
2	New test pits, drillholes, labels	11-4-91	PH
1	S/G detail by PROMAP DRAFTING LTD.	20-3-91	PH

REVISIONS

Karl Ricker, FGAC, Consulting Geologist

SURFICIAL GEOLOGY

CLIENT: PLACER DOME TECHNICAL SERVICES LIMITED

LOCATION: NTS 93-O/4

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

DESIGNED KJB
DRAWN RDT
CHECKED
APPROVED

CONTINENTAL GOLD CORP.

MT. MILLIGAN PROJECT

AREA C
TAILINGS STORAGE FACILITY
SUMMARY OF SITE INVESTIGATIONS

DATE FEB. 14, 1991 | SCALE AS SHOWN | DRG. NO. 1673.002 | REV.

14 000 N
15 000 N
13 000 N
19 000 E
20 000 E
21 000 E
22 000 E
GEOLOGICAL BRANCH
ASSESSMENT REPORT
21,488
PRELIMINARY
100 0 100 200 300 400 500 600 Metres
Scale
KARL RICKER, FGAC, Consult Geol.
SURFICIAL GEOLOGY (ANNOTATED)
KNIGHT AND PIESOLD LIMITED
CONSULTING ENGINEERS – VANCOUVER, B.C.
DESIGNED
DRAWN
CHECKED
APPROVED
PLACER DOME INC.
MT. MILLIGAN PROJECT
GEOTECHNICAL INVESTIGATIONS
TAILINGS AREA C
MAIN EMBANKMENT
DATE
SCALE AS SHOWN
DRG. NO. 1673.003
REV.
DRG. NO.
DESCRIPTION
REFERENCE DRAWINGS
REV.
DATE
DESCRIPTION
APPROVED
REVISIONS