005047

CURRAGH RESOURCES INC.

VANGORDA PLATEAU DEVELOPMENT

INITIAL ENVIRONMENTAL EVALUATION

30-Sep-1987

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

Curragh Resources Inc. currently owns and operates an open pit mine near the community of Faro in the Yukon as shown on Figure 1.1. The mine, which was previously owned by Cyprus Anvil, was reactivated by Curragh in 1986, and milling of the ore began in June of that year. Curragh is presently preparing plans for the development and operation of additional orebodies at the Vangorda Plateau located about 13 kilometres southeast of the Faro minesite. Development of the Vangorda Plateau deposits, namely Vangorda and Grum, would supplement and eventually replace production from the Faro Pit. With some augmentation from underground reserves at Faro, Curragh's operations would continue to at least 1999.

In accordance with the requirements of the Environmental Assessment and Review Process (EARP), an Initial Environmental Evaluation (IEE) has been initiated by Curragh to identify environmental and directly related socio-economic impacts of the Vangorda Project. The IEE would be reviewed by the Regional Environmental Review Committee (RERC) prior to Curragh's submission to the Yukon Territory Water Board for a Water Licence.

Stage I of the IEE was presented to RERC in September 1987. The Stage I report provided information and environmental impact assessment for the 1987 program of drilling, trenching and drainage ditch construction on the Vangorda Plateau. The report summarized existing data and current studies on water quality, groundwater geotechnical aspects, and fish and sheep population. This report is Stage II of the IEE and

presents an overall evaluation of the Vangorda Plateau Development.

1.2 OBJECTIVES

The objectives of the Stage II report are:

1. to describe the proposed Vangorda Plateau development;
2. to compile the baseline environmental and socio-economic information relative to the project;
3. to identify the environmental, social and economic impacts of the project;
4. to present mitigative measures for environmental protection and waste management;
5. to recommend a conceptual reclamation and abandonment plan, and waste and water management plans.

1.3 LOCATION AND ACCESS

The Vangorda Plateau is located about 13 kilometres southeast of the Faro minesite at an elevation of between 1200 to 1300 metres. Faro townsite is located approximately 200 air kilometres northeast of Whitehorse, Yukon Territory (Figure 1.1), and is about 8 kilometres from Vangorda Plateau.

Access to the Vangorda Plateau is provided by the main access road from Faro to the minesite. Construction is in progress for the main haul road from the minesite to the Vangorda Plateau. A vicinity map of the Faro area and the minesites is presented on Figure 1.2

1.4 Acknowledgements

The following companies,consulting firms and individuals participated in the preparation of Stage II of the Initial Environmental Evaluation Report:

Curragh Resources Inc.

Mr. G. Jilson
Mr. J. Huntley
Mr. J. Bowers
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P. A. Harder and Associates Ltd. conducted the fisheries habitat survey.

Dr. Horejsi conducted the study on the Fannin sheep.

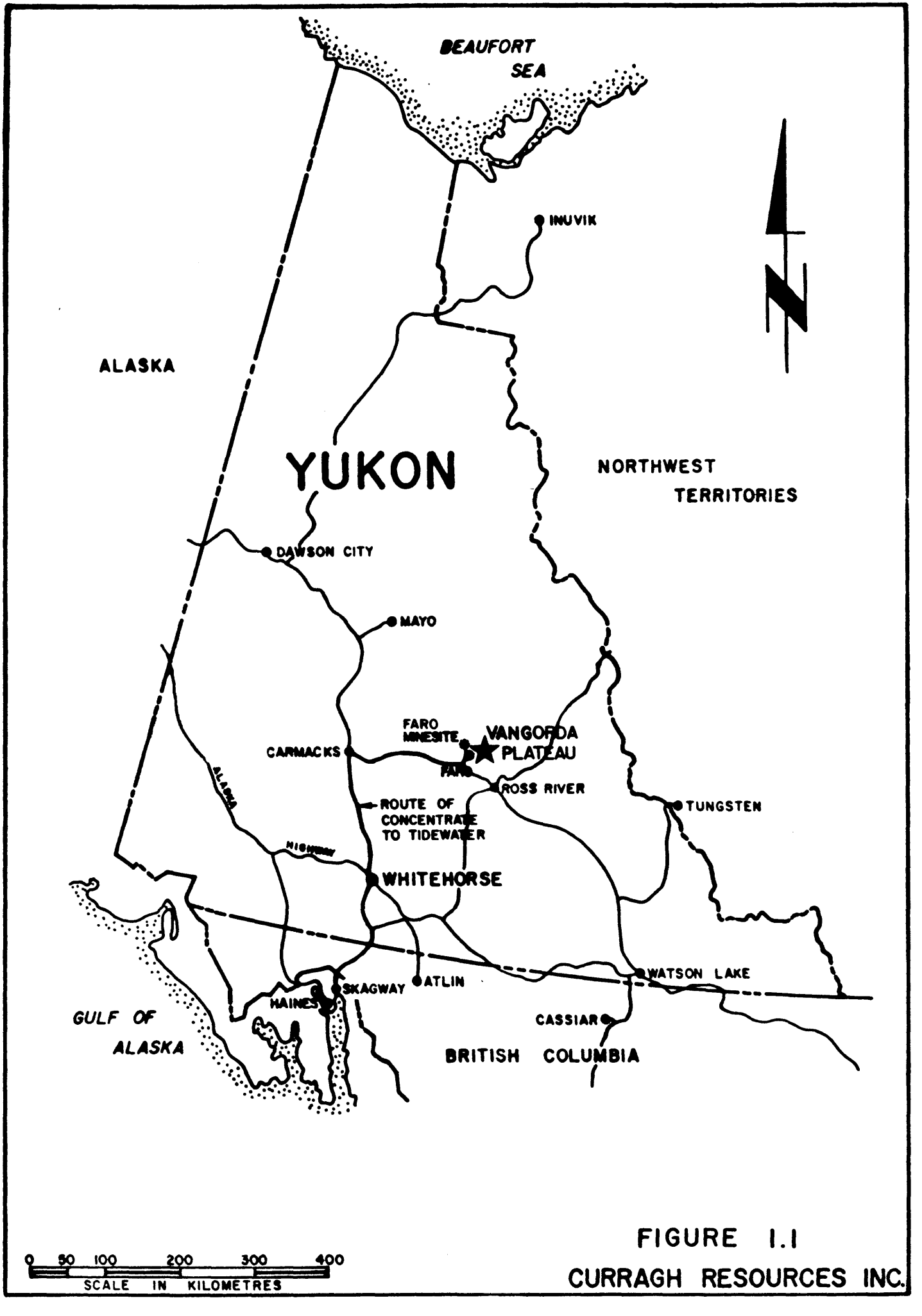


FIGURE 1.1

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FARO PIT
MILL
TAILINGS
NORTH FORK ROSE CREEK
FIGURE 2.18
FIGURE 2.19
RESERVOIR CREEK
GRAN RANGE CREEK
HAUL
RESERVOIR
ROAD
FIGURE 2.20
ROSE CREEK
AEX CREEK
FIGURE 2.21
FIGURE 2.22
GRUM
VANGORDA
ACCESS ROAD
DIXON CREEK
SHRIMP CREEK
SHRIMP LAKE
DRAINAGE AREA ABOVE DIVERSION (17.7 km²)
DRAINAGE AREA VANGORDA CREEK (90.8 km²)
VANGORDA CREEK
FARO
PELLY
NISUTLIN RIVER
13
12
11
10
09
08
07
06
05
04
03
02
01
00
99
98
80
61
G
F
0 1 2 3 4 5 km
0 1 2 3 miles

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VICINITY MAP & DRAINAGE AREAS

SCALE 1" = 1 Mile (approx)

FIGURE 1.2

SECTION 2

PROJECT DESCRIPTION

2.1 HISTORY OF PROPERTY

2.1.1 History

The Vangorda deposit, which was the initial mineral discovery in the Anvil Range, was first drilled by Prospector Airways, a predecessor of Kerr Addison Mines, between 1953 and 1955. However, it was the Faro deposit, which was discovered in 1964, that was developed and brought into production by Anvil Mining Corporation in 1969. Additional deposits, such as Grum and Dy, were subsequently discovered.

The Faro mine commenced operation in 1969, initially producing 5,000 tonnes of ore per day. The Anvil operation was amongst the major world producers of lead and zinc concentrates. In 1975 Anvil Mining Corp. was reorganized to form Cyprus Anvil Mining Corporation (CAMC). In 1974, production was increased to 9,300 tonnes per day; however, due to the depressed base metal prices, Cyprus Anvil ceased production in 1982. During this period, 62 million cubic metres of rock were mined from the Zone I and Zone II open pits.

Open pit waste stripping operations were carried out between June 1983 and October 1984, with about 9.7 million cubic yards of waste removed. The property was shut down and remained idle until the operation was acquired by Curragh Resources in November 1985.

The facilities were reactivated in December 1985 and waste stripping in the Faro pit commenced in January 1986 for a mill start-up in June 1986.

2.1.2 Recent Activity

The mill at Faro is currently operating at 13,500 tonnes of Faro ore per day. The mine produces two concentrate products: lead, which also includes viable quantities of gold and silver, and zinc. The concentrate is hauled via road to Skagway, Alaska, where it is loaded on ships for markets in Europe and Asia. The anticipated maximum milling rate of the Vangorda/Grum ore is 11,000 tonnes per day. The maximum average daily concentrate production rate would be 1,600 tonnes.

Previous studies have been completed by the former owners CAMC and Kerr Addison Mines in assessing the Grum and Vangorda deposits. These studies include:

- An assessment of ore transportation alternatives
- Metallurgical testing of the ore
- Extensive exploration drilling and geological interpretation
- Preliminary mine plans
- Environmental baseline studies.

2.2 GEOLOGY AND ORE RESERVES

2.2.1 District Geology

The stratigraphic sequence of the Anvil District ranges in age from latest Precambrian to Permian. The stratiform and stratabound lead-zinc deposits occur in a 150 m thick stratigraphic interval that straddles the boundary of two of the major formations, the Mt. Mye and the Vangorda. All rocks in the area to be affected by the Vangorda Plateau development can be referred to one of these two formations.

Rocks of the district were metamorphosed and complexly folded during mid-to late-Mesozoic polyphase deformation. A Cretaceous granitic batholith was intruded late in the deformation sequence arching the surrounding country rocks, as shown on Figure 2.1. Older and higher grade metamorphic rocks occur near the granite in the core of the arch. In the area of the ore deposits, metamorphic strata generally dip southwest away from the core of the arch. Near the granite, metamorphic conditions reached mid-amphibolite facies but most of the district was at greenschist facies or lower. Large scale, post-metamorphic and post-folding, extensional faults displace low grade rocks on the flank of the arch away from high grade rocks and granite in the core of the arch. Folding and metamorphism are significant since they are responsible for the form of the orebodies and the texture of the ores. The extensional faults truncate several of the ore bodies and have significant implications for exploration potential.

Additional details on the geology and structure of the Anvil District can be found in Jennings and Jilson (1986) and Templeman-Kluit (1972).

2.2.1.1 Mt. Mye Formation

The major lithology of the Cambrian and older Mt. Mye formation varies from non-calcareous, biotite-muscovite schist [unit 1CD] to non-calcareous, weakly carbonaceous, light to medium grey muscovite-chlorite phyllites [unit 3G]. On the Vangorda Plateau the latter unit dominates (Figure 2.2); the schistose variant occurs near the Anvil Batholith, in the footwall of the Tie fault and in some of the deeper drillholes. Lesser interlayered rock types are: black graphitic phyllite [unit 3E], marble [unit 3F], calc-silicate phyllite or schist [unit 3D], and greenstone or amphibolite [unit 3C]. The composition of the schists and phyllites is that of an average shale (Jennings and Jilson, 1986). On the Vangorda

Plateau, the formation outcrops mainly to the northeast of the ore deposits, as shown on Figure 2.2.

2.2.1.2 Vangorda Formation

The Cambrian and Ordovician Vangorda formation is characterized by light to medium-grey, calcareous, phyllitic rocks [unit 5B] made up of very thin (0.1-2 cm) interlayers of (a) medium grey, non-calcareous, weakly carbonaceous, muscovite-chlorite pelite and (b) light grey, generally calcareous quartz +/- calcite +/- dolomite siltstone. In areas of more intense metamorphism, such as near the Faro deposit, the calcareous phyllite is altered to a hard, banded, green, purplish brown and creme coloured calc-silicate rock [unit 3D]; this rock type does not occur in the Vangorda formation on the Vangorda Plateau. Other rock types interbedded with the calcareous phyllite include greenstone [unit 5C] and chloritic phyllite [unit 5F or 5D if banded], carbonaceous phyllite [unit 5A], and phyllitic limestone [unit 5E]. At the base of the formation, there is a significant carbonaceous phyllite member.

The formation is largely younger than the ore deposits and tends to underlie the area southwest of them, as shown on Figure 2.2. The Vangorda is strongly calcareous, commonly with 10% to 30% calcite. Its outcrops are always druse-covered, and groundwater from a well in the formation at the Grum Camp rapidly forms calcareous scale in pipes. This suggests that groundwater in areas underlain by the formation will have considerable buffering capacity.

2.2.1.3 Ore Deposits

The lead, zinc, silver deposits of Anvil Range are of the sediment-hosted, stratiform, massive pyritic sulphide type (Gustason & Williams, 1981). They occur as a single thick sulphide lens with little or no interbanded metasedimentary rocks (e.g. Faro) or as

multilayered deposits with several thinner lenses stacked approximately one above the other with substantial metasedimentary or metavolcanic interlayers (e.g. Grum and Dy). An individual mineralized layer was deposited parallel to the bedding of the host sediments. It consisted of an upper, often centrally positioned, commonly lead-zinc rich, massive sulphide facies and a lower and peripheral, lower grade, quartzose, disseminated sulphide facies. The idealized spatial distribution of these different ore types is shown on Figure 2.3. These sulphide sheets, or horizons, have since been deformed into complex fold structures. All deposits show a variably developed, white mica-dominant, alteration overprint in the wallrocks.

There are seven stratiform sulphide deposits in the Anvil Range, five of which are lead-zinc bearing. Collectively, they comprise one of the world's larger lead-zinc reserves, as shown on Table 2.1.

The Faro deposit is well known from exploratory work completed over the 20-year production period.

The Vangorda Plateau deposits have several characteristics that distinguish them from the Faro deposit. In large part, this is due to the lower metamorphic grade the deposits reached. The most outstanding difference between the Vangorda Plateau deposits and Faro is the form of the deposit. The Vangorda Plateau deposits consist of several distinct, highly contorted horizons separated by barren phyllite waste. Faro, on the other hand, is essentially one thick horizon in overall outline with lesser phyllitic waste but substantial barren sulphide waste banding. The next most obvious difference is a finer grain size and more complex mineral intergrowth, necessitating finer grinding than Faro ores. Also related to the difference in metamorphic grade is the content of gold which is eight times higher in the Vangorda Plateau deposits than at Faro.

TABLE 2.1

GEOLOGICAL RESERVES AND MINERAL INVENTORY

Deposit	Cut-off %Pb+Zn	Class	Tonnes	%Pb+Zn	%Pb	%Zn	Ag g/t	Au g/t
FARO								
Total Deposit	4.0	Proven	29,251,000	8.2	3.1	5.0	41	N.A.
GRUM								
Main Zone (61W-87W)	4.0	Proven	30,649,000	9.0	3.4	5.6	57	0.95
Champ Zone (51W-61W)	4.0	Probable	1,700,000	7.8	3.5	4.3	46	N.A.
N.W. Extension (87W-100W)	N.A.	Possible	8,000,000	10.0	N.A.	N.A.	N.A	N.A
Total Deposit 51W-100W)	N.A.	N.A.	40,349,000	9.1	N.A.	N.A.	N.A	N.A
VANGORDA								
Total Deposit	4.0	Probable	7,457,000	8.7	3.8	4.9	54	0.69
DY								
Total Deposit	9.0	Possible	21,059,000	12.2	5.5	6.7	84	0.95
SWIM								
Total Deposit	6.0	Possible	4,309,000	8.5	3.8	4.7	51	N.A.
TOTAL INVENTORY			102,425,000	9.4	N.A.	N.A.	N.A	N.A.

NOTES: Two other deposits, SB and Sea, contain sulphide mineralization but have not been evaluated due to sub-marginal grades.

Effective Date January 1, 1986. Since 1986 approximately 11 million tonnes were mined from the Faro open pit.

2.2.1.4 Description of Sulphide Rock Types

(a) Massive Pyritic Sulphides

The massive pyritic sulphides [unit 4E] consist of banded to homogeneous massive pyrite with lesser sphalerite and galena. Total sulphide content is at least 60%, generally greater than 80% and commonly nearly 100%. Gangue consists of quartz and/or barite and/or carbonates (calcite, dolmite, ankerite). Accessory minerals include pyrrhotite, chalcopyrite, magnetite, arsenopyrite and marcasite. Unit 4E is usually relatively high grade but, at Vangorda and locally at other deposits, a nearly barren massive to semi-massive pyrite unit with quartz gangue [unit 4EC] occurs that is commonly enriched in copper and gold relative to lead-zinc.

(b) Baritic, Massive Pyritic Sulphides

The baritic sulphides [Unit 4G] are strongly and thinly banded massive sulphide/sulphate rock consisting of pyrite, galena, sphalerite and commonly magnetite in a gangue of up to 50% off-white barite and lesser carbonates (calcite, dolmite, ankerite and probably barytocalcite). Most baritic layers are interbanded with pyritic sulphides and the two lithologies are lumped together as unit 4EG. The baritic facies is usually quite high grade (10-15% combined lead-zinc).

(c) Pyrrhotitic Massive Sulphides

This rock type [unit 4H] consists of massive, finely crystalline, usually well foliated pyrrhotite with less than 50% pyrite porphyroblasts and highly variable amounts of sphalerite and galena. Minor chalcopyrite is characteristic of this relatively copper-rich facies. Rounded to angular, rotated, foliated quartzite or quartz-veinclasts 2 cm or less in diameter are typical. This is a minor facies and is not known with certainty to be

primary as some pyrite in the massive facies may invert to pyrrhotite during regional metamorphism. At Faro, the pyrrhotitic facies is more volumetrically important than the other deposits.

(d) Ribbon Banded, "Graphitic", Pyritic Quartzite

This unit [unit 4A] is a dark grey to black, well banded, sulphide-bearing quartzite (metamorphic usage). Bands are: (a) dark grey, very fine grained carbonaceous phyllitic quartzite to siliceous phyllite (presumed metachert) and (b) light grey, quartz-sulphide (pyrite-sphalerite-galena) bands. These bands are usually 2 mm to 2 cm thick. Total sulphide content of unit 2A is usually between 10 to 30% but ranges from 2 to 60%. Pyrite is usually the dominant species but higher grade examples have sub-equal pyrite and lead-zinc sulphides.

(e) Pyritic Quartzite

The pyritic quartzites [units 4B, 4C, and 4D] are light to medium grey, generally poorly banded, moderately to weakly foliated, micaceous quartzites with highly variable lead-zinc and pyrite contents. Pyrite contents are generally 10 to 40% ranging between 2 and 60%. Although there is a complete gradation from massive to quartzose ores, there is usually little problem in separating this facies from the massive pyritic sulphides as the vast majority of examples have less than 40% total sulphides. Chalcopyrite, pyrrhotite and magnetite-bearing varieties are common especially in the Vangorda deposit footwall (see below).

(f) Sulphide Waste

The term sulphide waste is used here to denote any of the above rocks that have insufficient lead, zinc, and silver content to be economic to mine and process. Some of this material is moved to

gain access to deeper high grade ore during the mining sequence and accumulates in the waste piles. The potential for these materials to generate acidic and metal-bearing leachates is discussed below. The term waste carries with it an economic definition. Much of the sulphide waste carries some base metal and appreciable precious metals that may some day prove to be recoverable at a profit. Mine development planning and abandonment planning must address the possibility that this material, both in the dumps and remaining in the pit walls, may some day prove to be marginally economic ore rather than waste.

(g) Alteration

Both wallrocks of the ore deposits and certain ore types are overprinted by a prominent, easily recognized, light coloured alteration assemblage [unit 4L]. The most common alteration lithology on the Vangorda Plateau is a light green-grey chlorite muscovite phyllite with disseminated pyrite and/or pyrrhotite or the same sulphides in thin stringers. More intensely altered rocks are nearly white quartz + muscovite phyllite commonly with a few percent disseminated sulphides. The alteration unit is unusually abundant in the footwall of the Vangorda deposit where much of it is mixed with little altered phyllites of the Mt. Mye formation. A large proportion of the Vangorda waste dumps will thus be altered phyllite, conversely only a small part of the Grum waste dumps will be composed of altered phyllites. The altered phyllites only rarely contain sufficient lead-zinc to be considered ore. Because the phyllites are rarely ore, contain only minor sulphides and are not generally readily differentiated from unaltered phyllites, this unit has been excluded from the above category of sulphide waste. The altered phyllites acid-generating potential is however discussed below separately from other phyllites.

2.2.2 Vangorda Geology and Reserves

Vangorda was the initial discovery in the Anvil Range. Attention was drawn to the area by a prominent red iron oxide stain in Vangorda Creek. The stain was caused by seepage of groundwater that had interacted with the orebody. The seepage is sampled today as the "Red Spring"; the results are given below.

The deposit was drill-tested from 1953 to 1955 by Prospector Airways, a predecessor to Kerr Addison Mines. This drilling showed a significant deposit existed but a production decision was not warranted at that time. Minor additional drilling was done by Kerr Addison, largely for metallurgical sampling, until the deposit was sold to Cyprus Anvil in 1979. Cyprus Anvil geologists examined the available drill core and concluded that it would be necessary to redrill the deposit to provide adequate material to re-evaluate it.

In 1979, the portion of the deposit from 2W to 12E shown in Figure 2.4 was re-drilled with NQ core holes. Scattered core holes were put down in the southeast part of the deposit. Because of anticipated poor recoveries in this area, it was judged advisable to drill this part of the deposit with rotary methods. This fill-in drilling was done in 1981.

Selected fill-in holes were drilled by Curragh in 1987. Also in 1987, test holes were put down in the southeast part of the deposit. These holes showed good recovery and the remainder of the deposit was redrilled in 1988 with NQ core holes because of questionable and difficult to interpret results of the rotary drilling.

There are 153 modern diamond drill holes (since 1979), totalling 16,700 m (54,700 ft) defining the Vangorda deposit. The deposit is drilled off by a minimum of 30 m spaced holes on 60 m spaced sections with some fill-in drilling between sections shown on Figure 2.4.

The deposit is quite shallow, in most places subcropping beneath glacial till. The till blanket is up to about 30 m thick in the northwest part of the deposit, but thin in the southeast. Northwest of Vangorda Creek, till cover is also quite thin. Locally, the basal overburden and uppermost broken bedrock are cemented by iron oxides into a tough breccia. An orange stained till layer of unknown thickness occurs near the base of the overburden. It is sharply overlain by unoxidized brown till, which typifies the majority of the unconsolidated overburden in the area.

The Vangorda deposit consists of one major sulphide horizon, the "main horizon", about 50 to 120 m beneath the basal carbonaceous member of the Vangorda formation, as shown on Figures 2.5 and 2.6. The host rocks for the deposit are dominantly non-calcareous phyllites [unit 3G], probably part of the Mt. Mye formation. However, formational assignments near this deposit are ambiguous, largely due to the strong wall rock alteration developed around the deposit. Most phyllites, especially in the main horizon footwall, are bleached, locally silicified and/or chloritic and sulphide bearing [unit 4L].

A number of thin horizons occur above the main horizon. These horizons are too thin or too low grade to be mineable, with the exception of the southeast end of the deposit where they are shallow and the stripping ratio is low.

The deposit consists of the same sulphide rock types as the Grum and Faro deposits as outlined above. Two rock types are particularly prominent. The footwall of the main horizon of the deposit is a sulphide-rich quartzite [unit 4C] and quartz bearing semi-massive sulphides [unit 4EC]. This quartzite grades downwards into siliceous phyllite and, ultimately, altered phyllite. Parallel to this downward decrease in silica is a downward decrease in the abundance

of sulphides from quartz-rich semi-massive sulphide [unit 4EC] at the top to weakly pyritic altered phyllite at the base [unit 4LO]. Most of the sulphides in the quartzite are pyrite, however pyrrhotite is generally present and locally abundant or dominant. Magnetite is unusually well developed in the quartzite. The quartzite contains only minor lead and zinc but is relatively rich in copper and unusually high in gold. Most 4C and 4EC is sulphide waste on the basis of lead-zinc content (Table 2.2), mining of this material is minimal except as required to gain access to deeper high grade baritic sulphides of the main horizon.

The main horizon massive sulphides that overlie the pyritic quartzite are commonly baritic and rich in lead and zinc. The contact between the high grade ore and underlying barren footwall is commonly sharp. The unit is actually a mixture of about 50% 4E and 50% 4G ore types but separate treatment of pure types at Vangorda is not realistic from either the point of view of mining or the level of detail in the geological model. Of the mineralization exceeding 5% Pb+Zn, 90% is barite bearing massive sulphides [unit 4EG], as shown in Table 2.2.

Of the other sulphide rock types, only 4A is of any importance. As is usual for these deposits, it tends to be low grade and peripheral to the deposit. Much of the 4A is actually part of the uppermost horizon associated with the carbonaceous phyllite at the base of the Vangorda formation.

The Vangorda deposit occurs in the hinge of a large second phase fold, as shown on Figure 2.5. Overall, the deposit has the shape of a "3" in cross section. However, there is considerable uncertainty in the details of fold morphology. The deposit is elongate in the northwest-southeast direction, parallel to the second phase fold axis, and has been traced over an area of 1300 m by 200 m.

TABLE 2.2

VANGORDA RESERVES BY ROCK TYPE WITHIN THE ULTIMATE PIT

The northwest half of the deposit plunges about 10 degrees towards the northwest but the southeast half is sub-horizontal, as shown on Figure 2.7. An axial planar foliation (S2) dips shallowly toward the southwest but is locally quite variable. This foliation is the dominant plane of failure for the host rocks of the deposit and is a principal factor in the slope stability of pit walls.

The deposit is truncated by a steep normal fault at its northwest end. Steep normal or transcurrent faults offset the ore near 10E and 12E, as shown on Figure 2.7. Both these faults are late stage post-folding and metamorphism structures. Many gouge zones were observed in drill core but the orientation of the structures responsible for them is not known. A number of faults parallel to S2 are predicted. These are "required" to make the structure and stratigraphy fit regional data from surface mapping and drillholes. These low angle structures are best thought of as sheared-out fold limbs, they are not generally gouge zones and will pose no more serious a problem for slope stability than the S2 foliation itself and the myriad of small gouge zones that parallel it.

A plan of the open pit geology is shown on Figure 2.14.

2.2.3 Grum Geology and Reserves

The Grum deposit was discovered in 1973 by AEX Minerals in joint venture with Kerr Addison Mines. Discovery was the result of drill testing a gravity anomaly in an area down-fold plunge from the Vangorda deposit. Surface drilling in 1973 and 1974 indicated a significant deposit. In 1975 and 1976, an underground sampling and drilling program, along with further surface diamond drilling, was carried out to further define it.

Kerr Addison sold the deposit, along with Vangorda and Swim, to Cyprus Anvil Mining Corporation in 1979. From 1980 to 1982, Cyprus

Anvil drilled additional holes in and around the deposit and re-logged all existing holes in it. All available sulphide intersections were re-sampled and re-assayed at that time.

Curragh drilled additional holes in 1987 and 1988 to further define shallow reserves.

There are 382 drillholes totalling 55,300 m (181,430 ft) in the part of the deposit considered proven (sections 62W to 86W) as shown in Figure 2.8. The deposit is drilled off on 60 m spaced sections with many additional holes on 30 m spaced intermediate sections as required. The deposit was additionally explored by 2700 m of underground development from which 218 of the above holes were drilled in dense fans, as shown in Figures 2.9 to 2.11. An additional 85 more widely spaced holes are scattered near the deposit, mainly in the Champ Zone, as shown in Figure 2.8, and down plunge to the northwest of the pit area.

The subcrop of the ore deposit is covered by up to 100 m of till and better sorted glaciofluvial silts, sands and gravels. The material fills a buried channel trending north-south through the pit area, as shown on Figure 2.12. These unconsolidated sediments are water-saturated and may contain pockets of permafrost. The northeast wall of any pit designs at Grum must contend with thick sections of these sediments. Dewatering in advance of stripping will help increase stability substantially as well as simplify operations in the pit and limit the amount of water pumped from the pit.

The Grum deposit consists of three to five highly contorted layers of massive and disseminated sulphide mineralization within a 150 m section of barren phyllite. The most important mineralized horizon occurs just beneath the basal carbonaceous member of the Vangorda formation. There are thin low-grade horizons within the Vangorda

formation and more important horizons in the upper part of the Mt. Mye formation.

At Grum, the Vangorda formation consists of soft, highly fissile, calcareous phyllites [unit 5B]. Metabasites in the Grum area are minor and tend to be highly foliated chlorite phyllite rather than blocky, massive greenstones that typify the Vangorda formation elsewhere. The basal carbonaceous member of the formation [unit 5A] thickens across the deposit from about 10 m in the northeast to as much as 80 or 100 m southwest of the deposit. The sulphide horizons appear to be associated with the northeast pinchout of this unit. Immediately above the main ore horizon, the carbonaceous rocks are soft, highly sheared and gouged. Elsewhere they are moderately hard, highly fractured, black siliceous phyllites. The Mt. Mye formation also consists of soft phyllites [unit 3G] which are distinguished from those of Vangorda formation by being non-calcareous and less distinctly banded.

There are no significant post-metamorphic dykes at Grum. The Anvil Batholith crops out 1.5 km northeast of the deposit but is separated from it by major faults. The Batholith is unrelated to the deposit and does not appear to have significantly affected it.

A feature unique to Grum among the Vangorda Plateau deposits is the relative abundance of quartzose ore types, particularly carbonaceous pyritic quartzites [unit 4A] which comprise about 35% of the reserves above 4% Pb+Zn, as shown in Table 2.3.

The ore layers at Grum are contorted into a complex, shallowly northwest plunging, polyphase fold structure. The prominent S-shaped folds as shown on Figures 2.9 to 2.11 are second phase structures. They are superimposed on a larger Z-shaped first phase fold. The dominant plane of fissility or cleavage in the phyllites at Grum is axial planar to the second phase folds and dips shallowly (10 degrees

TABLE 2.3

to 30 degrees) generally to the southwest. This fissility is a major factor in assessing slope stability for the pit. The overall deposit elongation parallels the axial direction of the second phase folds (315 degree trend, 11 degree plunge).

There are several important faults at Grum. The largest displacements occur on moderately (35 degree to 45 degree) dipping structures that truncate the deposit at both its northwest and southeast ends, as shown on Figure 2.13. The Doal Lake and Tie fault at the NW end of the deposit is not shown. Neither of these structures would crop out in an open pit but smaller subparallel faults will be found in the pit. A steeply northwest dipping fault trending about 060 degrees, passes between sections 70W and 72W and downdrops the deposit about 60 m to the northwest. A myriad of smaller faults were mapped underground by Kerr Addison trending on the average 080 degrees and dipping steeply. Joints mapped underground and on surface tend to strike 060 degrees and dip subvertically.

A plan of the open pit geology of the ultimate Grum pit is shown on Figure 2.15.

2.3 MINE PLAN

2.3.1 Overview

Curragh Resources Inc. proposes to extend the life of the Faro operations by sequential mining of the Vangorda and Grum deposits using the open pit method. The Vangorda pit would be relatively small, with a proposed maximum depth of about 100 metres. The Grum pit, which contains greater ore reserves and has a greater depth of overburden, will be about 300 metres in depth. The locations of both pits are shown on Figure 2.16.

Ore from the Vangorda Plateau will be hauled to the Faro concentrator over the Vangorda Haul Road which is currently under construction. A power line, Mine Dry, and minimal maintenance facilities will be constructed as part of the new infrastructure required to handle the Plateau production. Waste Dumps for the overburden and waste rock will be established adjacent to pits at locations as shown on Figure 2.16.

Vangorda Creek will be diverted via a 680 metre long culvert or ditch lined with a half culvert located on a sloping in-pit bench, around the northern perimeter of the pit. Surface drainage at both pits will be intercepted and diverted around the minesite. Drainage from the minesite and waste dumps will be collected and treated. As the proposed development involves only mining on the Vangorda Plateau, all processing and tailings storage will be located at the existing Faro Minesite.

2.3.2 Schedule

Stripping of the Vangorda Pit overburden is currently scheduled to begin in mid 1989, with the first ore being removed towards the last quarter of 1989. Overburden removal from the Grum Pit area would begin early in 1989 but significant ore removal would not commence for another 2 to 3 years. It is estimated that the Faro open pit will be completely mined out by 1991 and the underground mining reserves by 1993. Future production after depletion of the Faro reserves will be provided by the Grum and Vangorda deposit. Open pit mining at the Vangorda Plateau is scheduled to be completed by 1998.

2.3.3 Mining Methods

The open-pit mining method to be utilized for both the Vangorda and Grum pits will involve (a) removal of the overburden with front end loaders and trucks, (b) rock stripping using electric shovels and

front end loaders, (c) stockpiling of the waste rock adjacent to the pits, and (d) stockpiling the ore outside the pit for transfer into haulage trucks to feed the crusher at the Faro Mill.

2.3.4 Access and Haulage Roads

2.3.4.1 Design and Construction

Several alternative systems to transport the ore from the Vangorda Plateau to the mill have been examined by both CAMC and Curragh Resources. The selected option is the use of "off-road" large size trucks in a manner similar to the operation of the existing mine. This option requires construction of a haul road from the new development site to the existing plant site. The proposed alignment for the haul road is shown on Figure 1.2.

The following roadway design criteria were developed:

Design Speed	55 km/h
Width of Finished Road Top	24 metres
Sideslopes:	
Overburden	2:1 (H:V)
Waste Rock	1.5:1 (H:V)
Maximum Grade	7%
Stopping Distance	60 metres
K (sag vertical curve)	30
K (crest vertical curve)	55
Horizontal Radius	5,000 m
Traffic Operation	Left hand side of road.

The haul road would be constructed primarily from locally available fill materials. The first 9 kilometres of the road will be constructed of waste rock from the mine consisting of non-acid

generating phyllite and calc-silicate. The road, for the last seven kilometres, will consist of a glacial till core covered with waste rock from the Faro Pit. The till material will be obtained from a borrow pit developed at the Vangorda Plateau. A 0.5 metre thick gravel surface of calc-silicate will be placed and compacted above the subgrade level. A typical section through the haul road is presented in Figure 2.17.

Preliminary horizontal and vertical alignments were prepared by Stanley Associates Engineering Ltd. and presented in a report titled "Vangorda Plateau Haul Road". The recommended alignment had an optional loaded direction gradient from km 14.7 to the north fork of Rose Creek. The selected route had a south facing slope which would minimize winter operating problems related to ice build-up on the driving surface.

The final road design was completed by the Engineering Department of Curragh Resources and the vertical and horizontal alignments are presented on Figure 2.18 to 2.22.

Construction of the haul road has already begun. Beginning in October 1986, waste rock from the pit was used to construct the first stage of the haul road: the crossing of the North Fork of Rose Creek. Design of the rock drain and creek crossing at this point was done by Golder Associates in September of 1986.

The alignment of the haul road is essentially that developed by Stanley Associates Engineering Ltd. (SAE) for CAMC in December 1980. The first 3000 metres of the Stanley design has been realigned in order to reduce the adverse grade on that portion of the haul road. Also, the last 3000 metres has been realigned to bring the haul road south of the Grum pit.

Completion of the haul road is expected to take two construction seasons.

2.3.4.2 Stream Crossings

The proposed Vangorda Plateau haul road crosses a number of streams which are tributary to Rose Creek and Vangorda Creek. Design and construction of these crossings is subject to the review and approval of the Yukon Territory Water Board. Several crossing structure alternatives were considered during the preliminary design stages. These included conventional bridges and corrugated metal pipe culverts (CMP). Based on the width of the road, the design loads and the height from stream bed to roadway elevation, the CSP was selected as the most economical choice.

During Fisheries studies completed by Montreal Engineering in 1970 and by P.A. Harder & Associates Ltd. in August of 1987, it was found that the tributary streams which would cross the proposed alignment, including South Fork of Rose Creek, were non-fish bearing. Consequently, the design criterion for the stream crossings was based on the 25-year flood event with no provisions for fish passage.

Design discharges calculated by SAE were based on a report titled "Hydrologic and Hydraulic Design of Down Valley Tailings Disposal, Cyprus Anvil Mining Corporation", May 8, 1980 prepared by Hydrocon Engineering. The appropriate culvert sizes were determined by application of Mannings equations.

Based on a report titled "Review of Peak Flow Estimates for Vangorda and Rose Creek" completed by Curragh Resources in June 1988, it was found that the method of analyses by Hydrocon Engineering Ltd. resulted in very high flood estimates compared with other methods. Following discussions with government agencies, it

was agreed that future hydrological analyses completed on the Vangorda Development Project would be based on the Yukon Regional Analysis Method of Flood Estimation developed by the Water Resources Division of the Department of Indian and Northern Development (DIAND). A comparison of the results from the two methods indicates that the culverts, which were designed based on the Hydrocon method, would most likely accommodate the 1 in 500 year event based on the DIAND method. A summary of the culvert design for each of the major stream crossings is presented in Table 2.4. The location and size of each culvert installed along the Vangorda Plateau haul road are shown on the plan and profile drawings presented on Figures 2.18 to 2.22. Watershed locations and drainage areas for the major streams which cross the haul road are presented on Figure 2.23.

TABLE 2.4

MAJOR CULVERT DESIGN SUMMARY

Station	Catchment Area (km^2)	Design Discharge* (m^3/sec)	Return Period (yrs)	Headwater at Inlet** (m)	Pipe Diameter (mm)	Stream Names
5+450	7.6	3.4(6.1)	25	1.8(4)	500	Reservoir Creek
7+460	3.4	1.8(3.75)	25	1.2(4)	1200	Gun Range Creek
8+610	1.9	0.83(1.9)	25	1.0(2.3)	900	Unnamed
10+250	24.9	7.5(23)	25	1.8(.9)	1400,1600	South Fork Rose Creek
11+950	3.3	1.32(2.9)	25	1.2(4)	900	AEX Creek***
12+370	2.7	1.4(3.1)	25	1.2(4)	900	South Fork AEX Creek

* Peak Discharge in brackets based on Hydrocon Engineering.

** Headwater Depth in brackets based on Hydrocon Peak Discharge Estimates.

*** The West Fork of Vangorda Creek is referred to as the AEX Creek.

2.3.4.3 Ramps

Limited access across the haul road will be provided for local trappers and hunters. In addition, ramps will be constructed within a specified corridor to allow Fannin sheep to approach and cross the road during the migration season. These ramps will be constructed of waste rock and glacial till.

2.3.4.4 Abandonment

Following abandonment of the Vangorda and Grum minesite, the section of haul road through the plateau area will no longer be regularly maintained. The Vangorda Creek diversion culvert would be removed following abandonment allowing Vangorda Creek to directly discharge into the newly formed lake in Vangorda pit.

In the event that the Dy and Swim deposits to the east are developed, it is most likely that the Vangorda Plateau haul road would be rerouted around and above the Vangorda minesite and a new road constructed to Blind Creek. As a result, the haul road culverts to the west fork of Vangorda Creek would be regularly maintained following abandonment of Vangorda.

2.3.5 VANGORDA PIT

2.3.5.1 General

The Vangorda Pit will be the first of the Vangorda Plateau deposits to be developed and mined. The Vangorda deposit, which is relatively small compared to Grum, extends 900 m in length, is 200 to 300 metres wide and 100 metres in depth. The longitudinal axis of the pit is approximately northwest/southeast with the deepest portion to the northwest end of the pit. Access to the pit will be a ramp with the entrance located at the southeast end of the pit. The pit is to be mined in its entirety as a single phase operation with each lift being mined to ultimate pit limits in sequence. It

is intended to prestrip and mine the deposit over a period of four years. The open pit site plan is presented on Figure 2.16.

2.3.5.2 Mining Reserves

The estimate of insitu reserves for the Vangorda open pit was completed using PC Mine computer model. A minimum 5% (Pb+Zn) for the high grade ore and 4% (Pb+Zn) for the low grade ore was selected. The ultimate pit was digitized and the quantities for overburden rock, low and high grade ore were calculated by benches of 4.5 metres. These reserve volumes were then adjusted to reflect a 95 percent mining recovery and 15 percent waste dilution. A summary of the current mining reserves is presented in Table 2.5.

TABLE 2.5

CURRENT MINING RESERVES - VANGORDA

	(Quantities in tonnes x 1000)	
Waste		
Rock	8,000	
Overburden	7,596	
Total Waste	15,596	
Ore		
High grade	5,400	>5% (Pb+Zn)
Low grade	532	>4% <5% (Pb+Zn)
Total Ore	5,972	>4% (Pb+Zn)
Effective Stripping Ratio (t/t)		
Total Ore	2.61	
High Grade	2.96	
High Grade Ore Quality	>5% (Pb+Zn)	
(Pb+Zn)	8.58%	
Pb	3.74%	
Zn	4.84%	
Ag	53 g/t	
Au	.59 g/t	

2.3.5.3 Pit Design and Mine Plan

The Vangorda ultimate pit design is based on sectional representation of the geology's ore grade. Sections were constructed at 60 metre intervals through the orebody. For each section, an optimum pit was determined, based on the model combined with geotechnical design parameters for the pit walls. After the sectional representations were complete, the walls were adjusted to give sectional continuity and the ultimate pit was defined.

The current pit design is based on an assumed 12-metre high bench in the waste and a 6-metre bench in the ore. The pit slope geometry assumes a 40 degree overall slope in the area where foliation is dipping into the pit (northeast wall), and a 45 degree overall slope where foliation dips into the wall (southwest wall). The overall slope angle for cut in the overburden would range from 30 to 35 degrees. The width of the ramps and pit roads would be 30 metres, with a maximum grade of 8 percent.

Based on the current mine plan, Vangorda pit will be mined in one stage with the excavation scheduled in 14 phases to delay the diversion of Vangorda Creek as long as possible. The mine waste and overburden would be selectively deposited in a designated waste dump immediately west and downslope of the pit. Details of the waste dump and Vangorda Creek diversion are discussed in Sections 2.4.3 and 2.5.1, respectively.

2.3.5.4 Pit Slope Stability

The structural geology of the Vangorda Pit area indicates that the rock stability will be predominantly governed by the orientation of foliation. From structural information obtained from the 1979 drilling program and based on observations at the Faro Pit, the S2 foliation is considered to be the most prominent discontinuity

affecting slope design. An average orientation of the S2 foliation was determined from measurements taken from the diamond drill core. Stereographic projections of the foliation data indicated an average foliation orientation of 220°/27° SW (dip direction/dip) on the northeast side of the pit and 220°/23° SW on the southwest side of the pit. As the foliation dips into the pit on the northeast wall and dips into the wall on the southwest wall, instability, along this major discontinuity set, may develop. Therefore, a more detailed analysis of foliation was completed on the northeast side of the pit using the Cumulative Sums Technique (Piteau and Russell, 1971). The current mean dips of foliation in selected drill holes were used to construct design sections, which are approximately normal to the strike of the foliation. An approximation of the foliation dip on four design sections was determined and incorporated into slope stability analyses for the purpose of slope design.

The slope stability analysis for the rock slopes was completed by considering three different types of failures, - namely plane, wedge and toppling. Analysis of circular failure of the overburden portion of the pit slopes was also completed.

The plane failure analysis was carried out using a limit equilibrium method of analysis as shown on Figure 2.24. The geometric relationship of the failure planes for each design section is shown on Figure 2.25. The rock shear strength parameters, which were established from direct shear and triaxial laboratory tests completed on rock samples from Grum and Faro, are summarized in Table 2.6. An allowable safety factor of 1.3 was established as the minimum acceptable value for overall slope angles. The recommended overall slope angles based on the stability analyses are presented in Table 2.7.

TABLE 2.6

ROCK SHEAR STRENGTH PARAMETERS

	Faro	Grum	Vangorda*
Discontinuity	Faults sub-parallel to foliation	Joints parallel to foliation	Foliation
Angle of Friction	ϕ_r = 21° and 24°	ϕ = 19.5° i = 6° ϕ + i = 25.5°	ϕ_r = 25° and 21°
Apparent Cohesion C	Low - 720 psf High - 2,880 psf	850 psf	Low - 864 psf = 6 psi High - 2880 psf, 20 psi

* Assumed Vangorda characteristics would be more similar to Grum than Faro.

TABLE 2.7

RECOMMENDED SLOPE DESIGN PARAMETERS FOR VANGORDA PIT

Design Sector	Recommended Overall* Slope Angle	Bench Design	
		Batter Face Angle	Bench Height
Northeast	40°	70°	12 m
		60°	17 m
Southwest	45°	65°-70°	12-24 m

* Overall Slope Angle is from top pit crest in rock to pit bottom toe with benches but not including haul roads. The slope angles do not assume a fully dewatered slope.

The stability analyses completed to date have been based on S2 foliation measurements obtained from unoriented drill core assuming only an average strike direction for all foliation. It is planned

that, during the early stages of pit excavation, a more detailed structural interpretation of the S2 foliation would be completed and used in a re-evaluation of the initial stability analysis.

Wedge failure could be a possible failure mode along the northeast wall, with sliding along the intersection of faults and foliation or joints and foliation. A wedge failure analysis involving an inferred fault orientation of 245°/80° N and foliation on the northeast wall was performed on a 20-metre bench height to determine stability. Bray's short solution (Hoek and Bray, 1977) was used to determine the possibility of wedge sliding. Results of the analysis indicated that the wedge formed by the fault and foliation was stable. Further, more detailed wedge failure analysis will be completed as more structural information is obtained on the Vangorda deposit.

Toppling is a possible failure mode along the southwest wall if a set of sub-parallel discontinuities exist that dip into the wall. Based on a toppling failure analysis completed by Montreal Engineering, any discontinuity set dipping shallower than 70° with a friction angle (ϕ) of 25° and a 45° slope, would not have a risk of toppling failure. Some steeply dipping faults of orientation 245°/80° N have been inferred in the Vangorda structural interpretation. These faults would be only sub-parallel the trend of the pit wall at the narrow northwest and southeast ends of the pit and they would not dip in the proper direction to cause toppling at these locations. Failure by toppling will be further assessed as more information on the discontinuity sets is obtained.

Slope stability of the overburden till was completed based on slope stability charts for circular failure developed by Hoek and Bray. The analysis indicated that, for a partially saturated overburden slope 50 feet high, a 36 degree slope would be stable. The slope

angle could be increased to 40 degrees if the material is fully drained.

Stability analyses for bench design were completed using a similar approach to the overall slope design. Based on observations at the Faro pit, the main type of bench failure is a plane or a wedge failure involving intersecting joints or foliations. As no joint data were available for the Vangorda deposit, the analysis was completed by analyzing plane failure on foliation. The results indicated that, generally, the bench height could exceed 12 metres, with stability maintained up to 17 metre height along the northeast wall and up to 24 metre height along the southwest wall. A summary of the slope and bench design parameters are presented in Table 2.7.

2.3.5.5 Groundwater and Pit Slope Dewatering

The results from groundwater investigations conducted by Curragh in 1987 indicate that high pore pressure conditions exist at the proposed Vangorda Pit site. The overburden till has a relatively low permeability and forms an upper confining layer. The competent impervious phyllite bedrock forms a lower confining layer. Interbedded between these layers is a water-bearing zone of sands and gravel over weathered bedrock. Based on measurements from the seven piezometers installed during the 1987 groundwater program and from data collected from previously installed piezometers, a groundwater flow net was developed. This flow net indicated that the groundwater seepage would enter the pit along the northeast slopes. Although gravity drainage towards the pit is expected to result in partial dewatering of the slopes in surficial soils and in bedrock, other measures would be implemented in an attempt to further lower the groundwater table and reduce pore pressures at the overburden/rock interface. These measures would include several peripheral wells or drain holes which would be located

outside the east perimeter of the pit. To determine the design parameters for these wells, it is planned to install, prior to mining, two additional piezometers and one observation well at the locations shown on Figure 2.16. (VPH-8 and VPH-9) Pump tests will be performed to assess the effectiveness of an interceptor well and to determine the pit dewatering requirements.

The results of the 1987 groundwater investigation, including logs of drill holes, and permeability calculations, are presented in the Appendix in Figures A-1 to A-16. Piezometer readings taken at the time are presented in Table A-1 and A-2. Details of other pit dewatering measures such as surface water diversion and Vangorda Creek diversion, are discussed in Section 2.5.

2.3.6 GRUM PIT

2.3.6.1 General

The Grum deposit will be the second of the Vangorda Plateau deposits to be developed and mined. The Grum pit, which will cover a larger area and be deeper than the Vangorda pit, extends approximately 1,100 m in length and 800 m wide. The maximum depth of the pit will be over 300 metres. The slopes in surficial soils will exceed 100 metres in height in the extreme east corner of the pit, and will average about 67 metres in height along the northeast and southeast walls. The pit will be mined in three overlapping stages. It is planned to prestrip and mine the deposit over a period of 8 years. The site plan for the Grum pit is presented on Figure 2.16.

2.3.6.2 Mining Reserves

The insitu reserves for the Grum pit were calculated, as for the Vangorda pit, using the PC Mine Computer model and assuming the

same ore grade criterion. A summary of the total mining reserves is presented on Table 2.8.

TABLE 2.8

CURRENT MINING RESERVES - GRUM

(Quantities in x1000 tonnes)

Waste		
Rock	145,005	
Overburden	27,980	
Total Waste	172,985	
Ore		
High Grade	20,869	>5% (Pb+Zn)
Low Grade	3,109	>4%<5 (Pb+Zn)
Total Ore	23,978	
Effective stripping Ratio	(tonnes of waste/tonnes of Ore)	
Total Ore	7.34	
High Grade	8.59	
High Grade Ore Quality	>5% (Pb+Zn)	
(Pb+Zn)	8.58%	
Pb	3.19%	
Zn	5.39%	
Ag	53.6 g/t	
Au	0.84 g/t	

2.3.6.3 Pit Design and Mine Plan

The current computer block model assumes a block height of 4.5 m. The design bench height used for waste rock and ore were 12 metres and 6 metres, respectively. The pit slope geometry is similar to Vangorda, assuming a 40 degree overall slope where foliation is dipping into the pit and 45 degrees elsewhere. The overburden slope angle would be 30 degrees with a 10 m wide berm maintained at

the overburden/rock interface. The pit roads would be constructed in rock or on rock backfill with a minimum width of 30 metres and a maximum grade of 8 percent.

The pit will be mined in three stages. The first stage of the pit will be excavated to El. 1120 m, with the intention of accessing the ore body as soon as possible with minimal prestripping. Stripping of the second stage will begin concurrently with the first stage. The total volume of excavation in Stage I would be 29.9 million cubic metres (74.5 million tonnes). The waste will be deposited in three dumps. The southeast and main dumps have been designated solely for overburden and waste rock, respectively. The southwest dump will receive both overburden and rock.

The second stage will involve pushing back both the southwest and northwest walls of the Stage I pit and extending the excavation down to El. 1040 m. The plan is to backfill the bottom of the pit and build the final roads on the backfilled material. The total volume of excavation in Stage II is 30.5 million cubic metres (84.1 million tonnes).

Stage III will involve excavation of the pit to the ultimate limits. The total volume of excavation in Stage III will be 15 million cubic metres (41.3 million tonnes). The total volume of excavation of the pit is 75.4 million cubic metres (200 million tonnes). Details of the design and configuration of the waste dumps are presented in Section 2.4.4.

2.3.6.4 Pit Slope Stability

As for the Vangorda Pit, the regional geology in the area of the Grum Pit indicates that the S2 foliation generally dips moderately towards the southwest. The design of the northeast wall of the pit is therefore controlled by the foliation. The recommended slope

design parameters for the Grum pit have been based on the stability analyses completed for the Vangorda pit, as discussed in Section 2.3.5.4. However, as the slope heights in both the overburden and bedrock will be substantially greater than at Vangorda, a reassessment of the final slope design recommendations will be completed based on observations and data collected from the trial interim slopes exposed during the initial phases of the pit excavations.

2.3.6.4 Groundwater and Pit Slope Dewatering

Six standpipe piezometers were installed in drill holes within the proposed Grum Pit area during the 1987 geology drilling program. Four pneumatic piezometers had been previously installed by Montreal Engineering in 1979. The measurements of the piezometric head at each piezometer indicated that the groundwater flow has a strong southerly component, with the probable sources of recharge being the high ground to the northeast and east of the pit. Groundwater conditions are expected to be worst on the northeast and east walls.

As for Vangorda, gravity drainage will cause some natural depressurization of the slopes in the surficial soils. However, based on observations in the Faro pit, depressurization of the bedrock slopes is expected to be minimal. In an attempt to reduce the pore pressure in the rock mass, a system of deep interceptor wells around the northern and eastern periphery of the pit, is planned. To determine design parameters for these wells, Curragh is proposing to install one observation well and three additional piezometers at locations as shown on Figure 2.16. Pump tests will then be completed to assess the total and individual capacity of the deep well pumps. Other pit dewatering measures including in-pit sumps, and surface drainage diversions, are discussed in Section 2.5.

2.4 WASTE MATERIAL DISPOSAL

2.4.1 General

It is anticipated that development of the Vangorda and Grum deposit will produce a total of about 75 million bank cubic metres (192 million tonnes) of waste material. This material, which consists of glacial till overburden and phyllite and sulphide waste rock, will be deposited in designated waste dumps within close proximity of the Pits. Based on experience at the Faro minesite and preliminary testing of the drill core at the Vangorda minsite, there is a good potential that acid drainage could develop from the sulphide-rich waste rock. Consequently, the problem of acid generating waste is a major consideration in the design and construction of the waste dumps.

2.4.2 Site Selection

Preliminary locations for the waste dumps were initially evaluated by Kerr Addison Mines and were presented in a report by Montreal Engineering dated August 1979. This work was based on an estimated 75 million tonnes of waste rock and about 25 million tonnes of overburden. Recent modelling of the mining reserves indicates that about 56 million tonnes of waste rock and 36 million tonnes of overburden could be produced. The final site selections were revised based on the most recent estimates of waste material quantities, the surficial soil conditions and the steepness of the terrain.

2.4.2 Site Description

2.4.2.1 Surface Condition

The Vangorda west dump will be located southwest of the Vangorda pit straddling a small gully and a westerly trending ridge. The

north flank of the ridge drains into the gully and eventually into Vangorda Creek. On the south side of the ridge, the hillside slopes down towards Dixon Creek, a tributary of Vangorda Creek. The area is presently cleared of trees with some minor vegetation cover remaining. The site is shown on Figure 2.16.

The Grum waste dumps consist of three discrete dumps to the southeast, southwest and south of the ultimate pit. The southeast dump will be located on a hillside which slopes towards Vangorda Creek with an average gradient of about 8 percent. The ground beneath the southwest dump has a relatively gentle slope in the order of 5 percent and drains in a southeast direction towards Vangorda Creek. Marshy conditions exist in the low lying areas beneath the proposed southwest dump. The main waste dump will be located between the southeast and southwest dumps on a hillside directly above Vangorda Creek. The ground in this area slopes at an angle of about 11 degrees. The vegetation cover over the dump area is moderate, with very few trees. The site for the Grum Waste Dumps is shown on Figure 2.16.

2.4.2.2 Subsurface Conditions

The results of three boreholes (BH-77-1, 12 and 13) drilled in 1977 by Montreal Engineering Co. Ltd., indicated that the subsurface soil conditions adjacent to the proposed Grum Pit consist of a glacial till overlying a phyllitic bedrock varying in thicknesses from 33 to over 61 metres. The till consisted of a gravelly sandy silt containing some clay with some sands and gravels. The gradation curves in the report show a content of 18 percent gravel, 37 percent sand and 45 percent finer than the No. 200 sieve size. The till has a high density and low plasticity. The results of an Atterberg limits test yielded a plastic limit ranging from 15 to 21 percent and a plasticity index of 10 to 16 percent. The logs of these boreholes are presented in the Appendix on Figures A-17A to

A-19F. The drillhole borelogs from earlier exploratory programs indicate that the depth of overburden beneath the southeast waste dump ranges from 10 to 40 metres. Beneath the main dump, the estimated overburden depth ranges from a thin colluvium to 30 metres in depth. The surficial soils beneath the southwest waste dump consist of a thin coluvium over bedrock. A map of the contours of overburden thickness is presented in Figure 2.12.

Two field programs were initiated by Curragh between August and September 1987 to assess the geotechnical properties of the glacial till overburden in the Vangorda Pit area. The field work for the first program, conducted on August 18, 1987, involved excavating 6 test pits inside the Vangorda pit ultimate pit. The results of the investigation indicated that the till overburden has an insitu density of about 2,200 kilograms per cubic metre with a natural moisture content of 11 percent. The laboratory analysis completed on samples obtained from the test pits indicated a relatively close correlation with results from the Grum Pit investigation completed by Montreal Engineering. A summary of the laboratory test results is presented in the Appendix on Figure A-20. Results of the gradation tests are presented in Figures A-21 to A-26.

The field work for the second program was completed in September 1987 and involved excavation of nine test pits at the locations shown on Figure 2.16. Soil conditions encountered consisted of 10 to 50 cm of organic topsoil over a loose to medium dense green-brown clayey silt with sand and pebbles. Bedrock was encountered in two of the test pits (6-87 and 3-87) at depths varying from 0.35 to 1.4 metres. The logs of the test pits are presented in the Appendix in Figures A-27 and A-28. From the borelogs of exploratory drillholes, the depth of overburden beneath the Vangorda Waste dump varies from less than 0.5 m to 40 metres (Figure 2.12).

2.4.2.3 Surface Hydrology

The watershed for the Vangorda Plateau, which covers an area of 17.7 square kilometres, drops about 760 metres in elevation from the highest point over a distance of about 8 kilometres. In the upper reaches of the basin, there are extensive rock outcrops. The lower portions of the basin are underlain by relatively impervious tills and the rock outcrops are less extensive. In general, as the watershed has very little topsoil or organic litter and virtually no tree cover, the potential for runoff is high. An outline of the drainage boundary for the minesite watershed is shown on Figure 1.2.

The Atmospheric Environment Service established a meteorological station at Faro in 1977 and at Grum camp in 1983. Based on the data recorded at the minesite since 1983, the mean annual precipitation is expected to be about 539 mm, of which 282 mm would be snowfall. The mean annual pan evaporation for the minesite would be about 300 mm. The climatological data are discussed in a more detail in Section 3.1.

At present, there is no streamflow recording station on Vangorda Creek at the minesite. In 1977, a recording station was established on Vangorda Creek at the town of Faro by DIAND. However, readings from this station are only available from between May and September each year. To estimate the mean monthly stream flows for the watershed above the Vangorda minesite, a correlation was developed between the Vangorda Creek and Pelly River catchments. Based on the results of this analysis, the mean annual yield for the drainage area above the minesite was estimated to be about 7.7 litres per second per square kilometre.

The peak flow estimates in Vangorda Creek at the Vangorda minesite were determined using the Yukon Regional Analysis method developed

by DIAND. The peak instantaneous discharges for the watershed with a return period of 50 years and 100 years were calculated to be 6.47 and 7.6 cubic metres per second.

2.4.2.4 Seismicity

The Vangorda Plateau is located in Earthquake Zone 1 as designated by the Peak Acceleration map for Canada developed by the Pacific Geoscience Centre. It is expected that, for this zoning, an earthquake resulting in a horizontal bedrock acceleration of 0.07 g would have a 10 percent probability of exceedance in 50 years. This is the definition for a Design Base Earthquake, which statistically would have a recurrence interval of 475 years. For this level of seismic activity, low to moderate structural damage is anticipated.

2.4.2.5 Groundwater

Groundwater was not encountered in any of the test pits excavated during the 1987 field program. In several of the piezometers installed in and around both pits, groundwater levels were measured within the glacial till overburden at depths ranging from 4 metres to 20 metres below the ground surface. Groundwater within the overburden could result from interbedded layers of sands and gravels, which create a confined perched water table.

2.4.3 Vangorda Dump

2.4.3.1 Design and Construction

The Vangorda waste dump has been designed to (a) facilitate selective dumping of sulphide and phyllite waste rock, (b) minimize acid generation potential of the waste rock both during mine operation and at abandonment. The volume of waste material produced

over the life of the Pit comprises 3.62 million bank cubic metres (7.6 m. tonnes) of glacial till, 1.87 million bank cubic metres (5.4 m. tonnes) of phyllites and 0.91 million bank cubic metres (2.63 m. tonnes) of sulphide.

The Vangorda waste dump will consist of two separate cells retained on all sides by till berms and covers. The cellularization of the waste rock is an attempt to segregate the potentially high acid-generating pyritic massive sulphide from the potentially low acid-generating phyllite, altered phyllite and carbonaceous phyllite. The sulphide waste will be dumped into the east cell nearest to the pit, while phyllite waste will be dumped into the west cell. The waste rock will be spoiled in three levels or stages at El. 1130 m, El. 1140 m and El. 1150 m. During Stage I of the disposal, some of the phyllite waste will be deposited in the small gully located at the bottom of the sulphide cell. A layout of the dump configuration at El. 1130 m and El. 1140 m is shown on Figures 2.26 and 2.27. When the waste rock reaches the ultimate cell level at El. 1148 m, a 3-metre thick till cover will be placed over the rock to reduce oxygen transmission and water penetration. The lower 1 metre of till will be compacted to 93 percent of the Modified Proctor maximum dry density. The upper 2 metres will be loosely compacted by the bulldozer used to spread the material. Compaction of the till berm will be performed by the haul trucks and bulldozers as the berms are constructed. The surface of the till cover will be contoured both during the mining operation and at abandonment to direct surface runoff away from the waste rock. The details of the recontoured surface are discussed in Section 4.4. The till berms and side slope covers will be constructed with slopes no steeper than 2:1 (horizontal to vertical). The minimum width of the benches between each lift will be 15 m. The maximum bench height would be about 20 m. A summary of the geometry of the waste dump is shown in Table 2.9. Typical sections through the Vangorda Dump are shown on Figure 2.28.

TABLE 2.9

VANGORDA WASTE DUMP GEOMETRY

Location	No. of Benches	Bench Height (m)	Bench Angle (deg)	Berm Width (m)	Dump Height (m)	Overall Slope (deg)	Ground Slope (deg)
N slope A-A	3	10-13	26	20-30	35	15	5.7
NW corner D-D	3	10-12	26	15	31-32	18-20	7.1
E Slope B-B	1.5	10	26	8	14	21	
W slope B-B	2	17	26	15	34	22	4.5
NE slope C-C	3	20	26	23-30	41	18	2.9

Prior to construction of the till berms, the existing ground beneath the berms will be cleared and stripped to remove any organic or marshy soils. In areas where seeps and springs are located, a layer of coarse durable rock will be placed over the discharge prior to placing till. This will provide internal drainage to the toe of the berm.

As it is anticipated that a build-up of water would occur within the impoundment both during waste deposition and after abandonment, an internal rock drain will be incorporated into the system. The drain has been designed to allow water to escape while inhibiting oxygen entry. Water collected by the drain would flow into a collector ditch located along the toe of the dump. The drain will be 3 metres wide and 1 metre thick and will consist of free draining calc-silicate rock from the Faro minesite. These finger drains would extend beneath the till berms at locations as shown on Figure 2.26. At the downstream toe of the till berm where the

drain exits, a sump would be constructed to impede the flow of air through the drain. A typical section through the syphon is shown on Figure 2.29.

2.4.3.2 Stability Analysis

The stability of the proposed Vangorda Waste dump slopes was evaluated under static and pseudo-static conditions by using the Modified Bishop Effective Stress Method of analysis for circular trial failure surfaces. The computations were completed using the STABL2B computer program. The analysis concentrated on the downstream slope of the till berms at abandonment, with an assumed phreatic surface.

Both seismic and static loading conditions were considered in the analyses. Seismic forces were represented in the analyses by the application of a horizontal force expressed as a percentage of gravitational acceleration. The Design Base Earthquake (475-year recurrence interval) is about 0.07 g.

The soil parameters used for the rock waste and glacial till were based on results of laboratory testing completed by Montreal Engineering and documented in their report titled "Preliminary Engineering and Environmental Investigation of the Proposed KER-AEX Grum Joint Venture" dated January 1976. A summary of the parameters and results of the analyses are presented on Figures 2.30 and 2.31.

Based on the proposed configuration and conditions, the analyses indicate that the till berms would be safe against major instability. Under design seismic conditions, some localized ravelling of the slopes could occur, but the integrity of the embankments would not be jeopardized.

2.4.3.3 Seepage Control

To collect the seepage escaping from the waste dump, an interceptor ditch would be constructed along the toe of the dump. The ditch would collect seepage from the finger drains beneath the till berms and direct the flow to the collection pond located immediately below the Sulphide cell. Water stored in this pond would be pumped to the in-pit sump for recycling to the Water Treatment Plant.

The sideslopes of the ditch would be 1.5:1 (horizontal to vertical) with a minimum depth of 1 metre. The base of the ditch would be about 2 metres wide.

2.4.4 GRUM DUMPS

2.4.4.1 Design and Construction

The waste from the Grum pit will be deposited into three separate dumps and in three stages to coincide with the staged excavation of the pit. The proposed layouts for Stages I and II of the Grum Waste Dumps are presented on Figures 2.32 and 2.33. The overburden excavated from the upper benches during Stage I will be deposited into the southeast dump. The total volume of till overburden to be deposited at this dump is estimated to be about 6.8 million bank cubic metres or 8.5 million cubic metres with a swell factor of 25 percent. The dump will be constructed with a maximum of four lifts with a maximum bench height of 15 metres. The width of the bench maintained between each lift would vary from 20 to 30 metres. The overall slope angle of the dump would be no more than 17 degrees.

The overburden from the lower benches of Stage I and some waste rock from the upper benches would be deposited into the Southwest dump. Most sulphide-bearing waste rock from the Grum pit will be returned to the pit if the mine sequence allows. Sulphide waste

not returned to the pit will be deposited in the southwest dump. A separate cell will be constructed in the northwest corner of the dump to accommodate the sulphide waste. This cell will be constructed, as for the Vangorda Waste Dump, with till berm covers, and internal drains. An estimated 3 million tonnes of sulphide-bearing rock will be excavated from the Grum Pit, of which about 50 percent will be used as backfill material in the pit. The total volume of material which will be deposited into the southwest dump is estimated to be about 10.5 million bank cubic metres or 14 million cubic metres bulked.

The main dump will receive mainly waste rock with some till overburden dumped over the slopes and berms during Stage III.

The estimated total volume of waste material which will be deposited in the main dump is 46.4 million bank cubic metres or 60 million cubic metres bulked. It is anticipated that 3.6 million cubic metres will be backfilled into the pit. Typical sections through the waste dumps are presented on Figures 2.34 and 2.35. A summary of the staged deposition of the waste at the Grum dumps is presented in Table 2.10.

TABLE 2.10

STAGED DEPOSITION OF GRUM WASTE

		Dumps (m^3 x 10^3 Bank)					
		Main	Southwest	Southeast	Backfill	Roads	TOTAL
STAGE I							
	Rock	14,600	400	-	-	-	15,000
	Overburden	-	5,000	6,800	-	700	12,500
STAGE II							
	Rock	23,200	2,800	-	300	-	26,300
	Overburden	-	700	-	-	-	700
STAGE III							
	Rock	8,500	1,600	-	3,300	-	13,400
	Overburden	100	-	-	-	-	100
TOTAL	Rock	46,300	4,800	-	3,600	-	54,700
	Overburden	100	5,700	6,800	-	700	13,300
	TOTAL	46,400	10,500	6,800	3,600	700	68,000

A summary of the geometry of the Grum waste dump is presented in Table 2.11.

TABLE 2.11

GRUM WASTE DUMP GEOMETRY

Location	No. of Benches	Bench Height (m)	Bench Angle (deg)	Berm Width (m)	Dump Height (m)	Overall Slope (deg)	Ground Slope (deg)
Main Waste Dump A-A'	4	40-80	35	35-45	200	25	11
Main Waste Dump B-B'	3	35-40	35	30	115	25	-4
Main Waste Dump C-C'	4	15-20	35	15	140	25	9-12
SE Overburden Dump D-D'	4	15	26	20-30	60	17	11
SE Overburden Dump E-E'	4	15	26	30	60	17	17
SW Waste Dump F-F'	2	10-15	26	35-45	40	19-22	4.5
SW Waste Dump G-G'	2	10-20	26	100	40	13	0-3

2.4.4.2 Stability Analyses

The stability of the Grum waste dump slopes was evaluated using the same method and under similar conditions as discussed in Section 2.4.3.2 for the Vangorda Dump. The results of the analyses are presented on Figures 2.36 and 2.37. Under the conditions analyzed and for the proposed slope configurations, the waste rock and till dumps would be safe against major instability. Under design seismic conditions, some localized sloughing of the slopes could occur, but the integrity of the dumps would not be jeopardized.

2.4.4.3 Seepage Control

Based on results of an on-going rock testing program, there is low risk of acid generation from the Grum dumps. During the life of the mine, however, regular monitoring of seeps along the toe of the Grum dumps will be completed. In the event that acid generation and leaching of contaminant metals is detected, a seepage collection system will be constructed along the toe of the dump. The ditch will collect seepage and direct the flow to a sump located at the low point of the dump. The seepage collected in the sump will be pumped to the Water Treatment Plant.

2.4.5 WASTE ROCK

2.4.5.1 Acid Generation Potential

The processes of chemical and bacterial oxidation of sulphide-bearing rock in the presence of water, results in the production of low pH water. This low pH water may leach metals contained in the rock, notably zinc and copper, which may be transported to down-stream receiving waters. This is the phenomenon that is known as Acid Mine Drainage (AMD).

Preliminary laboratory testing has been completed on drill core samples from both the Vangorda and Grum deposits to assess the potential for the waste rock to generate or to consume acid. The waste rock at both sites consists of pyritic and graphitic quartz-ites, massive sulphides, carbonaceous and calcareous phyllites, and altered phyllites. Results from the acid-base accounting tests indicate that the quartzites and sulphides have a high potential for generating acid. The altered and carbonaceous phyllites have a moderate to low acid-generating potential. The only acid-consuming rock is the calcareous phyllite. The mining reserves indicate that about 33 percent of the waste rock from the Vangorda deposit will

be sulphide-bearing rock with a high potential to generate acid. By comparison, the sulphide-bearing rock at Grum would represent only 2 percent of the total waste rock. It is anticipated that very little acid-consuming rock will be excavated from the Vangorda pit, whereas at Grum the acid-consuming calcareous phyllite could exceed 50 percent of the total waste rock deposited in the dumps.

2.4.5.2 Rock Testing Program

A rock testing program was initiated by Curragh Resources to evaluate the geochemical and physical characteristics of (a) the waste rock that would be stockpiled in dumps located around each of the pits, and (b) the exposed rock in the pit walls. These tests include slake tests, freeze-thaw tests, extraction tests and tests to assess the potential to generate or consume acid.

In 1986 selected short hole drill intervals were collected for the testing program. The initial tests were static acid base accountings. A number of samples of each rock type were selected with the intention of establishing a range of parameters for each type. This was done because geological observations on drill core showed that the rocks are quite heterogeneous and change character significantly in short lengths of drill core. This heterogeneity involves both the distribution of sulphide amount and type, (pyrite or pyrrhotite) and the distribution of amounts carbonates and carbonate type (calcite, dolomite and possibly ankerite)

Composite samples representing each of the rock types at Vangorda and Grum were tested by Chemex Labs in North Vancouver, B.C. The samples were crushed, sub-sampled and analyzed for sulphur content, paste pH and neutralization potential. The maximum acidity potential was calculated from the percent of sulphur content and the net effective neutralization was calculated as the difference between the neutralization potential and the maximum acidity

potential. A summary of the results of this test is shown in Table 2.12. These results represent the average values for each major rock type. A complete set of the results from the acid/base accounting test is presented in the Appendix in Tables A-6 and A-7.

Later in the program comparable samples were taken for slaking tests and freeze thaw tests. These samples were again short lengths of diamond drill core, mainly NQ drill core, whose locations are shown on the Vangorda Pit geology map (Figure 2.4).

TABLE 2.12

RESULTS OF ACID/BASE ACCOUNTING TEST

VANGORDA

Rock Type	Paste pH	% S	Max. Acidity Potential*	Neutral Poten.	Effective Neutralization
Graphitic and Pyritic Quartzite,	6.2	16.1	503	7.0	-496.0
Pyritic Massive Sulphide	7.6	38.5	1200.0	209.0	-991.0
Altered Phyllite	7.3	2.9	91.0	8.0	-83.0
Carbonaceous Phyllite	7.9	1.9	58.0	35.0	-23.0
Weakly Calcareous Phyllite	7.3	0.6	19.0	26.0	+7

GRUM

Rock Type					
Graphitic Pyritic Quartzite	6.6	8.7	271.0	30.0	-241.0
Pyritic Massive Sulphide	5.9	44.9	1400.0	33.0	-1367.0
Altered Phyllite	8.0	1.9	59.0	23.0	-35.0
Carbonaceous Phyllite	7.6	1.45	45.0	26.0	-19
Calcareous Phyllite	8.2	.2	7.0	130	+123
Non Calcareous Phyllite	8.0	0.4	14	39	+25

* Units are in kg of $CaCO_3$ equivalent/tonne of material.

The slake test was used to determine the slaking characteristics of the rock in the waste dumps and pit walls. Two tests, the Severe Slaking test and the Wet-Dry Cycles test, were conducted. The Severe Slaking test, which identified rock types that would slake

rapidly, was completed on a number of rock types from each deposit. After soaking for 48 hours, the estimated weight loss of material for each sample was generally less than one percent. It was observed, however, that the carbonaceous phyllite sample was less stable than the other rock types. A summary of the results of this test is presented in the Appendix in Tables A-3 and A-4.

For freeze thaw cycle testing, twenty-seven samples were wrapped in coarse cheese cloth, dipped in water and frozen for 24 hours. They were then removed from the freezer and placed in water 24 hours. Each sample was then observed for signs of any disintegration. After recording the observations, they were again frozen and then the cycle repeated. Each cycle lasts generally 24 hours but may be up to three days because of weekends.

Results to date indicate that two samples are breaking apart. Both samples consist of six inch long pieces of core which have broken into four or five pieces along the foliation. Minor amounts of coarse sandsized phyllitic chips have accumulated in the water. One sample is an altered phyllite and the other is a piece of carbonaceous phyllite. Most importantly, both the massive and disseminated sulphides appear quite stable. The freeze thaw cycle testing is on day 66 of 102 days. Results of the test to date are presented in the Appendix on Tables A-5 and A-6.

For wet dry cycle testing, twenty-seven samples wrapped in coarse cheese cloth are dipped in water for one minute each second day and observed for signs of disintegration.

Three to four of the phyllites have broken into two parts and minor coarse sand size flakes of phyllitic material have chipped off and collected in the water. This testing is on day 67 of 102 days. Results of the test to date are presented in the Appendix on Table A-7.

A 24-hour Extraction test was completed on weathered samples selected from the Vangorda drill core. The purpose of this test was to predict the acidity loading and what contaminant metals can be anticipated from the oxidized material that will be uncovered during stripping. The results of this test are presented in Table 2.13.

The acid-base accounting provides information on the maximum capacity of the rock for acid production and acid consumption. Kinetic testing models the field situation and provides information on the chemical reactivity of the rock type. A kinetic test, namely the Humidity Cell Test, is currently in progress on composite samples of two of the major rock types found at Vangorda. The test is being performed by Coastec Research Inc., North Vancouver, B.C. This test provides optimum oxidizing conditions to small particle size samples. Rock types with the potential to produce acid will do so under these conditions. It is thus a worst case test for acid generation.

The two rock types tested were the variably sulphide-bearing altered phyllites and the pyritic quartzite mixed with massive sulphides.

Because of the heterogeneous nature of the rock types, it was felt that in order to provide a reasonable sample that was representative of the material to be deposited in the waste dumps, the sample would have to be quite large. Therefore, several composites were gathered to reflect the phyllite waste in certain stratigraphic intervals. These intervals are indicated conceptually on Figure 2.? and the locations of the samples are shown on Figure 2.4. The composites generally involve intervals of approximately 20 to 30 metres of NQ core in each of 3 or 4 holes. The samples were collected from contiguous intervals in the drill hole; nothing was

TABLE 2-13 EXTRACTION TEST RESULTS ON WEATHERED ROCK

Sample #	Drill Hole	Depth m.	weather index	Core Type	Description	pH	Acidity mg/l $CaCO_3$	Soy ppm	dissolved Cu ppm	dissolved Zn ppm	Diss. Fe ppm	Diss. Mn ppm
1A	79V095R	30.6 - 32.9	2	3G42+1	non-calcareous muscovite phyllite/schist	3.82	158.8	144	.024	19.8	46	0.82
1B						4.35	135.2	160	.018	32.5	41.5	0.65
8A	79V095R	32.9 - 34.7	1	4L4+1	muscovite quartz phyllite; siliceous	6.23	7.8	~~.005~~	.005	.24	.09	0.33
8B						6.43	17.6	20	.004	2.65	0.08	1.15
3A	79V035R	22.6 - 23.0	2	3G0+2	non-calcareous muscovite, phyllite/schist	4.38	66.6	181	0.005	10.7	11.8	6.25
3B						6.10	58.7	238	0.002	18.5	0.95	5.65
4A	79V035R	23.0 - 23.5	2	3G0+2	non-calcareous muscovite, phyllite/schist	5.61	25.4	36	0.002	1.08	5.1	1.28
4B						4.39	80.3	125	0.011	4.1	32.5	3.6
10A	79V035R	23.5 - 24.4	1	3G09	non-calcareous muscovite, phyllite/schist	4.51	47.0	51	0.005	6.3	7.25	2.3
10B						5.92	19.5	29	0.002	2.5	3.2	1
2A	79V049R	47.1 - 49.5	2	4L3+1	muscovite quartz talc/kaolinite	4.15	131.2	283	0.006	11.5	37	12.6
2B						6.45	27.4	113	0.002	13.5	0.14	4.9
5A	79V133R	9.8 - 11.0	2	3G46	non-calcareous muscovite, phyllite/schist	4.87	43.0	51	0.009	2.02	11.7	1.5
5B						6.68	* - 2.0	25	0.002	0.22	0.1	1.02
6A	79V314	18.8 - 20.1	1	5B62	calcareous muscovite carbonaceous	6.84	- 2.0	27	0.003	0.285	0.105	0.265
6B						6.71	- 7.9	13	0.011	0.565	0.025	0.235
7A	79V053R	38.7 - 40.6	1	3G48	non-calcareous muscovite phyllite/schist	7.02	- 6.0	10	0.002	0.8	0.06	1.19
7B						6.83	- 0.1	6	0.004	0.155	0.06	0.055
9A	79V096R	35.7 - 37.8	1	5B76	cal caveous, muscovite phyllite, chlorite	4.48	84.2	99	3.6	27	11.2	0.29
9B						5.92	11.7	12	0.115	3.25	0.135	0.68
11A	79V307	16.9 - 18.6	1	5B649	calcareous muscovite phyllite, sulfide bearing	3.55	262.6	271	0.046	6.8	102	3.65
11B						4.10	103.8	128	0.009	5.05	3.6	3.1
12A	79V319	15.8 - 18.3	1	5B62	calcareous muscovite phyllite, carbonaceous	5.52	58.9	105	0.004	20.5	10.7	2.9
12B						5.27	47.0	101	0.004	5.65	14.8	2.35

NOTE: A is subsample
R is composite Sample

* negative acidity represents excess alkalinity

** 2a indicates most weathered

left out of the sample and the sample locations were selected at random within the target stratigraphic interval. One of these composites was selected to be the basis for initial humidity cell testing. The sample of phyllite waste is composite "B". This sample is an altered phyllite which is intermediate in the range of sulphide content for such phyllites at Vangorda. Two other composites ("A" and "C") of altered phyllite were collected, but, no test work has been started. A composite of carbonaceous phyllite was also collected. The constituent intervals and rock types comprising composite "B" are shown on Table 2.14.

A sample of sulphide rock types was collected using similar procedures as outlined above. In collecting this sample, drill holes known to penetrate the rock type that will be exposed in the pit walls, were selected in preference to sulphide waste at any other location. The drill holes are tabulated in Table 2.15. These hole locations are given on Figure 2.4. It is felt that these large samples, which consist of over 100 kilograms of rock material, are representative of the variation in the waste types at Vangorda.

The phyllite sample was prepared by jaw crushing to 25 mm minus, all the selected core samples from each drill hole in Composite B to create one homogeneous sample. A 60 to 70 kilogram composite sample was then extracted by cone and quartering. This composite was finally jaw and cone crushed to minus 6 mm and riffle split into two, one kilogram sub samples for the test. The first sub-sample was subjected to a standard Humidity Cell test initiated at the natural pH of the rock. The second sub-sample underwent an accelerated weathering test where the pH is adjusted to the preferred biochemical oxidation range and inoculated with sulphide-oxidizing bacteria. The test, which is presently in progress, normally requires a period of at least 10 weeks. During this time,

TABLE 2.14 COMPOSITE SAMPLES OF ALTERED PHYLLITES FOR HUMIDITY CELL TEST

Drill Hole	Sample Interval From (m)	To (m)	Interval (m)	Weather Index	Unit
79V046R	38.1	41.8	3.7	0	3G048 stringered Minor
79V046R	41.8	44.5	2.7	0	4L17
79V046R	44.5	47.5	3.0	0	3G48 &6 (po) &2 calc-silicaty
79V046R	47.5	49.1	1.5	0	3G0948 &6 (po) Minor
79V046R	49.1	52.4	3.4	0	3G48 stringered (4L0) 80:20
79V046R	52.4	53.9	1.5	0	3G46
79V046R	53.9	55.7	1.7	0	4L124
79V046R	55.7	56.4	0.7	0	10Q09 (py)
79V046R	56.4	60.3	3.9	0	3G48 stringered
79V046R	60.3	62.2	1.9	0	4L07 &1 -> (3G48 stringered) 90:10
79V049R	47.1	49.5	2.4	2	4L3 &1 Weathered
79V049R	49.5	56.2	6.6	0	5B67 &9 &4 [3G48 stringered]
79V049R	56.2	56.8	0.6	0	5C*
79V049R	56.8	58.7	1.9	0	5B6 &4 Minor
79V049R	58.7	59.8	1.1	0	5B23
79V049R	59.8	61.6	1.8	0	4L7 [3G46] (5C*) Minor
79V049R	61.6	63.9	2.3	0	5B6 &4 &9 (po)
79V049R	63.9	65.7	1.8	0	5B26 &0
79V049R	65.7	67.4	1.7	0	4L67 [3G48 spotted/stringered]
79V053R	64.3	65.8	1.5	0	4L0 ? (5D@)?
79V053R	65.8	67.4	1.5	0	5B648 [3G48] [4L6]
79V053R	67.4	69.8	2.4	0	5B26 (5D*)
79V053R	69.8	72.2	2.4	0	5B62 &48 minor
79V053R	72.2	75.3	3.0	0	5B62 [5A6]
79V053R	75.3	78.2	2.9	0	4L06 weak (4K48)
79V053R	78.2	81.4	3.2	0	3G48 &9
		TOTAL	61.4		

leachates will be analyzed weekly for pH, redox, conductivity, sulphate, acidity and alkalinity. A multi-element analyses (ICP) and acid-base accounting will also be determined on a weekly basis. The results available to date are presented in the Appendix in Tables A-8 to A-11.

A weighted composite sample of the sulphide rock type was prepared by combining the various core samples according to the ratio of the sample interval to the total length of extracted core as shown in Table 2.15. A 10 kilogram portion of sample which had previously been jaw crushed to minus 25 mm, was cone crushed to 6 mm and riffle split. The Humidity Cell Test was then completed under similar conditions as previously discussed for the phyllite sample. The results of the test to date are presented in the Appendix in Tables A-12 to A-15.

TABLE 2.15

COMPOSITE SAMPLE OF SULPHIDE ROCK
FOR HUMIDITY CELL TEST

Drill Hole	Sample Interval (m)	Rock Type	Weight (kg)	Composite (%)	Section
88V-17	36.0 - 42.0	4CO	14.420	10.5	16E
88V-17	25.2 - 33.5	4EC	28.09	14.6	16E
88V-39	17.0 - 26.0	4EC	20.02	15.8	24E
88V-14	32.5 - 42.2	4CO	23.15	17.0	16E
79V-26R	34.7 - 42.1	4AO	15.64	42.1	00
			101.32	100	

2.4.6 TAILINGS COMPOSITION

2.4.6.1 Metallurgy

Metallurgical recoveries were predicted by Kamloops Research and Assay Lab from extensive testwork conducted in 1980 on diamond drillcore from Faro, Vangorda and Grum deposits. These results are based on a grind of 80% less than 50 microns. The predicted Faro Zone III metallurgy is better than has been achieved in the plant since start up because of higher tonnages and coarser grinds than the 1980 design. At present, milling of the Vangorda and Grum deposits is expected to take place at the original 11,160 dmtpd (dry metric tonnes per day) rate and at the finer grind.

Using these grades and recoveries, and the mineable reserves delineated in 1980, estimates for tailings composition were derived and are shown on Table 2.16.

TABLE 2.16

ESTIMATED TAILINGS COMPOSITION AT FARO ZONE III, VANGORDA AND GRUM

	ASSAYS (%)		DISTRIBUTION (% OF HEADS)		
	Pb	Zn	Weight	Pb	Zn
FARO ZONE III (PREDICTED)					
heads	3.50	4.80			
tailings-pred	0.36	0.42	87.49	9.1	7.7
tailings-actual	0.6	0.9			
VANGORDA					
heads	3.50	4.55			
tailings	0.65	0.55	87.76	16.2	10.7
GRUM					
heads	2.75	5.0			
tailings	0.49	0.67	88.78	8.7	11.9

2.4.6.1 Acid Generation Potential

All tailings from sulphide ore deposits have the potential to generate acid under oxidizing conditions. There are several characteristics of the tailings which may influence the rate of acid production. Differences among the ore bodies which will influence these characteristics of the tailings are discussed below.

Compared with the Faro ore, Vangorda ore contains a greater proportion of barite ($BaSO_4$--a stable compound containing oxidized

sulphur) and a smaller proportion of pyrite (FeS_2). The tailings from the Vangorda ore will thus contain less iron and less unoxidized sulphur than the Faro tailings.

At Grum, as at Faro, most sulphur is in the form of pyrite, but much of the Grum ore is disseminated rather than massive sulphides. Thus Grum ore contains less pyrite and the percentage of sulphur in the tailings will be less than at either Vangorda or Faro. Iron content will also be lowest in tailings from Grum ore for similar reasons. The average for Faro Zone III since start up in June, 1986 has been about 30% iron. From head sample composites, it appears that Vangorda tailings will average about 25% iron and Grum tailings will be approximately 22% iron.

The pyrrhotite content of the ore is much lower at Vangorda and Grum than at Faro. As pyrrhotite (FeS) is much more reactive than pyrite, the rate of acid generation from Vangorda and Grum tailings may be slower.

Acid generation rates are also influenced by the particle size of the rock. The finer grind of the Vangorda and Grum tailings will tend to increase the rate of acid generation. However, this finer grind will also decrease the permeability of the tailings, which will inhibit transport of oxygen and water and of acid and metal contaminants. This will also lessen the proportion of the tailings that are sandy and permeable.

2.4.6.2 Tailings Disposal

Tailings from the Faro mill are currently placed in the tailings pond system. It is probable that the Vangorda and Grum tailings will be disposed of in the abandoned Faro Pit. The pit will be allowed to flood when mining ceases and thus the tailings will be covered with water. This is currently considered to be the most

effective method of tailings disposal as water is of sufficiently low permeability to oxygen to inhibit acid generation (ref). Tailings disposal from the Faro mill is regulated under Water Licence No. Y-IN85-05AL and changes in tailings disposal practices will be dealt with through that licence.

2.5 WATER MANAGEMENT PLAN

2.5.1 Vangorda Creek Diversion

Vangorda Creek currently bisects the proposed Vangorda pit and must be diverted in order to facilitate mining of the ore body. Several alternative diversion methods have been considered. The first alternative involves a diversion dam and trench, which follows the 1182 m contour around the north perimeter of the pit. The disadvantages of this proposal include (a) water quality could be affected by waste dumps and haul roads, (b) the alignment would be constructed in shallow highly fractured bedrock, potentially resulting in increased seepage into the pit, and (c) the outlet to the diversion is very steep and would require a carefully engineered channel to prevent erosion. Another alternative still under consideration is a diversion ditch located along a bench within the pit and lined with a half-round culvert. The current proposal involves a 600-metre long, 1800-mm diameter corrugated metal culvert positioned on a bench within the pit. This alternative envisages the culvert as a temporary structure that will be salvaged at abandonment of the Vangorda minesite. Vangorda Creek would then be rerouted to its natural course. The proposed culvert diversion would involve construction of a 7-metre high diversion dam located about 60 metres upstream from the ultimate pit perimeter, as shown on Figure 2.38. The culvert would pass beneath this dam and extend within the creek bed and enter the pit at El. 1139 m. The culvert would be supported on a 12-metre wide bench cut into rock with a gradient of about 3.5

percent. The culvert would exit the pit at El. 1123 m and pass beneath the haul road to discharge eventually back to the channel of Vangorda Creek.

The diversion dam would be constructed of compacted glacial till with a crest width of 10 metres and upstream and downstream sideslopes of 2:1 (Horizontal to Vertical). The inlet to the culvert would consist of a standard inlet end section with rip-rap erosion protection extending several metres each side of the pipe. A debris barrier consisting of vertical steel rails embedded in concrete would be located 2 to 3 metres upstream from the inlet. A typical section through the dam is shown on Figure 3.39.

Where the culvert enters and exits the pit, concrete thrust blocks will be required to resist the impact of high velocity flows during periods of heavy runoff. A rip-rap armoured apron will also be constructed where the culvert discharges into Vangorda Creek.

The culvert has been designed to accommodate the 20-year peak flow, with contingency capacity for the 100 year flood. The design discharge is based on the Yukon Regional Analysis method developed by DIAND. The catchment area above the diversion is 17.7 square kilometres. The 20-year peak flow for this catchment was estimated to be 5.2 cubic metres per second. The 100-year peak flow was estimated to be 7.6 cubic metres per second. The mean annual flood, which has a return period of 2.33 years, was calculated to be 2.7 cubic metres per second. During the 20-year storm, the culvert would flow under inlet control with a headwater of 1.94 metres.

2.5.2 Surface Water Diversion

The objective of surface water diversion is to divert uncontaminated water around the site in order to reduce the volume of pit water. Water entering the pit will become contaminated and will need to be

collected and pumped to the Water Treatment Plant. During the 1987 drilling/trenching/drainage program, which is discussed in Stage I of the IEE, diversion ditches were constructed around the Grum and Vangorda Pit areas.

The northeast diversion ditch above the Grum pit intercepts runoff which formerly drained into Doal Lake and diverts the flow into the east fork of Grum Creek, as shown on Figure 2.16. During site preparation, this ditch will be extended down the east side of the Grum pit and along the uphill side of the haul road. A culvert will carry the flow beneath the haul road and eventually into Vangorda Creek.

Diversion ditches were also constructed above the Vangorda Pit during the 1987 program. The southeast diversion ditch, as shown on Figure 2.16, intercepts a small creek above the northeast corner of the Vangorda pit and diverts the flow to a small tributary of Dixon Creek. Another ditch was constructed north of the southeast ditch to intercept runoff from the small catchment above the pit. This ditch discharges into the southeast ditch. A third ditch is proposed along the northern perimeter of the Vangorda pit to intercept runoff from the catchment area to the north.

The ditches have been designed to accommodate peak flows during a storm with a 50 year return period. The peak flows were based on the Yukon Regional Analysis Method by DIAND as discussed in Section 3.2.1.4. The following equation was used to estimate the 50-year peak flow:

$$Q_{50} = .629A^{.811}$$

where Q_{50} = 50 year instantaneous flow in m^3/s

and A = Drainage Area in km^2

A summary of the design parameters for each ditch is presented in Table 2.17. The ditch design is based on sideslopes of 1.5:1 (horizontal to vertical) and a base width of one metre.

TABLE 2.17

DIVERSION DITCH DESIGN PARAMETERS AT VANGORDA MINESITE

Diversion Channel	Catchment Area (km^2)	50-year Peak Flow (m^3/s)	Depth of Flow (m^3)	Velocity (m/s)	Channel Gradient (%)
Grum NE	2	1.1	1.2	.33	2.5
Vangorda SE	1.1	0.68	1.1	.24	1.5
Vangorda N	1.0	.63	.8	.36	4.0

2.5.3 Doal Lake Drainage

In preparation for the overburden stripping at the Grum pit, it was necessary to drain and remove the sediment from a small lake located along the northern edge of the ultimate perimeter. In October 1987, this lake (Doal Lake) was drained to Vangorda Creek. The volume of water within the lake was estimated to be about 40,000 cubic metres. The sediment at the base of the lake is approximately 2 metres thick and will be removed and transported during the winter months to a flat vegetated area adjacent to the proposed southeast waste dump. Following removal of the sediment, finger drains will be constructed to facilitate drainage of the surficial soils in preparation for overburden stripping.

Monitoring of the suspended sediment loading in Vangorda Creek was conducted during and after the drainage to assess the impact of the drainage operation. Clarity wedge readings were also recorded at five of the established water quality sampling stations. Results of

the monitoring program indicated that there was minimal impact on Vangorda Creek from sediment due to the drainage of Doal Lake and the construction of the diversion ditches. A further discussion on the monitoring program and a summary of the results is presented in Section 3.2.2.

2.5.4. Surface and Pit Dewatering

Surface drainage of the site prior to overburden stripping has already commenced at the Vangorda site. The drainage system consists of a series of trenches excavated within the overburden to drain the surficial soils in advance of the mining operations. A series of test pits will be excavated to depths of about 4 metres to establish an effective depth and location for the trenches. The trenches will drain to Vangorda Creek.

Once mining has commenced at the Vangorda pit, localized runoff and seepage that bypasses the northeast diversion ditch will be collected by small ditches located along the 1128 m Bench and gravity fed to the sumps which will be established within the pit. In the Grum pit, similar in-pit ditches will be required to intercept water on a bench at the base of the till slope. This ditch would collect seepage which enters the pit through surficial soils or along the surficial soils/bedrock interface. A sump would be maintained on the bench to enable the collected seepage to be pumped from the pit.

Currently, it is planned to install two sumps within each pit. At the Vangorda pit, sumps will be established at El. 1050 m and El. 1115 m. At Grum, in-pit sumps will be established at El. 1035 m and El. 1195 m, as shown on Figure 2.16. Water collected in these sumps will be pumped to the Water Treatment Plant.

2.6 WATER TREATMENT

2.6.1 General

Preliminary laboratory testing of drill core samples from the Vangorda and Grum deposits indicates that there is a potential for the generation of Acid Mine Drainage (AMD) during the mining at both sites. This AMD will be produced due to the inevitable seepage and precipitation runoff both from within the pit and the waste dumps.

At the Faro mine, all AMD produced is discharged directly to the mill tailings pond, where it is treated with excess lime. The Grum/-Vangorda minesite is about 14 km from the Faro tailings pond and ore will be hauled to the Faro mill for processing. As pumping of this water to Faro was considered too costly and inefficient, a separate effluent treatment facility will be established at the Vangorda Plateau.

2.6.2 Water Quantity

The quantity of AMD would be minimized by intercepting surface runoff and groundwater before it enters the pit area and is exposed to acid-generating rock. Some interceptor ditches have already been constructed at both Grum and Vangorda.

At the Grum pit, the main source of water will be groundwater seepage and runoff. It is anticipated that most of the groundwater within the pit will occur within a confined aquifer near the till overburden/bedrock interface. Preliminary data from falling head tests performed on the existing piezometers indicate that an estimated 200 to 300 litres per second of groundwater would be intercepted by the peripheral wells above the Grum pit. Based on water quality analyses of samples from an artesian well adjacent to the proposed interceptor wells, the heavy metal concentrations are within acceptable limits.

Water pumped from these wells would be pumped to the Grum NE diversion ditch. However, it is expected that about 30 litres per second of groundwater will bypass the peripheral well system and enter the pit. This water would require treatment. A pump test will be performed during the first half of 1989 to finalize the design of the deep-well groundwater interceptor system.

It is estimated that runoff from precipitation and snowmelt entering the pit would contribute a mean monthly flow in the order of 10 litres per second. However, during periods of heavy precipitation this flow could range between 40 and 60 litres per second. The total quantity of water from Grum pit that would require treatment is estimated to be in the order of 100 litres per second (1,500 USGPM).

The total quantity of water from the Vangorda Pit that would also require treatment is summarized as follows:

Groundwater seepage from along the North and North-east Walls	15 l/s	
Miscellaneous Seepage from Vangorda Creek	35 l/s	
Precipitation	50 l/s	
Total:	100 l/s	(1,500 USGPM)

The treatment plant would be designed to accommodate up to 200 l/s (3,000 USGPM) during the active operation of the Vangorda Project.

2.6.3 Water Quality

Water quality sampling has been carried out in the Vangorda Basin since 1975. Monitoring sites were established not only in streams but also at natural spring locations, drill holes and where diversion ditches have been constructed. A full discussion of the water quality monitoring program is presented in Section 3.2.2. Based on the water quality analyses completed on groundwater samples from both

Grum and Vangorda, it is anticipated that the quality of the groundwater will be below the existing Faro licence limits and consequently treatment of water pumped from the interceptor wells could be discharged directly into the diversion ditches without treatment. A summary of the water quality of the groundwater at representative locations at both Vangorda and Grum compared to the current water licence limits at Faro Pit, is presented in Table 2.18.

TABLE 2.18

MINE WATER QUALITY - SUMMARY

Metals (mg/l Total)	Water Licence Limits	Faro Pit Water	Grum Adit Water	Vangorda Groundwater DDH-322 Max. Values	Grum Groundwater GPH-4 Max. Values
Zn	0.50	40.73	2.120	0.3	0.003
Cu	0.20	0.02	0.002	0.03	0.003
Pb	0.20	0.12	0.012	0.05	0.003
Fe	N/A	2.63	5.250	0.61	0.020
Mn	N/A	2.66	0.176	0.03	0.166
Other Substances and Characteristics					
NH_3 mg/l	1.0	2.54	0.45	0.4	0
SO_4 mg/l	N/A	511	92.1	30	11
Suspended Solids mg/l	<15	65.25	20.1	2	0
pH	>6.5	7.04	7.7	7.9	7.2
Alkalinity	N/A	173.82	256.08	118.5	87.2

The results of recent laboratory tests completed on selected composite rock samples from the Vangorda basin, combined with results of ongoing monitoring at the Faro Pit, indicate that treatment of the pit water and the seepage from certain waste dumps will be necessary. A summary of the water quality of the Faro effluent compared to results from the Humidity Cell Test currently in progress is presented in Table 2.19. Treatment will be required to regulate the concentration of zinc, copper, lead, suspended solids, and ammonia, which it is anticipated will be above the acceptable levels.

TABLE 2.19

MINE DRAINAGE PROPERTIES

				Vangorda Waste Rock Humidity Cell Test Results to date			
		Faro Effluent		Sulphide	Phyllite	Sulphide (Inoc)	Phyllite (Inoc)
Parameter	Units	Range	Mean	Range	Range	Range	Range
Alkalinity	mg/l($CaCO_3$)	50-280	173.8	4.2-9.5	3.2-17.4	0-16.8	7.4-31.5
Zn	mg/l	4.3-118	40.7	17.7-35.8	.99-15.7	4.52-353.0	NC
Fe	mg/l	2.4-2.85	2.63	0.066-.510	<.05-2.67	<.015-17.4	NC
Pb	mg/l	0-0.92	0.12	.49-2.2	<.05-.41	<.05-3.3	NC
Mn	mg/l	.02-8.35	2.66	17.2-35.7	1.52-10.10	18.9-113.0	NC
NH_3	mg/l	0-.32	2.54	NA	NA	NA	NA
SO_4	mg/l	21-1110	511	210-360	275-500	390-2150	325-1000
Suspended Solids	mg/l	1.0-990	65.25	NA	NA	NA	NA
pH		5.8-7.9	7.04	4.2-6.41	5.24-7.31	4.03-7.35	6.5-7.51

NA = Not Analyzed
NC = Not Completed

2.6.4 Treatment Process

The treatment of the acid water involves (a) the addition of an alkali to raise the pH, (b) precipitation of metals, (c) facilities for solid/liquid separation to remove the metal hydroxides and other precipitates, and (d) the disposal of the resulting sludge.

The proposed treatment system will consist of the neutralization of the AMD, followed by flocculation and sludge dewatering in alternating ponds. The plant will be designed to treat up to 3,000 USGPM of AMD, but the dual reactors will allow for periods of lower AMD volumes, when only half of the design capacity would be actively required.

This arrangement would accommodate a preventative maintenance program, and minimize the probability of a total system shutdown for maintenance.

Quicklime will be used for the neutralization process. The lime will be stored in a 50-ton capacity silo, and will be slaked with water provided from the peripheral well system at the Grum pit.

It is estimated that 1.7 to 3.3 tons per day of lime will be consumed by AMD neutralization. The neutralization process will take place in mixing tanks called neutralization reactors. There will be two in parallel, each with a capacity to treat 1,500 USGPM with a retention time of 30 minutes. Rapid mixing will be achieved with propeller type axial flow mixers.

The retention time of 30 minutes will ensure complete mixing of the slaked lime with the AMD, to attain and maintain a pH of about 9.5, and to allow the hydrolysis of the metal ions.

Neutralized AMD will be gravity fed to the flocculation reactors via an "underflow decant" system of piping.

Two 30,000 USG capacity tanks connected in parallel, will be used for flocculation. They will have an individual retention of 20 minutes.

Gentle mixing with axial-flow agitators will ensure complete mixing of the flocculant, and the formation of large floc particles.

The flocculant will be Percol solution, which will be premixed with clean water from the peripheral groundwater interceptor well system proposed for Grum.

The AMD sludge will be gravity-fed to a system of three settling ponds, as shown on Figure 2.16. These ponds are designed to provide

an individual 7-day retention time for sludge settling, at 3,000 USGPM AMD flow.

The sludge will be discharged in suspension into the ponds. As the sludge settles out, the supernatant clear, clean water will overflow through a culvert near the top of the retaining dyke, and be returned to Vangorda Creek.

The sludge will be initially at about 2% solids. However, a key step in the dewatering and densification of the sludge will be to induce a freezing and thaw process in a system of rotating ponds. This will be accomplished by diverting the sludge to an alternate pond, and then decanting as much of the supernatant water as practicable from the first pond by pumping. This pond will be left idle to freeze before being used again for further sludge storage.

The design assumes that a 15% solids cake could be achieved by this process.

In the freezing step, the bound water is stripped from the hydroxide to form ice crystals. When thawed, the water melts and does not rehydrate the precipitate.

The freeze-thaw sludge dewatering technique has been studied by Noranda Research, and has effectively been applied at their Waite Amulet plant near Rouyn. A 21-23% solids cake has reportedly been achieved with a single freeze-thaw cycle.

A typical section through the ponds is presented on Figure 2.408. A flow diagram representative of the proposed water treatment system is presented on Figure 2.41.

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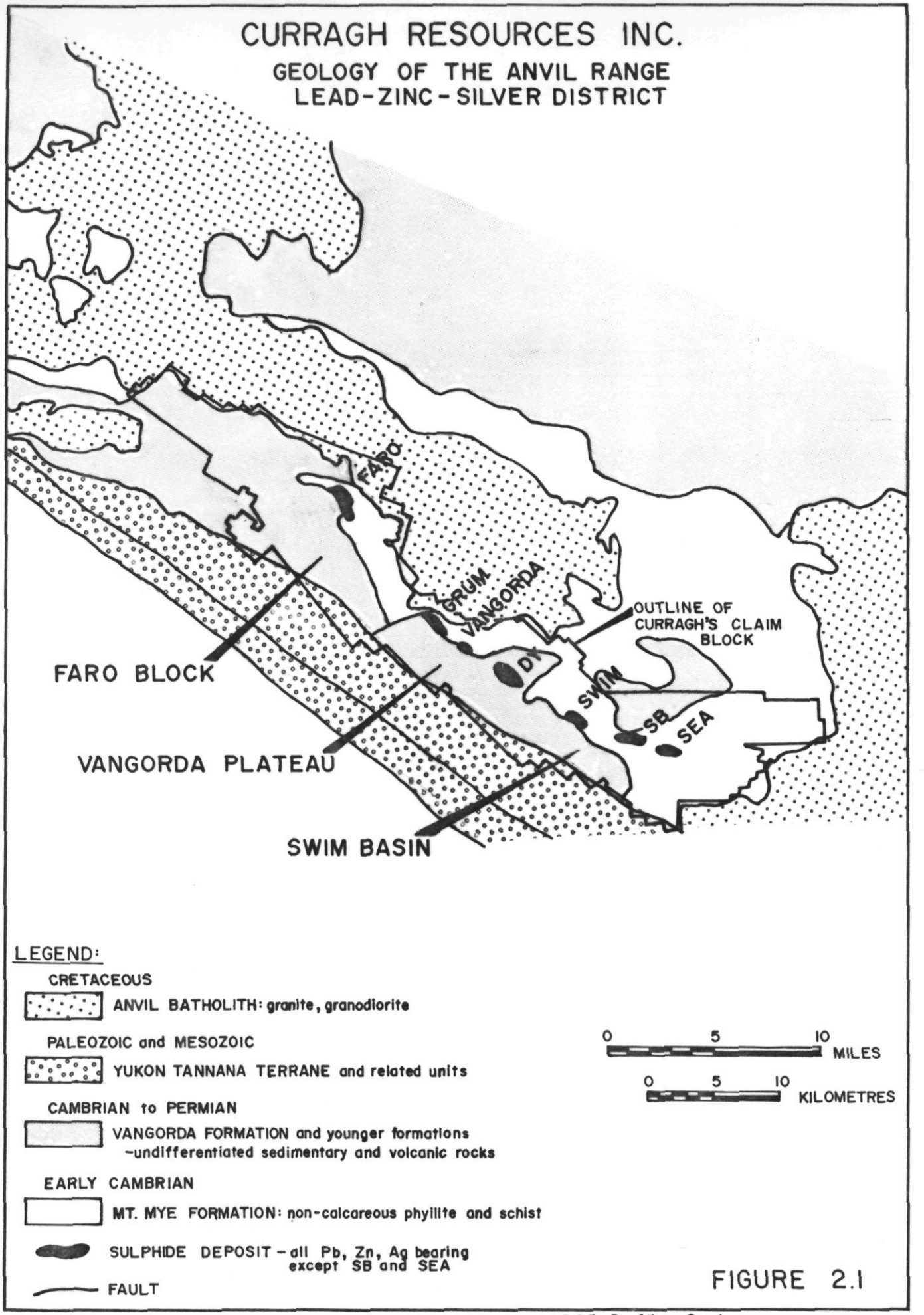


FIGURE 2.1

BCB Drafting Service

CURRAGH RESOURCES

VANGORDA PLATEAU GEOLOGY MAP

Scale 1:5000

Contour Interval 5 Metres

NOTE THIS MAP DOES NOT YET SHOW ALL PROSPECTOR AIRWAYS' DRILL HOLES AROUND VANGORDA AND THE CHAMP ZONE.

- ROTARY DRILL HOLE not located in field
- ROTARY DRILL HOLE located in field
- DIAMOND DRILL HOLE not located in field
- DIAMOND DRILL HOLE located in field
- PROPOSED DDH SITE

This reference scale bar was created when the original maps were at scale of the same ratio as this figure and can be used as a reference for the original size.

YUKON GEOLOGICAL SURVEY

LEGEND

ANVIL DYKE SUITE
- 10F quartz feldspar porphyry

ANVIL BATHOLITH
- 10AB granite and quartz monzonite

VANGORDA FORMATION
- 5B calcareous phyllite, chlorite phyllite and greenstone
- 5A graphitic phyllite

ORE HORIZONS
- 4 undifferentiated ore types

MT. MYE FORMATION
- 3G non-calcareous phyllite
- 3F marble
- 3E graphitic phyllite
- 3D calc-silicate
- 1CD non-calcareous pelitic schist

ADJOINS SHEET NR F-6-3 W ½

BANKRUPTCY BREAK

MAKE-BELIEVE FAULT

GRUM DEPOSIT

CHAMP ZONE

LAKE FAULT

GRUM-FIRTH LONGITUDINAL SECTION

VANGORDA PLATEAU ROAD

VANGORDA DEPOSIT

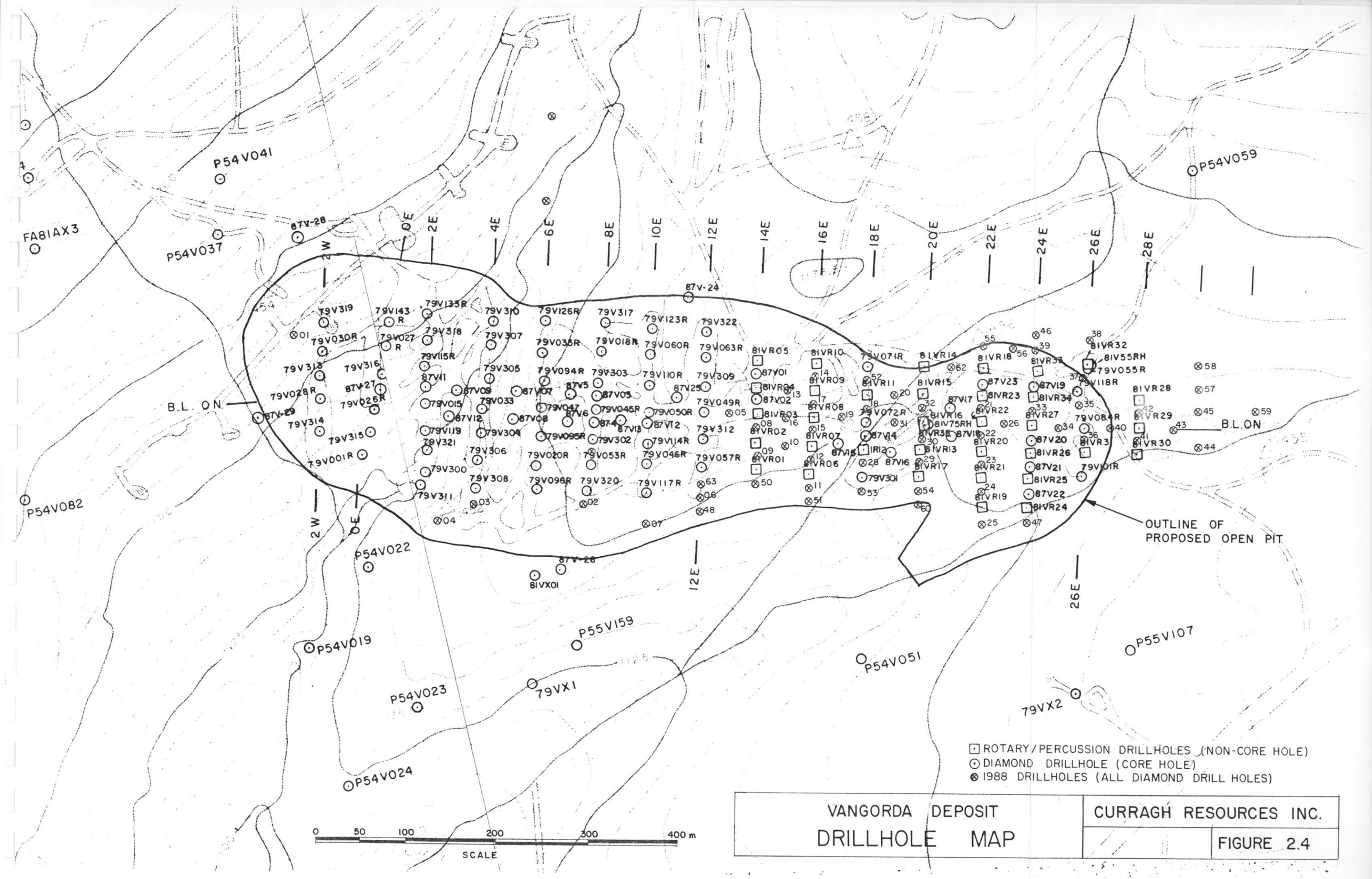
AREA OF "WHALESBACK ANOMALY"

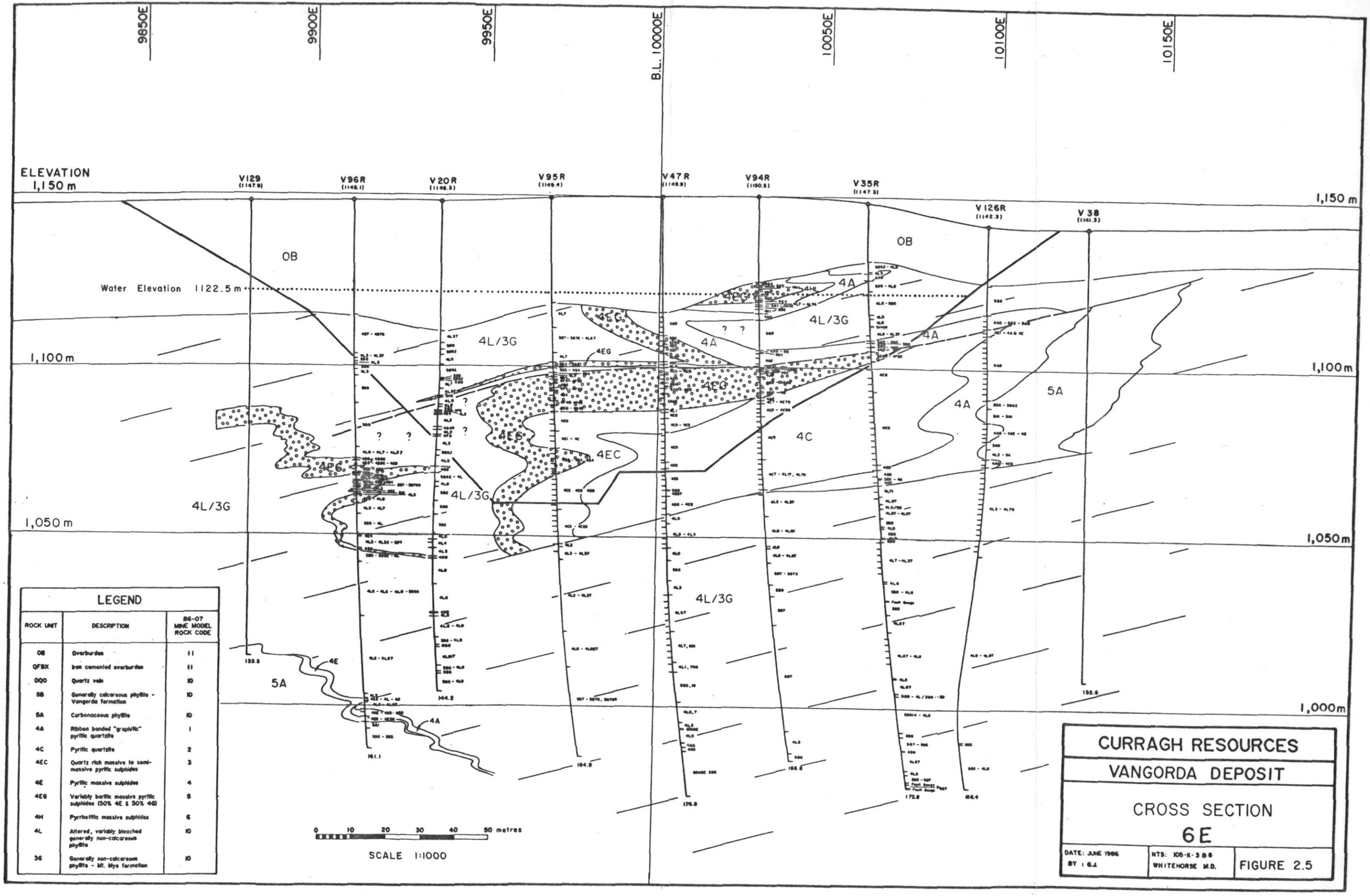
DIXON CREEK DIKES

5A+5B UNDIFF.

LIMIT OF AREA INTERPRETED

FIGURE 2.2


P54V041
FA81AX3
P54V037
P54V059
P54V082
P54V022
P54V019
P54V023
P54V024
P55V159
P54V051
P55V107
79VX1
79VX2
87V-28
87V-24
87V-29
2W
0E
2E
4E
6E
8E
10E
12E
14E
16E
18E
20E
22E
24E
26E
28E
B.L. ON
B.L.ON
81VX01
OUTLINE OF PROPOSED OPEN PIT
0 50 100 200 300 400 m
SCALE
⊡ ROTARY/PERCUSSION DRILLHOLES (NON-CORE HOLE)
⊙ DIAMOND DRILLHOLE (CORE HOLE)
⊗ 1988 DRILLHOLES (ALL DIAMOND DRILL HOLES)
VANGORDA DEPOSIT
DRILLHOLE MAP
CURRAGH RESOURCES INC.
FIGURE 2.4



LEGEND

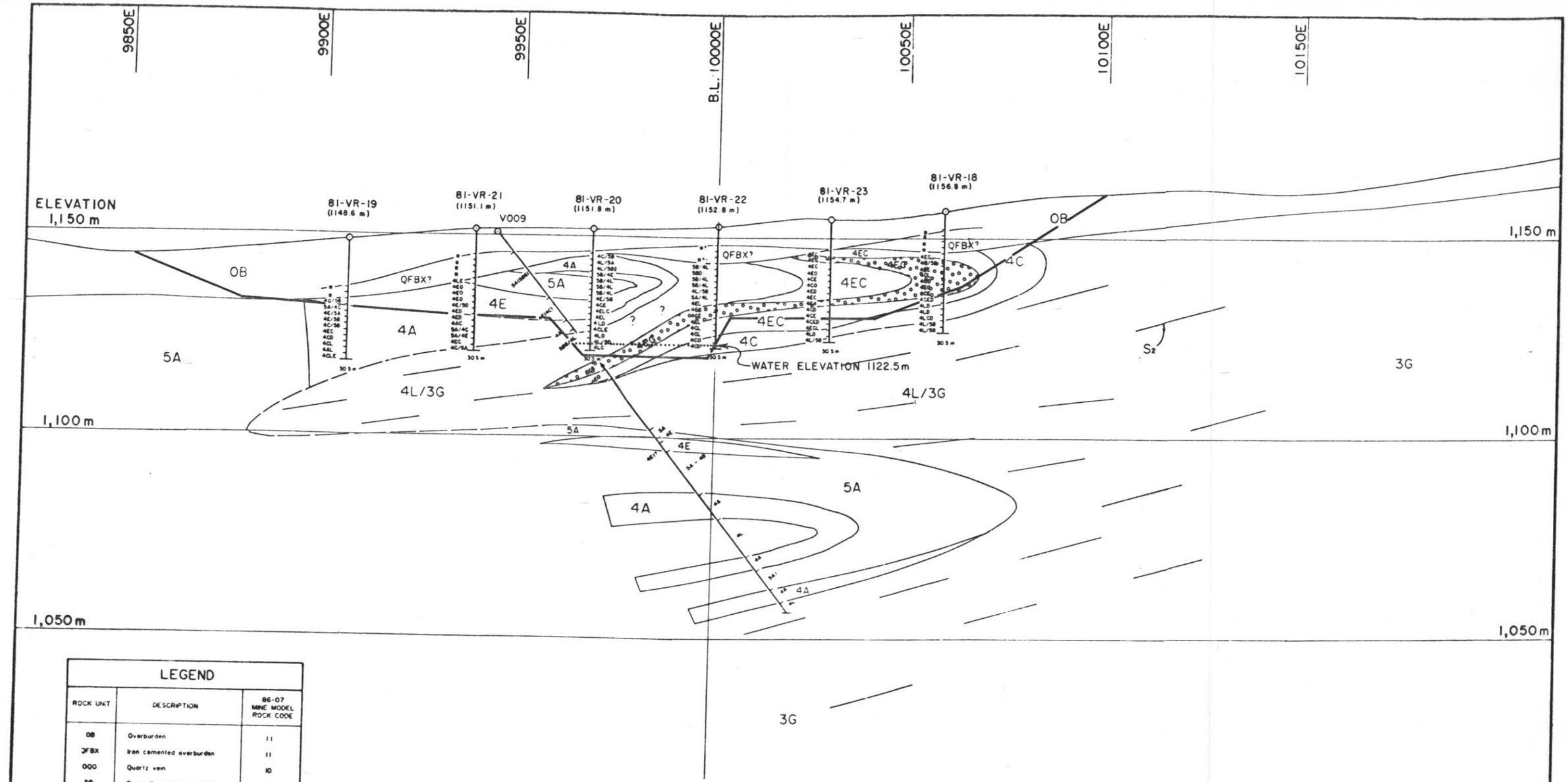
ROCK UNIT	DESCRIPTION	86-07 MINE MODEL ROCK CODE
OB	Overburden	11
QFBX	Iron cemented overburden	11
QQQ	Quartz vein	10
SB	Generally calcareous phyllite - Vangorda formation	10
SA	Carbonaceous phyllite	10
4A	Ribbon banded "graphitic" pyritic quartzite	1
4C	Pyritic quartzite	2
4EC	Quartz rich massive to semi-massive pyritic sulphides	3
4E	Pyritic massive sulphides	4
4EG	Variably baritic massive pyritic sulphides (50% 4E & 50% 4G)	5
4H	Pyrrhotitic massive sulphides	6
4L	Altered, variably bleached generally non-calcareous phyllite	10
3G	Generally non-calcareous phyllite - Mt. Mye formation	10

CURRAGH RESOURCES

VANGORDA DEPOSIT

CROSS SECTION
6E

DATE: JUNE 1986 | BY : G.J. | NTS: 105-K-3 & 6 WHITEHORSE M.D. | FIGURE 2.5



LEGEND		
ROCK UNIT	DESCRIPTION	86-07 MINE MODEL ROCK CODE
OB	Overburden	11
QFBX	Iron cemented overburden	11
QQQ	Quartz vein	10
5B	Generally calcareous phyllite - Vangorda formation	10
5A	Carbonaceous phyllite	10
4A	Ribbon banded "graphitic" pyritic quartzite	1
4C	Pyritic quartzite	2
4EC	Quartz rich massive to semi-massive pyritic sulphides	3
4E	Pyritic massive sulphides	4
4EG	Variably baritic massive pyritic sulphides (50% 4E & 50% 4G)	5
4H	Pyrrhotitic massive sulphides	6
4L	Altered, variably bleached generally non-calcareous phyllite	10
3G	Generally non-calcareous phyllite - Mt Mye formation	10

0 10 20 30 40 50 metres

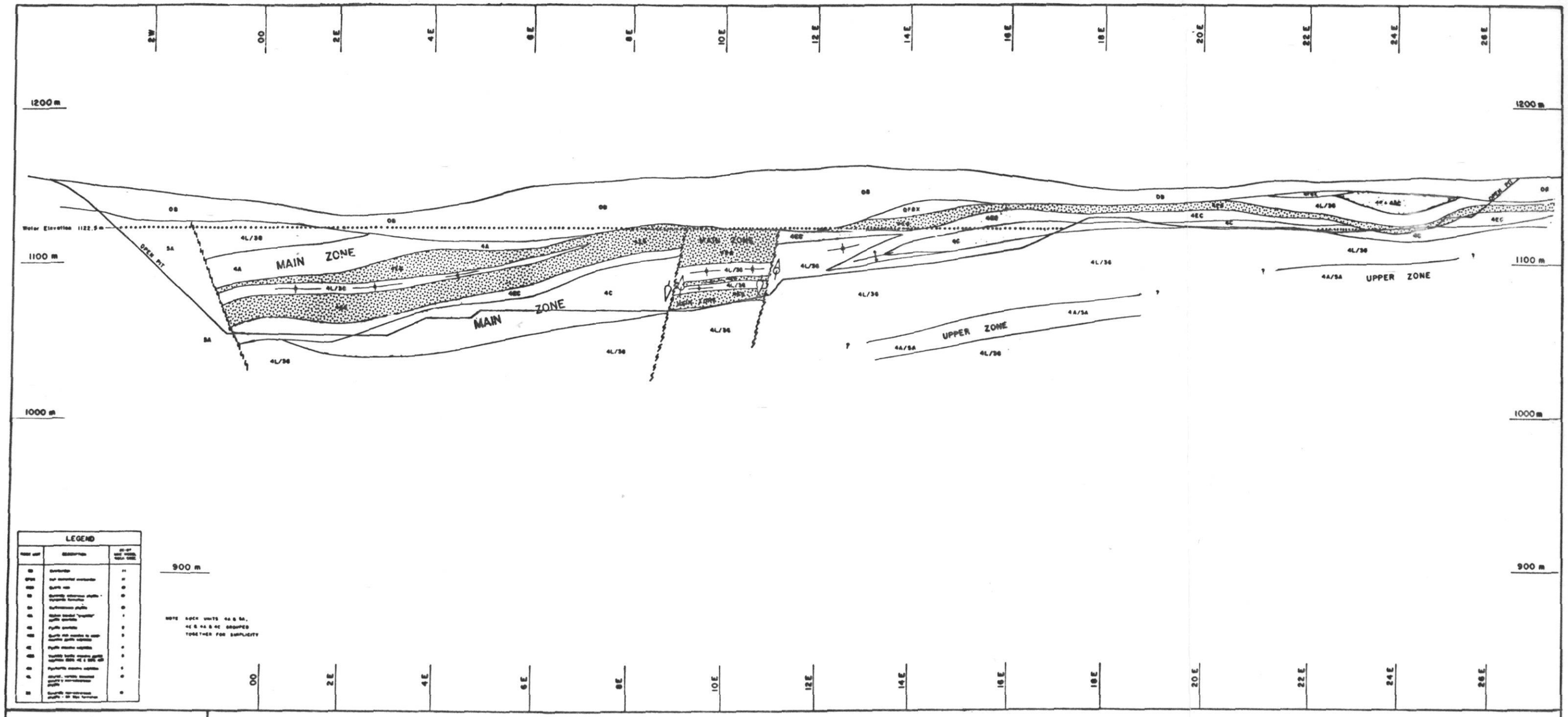
SCALE 1:1000

CURRAGH RESOURCES

VANGORDA DEPOSIT

VERTICAL CROSS SECTION 22 E

DATE: JUNE 1986 BY : G.J.	NTS. 105-K-3 & 6 WHITEHORSE M.D.	FIGURE 2.6



Curragh Resources Inc.

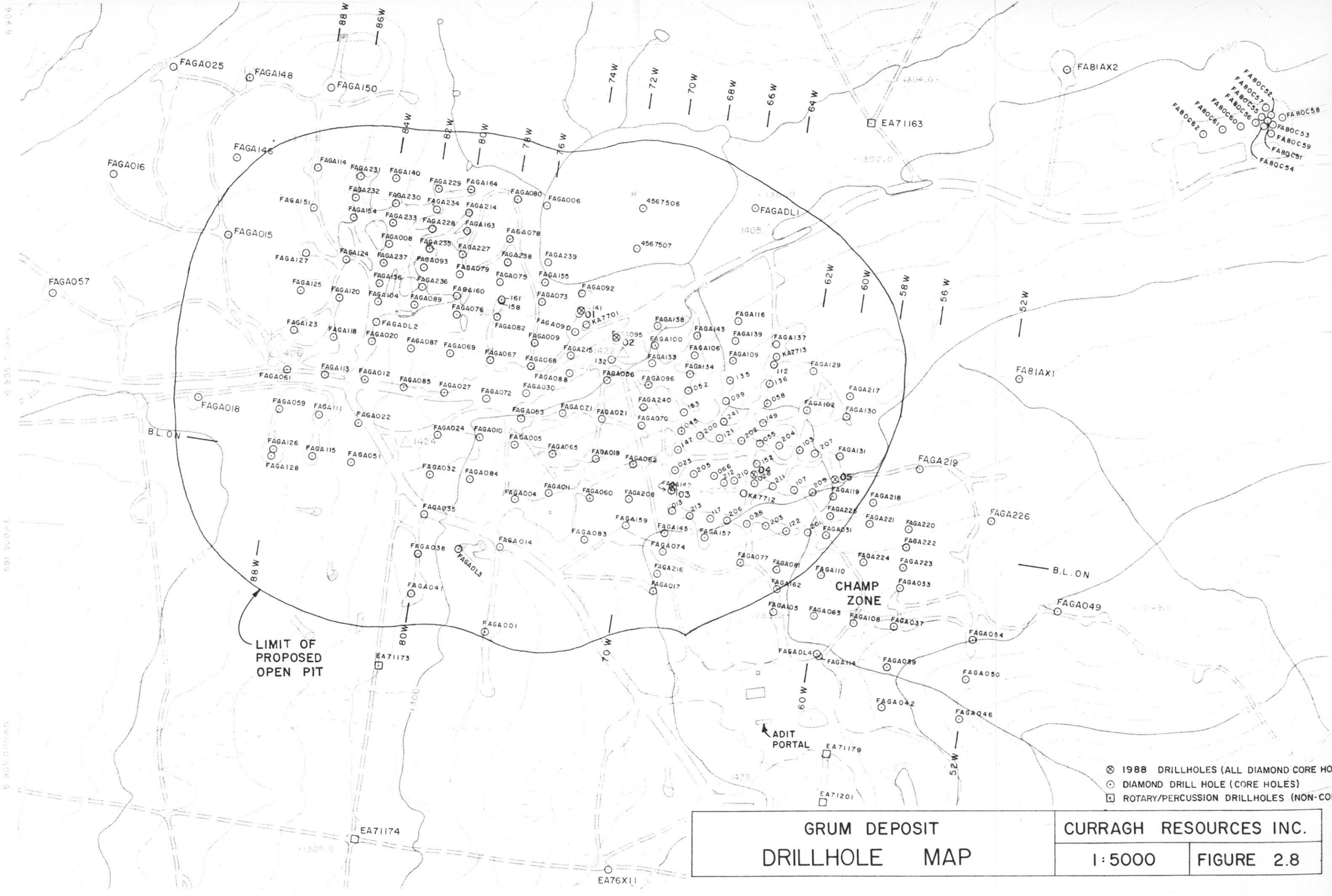
VANGORDA OPEN PIT

LONG SECTION 0+00

LOOKING NE

SCALE 1:2500

FIGURE 2.7



⊗ 1988 DRILLHOLES (ALL DIAMOND CORE HOLES)
⊙ DIAMOND DRILL HOLE (CORE HOLES)
⊡ ROTARY/PERCUSSION DRILLHOLES (NON-CORE)

GRUM DEPOSIT DRILLHOLE MAP	CURRAGH RESOURCES INC.	
	1:5000	FIGURE 2.8

8S 6S 4S 2S O B/L 2N 4N 6N 8N 10N 12N 14N 16N 18N

1300

1200

1100 m ELEV.

1000

900

A-17 A-216 A-74 A-145 A-13 A-142 A-23 A-147 A-45 A-153 A-52 A-134 A-106 A-143

WATER ELEVATION 1265 m

CHAMP ZONE WATER ELEV. 1240 m

OB

OB

OB

3G

3G

3G

3G

5B

5A

U-181

U-183

MAIN HORIZON

ULTIMATE PIT

"UPRIGHT PANEL"

1200

1100

1000

LEGEND

OB	OVERBUDEN (TILL)
3G	NON-CALCAREOUS PHYLLITE
4L	ALTERED PHYLLITE
5A	CARBONACEOUS PHYLLITE
5B	CALCAREOUS PHYLLITE
	MASSIVE SULPHIDES
	DISSEMINATED SULPHIDES

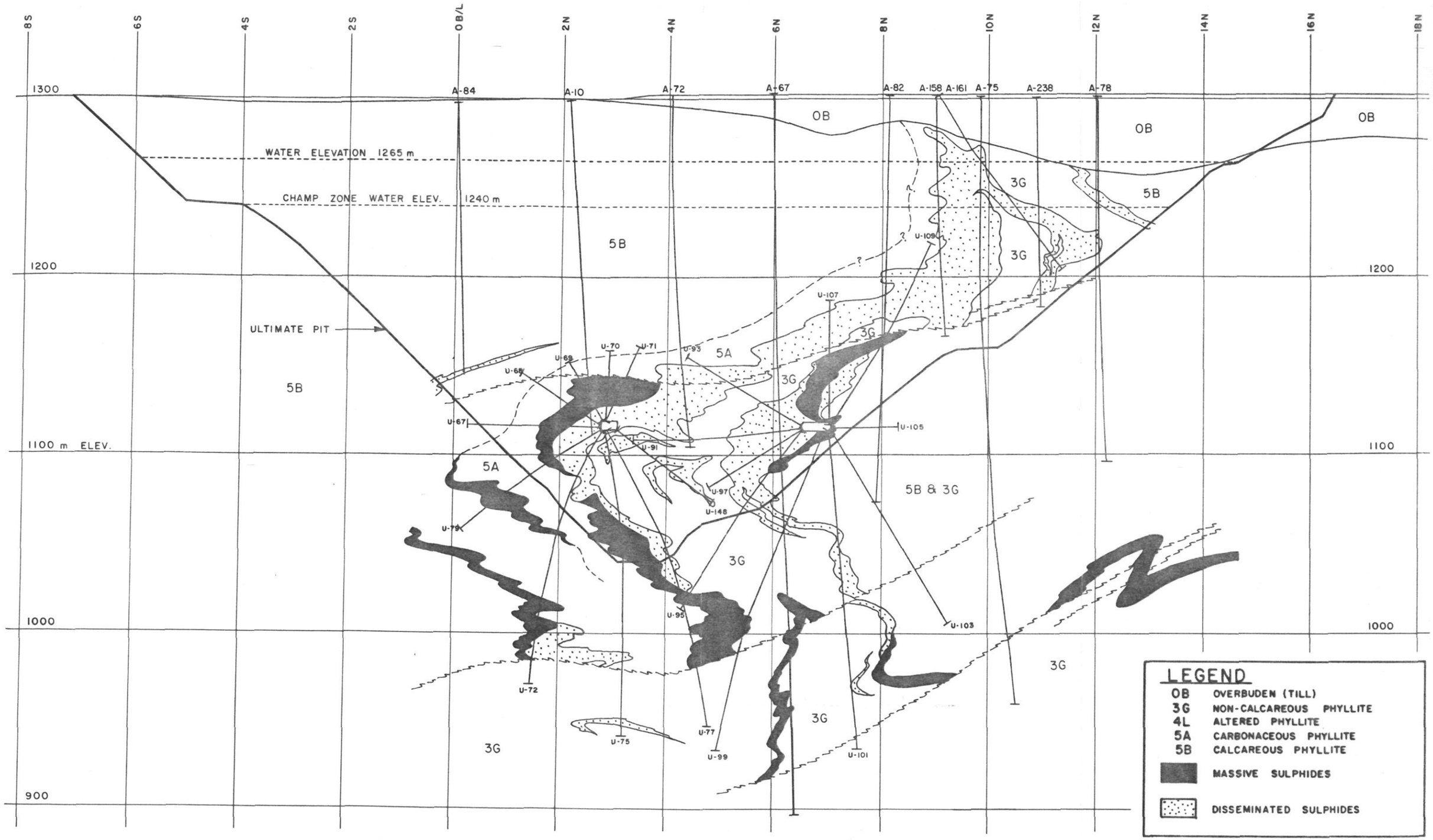
GRUM DEPOSIT

CROSS SECTION 68W

CURRAGH RESOURCES INC.

1:2000

FIGURE 2.9



GRUM DEPOSIT
CROSS SECTION 78W

CURRAGH RESOURCES INC.

1:2000

FIGURE 2.10

8S 6S 4S 2S 0 B/L 2N 4N 6N 8N 10N 12N 14N 16N 18N

A-115 A-111 A-113 A-118 A-120 A-124 A-154 A-232 A-231

1300 1200 1100 m ELEV. 1000 900

WATER ELEVATION 1265 m

CHAMP ZONE WATER ELEV. 1240 m

ULTIMATE PIT

OB

5B

5A

3G

4L

MAIN HORIZON

MAIN HORIZON ?

5B & 3G

LEGEND

OB	OVERBUDEN (TILL)
3G	NON-CALCAREOUS PHYLLITE
4L	ALTERED PHYLLITE
5A	CARBONACEOUS PHYLLITE
5B	CALCAREOUS PHYLLITE
	MASSIVE SULPHIDES
	DISSEMINATED SULPHIDES

GRUM DEPOSIT
CROSS SECTION 86W

CURRAGH RESOURCES INC.

1:2000

FIGURE 2.11

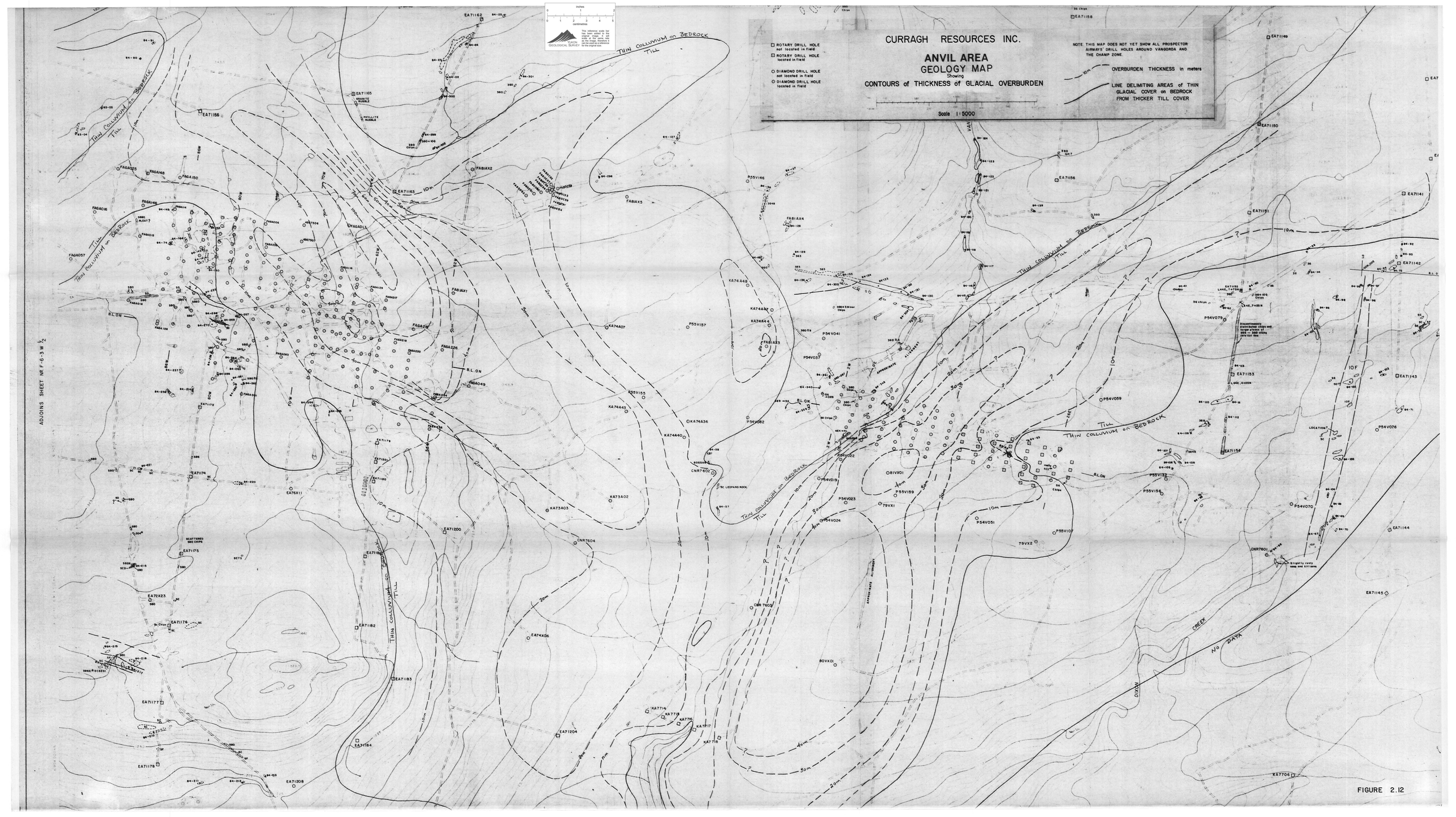
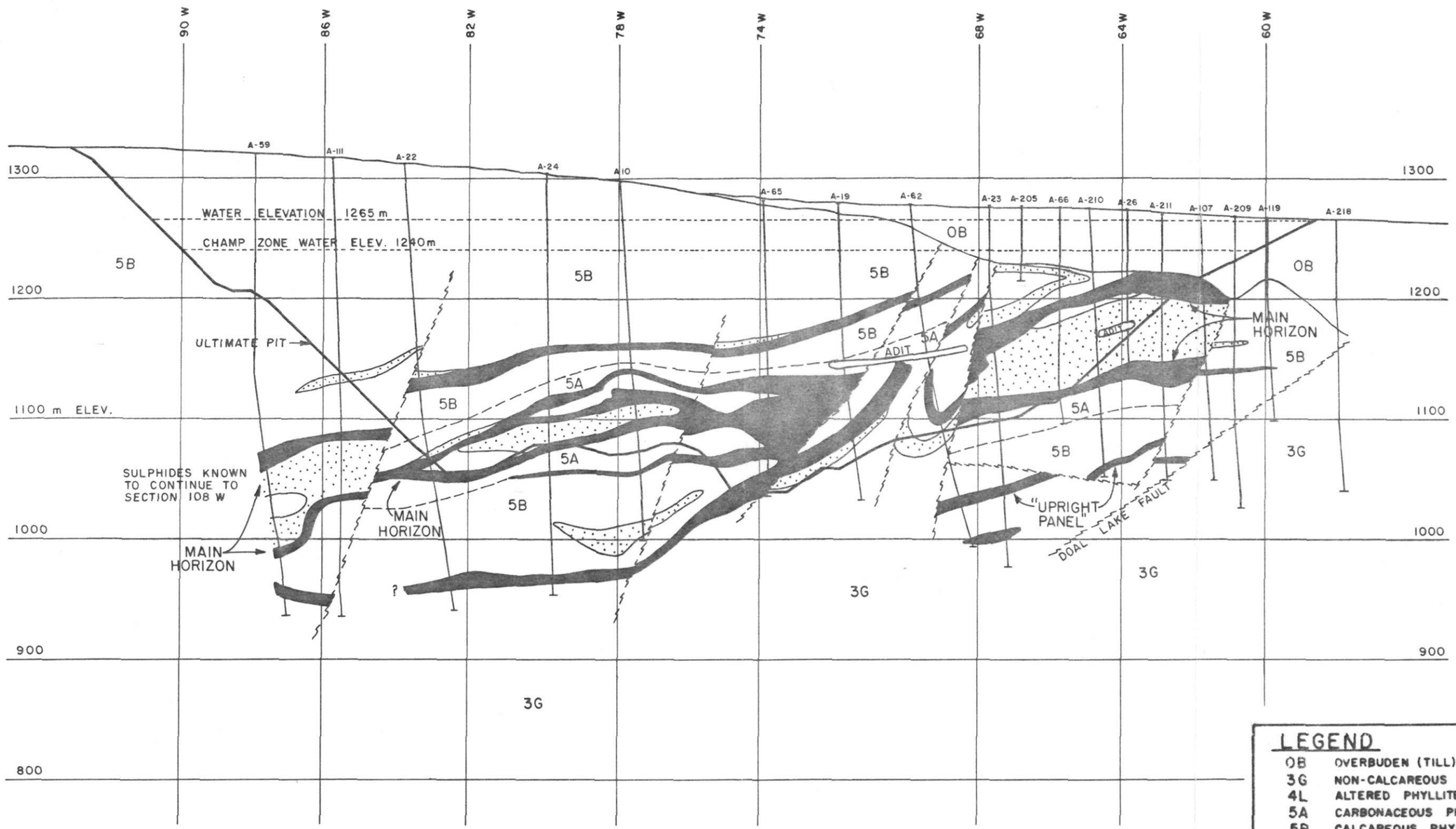

CURRAGH RESOURCES INC.
ANVIL AREA
GEOLOGY MAP
Showing
CONTOURS of THICKNESS of GLACIAL OVERBURDEN
Scale 1:5000
ROTARY DRILL HOLE not located in field
ROTARY DRILL HOLE located in field
DIAMOND DRILL HOLE not located in field
DIAMOND DRILL HOLE located in field
NOTE THIS MAP DOES NOT YET SHOW ALL PROSPECTOR AIRWAYS' DRILL HOLES AROUND VANGORDA AND THE CHAMP ZONE.
OVERBURDEN THICKNESS in meters
LINE DELIMITING AREAS of THIN GLACIAL COVER on BEDROCK FROM THICKER TILL COVER
THIN COLLUVIUM on BEDROCK
TILL
ADJOINS SHEET NR F-6-3 W 1/2
YUKON GEOLOGICAL SURVEY
DIXON CREEK
No DATA

FIGURE 2.12



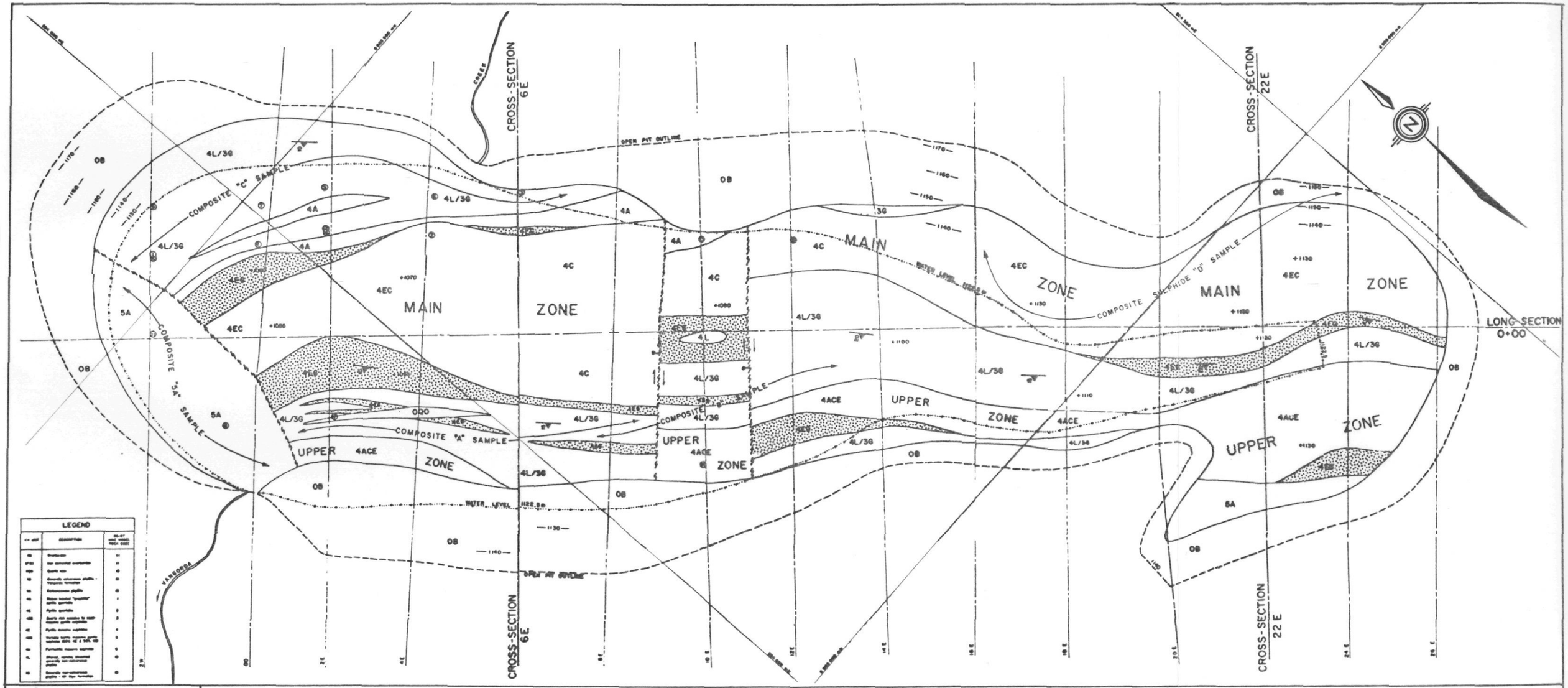
LEGEND

OB	OVERBUDEN (TILL)
3G	NON-CALCAREOUS PHYLLITE
4L	ALTERED PHYLLITE
5A	CARBONACEOUS PHYLLITE
5B	CALCAREOUS PHYLLITE
	MASSIVE SULPHIDES
	DISSEMINATED SULPHIDES

GRUM DEPOSIT
LONG SECTION 02N

CURRAGH RESOURCES INC.

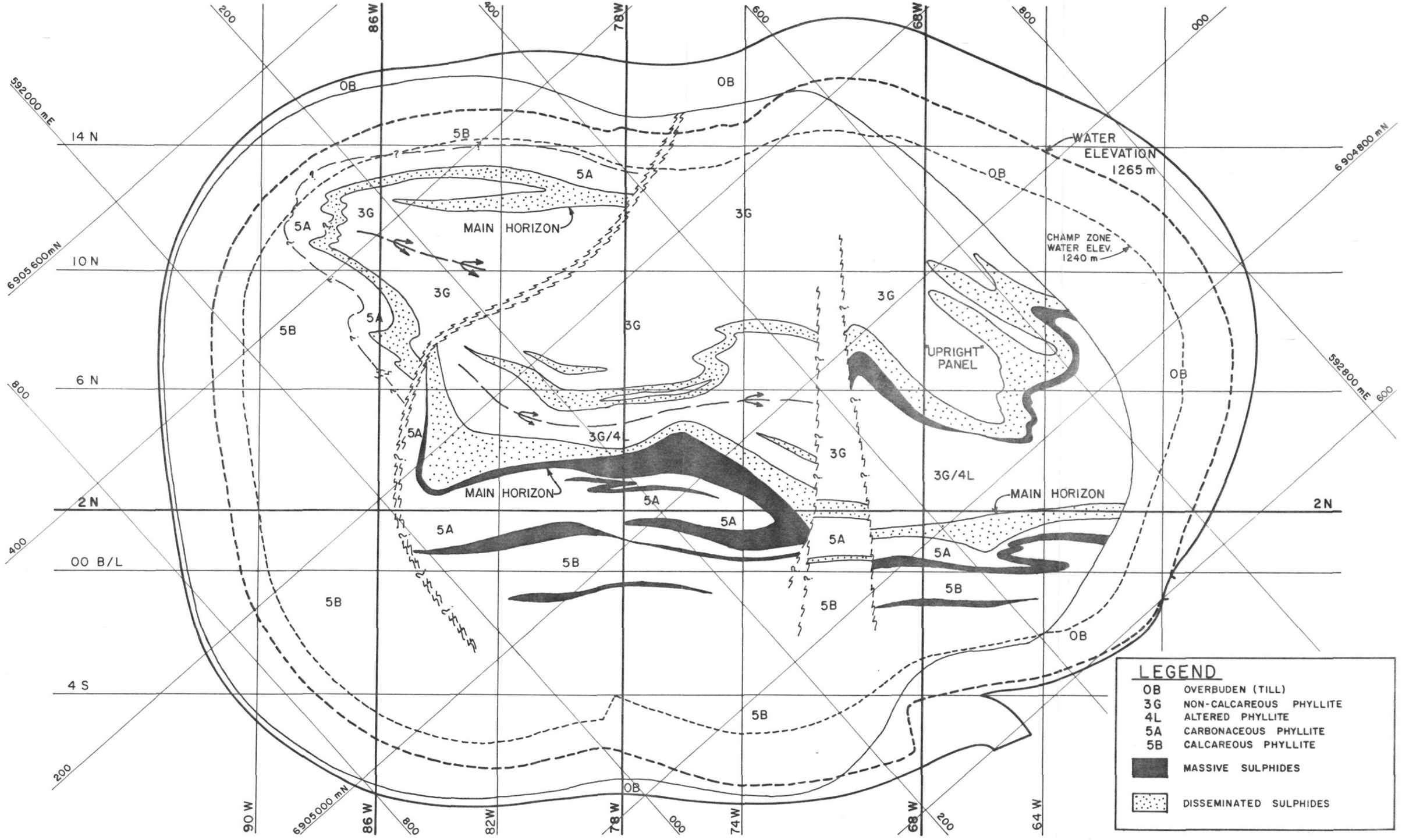
1:3500 | FIGURE 2.13



Carrugh Resources Inc.

VANGORDA OPEN PIT
GEOLOGY

FIGURE 2.14



GRUM OPEN PIT
GEOLOGY

CURRAGH RESOURCES INC.

1:3500 | FIGURE 2.15

VANGORDA PLATEAU SITE PLAN

SCALE 1:5000

0 50 100 200 300 400 500 1000 metres

NOTE: CONTOUR INTERVALS
- TOPOGRAPHY - 5m
- VANGORDA PIT - 12m
- GRUM PIT - 10m

Curragh Resources Inc.

LEGEND

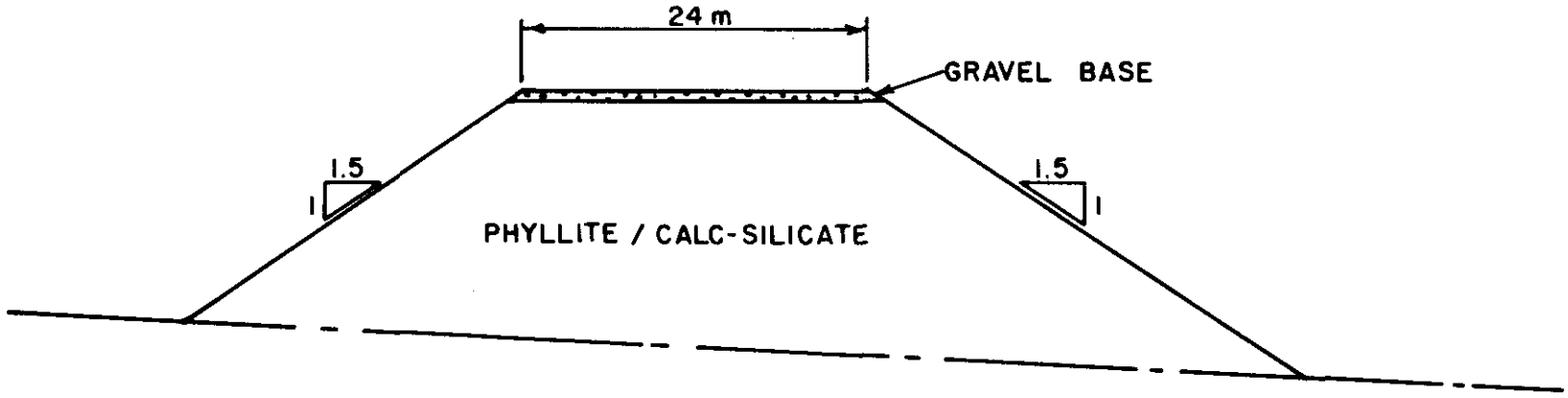
- ● EXISTING PIEZOMETER
- ○ PROPOSED PIEZOMETER
- ⛀ ADIT
- ○ PROPOSED WELL
- ⊕ BOREHOLE
- □ TEST PIT
- △1456 NUMBERED SURVEY STATION
- +1230 SPOT ELEVATION IN METRES

This reference scale bar is valid only when the original maps & will scale at the same rate when reduced. It can be used as a reference for the original size.

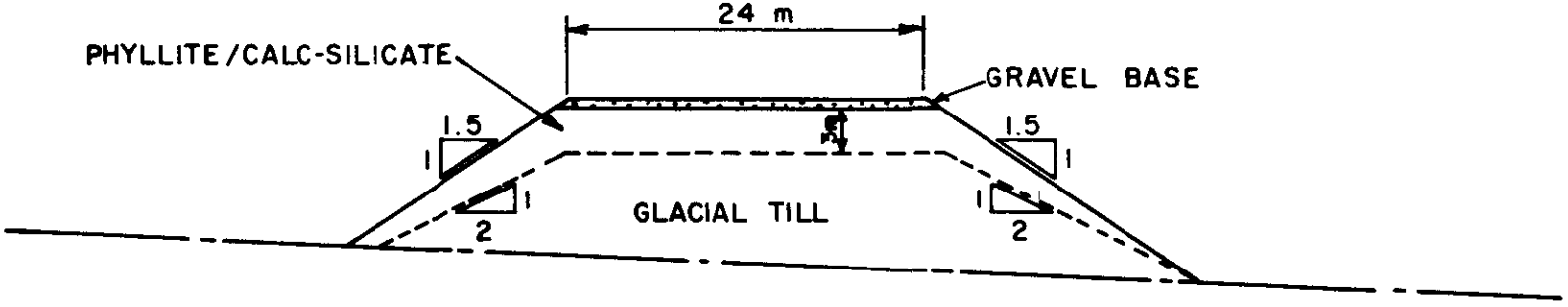
SYKON GEOLOGICAL SURVEY

REVISED	DATE
REVISED TP	DATE 89-01-20
REVISED TP	DATE 88-12-13
DRAWN BY BCB	DATE 88-07-14

FIGURE 2.16

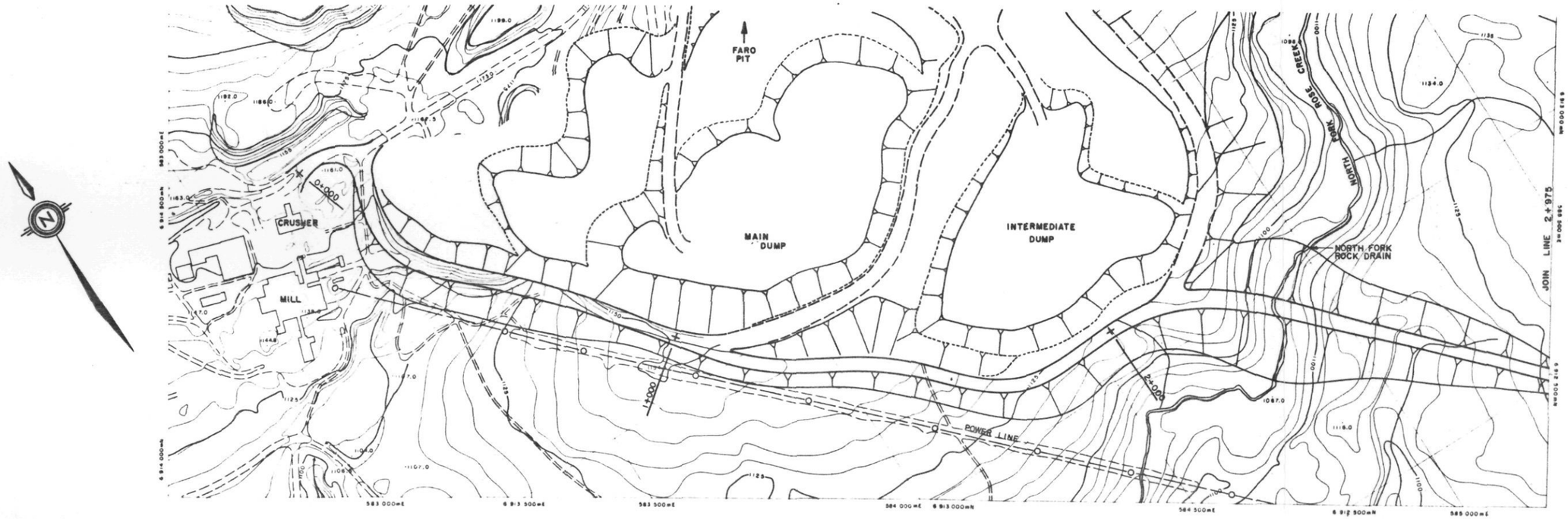


TYPICAL ROAD SECTION
STATION 0+000 to 10+000



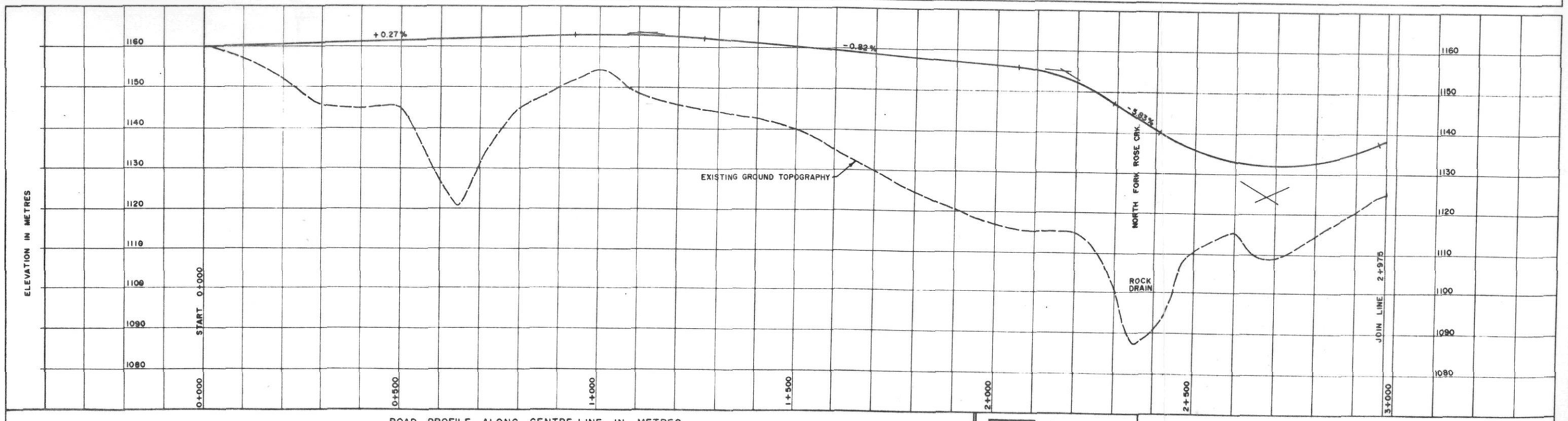
TYPICAL ROAD SECTION
STATION 10+000 to 16+000

TYPICAL HAUL ROAD SECTIONS	CURRAGH RESOURCES INC.	
	1:500	FIGURE 2.17



Scale 0 50 100 200 300 400 500 metres

PLAN VIEW



ROAD PROFILE ALONG CENTRE-LINE IN METRES

Vertical Exaggeration X 10

HORIZONTAL SCALE 0 50 100 200 300 400 500 metres

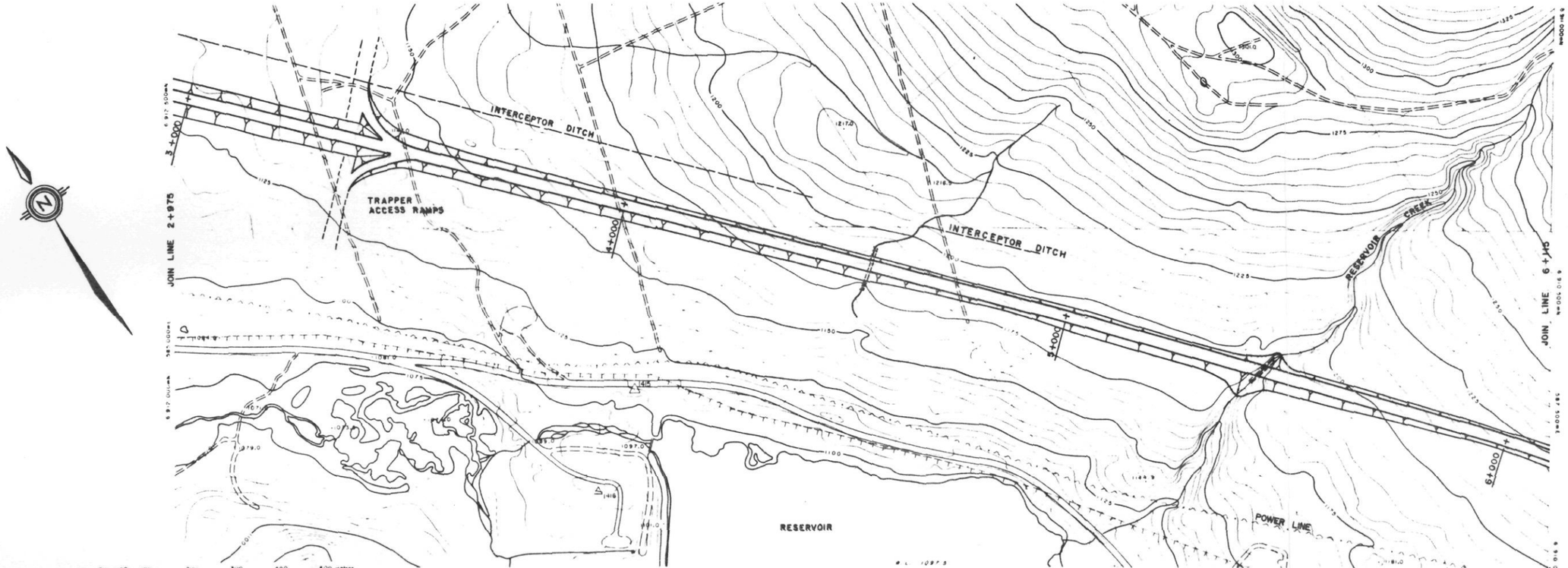
VERTICAL SCALE 0 5 10 20 30 40 50 metres

Curragh Resources Inc.

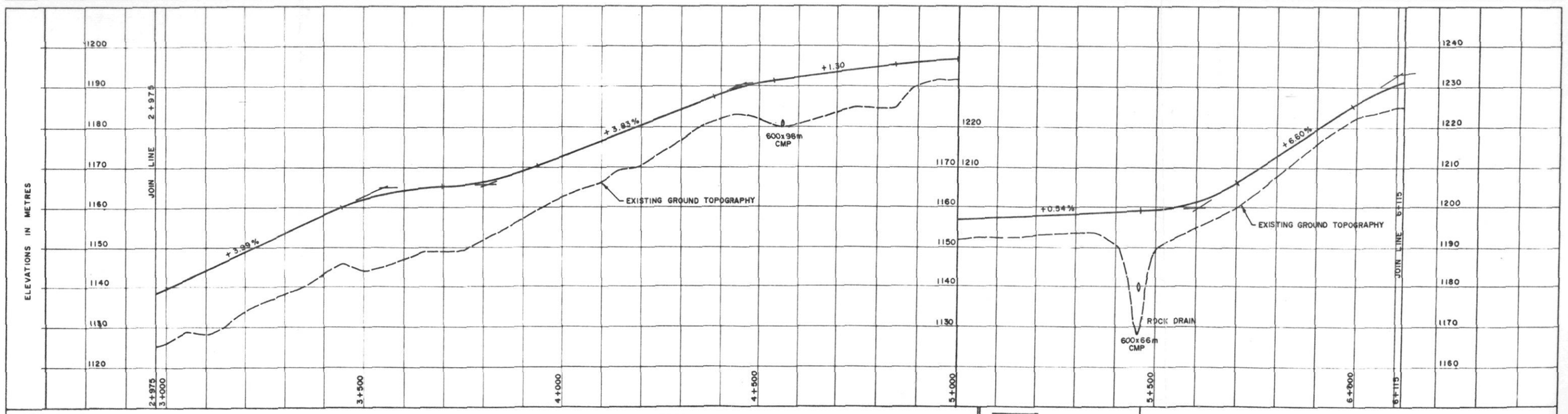
VANGORDA PLATEAU HAUL ROAD PLAN & PROFILE

STATION 0+000 to STATION 2+975

FIGURE 2.18



PLAN VIEW



ROAD PROFILE ALONG CENTRE-LINE IN METRES

Vertical Exaggeration X 10

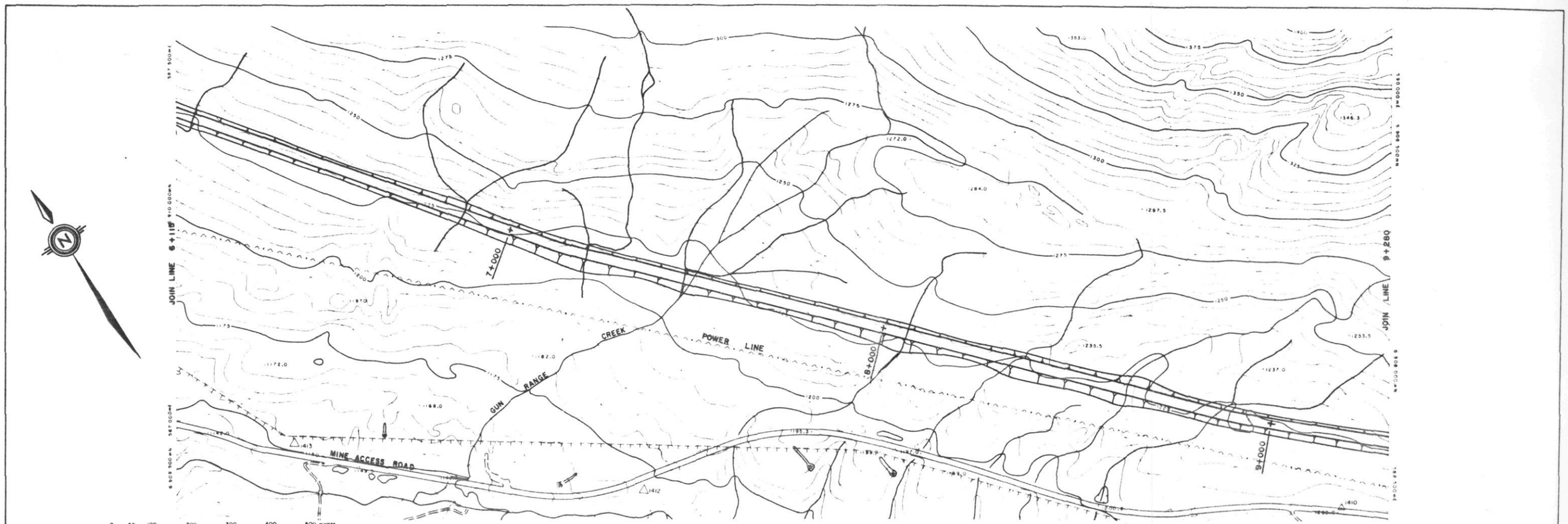
HORIZONTAL SCALE 0 50 100 200 300 400 500 metres

VERTICAL SCALE 0 5 10 20 30 40 50 metres

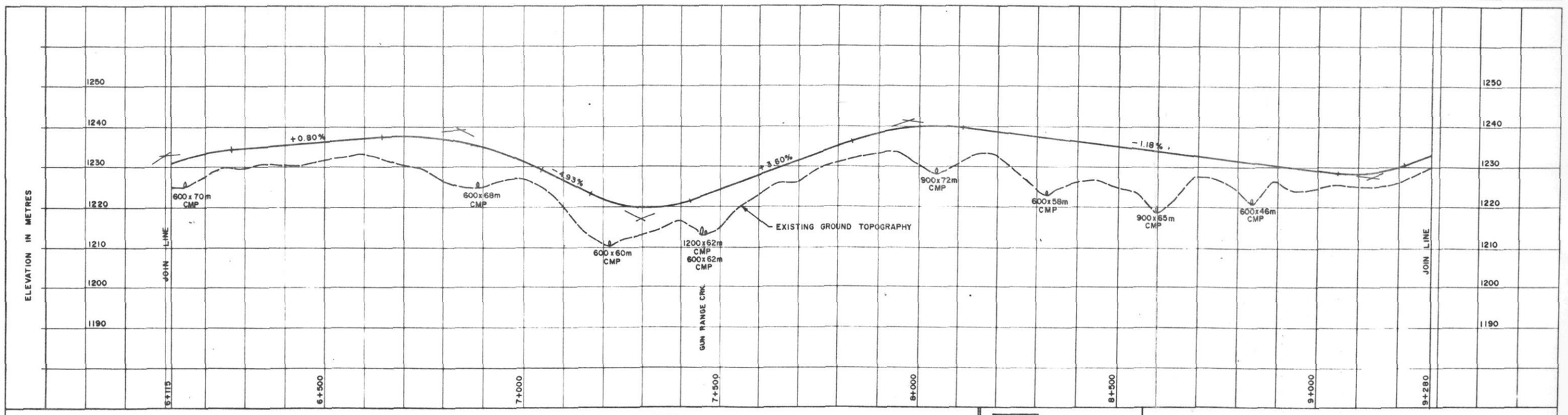
Curragh Resources Inc.

VANGORDA PLATEAU HAUL ROAD PLAN & PROFILE

STATION 2+975 to STATION 6+115 | FIGURE 2.19



PLAN VIEW



ROAD PROFILE ALONG CENTRE-LINE IN METRES

Vertical Exaggeration X 10

HORIZONTAL SCALE 0 50 100 200 300 400 500 metres

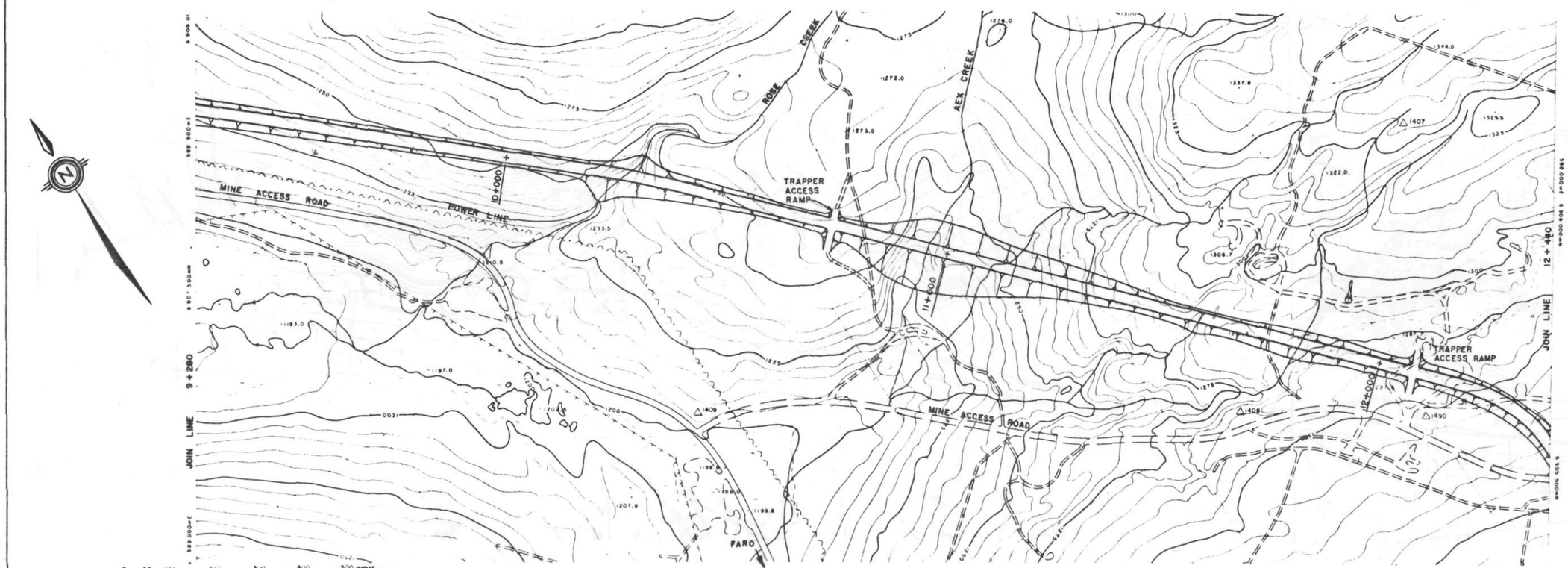
VERTICAL SCALE 0 5 10 20 30 40 50 metres

Carnegie Resources Inc.

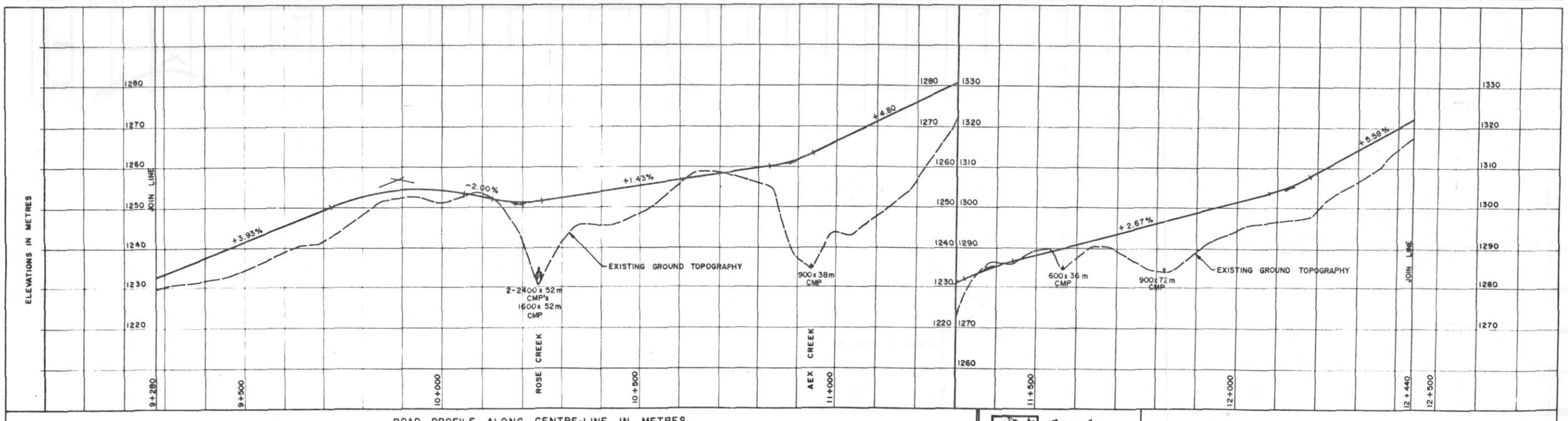
VANGORDA PLATEAU HAUL ROAD
PLAN & PROFILE

STATION 6+115 to STATION 9+280

FIGURE 2.20



PLAN VIEW



ROAD PROFILE ALONG CENTRE-LINE IN METRES

Vertical Exaggeration X 10

HORIZONTAL SCALE 0 50 100 200 300 400 500 metres

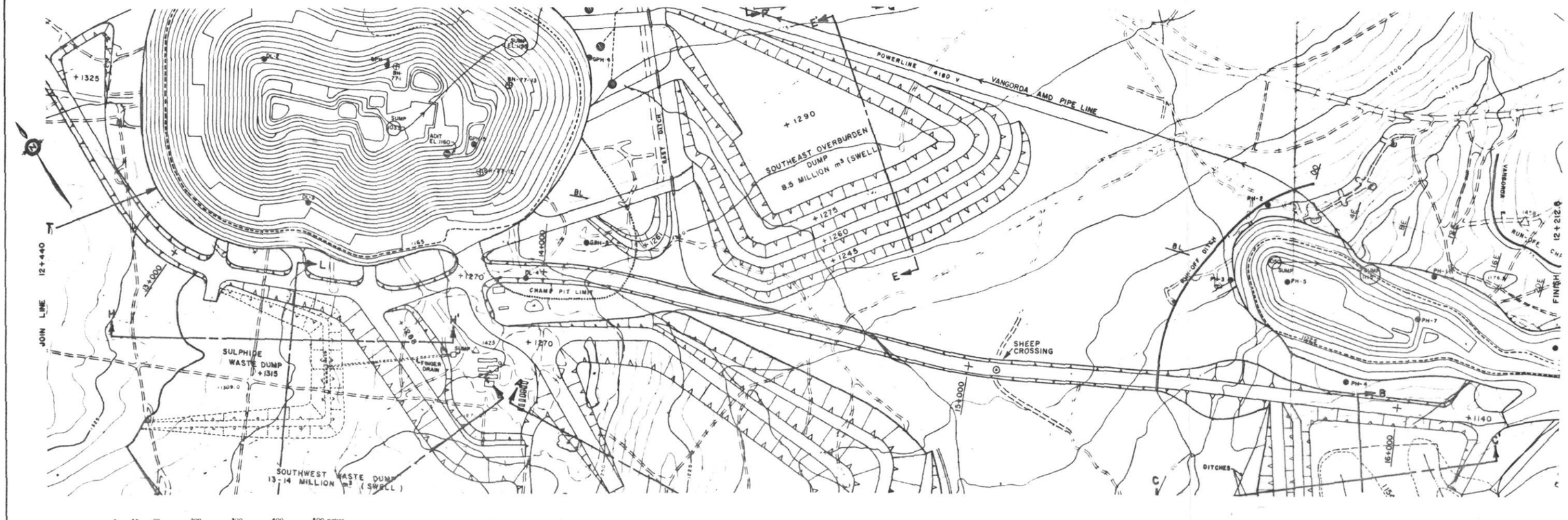
VERTICAL SCALE 0 5 10 20 30 40 50 metres

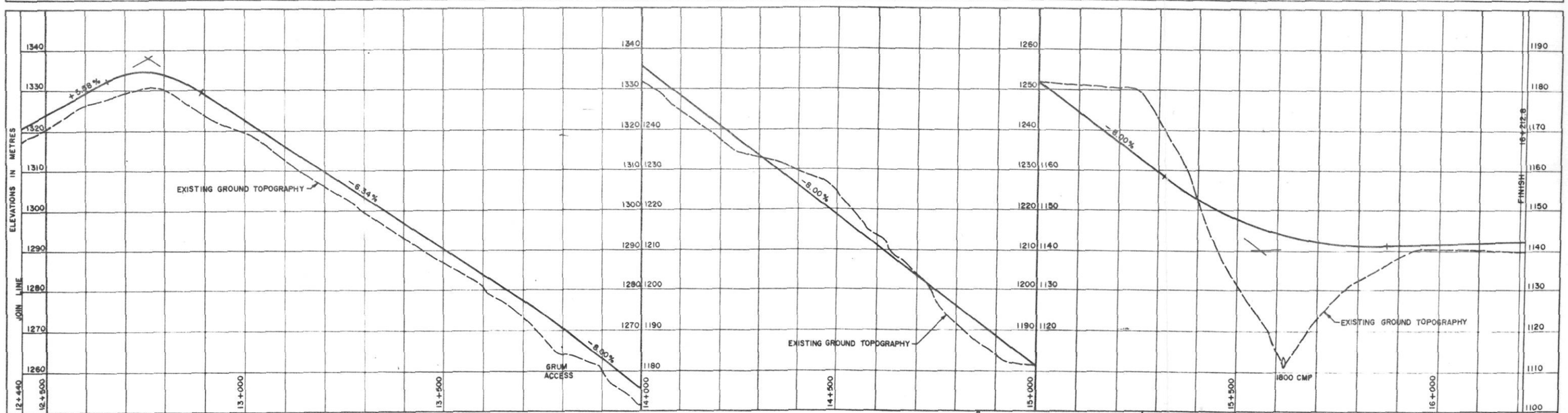
Curragh Resources Inc.

VANGORDA PLATEAU HAUL ROAD
PLAN & PROFILE

STATION 9+280 to STATION 12+440

FIGURE 2.21



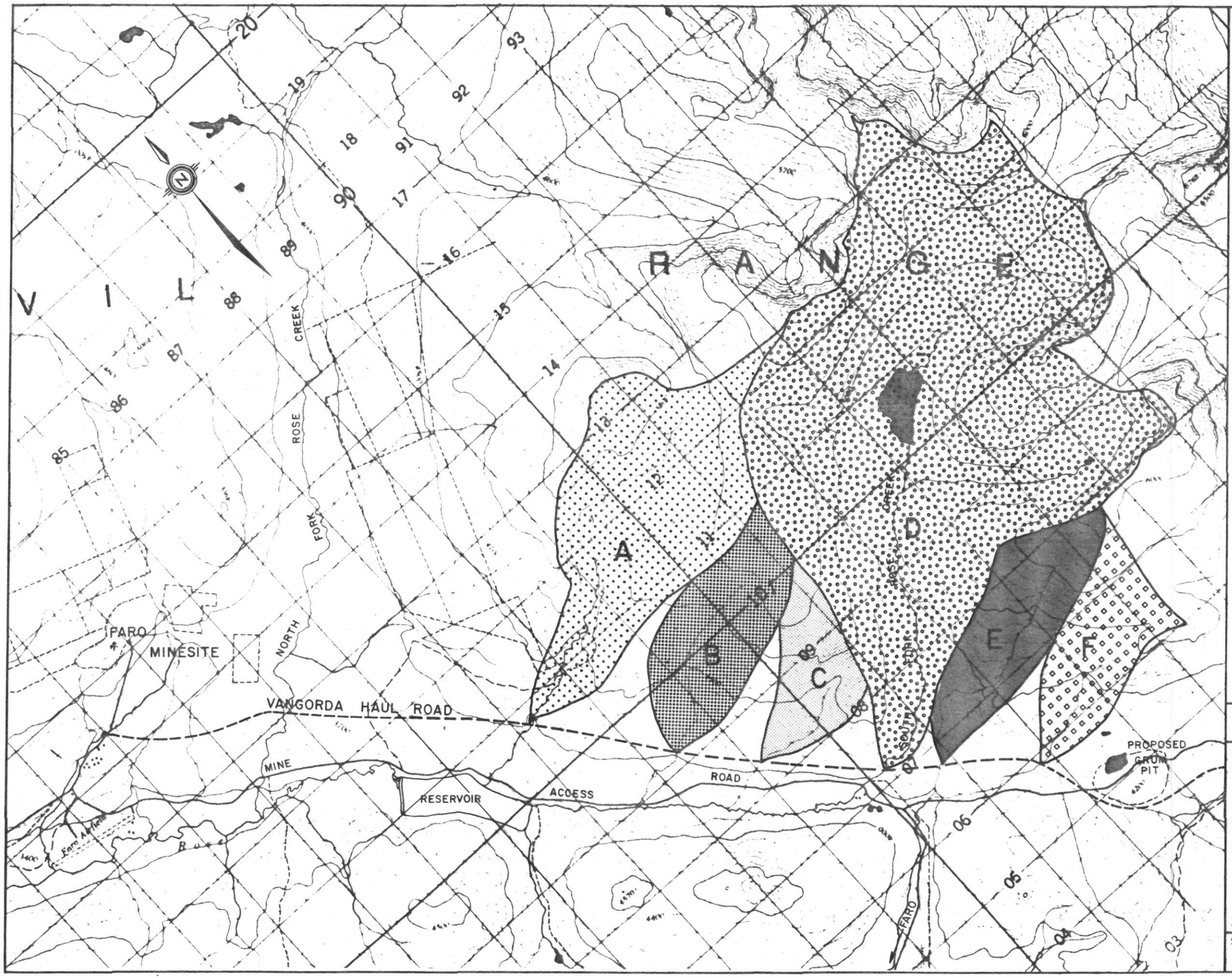


ROAD PROFILE ALONG CENTRE-LINE IN METRES

Curragh Resources Inc.

VANGORDA PLATEAU HAUL ROAD
PLAN & PROFILE

STATION 12+440 to STATION 16+212.8 | FIGURE 2.22



WATERSHED AREAS

WATERSHED		AREA (km²)
A	RESERVOIR CREEK	7.6
B	GUN RANGE CREEK	3.4
C	UN-NAMED CREEK	1.9
D	SOUTH FORK ROSE CREEK	24.9
E	AEX CREEK	3.3
F	SOUTH FORK AEX CREEK	2.7

CURRAGH RESOURCES INC.

WATERSHED AREAS of CREEK & STREAMS crossing VANGORDA HAUL ROAD

SCALE	DATE	
1:50000	88·06·29	FIGURE 2.23

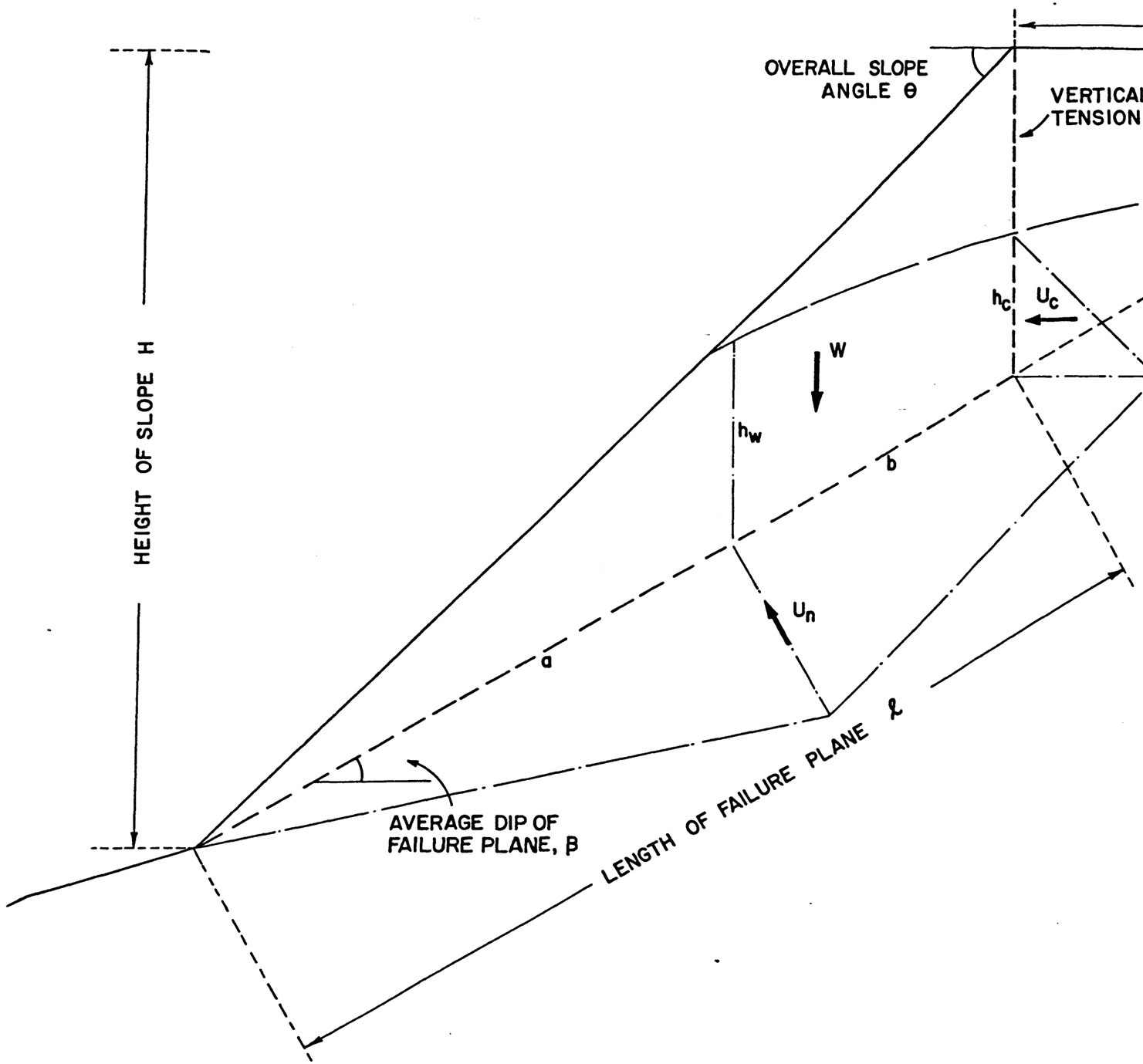


FIGURE 10

I. Summary of Forces:

1. Weight of Block, W:

$$W = \frac{\gamma H^2}{2}\left(\frac{1}{\tan\beta} - \frac{1}{\tan\theta}\right) - \frac{\gamma y^2}{2}\tan\beta$$

Where γ = Unit Weight of Rock = 170 lb./ft.^{3}

2. Normal Water Pressure, Un

$$Un = \frac{\gamma_w h_w a}{2} + \gamma_w(h_w + hc)\frac{b}{2}$$

Where γ_w = Unit Weight of Water [illegible] lb./ft.^{3}

3. Crack Water Pressure, Uc:

$$Uc = \frac{\gamma_w hc^2}{2}$$

II. Resolution of Forces:

1. Forces Along the Failure Plane:

Force due to W = W sin β
Force due to Uc = Uc cos β

2. Forces Normal to the Failure Plane:

Normal force due to W = W cos β
Normal force due to Un = - Un
Normal force due to Uc = - Uc sin β

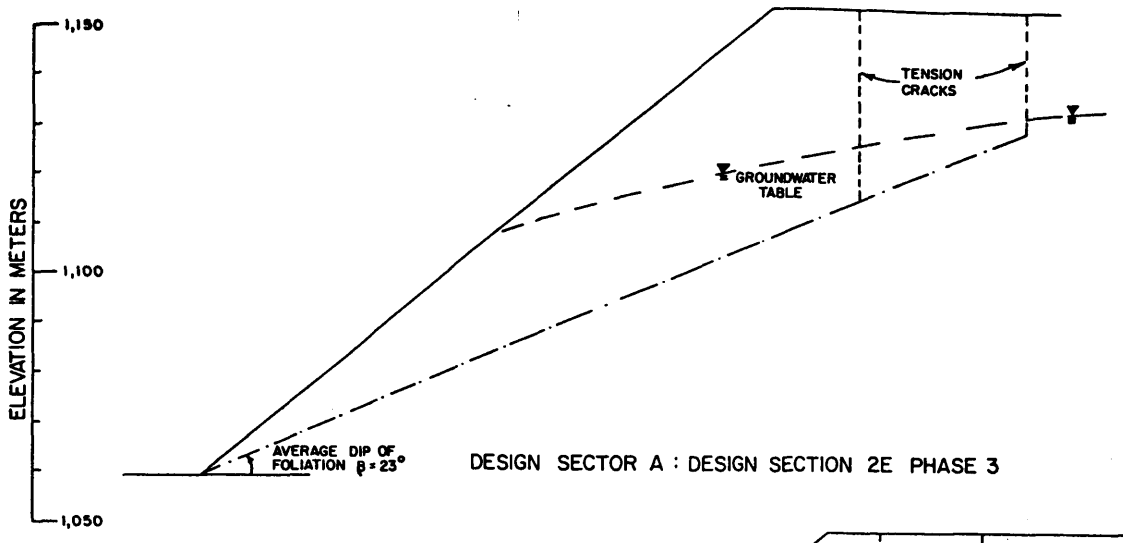
III. Calculation of Factor of Safety:

1. Disturbing Forces = Σ Forces along the Failure Plane
= W sin β + Uc cos β

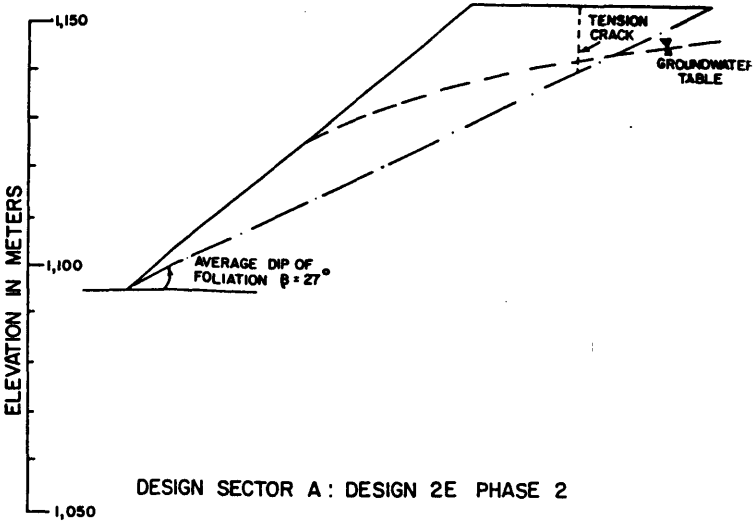
2. Resisting Forces = [Σ Normal Forces] tan ϕ + (ℓ)(c)
= [W cos β - Un - Uc sin β] tan ϕ + (a + b)(c)

3. $$F = \frac{[W\cos\beta - Un - Uc\sin\beta]\tan\phi + (a+b)(c)}{W\sin\beta + Uc\cos\beta}$$

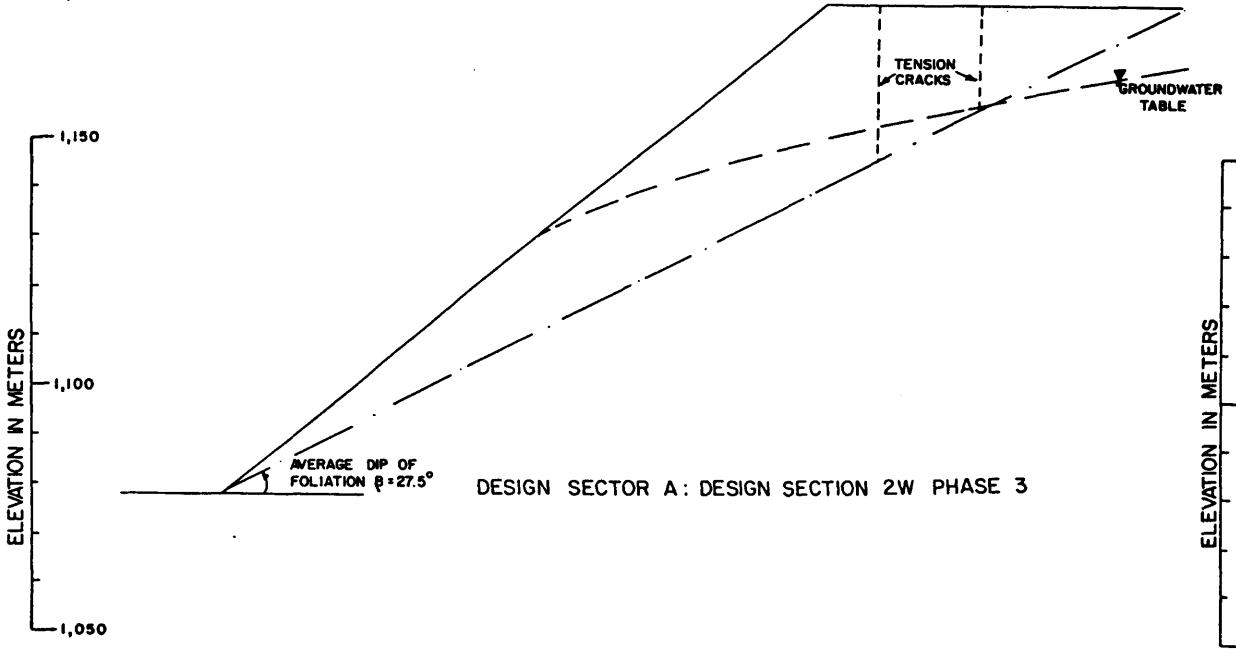
ROCK STABILITY ANALYSIS LIMIT EQUILIBRIUM METHOD	CURRAGH RESOURCES INC.
	FIGURE 2.24



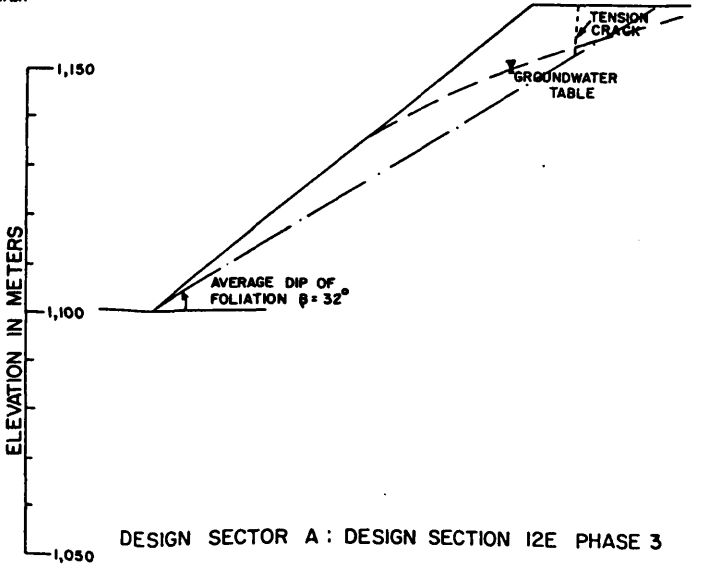
DESIGN SECTOR A : DESIGN SECTION 2E PHASE 3



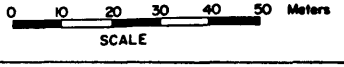
DESIGN SECTOR A : DESIGN 2E PHASE 2



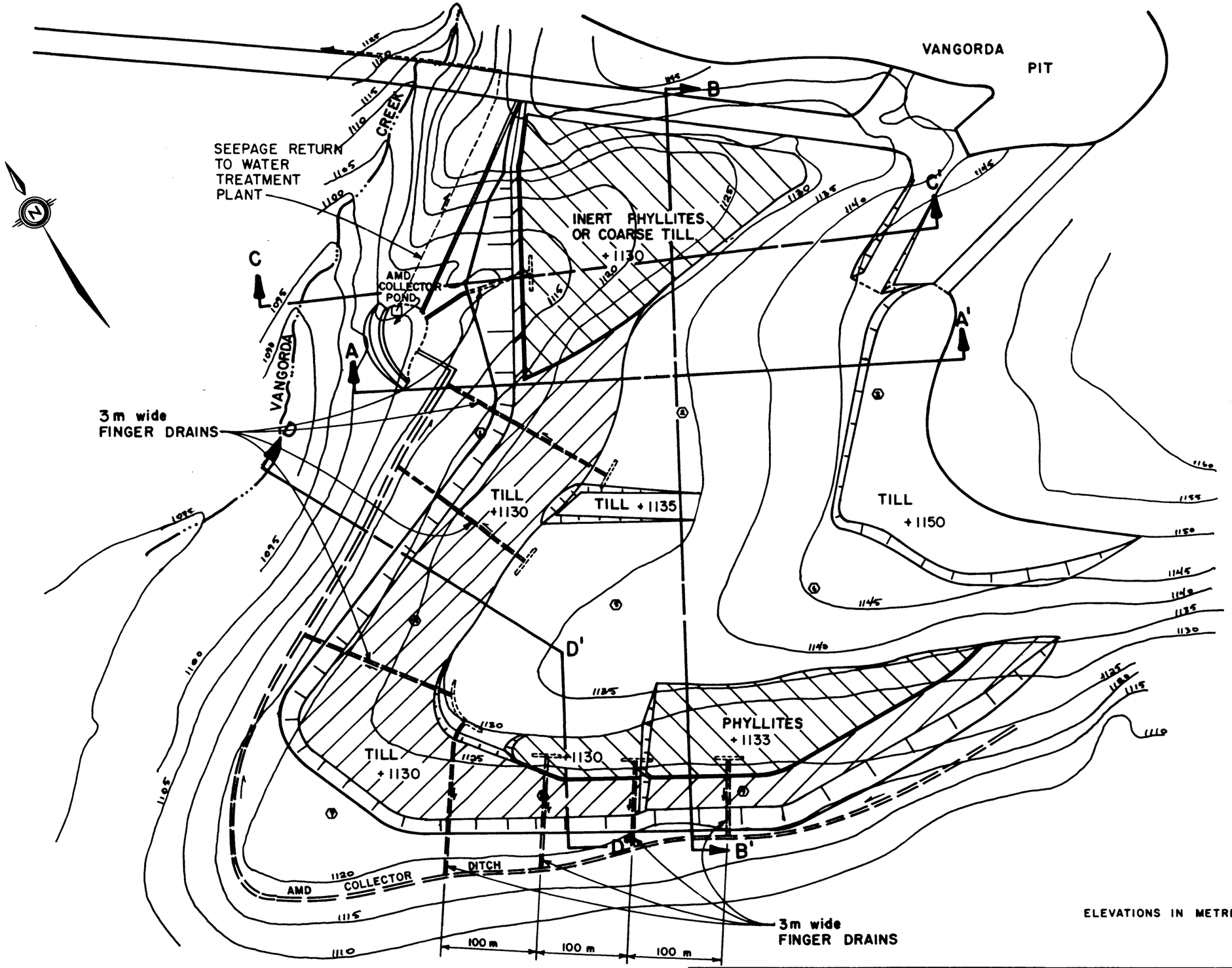
DESIGN SECTOR A : DESIGN SECTION 2W PHASE 3



DESIGN SECTOR A : DESIGN SECTION 12E PHASE 3

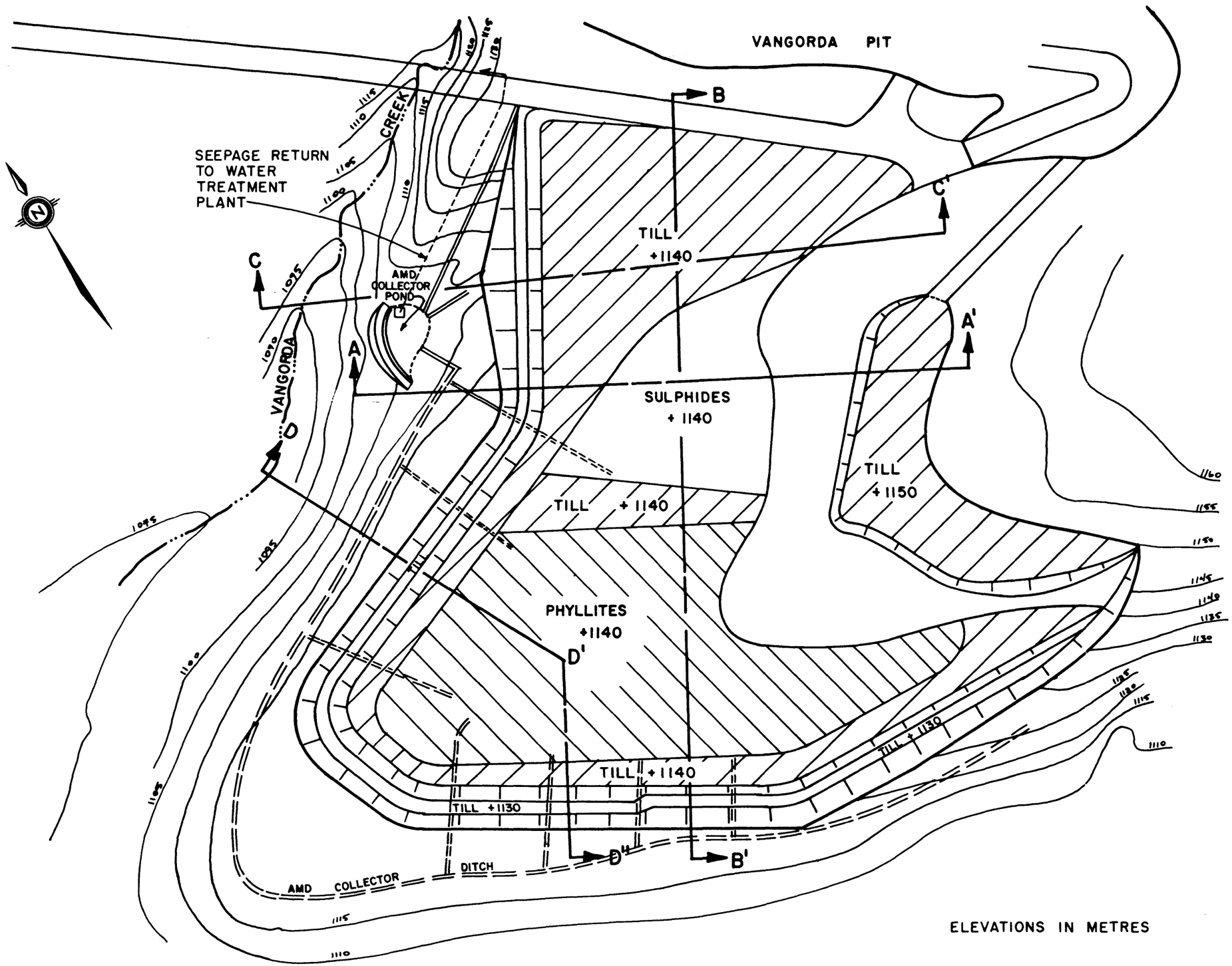


ROCK STABILITY ANALYSIS FAILURE PLANES	CURRAGH RESOURCES INC. FIGURE 2.25



ELEVATIONS IN METRES

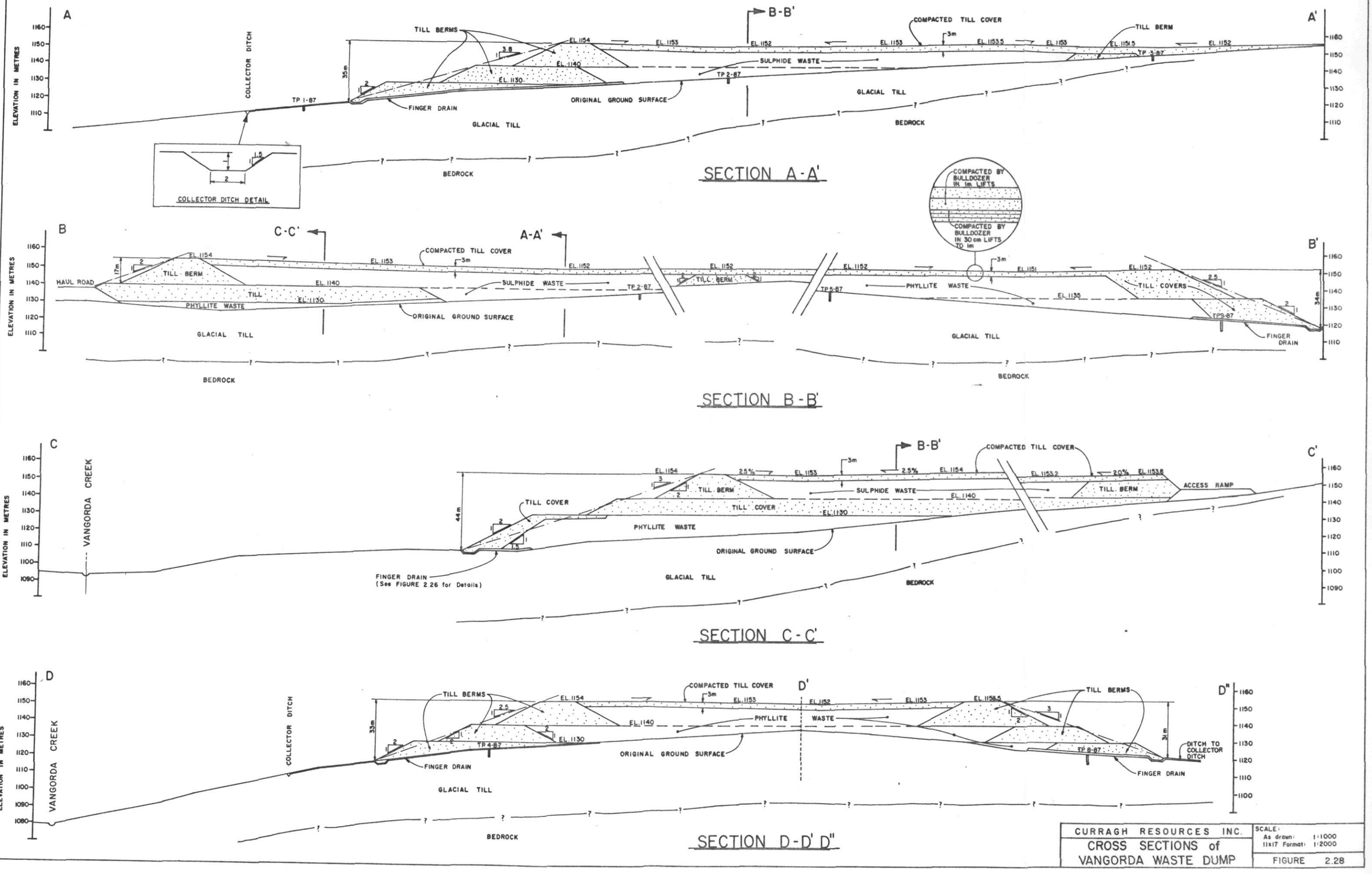
VANGORDA WASTE DUMP STAGE 1 at ELEV. 1130	CURRAGH RESOURCES INC.	
	SCALE 1:5000	FIGURE 2.26



ELEVATIONS IN METRES

0 50 100 200 300 400 500 m

VANGORDA WASTE DUMP STAGE 2 at ELEV. 1140	CURRAGH RESOURCES INC.	
	SCALE 1:5000	FIGURE 2.27

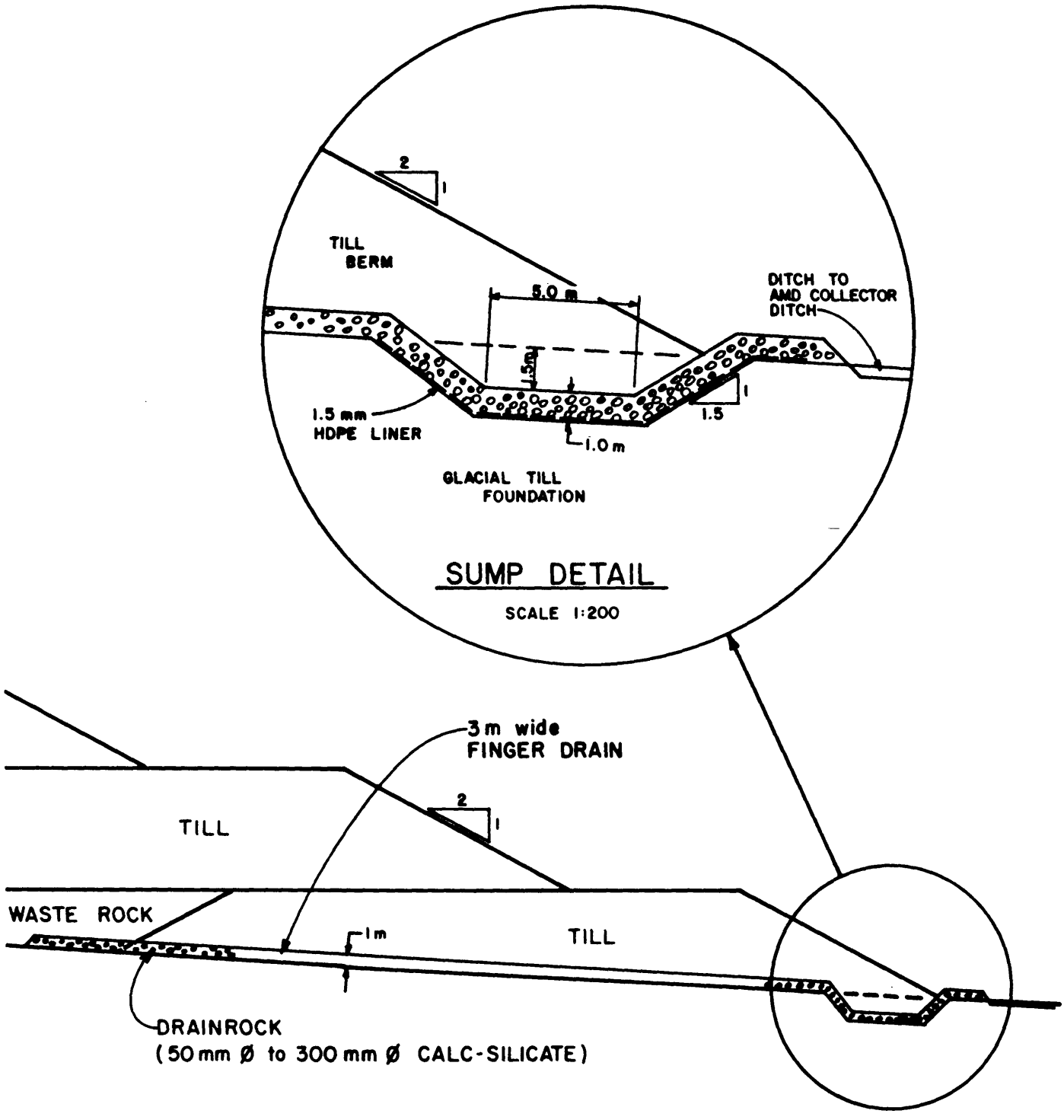


CURRAGH RESOURCES INC.

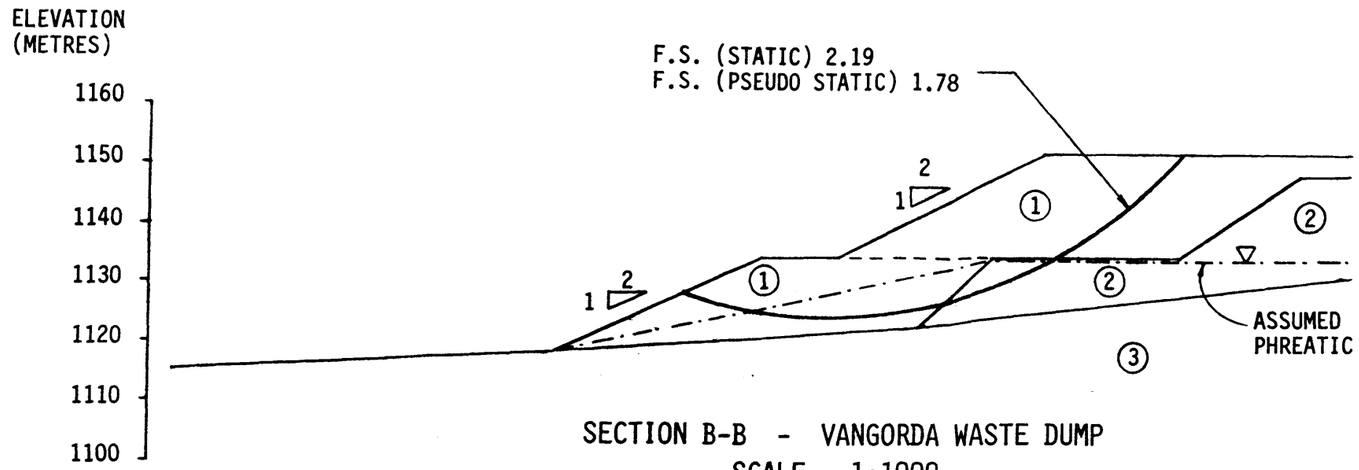
CROSS SECTIONS of VANGORDA WASTE DUMP

SCALE:
As drawn: 1:1000
11x17 Format: 1:2000

FIGURE 2.28

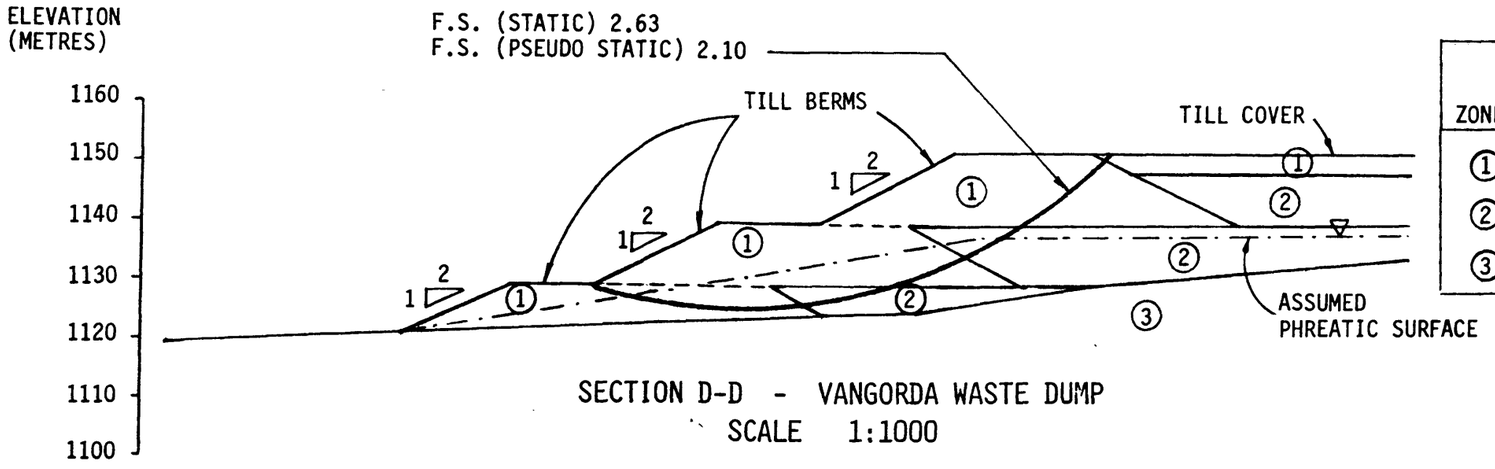


TYPICAL DETAILS FINGER DRAIN & SUMP	CURRAGH RESOURCES INC.	
	1:500	FIGURE 2.29



ZONE	TOTAL DENSITY Kg/m^3	COHESION Kg/m^2	FRICTION ANGLE	MATERIAL
①	2200	1760	30	TILL COVER/BERMS
②	2200	0	35	WASTE ROCK
③	2300	2000	38	FOUNDATION TILL

SECTION B-B - VANGORDA WASTE DUMP
SCALE 1:1000



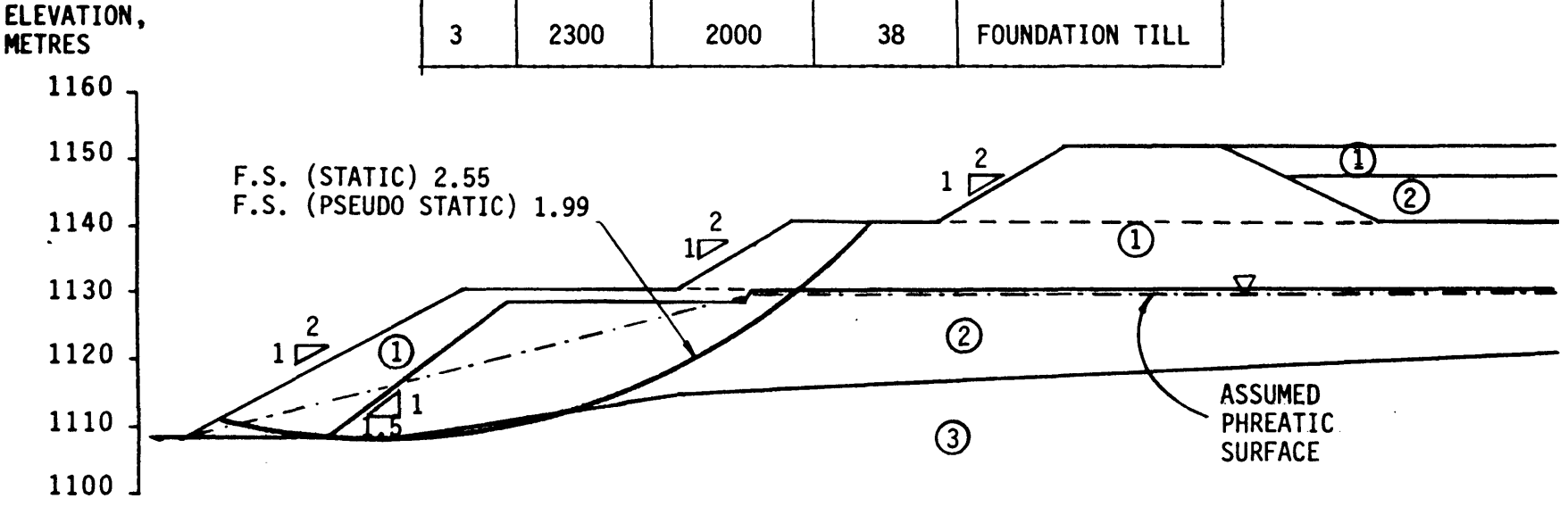
ZONE	TOTAL DENSITY Kg/m^3	COHESION Kg/m^2	FRICTION ANGLE	MATERIAL
①	2200	1760	30	TILL COVER/BERMS
②	2200	0	35	WASTE ROCK
③	2300	2000	38	FOUNDATION TILL

SECTION D-D - VANGORDA WASTE DUMP
SCALE 1:1000

STABILITY ANALYSES
VANGORDA WASTE DUMPS
SECTIONS B-B AND D-D

FIGURE 2.30

ZONE	TOTAL DENSITY Kg/m^3	COHESION Kg/m^2	FRICTION ANGLE	MATERIAL
1	2200	1760	30	TILL COVER/BERMS
2	2200	0	35	WASTE ROCK
3	2300	2000	38	FOUNDATION TILL



SECTION C-C - VANGORDA WASTE DUMP
SCALE 1:1000

STABILITY ANALYSES
VANGORDA WASTE DUMP
SECTION C-C

FIGURE 2.31

GRUM PIT

HAUL ROAD

Adit

H

H'

L

To Water Treatment Plant

1423

Sump

ROCK FINGER DRAIN

SULPHIDE WASTE DUMP

+1315

+1300

+1315

+1290

MAIN WASTE DUMP

17-18 Million m³ (swell)

+1270

SOUTHWEST WASTE DUMP

7-8 Million m³ (swell)

+1300

F

F'

L'

A

A'

1461

1329.5

1325

1325

1309.0

1262.0

1249.9

1167.0

1300

1275

1250

1200

1175

1150

1225

GRUM WASTE DUMPS

STAGE I CONFIGURATION

CURRAGH RESOURCES INC.

SCALE: 1:5000

FIGURE 2.32

GRUM PIT

HAUL ROAD

Adit

To Water Treatment Plant

SUMP

FINGER DRAIN

SULPHIDE WASTE DUMP
1.5 Million m³

+1300

+1300

SOUTHWEST WASTE DUMP
11-12 Million m³ (swell)
+1315

+1290

MAIN WASTE DUMP
48-50 Million m³ (swell)
+1270

+1300

L

L'

H

H'

4

4'

1423

1309.0

1461

1329.5

1325

1325

1300

1250

1225

1200

1175

1167.0

1275

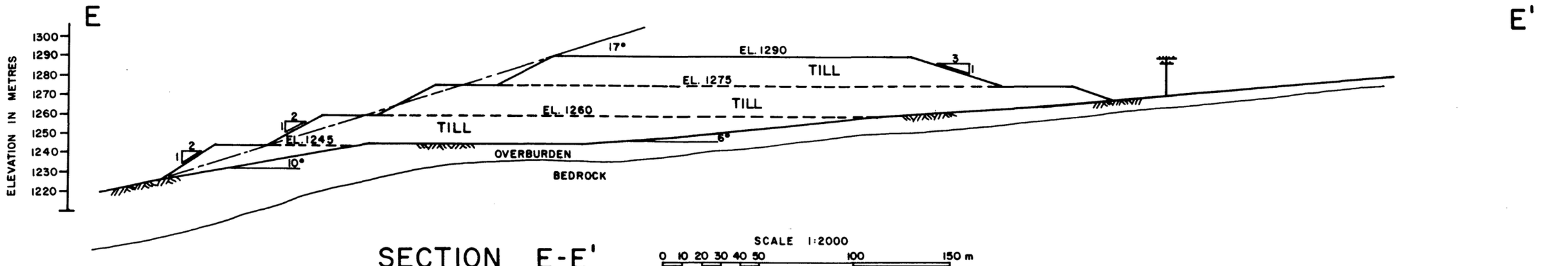
1275

GRUM WASTE DUMPS
STAGE II CONFIGURATION

CURRAGH RESOURCES INC.

SCALE: 1:5000

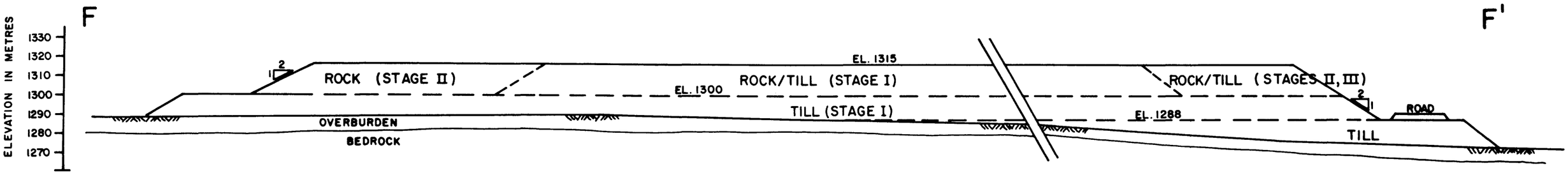
FIGURE 2.33



SECTION E-E'

SCALE 1:2000

0 10 20 30 40 50 100 150 m



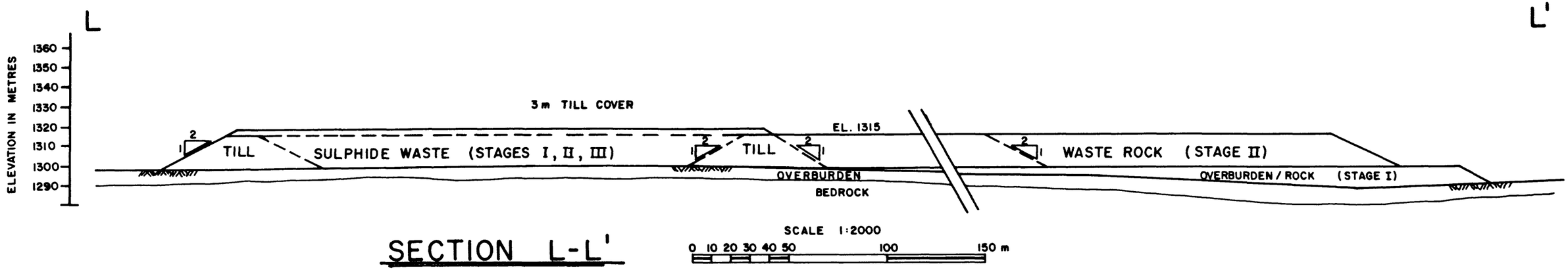
SECTION F-F'

SCALE 1:2000

0 10 20 30 40 50 100 150 m

NOTE: SEE FIGURE 2.16
FOR LOCATION OF SECTIONS

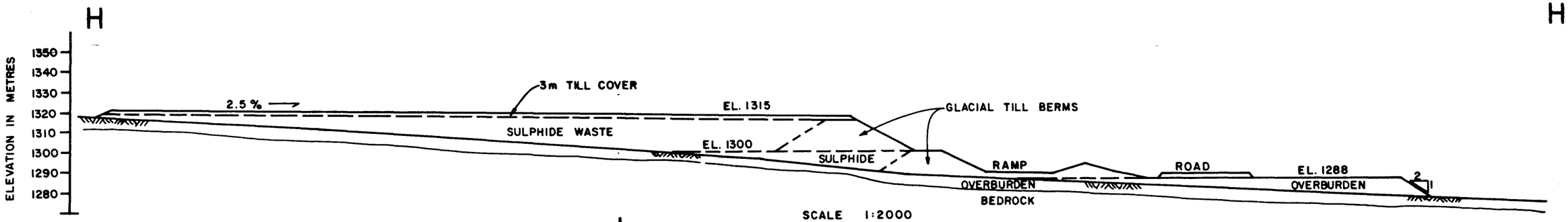
GRUM WASTE DUMPS SECTIONS E-E, F-F	CURRAGH RESOURCES INC.	
	SCALE: AS SHOWN	FIGURE 2.34



SECTION L-L'

SCALE 1:2000

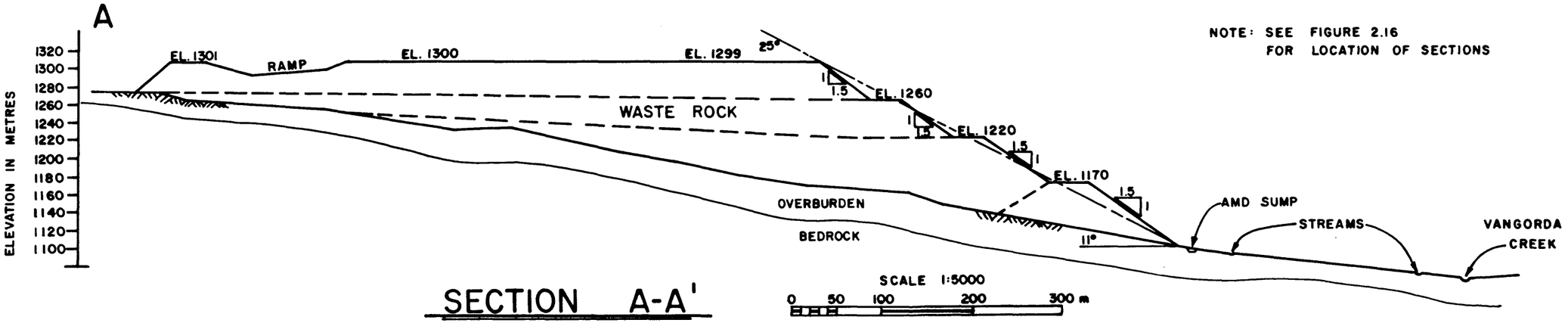
0 10 20 30 40 50 100 150 m



SECTION H-H'

SCALE 1:2000

0 10 20 30 40 50 100 150 m



NOTE: SEE FIGURE 2.16
FOR LOCATION OF SECTIONS

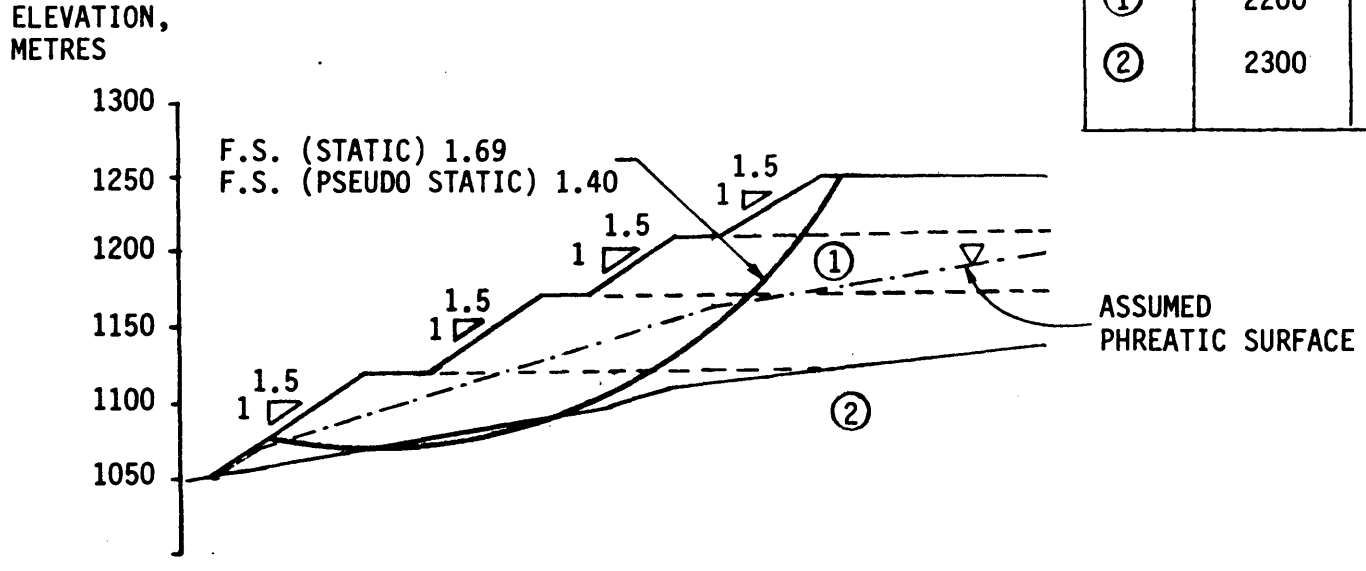
SECTION A-A'

SCALE 1:5000

0 50 100 200 300 m

GRUM WASTE DUMPS SECTIONS A-A', H-H', L-L'	CURRAGH RESOURCES INC.	
	SCALE: AS SHOWN	FIGURE 2.35

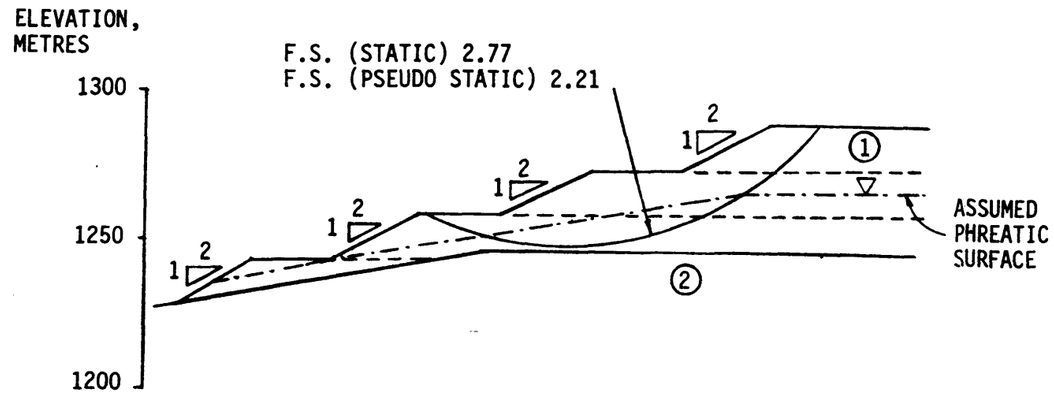
ZONE	TOTAL DENSITY Kg/m³	COHESION Kg/m²	FRICTION ANGLE	MATERIAL
①	2200	0	35	WASTE ROCK
②	2300	2000	38	FOUNDATION TILL



SECTION A-A - GRUM MAIN WASTE DUMP
SCALE 1:5000

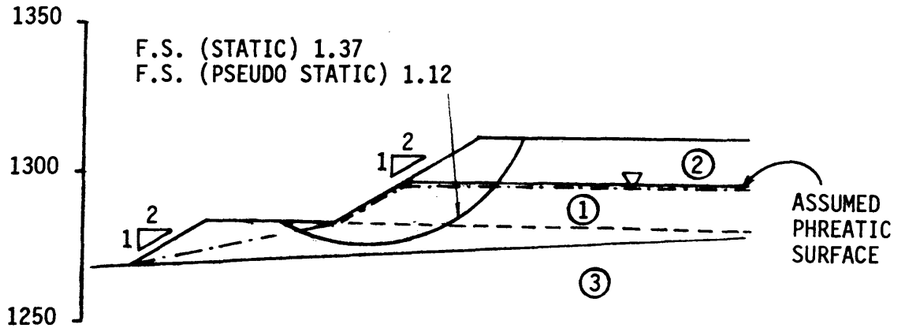
STABILITY ANALYSES
GRUM WASTE DUMP
SECTION A-A

FIGURE 2.36



SECTION E-E - GRUM S.E. OVERBURDEN DUMP
SCALE 1:2000

ZONE	TOTAL DENSITY Kg/m^3	COHESION Kg/m^2	FRICTION ANGLE	MATERIAL
①	2200	1760	30	TILL COVER/BERMS
②	2300	2000	38	FOUNDATION TILL

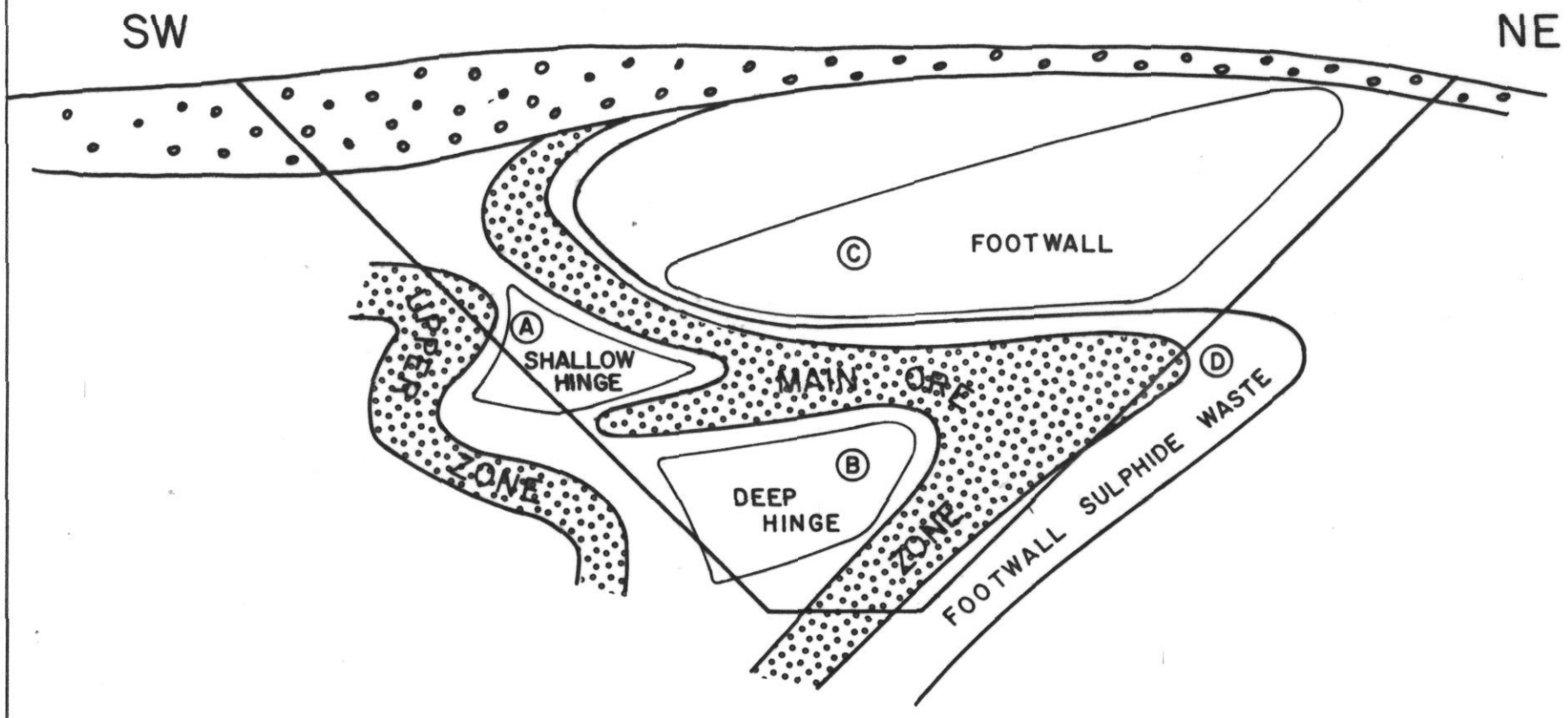


SECTION F-F - GRUM S.W. WASTE DUMP
SCALE 1:2000

ZONE	TOTAL DENSITY Kg/m^3	COHESION Kg/m^2	FRICTION ANGLE	MATERIAL
①	2200	1760	30	TILL COVER/BERMS
②	2200	0	35	WASTE ROCK
③	2300	2000	30	FOUNDATION TILL

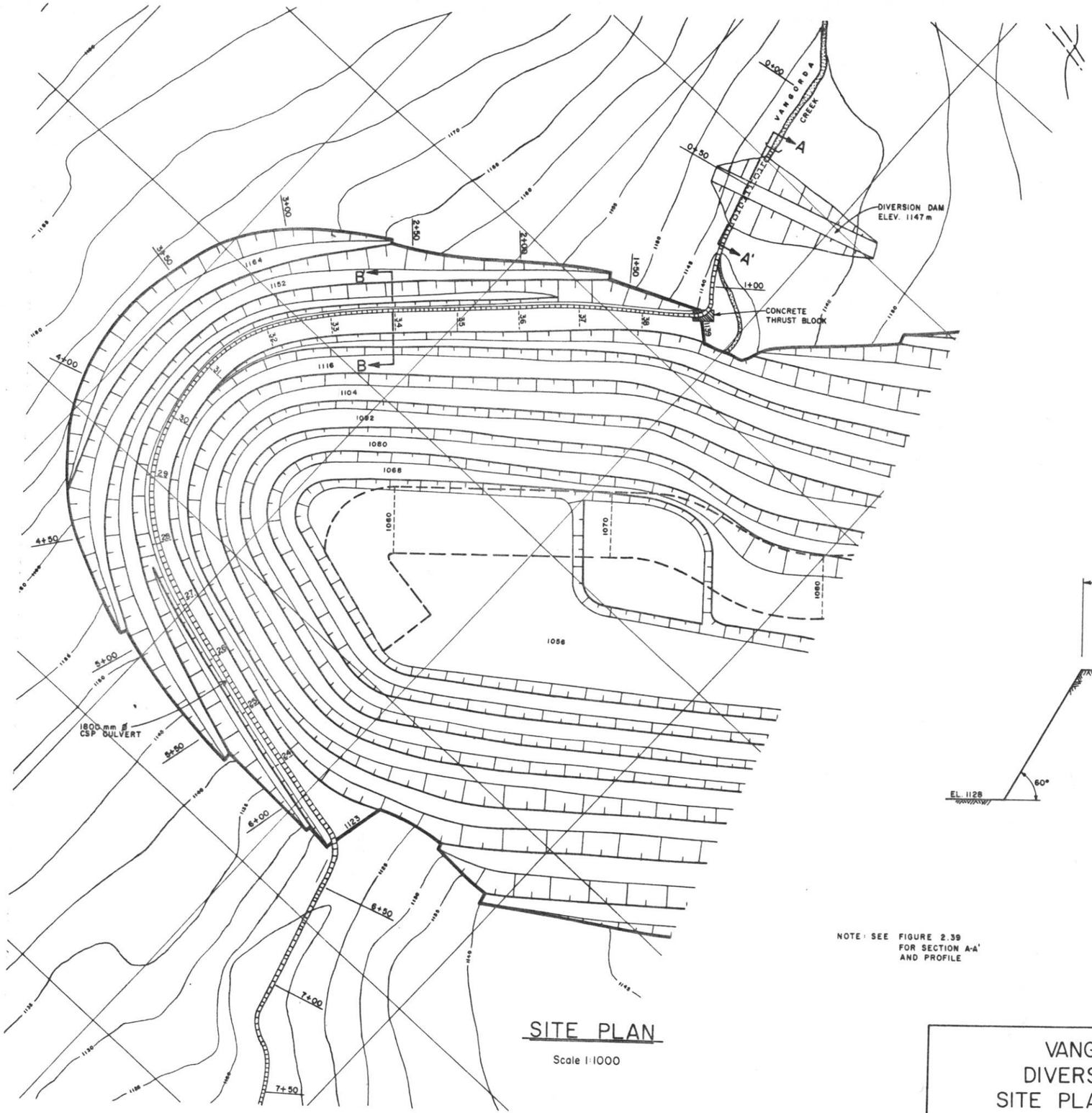
STABILITY ANALYSES
GRUM WASTE AND OVERBURDEN DUMPS
SECTIONS E-E AND F-F

FIGURE 2.37



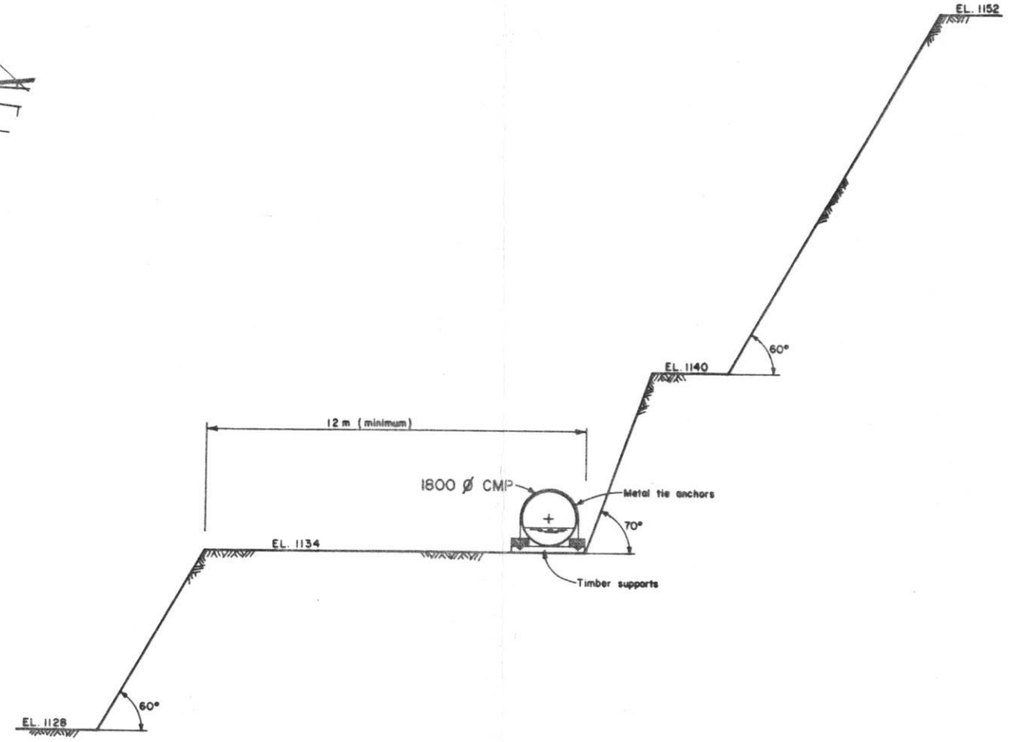
Diagramatic section through the Vangorda Deposit showing the stratigraphic position of the composite waste samples with respect to the ore zones and pit outline.

FIGURE 2.38



SITE PLAN

Scale 1:1000

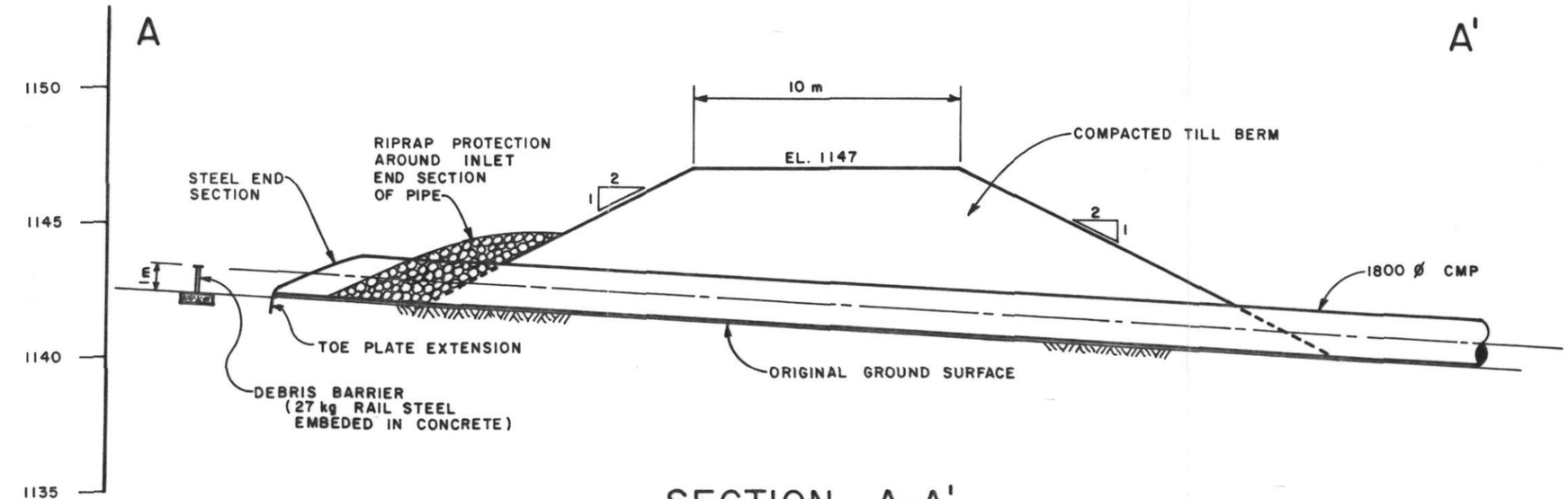


SECTION B-B'

Scale 1:100

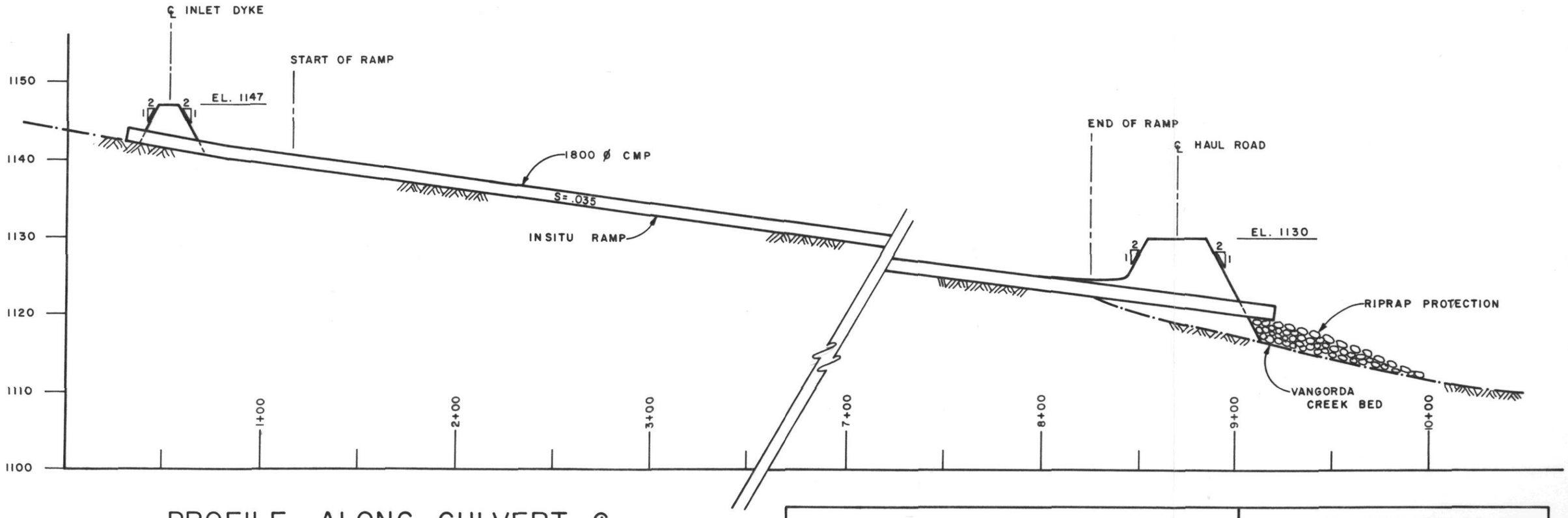
NOTE: SEE FIGURE 2.39 FOR SECTION A-A' AND PROFILE

VANGORDA CREEK DIVERSION CULVERT SITE PLAN & SECTION B-B'	CURRAGH RESOURCES INC.	
	DATE: 89-01-07	
	SCALE: As shown	FIGURE 2.39



SECTION A-A'

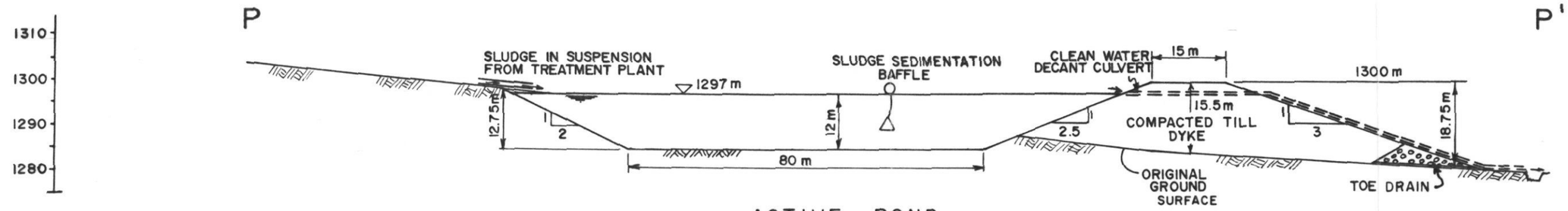
SCALE 1:200



PROFILE ALONG CULVERT ℄

VERTICAL SCALE 1:500
HORIZONTAL SCALE 1:2000

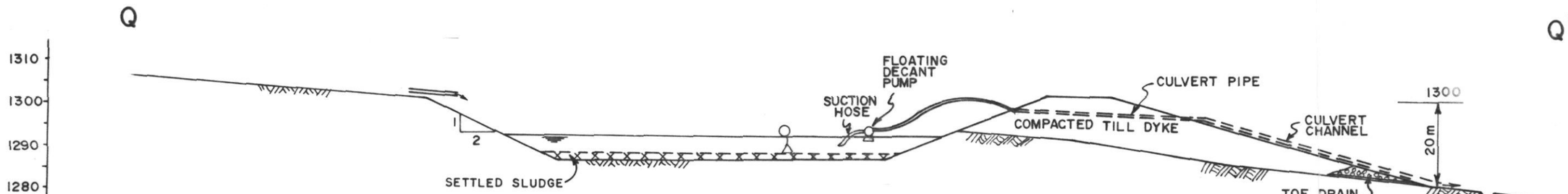
VANGORDA CREEK DIVERSION CULVERT PROFILE & SECTION	CURRAGH RESOURCES INC.	
	SCALE: AS SHOWN	FIGURE 2.40



ACTIVE POND

SLUDGE SETTLES OUT WHILE THE CLEAN WATER IS DECANTED OFF

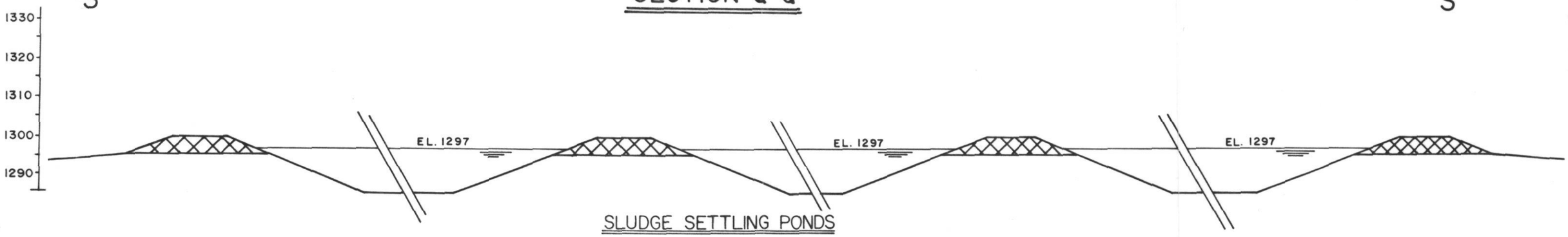
SECTION P-P'



INACTIVE POND

POND BEING PUMPED TO INDUCE DEWATERING AND DENSIFICATION OF SLUDGE

SECTION Q-Q'

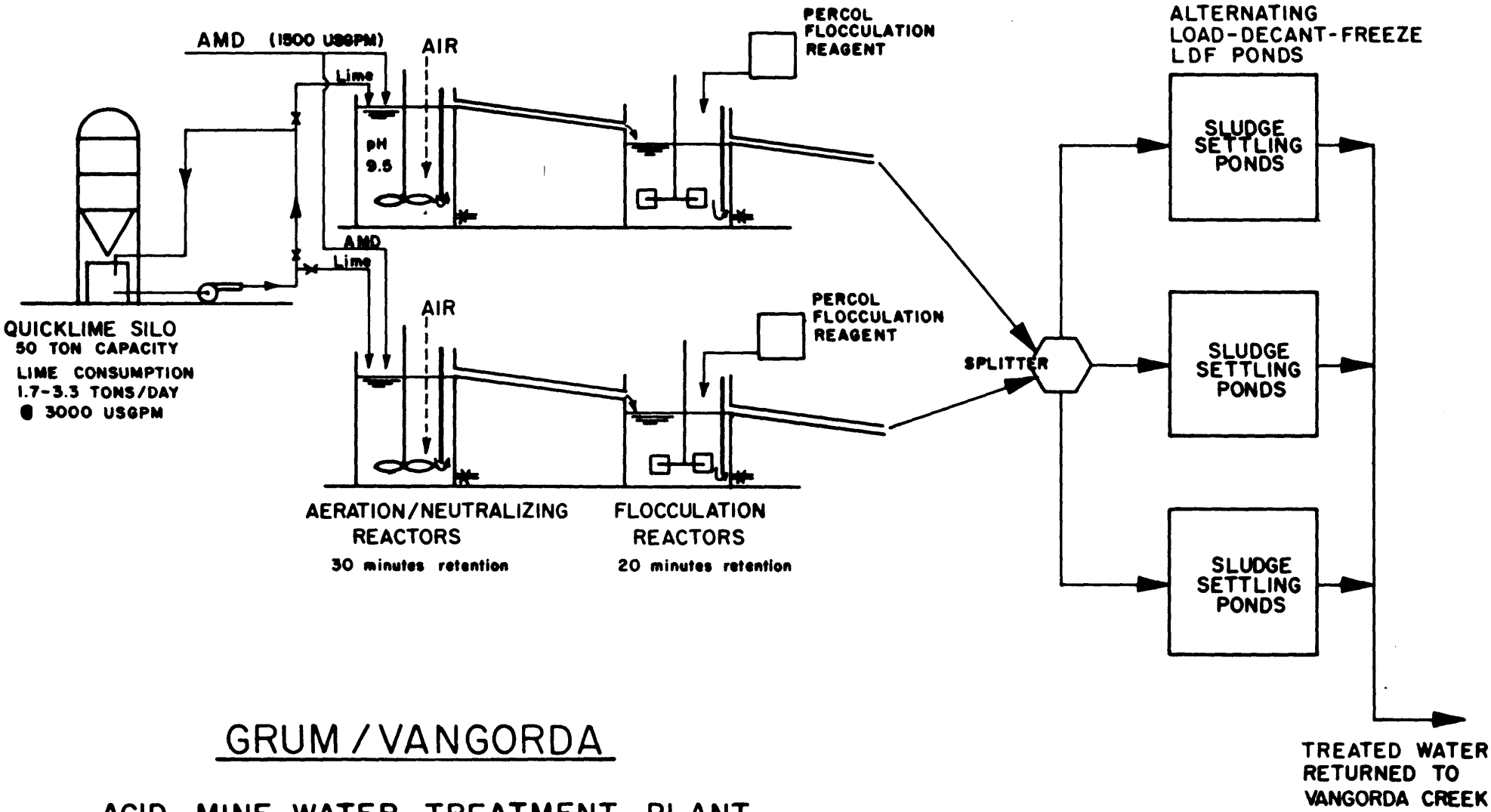


SLUDGE SETTLING PONDS

SECTION S-S'

NOTE: SEE FIGURE 2.16 FOR SECTION LOCATIONS

GRUM/VANGORDA SETTLING PONDS SECTIONS P-P', Q-Q', S-S'	CURRAGH RESOURCES INC.	
	SCALE 1:1000	FIGURE 2.41



GRUM / VANGORDA

ACID MINE WATER TREATMENT PLANT

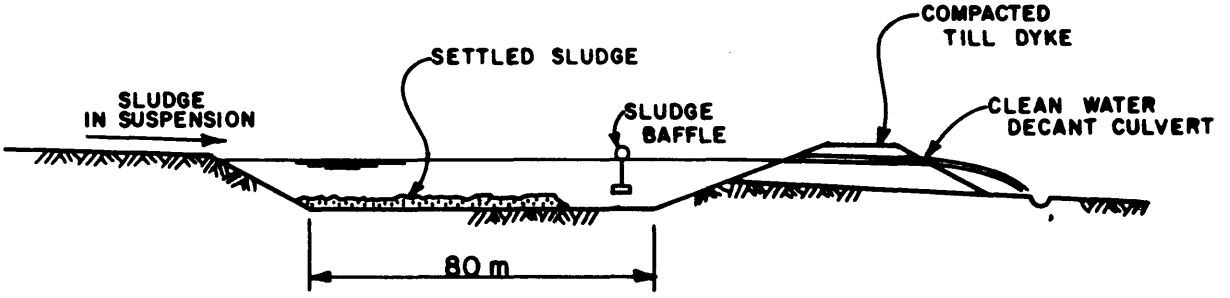
PRELIMINARY SYSTEM FLOWSHEET

-Rated capacit @ 3000 USGPM (16400 m^3/day)

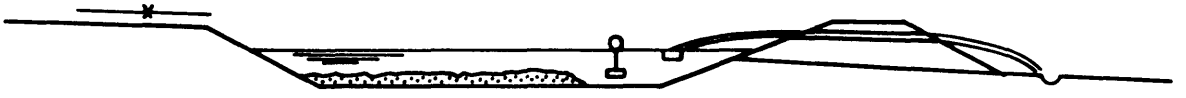
CURRAGH RESOURCES INC.	
DESIGN: JFH	FIGURE 2.42

SECTION Q-Q THROUGH SLUDGE POND

① DECANTING VIA OVERFLOW CULVERT



② INFLOW DIVERTED TO ANOTHER POND
DECANTING SUPERNATANT WATER BY PUMPING



③ DECANTING COMPLETED - POND IDLE
SLUDGE ALLOWED TO FREEZE



STAGES of LOAD-DECANT-FREEZE CYCLE

CURRAGH RESOURCES INC.	
N.T.S.	FIGURE 2.43

SECTION 3

BASELINE ENVIRONMENTAL CONDITIONS

3.1 METEOROLOGY

3.1.1 Regional Climate

The Faro area has no pronounced wet or dry season. The average number of days with some precipitation is generally in the order of 100 to 120. Snow can be expected at any time of the year and will generally cover the ground in most years from October to May. Evaporation in the Yukon generally exceeds the total precipitation and ranges between 350 and 450 mm per annum.

3.1.2 Local Climate

3.1.2.1 General

The Atmospheric Environment Service (AES) established a meteorological station in Faro in 1977, and at Grum Camp in 1983. Daily measurements of temperature and precipitation have been recorded. The climate station at Grum is located at coordinates 62°18'N and 133°16'W and at El. 1150 metres.

3.1.2.2 Temperature

Based on the limited period of record, the mean monthly temperatures range from a high of 11.7° C in July to a low of -13.4° C in December. Extreme cold temperatures have been recorded at Faro as low as -55° C, with extreme maximums in the order of 33° C. The extreme cold temperatures in the region make outside construction in the winter very difficult. The working season for outside construction will generally be from May to September. The ground

is normally still frozen in May, and earthworks such as fill for dams could not be started until June or even July.

The mean temperature monthly distribution for both Grum and Faro is shown in Table 3.1.

TABLE 3.1

MEAN DAILY TEMPERATURES IN DEGREES CELSIUS

Month	Faro	Grum Camp
January	-24.5	-10.8
February	-15.9	-13.1
March	-10.1	- 9.3
April	- .8	- 4.3
May	7.1	2.9
June	12.5	8.1
July	14.9	11.7
August	12.4	8.1
September	7.1	3.0
October	- 0.4	- 2.9
November	-13.8	-13.1
December	-21.7	-13.4
Mean Monthly	- 2.8	- 2.8
Elevation (m)	694	1150
Years of Record	11	5

The relatively high temperature in January and December at Grum Camp compared to the temperature recorded in Faro for the same month, is attributed to the warm temperatures recorded for 1985 and 1986.

3.1.2.3 Precipitation

The mean annual precipitation recorded at the Grum Camp station based on 6 years of data collection, is 539 mm (21.2 inches). The maximum total monthly precipitation occurs in July and consists only of rainfall. The least precipitation occurs in November and consists of snowfall. No measurements of the greatest 24-hour

precipitation have been recorded at Grum. However, at Faro, the greatest 24-hour rainfall recorded was 46.7 mm. The mean monthly precipitation distribution based on data recorded at the Grum Camp is presented in Table 3.2.

TABLE 3.2

MEAN MONTHLY PRECIPITATION DISTRIBUTION AT THE GRUM CAMP

Months	Total Precip. (mm)	Total Rainfall (mm)	Total Snowfall (cm)
January	25.35	0.00	25.35
February	25.90	0.00	25.90
March	31.23	0.00	31.23
April	32.75	0.75	32.00
May	51.88	7.88	44.00
June	56.63	49.73	6.90
July	98.48	98.48	0.00
August	80.40	67.60	12.80
September	42.26	25.06	17.20
October	47.84	7.64	40.20
November	22.34	0.00	22.34
December	23.72	0.00	23.72
Mean Annual	538.77	257.13	281.64
Years of Record	6	6	6

3.2 AQUATIC ENVIRONMENT

3.2.1 Surface Water Hydrology

3.2.1.1 Local Drainage

The minesite is located at the centre of the Vangorda watershed, which drains to the Pelly River. The South Fork of Vangorda Creek drains the west half of the watershed and Vangorda Creek, with the Dixon and Shrimp tributaries, drains the east. The proposed Grum Pit lies on a gently sloping broad plateau which forms the local

drainage divide. The south-facing slope of the plateau sheds runoff directly to Vangorda Creek. The north and west slopes drain to the West Fork. The proposed Vangorda pit bisects Vangorda Creek and two small tributaries. The waste dumps will be located on a westerly trending ridge which drains partly to Vangorda Creek and partly to Dixon Creek. Dixon Creek discharges into Shrimp Creek, which eventually flows into Vangorda.

3.2.1.2 Stream Flow Records

In 1977, an automatic recording station was established by DIAND on Vangorda Creek at Faro to monitor streamflows. The station was operated only during ice-free periods between May and September, and there are periods of missing data resulting from problems of vandalism. The maximum and minimum daily and instantaneous flows for a 9-year period between 1977 and 1985 are presented in Table 3.3.

To develop mean monthly streamflow estimates at the minesite, a review of long-term stream gauging stations was completed. The nearest long-term station is located on the Ross River, about 65 kilometres southeast of Faro. Ross River is a major tributary of the Pelly River and has a drainage area of 7,250 square kilometres. The 1985 mean monthly unit discharges (cubic metres/sec and litres per second per square kilometre) were computed for Ross River, Pelly River and Rose Creek and are presented in Tables 3.4 and 3.5 The unit discharges were compared with those recorded at Vangorda Creek for the period June to September. A reasonable correlation between the Vangorda Creek and the Pelly and Ross Rivers was derived. Normalized mean monthly unit discharges were then extrapolated for the Vangorda Creek based on the historical mean monthly yields for both the Pelly and Ross Rivers. The results of the analyses are presented in Tables 3.6 and 3.7. The estimated mean monthly discharge distribution for Vangorda Creek

at the minesite (drainage area 17.7 km²) was computed from the unit discharge derived for Vangorda Creek at Faro (Drainage Area 90.8 km²).

TABLE 3.3

SUMMARY OF VANGORDA CREEK FLOW RECORDS[1] AT FARO

Year	Freshet Period	Daily Flows (Date: m³/s) max	Daily Flows (Date: m³/s) min	Instantaneous Flows (Date: m³/s) max	Instantaneous Flows (Date: m³/s) min
1977	May 16-Jun 16	May 30: 2.93	Aug 21: 0.33	May 29: 3.62	Aug 19: 0.32
1978	Jun 8-Jun 23[2]	Jun 8: 1.59	Jul 20: 0.42	Jun 15: 2.00	Jul 19: 0.42
1979	Jul 18-Jul 30[3]	Jul 21: 1.20	Sep 1: 0.52	Jul 21: 1.37	Sep 1: 0.52
1980	Jul 14-Aug 2	Jul 17: 3.32	Jul 9: 0.63	Jul 17: 4.73	Jul 10: 0.58
1981	Jun 13-Jul 11	Jun 23: 1.47	Aug 29: 0.47	Jun 22: 1.74	Aug 26: 0.47
1982	Jun 8-Jun 30[4]	Jun 9: 5.54	Aug 30: 0.25	Jun 8: 6.9	Aug 29: 0.25
1983	May 30-Jun 29	May 31: 6.23	Jul 30: 0.49	May 30: 7.36	Jul 29: 0.49
1984	May 30-Jun 14	Jun 6: 5.62	Aug 4: 0.30	Jun 6: 6.11	Aug 3: 0.30
1985	May 25-Jun 12	Jun 4: 4.60	Aug 8: 0.43	Jun 3: 6.44	Aug 7: 0.42
AVERAGES		3.91	0.43	4.86	0.42

(1979 data are excluded from averages of maximum flows as it is probable that the peak flow was not measured)

[1] Flow station in operation during ice-free period only
[2] Missing data between June 24 and July 18, 1978
[3] Flow measurements began July 18, 1979
[4] From beginning of rising limb to a similar level on recession

TABLE 3.4

MEAN MONTHLY DISCHARGE (1985) IN CU.M/S AT SELECTED GAUGING STATIONS

Months	Pelly River (09BC004)	Ross River (09BA001)	Vangorda Creek (at Faro)	Rose Creek (1968)
January	27.00	9.42	NR	0.27
February	23.60	7.52	NR	0.21
March	22.70	6.42	NR	0.20
April	24.60	7.51	NR	0.24
May	321.00	132.00	NR	4.01
June	837.00	295.00	2.01	6.14
July	548.00	184.00	1.26	4.58
August	277.00	94.00	1.06	4.24
September	260.00	68.10	1.05	5.43
October	165.00	52.00	NR	1.39
November	49.90	11.60	NR	0.92
December	36.40	8.50	NR	0.64
Mean Monthly	216.02	73.01		2.36
Drainage Area (sq.km)	22,100	7,250	90.8	208.00

TABLE 3.5

MEAN MONTHLY YIELD (1985) IN L/S/SQ.KM AT SELECTED GAUGING STATIONS

Months	Pelly River (09BC004)	Ross River (09BA001)	Vangorda Creek (at Faro)	Rose Creek (1968)
January	1.22	1.30	NR	1.32
February	1.07	1.04	NR	1.00
March	1.03	0.89	NR	0.97
April	1.11	1.04	NR	1.13
May	14.52	18.21	NR	19.28
June	37.87	40.69	22.14	29.52
July	24.80	25.38	13.88	22.02
August	12.53	12.97	11.67	20.38
September	11.76	9.39	11.56	26.11
October	7.47	7.17	NR	6.68
November	2.26	1.60	NR	4.41
December	1.65	1.17	NR	3.08
Mean Monthly	9.77	10.07		11.32
Drainage Area (sq.km)	22,100	7,250	90.8	208.00

TABLE 3.6

HISTORICAL MEAN MONTHLY DISCHARGE IN CU.M/S AT SELECTED GAUGING STATIONS

Months	Pelly River Below Vangorda (09BC004)	Ross River (09BA001)	Vangorda Creek (at Faro)	Vangorda* Creek (at Faro)	Vangorda* Creek (at Diversion)
January	26.20	8.74	NR	0.09	0.02
February	21.80	6.90	NR	0.09	0.02
March	19.50	6.21	NR	0.09	0.02
April	23.10	7.24	NR	0.09	0.02
May	412.00	154.00	1.61	1.73	0.34
June	715.00	257.00	1.88	2.27	0.44
July	387.00	124.00	1.06	1.18	0.23
August	250.00	80.90	0.74	1.00	0.19
September	209.00	67.80	0.72	0.82	0.16
October	157.00	49.00	NR	0.54	0.11
November	68.70	19.60	NR	0.27	0.05
December	38.70	13.10	NR	0.18	0.04
Mean Monthly	194.00	66.21	NA	0.70	0.14
Period of Record	1972-86	1960-86	1977-85		
Drainage Area (sq.km)	22,100	7,250	90.8	90.8	17.7
Years of Record	15	27	9		

* Normalized flows based on Pelly River and Ross River records

TABLE 3.7

HISTORICAL MEAN MONTHLY YIELD IN L/S/SQ.KM
AT SELECTED GAUGING STATIONS

Months	Pelly River (09BC004)	Ross River (09BA001)	Vangorda Creek (at Faro)	Vangorda* Creek (at Faro)
January	0.19	1.21	NA	1.00
February	0.99	0.95	NA	1.00
March	0.88	0.86	NA	1.00
April	1.05	1.00	NA	1.00
May	18.64	21.24	17.73	19.00
June	32.35	35.45	20.70	25.00
July	17.51	17.10	11.67	13.00
August	11.31	11.16	8.15	11.00
September	9.46	9.35	7.93	9.00
October	7.10	6.76	NA	6.00
November	3.11	2.70	NA	3.00
December	1.75	1.81	NA	2.00
Mean Monthly	8.78	9.13		7.67
Period of Record	1972-86	1960-86	1977-85	
Drainage Area (sq.km)	22,100	7,250	90.8	208.0
Years of Record	15	27	9	

* Normalized flows based on Pelly River and Ross River records

3.2.1.3 Site Hydrology

The watershed for the Vangorda Plateau, which covers an area of 17.7 square kilometres, drops about 760 metres in elevation from the highest point, over a distance of about 8 kilometres. In the upper reaches of the basins, there are extensive granitic rock outcrops with alpine tundra. In the lower areas of the basin lthe rock outcrops are less extensive and much of the area is underlain by relatively impervious tills. In general, as the watershed has very little topsoil or organic litter and virtually no tree cover, the potential for runoff is high. An outline of the drainage boundary for the Vangorda minesite watershed is shown on Figure 1.2.

3.2.1.4 Design Peak Flows

Estimates of peak flows in the Vangorda Creek are required to design and evaluate dams, culverts and diversion structures both during the mining operation and after abandonment. Several hydrological studies on Vangorda Creek have been completed by a number of consultants and Government agencies over the last few years. These studies include:

- Vangorda Creek Flood Estimates for Kerr-AEX Grum Joint Venture (Montreal Engineering 1978)
- Hydrologic and Hydraulic Design of Down Valley Tailings Disposal Project (Hydrocon Engineering 1980)
- Method of Flood Estimates for the Rose Creek Reservoir Study (Acres 1985)
- Yukon River Basin Flood Risk Study (Underwood McLellan Ltd., 1983)
- Yukon Regional Analysis - DIAND (Janowicz 1986)

Curragh Resources was requested by the Regional Environmental Review Committee (RERC) to re-evaluate the flood estimates for Vangorda Creek as part of the IEE. The results of this review were presented in a report titled "Review of Peak Flow Estimates for Rose and Vangorda Creeks, June 1988".

On the basis of this review, it was decided that future peak flow estimates for structures associated with the Vangorda Plateau project would be determined by using the Yukon Regional Analysis Method developed by DIAND. This method, which adopts a regional approach, was developed for estimating peak flows for the design of hydraulic structures in the Yukon Territory. Single station flow-frequency analyses were carried out on 90 hydrometric

stations (DIAND and WSC stations) with at least six years of record using a two parameter log-normal theoretical probability distribution (no skew factor) which was considered by the author to be the most appropriate for sparse data regions. Simple linear regression relationships were developed between maximum annual instantaneous discharge at selected return periods and drainage area for two hydrologic regions. A second analysis was conducted including a storage index factor to account for lake storage within a basin.

This method is currently in use in the Yukon for flood estimation by DIAND and for design of stream crossings by the Yukon Territorial Government Department of Highways.

The equation used to calculate the peak flow estimates for the Vangorda watershed is as follows:

$$Q_{50} = .629(D.A.)^{.811}$$

where Q_{50} = Peak flow with a return period of 50 years

D.A. = Drainage Area in square kilometres.

A summary of the peak flow estimates at various return periods for the Vangorda Watershed above the proposed diversion is presented in Table 3.8

TABLE 3.8

PEAK FLOW ESTIMATES FOR
VANGORDA CREEK ABOVE DIVERSION

Return Period	Peak Discharge (cu.m./s)
MAF	2.6
10	4.4
20	5.2
25	5.8
50	6.47
100	7.6

3.2.2 Surface Water Monitoring

3.2.2.1 Sampling Locations

Water quality sampling has been carried out since 1975 in the Vangorda basin by Kerr Addison Mines Ltd., by Cyprus Anvil Mining Corporation and by the Federal Department of Indian and Northern Affairs. Curragh Resources Inc. initiated a monitoring program in June, 1987 to augment the water quality data base at Vangorda Creek and to establish additional sampling sites that will allow monitoring of impact during the mining operation and after abandonment.

In 1977 DIAND established a continuous flow recording station in the lower part of Vangorda Creek near the town of Faro. This station is only operative between June and September each year because of ice build-up. A similar station has been proposed in Vangorda Creek above the proposed diversion dam prior to commencement of the mining operation.

Eight sampling stations were originally established at sites along Vangorda Creek. Curragh has increased the number of sampling stations to include recently excavated diversion ditches, piezometers and drillholes. Sites were also established in order to sample groundwater that had been in contact with ore body. The sampling stations are shown on Figure 3.1 and listed as follows:

V01	Vangorda Creek above Vangorda Road crossing
V02	Grum Creek at mouth
V03	Vangorda Creek 100 m d/s of Grum Creek
V04	Shrimp Creek at mouth
V05	West Fork Vangorda Creek above Mine Road at km 1.
V06	West Fork Vangorda Creek at Vangorda Road crossing

V06A	Creek entering West Fork Vangorda Creek from south-above V6
V06B	Creek entering West Fork Vangorda Creek from south-below V6
V07	Vangorda Creek above Faro, east of rock cut on Mine Road
V08	Vangorda Creek below Faro
V10	Vangorda Creek 100 m below Shrimp Creek confluence
V11	Vangorda Creek 200 m above Grum Creek
V14	Rose Creek below mine access road crossing
DDH-322	Flowing drill hole at Vangorda pit area
GA	Grum Adit
GRUM PH4	Piezometer PH4
RS	Red Spring
Doal Lake Ditch	- Temporary Drainage trench above road
Vangorda Ditch	- The northeast diversion ditch above Vangorda Pit

Water samples are collected monthly and are sent to commercial laboratories for analysis. Temperature is measured with a pocket thermometer in the field and pH is measured by meter at Curragh's assay lab.

3.2.2.2 Water Analyses Methods

Parameters analyzed to date are presented in Table 3.9

TABLE 3.9

WATER QUALITY PARAMETERS

Parameter	Method
pH	Potentiometer
Conductivity	Conductivity Meter
Total Suspended Solids (mg/l)	Oven
Alkalinity (mg/l $CACO_3$)	Titration
Sulphates (mg/l)	Turbidity
Ammonia (mg/l)	Titration
Zn (T&D) (mg/l)	ICP
Cu (T&D) (mg/l)	ICP
Pb (T&D) (mg/l)	ICP
Mn (T&D) (mg/l)	ICP
FE (T&D) (mg/l)	ICP

The results of the water quality analyses to date have been summarized in Table 3.10. This table indicates average values for pH and Alkalinity and maximum values for other parameters. A complete set of results of the water quality analyses completed on samples collected since June 1987 is presented in the Appendix in Tables A-16 to A-34. A summary of background water quality data collected between 1975 and 1980 at 8 sampling stations at the Vangorda site is also presented in the Appendix in Table A-35.

The existing data base indicates that current metal concentrations in the streams are relatively low. Zinc metal concentrations from the Grum adit average 2.12 mg/l, reaching a maximum of 2.67 mg/l. This is above the 0.5 mg/l effluent limits currently set of Faro, however, there appears to be little effect on the downstream water quality. The zinc concentration levels at Red Springs (RS) average .68 mg/l with a maximum of 1.06 mg/l. These relatively high readings are not usual as groundwater seepage from this area has been exposed to the ore body.

The data recorded in the diversion ditches at Grum and Vangorda indicate maximum zinc concentrations of .285 and .56 mg/l,

respectively. These moderately high readings were recorded during the spring runoff in May and also coincided with high levels of suspended solids recorded on the same day. The average zinc concentrations for both ditches are significantly lower, ranging from .08 to .13 mg/l. Metal levels in the groundwater, as indicated by results from drill hole DDH-322 and the piezometer at GPH-4, are relatively low and well within acceptable effluent limits.

TABLE 3.10
WATER QUALITY DATA
VANGORDA CREEK - MAXIMUM TOTAL VALUES

Site	pH*	Alkalinity*	Susp. Solids (mg/l)	SO_4 (mg/l)	NH3 (mg/l)	Zn (mg/l)	Cu (mg/l)	Pb (mg/l)	Mn (mg/l)	Fe (mg
V01	7.6	18.6	10.0	11.0	.81	.1	.005	.072	.036	.52
V02	8.0	86.96	42	40.0	.65	.07	.011	.037	.047	4.4
V03	7.7	44.78	18	21	.61	.050	.006	.037	.034	1.8
V04	8.1	210.80	23	73	.4	.04	.004	.050	.060	1.2
V05	8.2	135.56	130	142	.91	.048	.011	.050	.124	3.75
V06	7.1	37.47	550	15	.78	.182	.039	.074	.455	11.3
V06A	7.7	30.18	13.0	13.0	-	.012	.005	.011	.034	.70
V06B	7.5	36.48	7.0	8.0	.72	.012	.003	.003	.018	.450
V07	8.1	-	16	26	.42	.018	.004	.025	.011	-
V08	8.1	96.01	71	97	.65	.052	.030	.050	.103	2.75
V10	8.1	98	18	37	.38	.040	.005	.006	.039	1.14
V11	7.4	23.35	9.0	10	.46	.030	.003	.003	.026	.610
V14	7.6	15.55	37	9	.62	.026	.003	.036	.135	1.62
DDH-322	7.9	146.98	2.0	30	.35	.030	.003	.050	.030	.610
GA	7.7	269.59	98	102	1.02	2.670	.005	.050	.197	5.9
GRUM PH4	7.3	87.23	0.5	11	-	.003	.001	.003	.066	.020
RS	7.2	95	50	55	.14	1.06	.054	.210	.030	5.00
GRUM DTCH	7.5	-	7900	43	-	.56	.28	.015	.385	220
VANGORDA DITCH	7.3	31.50	415	52	-	.285	.163	.005	.028	51.5

* Average Values

3.2.2.3 Sedimentation

Daily Clarity Wedge sampling was completed at the culvert on the road into Faro, between October and November 1987. During the same period, weekly Clarity Wedge readings and suspended solids sampling were completed at four sampling stations V1, V2, V3 and V8. This monitoring program was intended to evaluate the short duration impact of the construction of the diversion ditches and the drainage of Doal Lake. The results of the daily Clarity Wedge readings, which are presented in the Appendix in Tables A-36 to A-40, indicate that there was negligible impact on the turbidity of water in Vangorda Creek below Faro. The levels of suspended solids recorded at the four sampling stations were in the order of 0.5 mg/l, well below the suspended sediment levels recorded in the Pelly River. These results are presented in the Water Quality Analyses Test Results shown in the Appendix in Tables A-16 to A-34.

During a period of high runoff in May 1988, 11 sites were samples for suspended solids. The results of this monitoring program are presented in Table 3.11.

Levels of suspended solids were recorded as high as 7900 mg/l at the temporary drainage ditch below Doal Lake. The sediment load in Vangorda Creek below Faro was recorded later the same day at 71 mg/l. Based on these results, and the high background levels of suspended solids in the Pelly River, the impact on the Pelly River from sedimentation originating from the Grum minesite, is considered to be minimal.

During critical periods of construction and high runoff, estimates of suspended solids using a Clarity Wedge will be completed in conjunction with weekly water quality sampling.

TABLE 3.11

SUSPENDED SOLIDS IN DITCHES AND RECEIVING WATERS

(Values are suspended solids in mg/l)

Site	May 2	May 6	May 12-13	May 18	May 26-27	June 7-8
Doal ditch - above road		3050				
- below road		305	7900		104	435
- near adit			287			
Vangorda ditch at road (at end of ditch)		415	18		8	14
V1: Vangorda upstream site	<1		10	2	2	2
V11: Vangorda upstream Grum Cr			9	<1	8	2
V2: Grum Cr		3	42	<1	1	2
V3: Vangorda downstream Grum Cr			28	<1	2	2
V4: Shrimp Cr			25			5
V10: Vangorda downstream Shrimp			18			3
V8: Vangorda near Pelly R	6		71	10		23
FIELD NOTES:	low flow, melt beginning		high flow, natural colour and turbidity	flow down less colour and turbidity		peak flow no colour, little turbidity

TABLE 3.12

FLOWS AND SUSPENDED SEDIMENT LOADS IN THE PELLY RIVER[1]

Year	Suspended Sediment Load (Pelly R at Pelly Crossing)			Flow (Pelly R below Vangorda Creek)	
	number of samples[2]	max. (mg/l)	min. (mg/l)	max. monthly mean (m^3/s) (June except where noted)	min. monthly mean (m^3/s) (March for all years)
1970	3	355	11		
1971	6	291	3		
1972	3	309	11		
1973	2	40	1	712	17.7
1974	3	158	4	680	10.0
1975	3	462	30	972	21.3
1976	3	243	15	704	20.5
1977	3	114	38	662	24.9
1978	3	221	11	620	15.5
1979	3	652	9	892	21.4
1980	2	138	22	400	20.3
1981				567 (May)	22.4
1982				615	14.8
1983	1	349	349	847	20.1
1984	1	310	142	646	23.2
1985	1	451	305		

[1]Flow data from Water Survey of Canada 1974 to 1985
Sediment data from Water Survey of Canada 1987.

[2]Each sample consists of several samples taken from fixed points along a vertical cross-section of the river.

3.2.3 Fisheries Resources

3.2.3.1 Previous Studies

Fisheries studies carried out by Montreal Engineering Company in the 1970's (Montreal Engineering Company Limited 1976, 1977 and 1978) are summarized in the Stage One Initial Environmental Evaluation (Curragh Resources Inc. 1987). The data indicated that several species, including chinook salmon and Arctic grayling, utilize the lower part of Vangorda Creek. Shrimp Lake was found to contain no fish.

3.2.3.2 Curragh Resources' 1987 Fisheries Study

In August, 1987, a field survey of Vangorda Creek was conducted by Paul Harder of P.A. Harder and Associates Ltd. on behalf of Curragh Resources. Sampling was by electrofishing (two pass catch and removal sampling, using stop nets), baited minnow traps and an overnight gillnet set in Doal Lake. A video-recorded helicopter flight of the creek was made in September, 1987 in order to complete the bio-physical habitat assessment. Additional minnow trapping was undertaken by Curragh personnel in September, 1987. The results of these studies are presented in P.A. Harder and Associates (1987). This report is summarized below.

Figure 3.2 presents a reach by reach description of the Vangorda creek, showing physical characteristics and species present. The main channel of Vangorda Creek was found to be relatively steep, with gradients ranging from 2.7 percent in the lower three reaches to an average of 4.0 percent in the mid-reaches and over 6.0 percent in the headwaters. A major water fall is located in Reach 4, 3.3 km upstream of the confluence with the Pelly River.

Fish were found only in the lower two reaches of the creek, below the Faro town culvert (2.2 km of creek). Species found in the survey were chinook salmon, Arctic grayling, round whitefish, burbot, slimy sculpin and sucker. Juvenile chinook salmon were found in relatively high densities in this lower section of the creek. Juvenile Arctic grayling were also found throughout the lower part of the creek, at densities approximately 30 percent of the chinook fry densities.

There was no indication that adult chinook salmon spawn in the system. Low flows and the absence of pools are probably major constraints on the over-winter habitat use by juvenile salmon. Use of the stream by chinook is probably restricted to the summer period.

3.2.3.3 Curragh Resources' 1988 Minnow Trapping

Minnow traps, baited with shrimp, were set overnight at locations in lower Vangorda Creek in the summer of 1988. The results are presented in Table 3.12.

3.3 THIN-HORNED SHEEP

A population of approximately 80 Fannin sheep (a colour phase of Stone sheep, or coloured thin horn sheep) migrate across the Vangorda Plateau, which lies between their winter range on Sheep Mountain and their summer range on Mt. Mye. The ewes and lambs cross the Plateau in the region of the future Grum pit and in the area between the Grum and Vangorda pits. The rams are less set in their migration patterns.

Fannin sheep are relatively rare, with an estimated population of 3000, all in the Yukon (Hoefs and Barichello 1985). Fannin sheep, while officially of the same taxonomic classification as the more numerous Stone sheep, are lighter and more variable in colour and are considered

by hunters and wildlife enthusiasts to be unique. Sheep Mountain near Faro is the only place where these sheep can be observed at relatively close range from an accessible location.

There have been several studies done on this population of sheep in relation to proposed mining developments on the Vangorda Plateau. The scope and major findings and recommendations of these reports are summarized below:

- Montreal Engineering Company Limited (1976). This broad environmental assessment highlighted the Mt. Mye sheep population as the primary wildlife resource that could be impacted by development of the Vangorda Plateau.

- McLeod (1981). This study was a cooperative effort between the Yukon Territorial Government and Cyprus Anvil Mining Corporation. Field work was carried out to define the patterns and timing of the sheep migration across the Plateau. Aerial surveys also provided estimates of population size and structure and information on seasonal distribution. Major recommendations relevant to the current development were: 1) maintain a corridor through the development area or establish alternate migration routes to bypass the area, and 2) monitor the sheep movements during critical migration periods with the aid of radio telemetry.

- Curragh Resources (1987). This report was prepared by Curragh Resources during the early stages of planning the Vangorda Plateau development as a first step towards the implementation of mitigative measures to reduce the impact of mining activity on the sheep population. Previous studies were summarized, the mining development was described and the construction of an alternate migration route was proposed.

- Horejsi (1988). This study was commissioned by Curragh Resources. Dr. Horejsi, an expert on sheep behaviour, was hired to assess the proposal and to make recommendations. He further defined the migration routes, made observations on behaviour during migration and presented data on population size and structure. His recommendations, which were directed both to the Yukon Territorial Government and to Curragh Resources, emphasized the need to protect this population on its winter and summer ranges as well as during the migration period. The major recommendations directed to Curragh were: 1) development of an alternate migration trail and habituation of the sheep to it through the use of bait; 2) monitoring of the sheep population through field observations by a biologist and the radio-collaring of 10 ewes to enhance this work; and, 3) joint participation in and funding of this project by Curragh Resources and the Yukon Territorial Government and promotion of the project as an example of the World Conservation Strategy in action.

- Lortie (1988). This is a report on field work carried out from April 7 to June 6, 1988. The author was contracted by the Yukon Territorial Government, under a joint funding agreement with Curragh Resources, to trap and radio-collar 10 ewes on Sheep Mountain and to observe habitat use and lambing on the winter range and migration during the spring. The trapping effort was unsuccessful, but the study yielded useful information on the sheep's use of winter range, mineral licks and lambing areas. The migration route from the Sheep Mountain side was also further defined and details of an alternate migration trail were worked out in consultation with Dr. Horejsi. Further recommendations were made to the Yukon Territorial Government regarding the management of the winter range.

WATER QUALITY MONITORING SITES

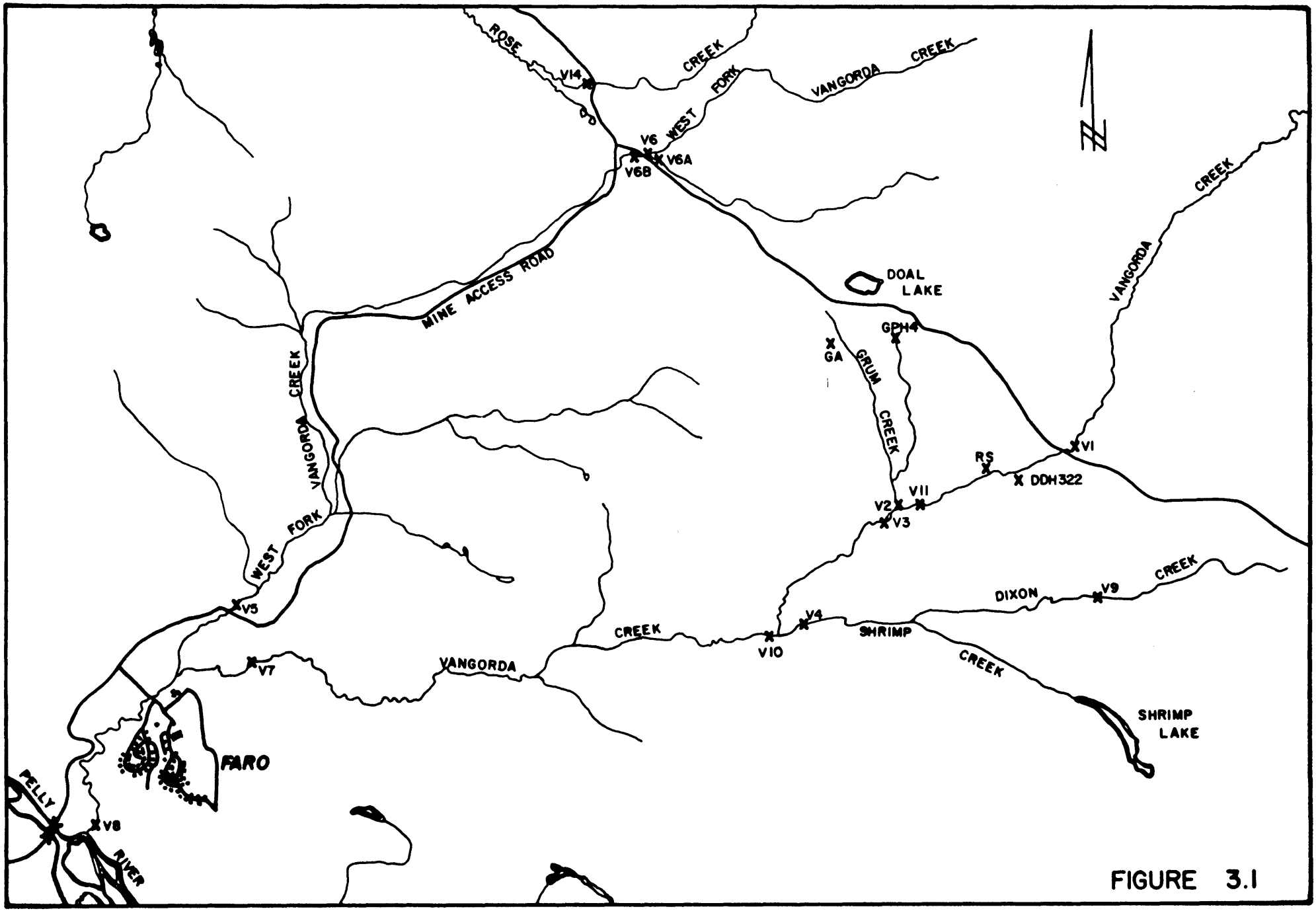
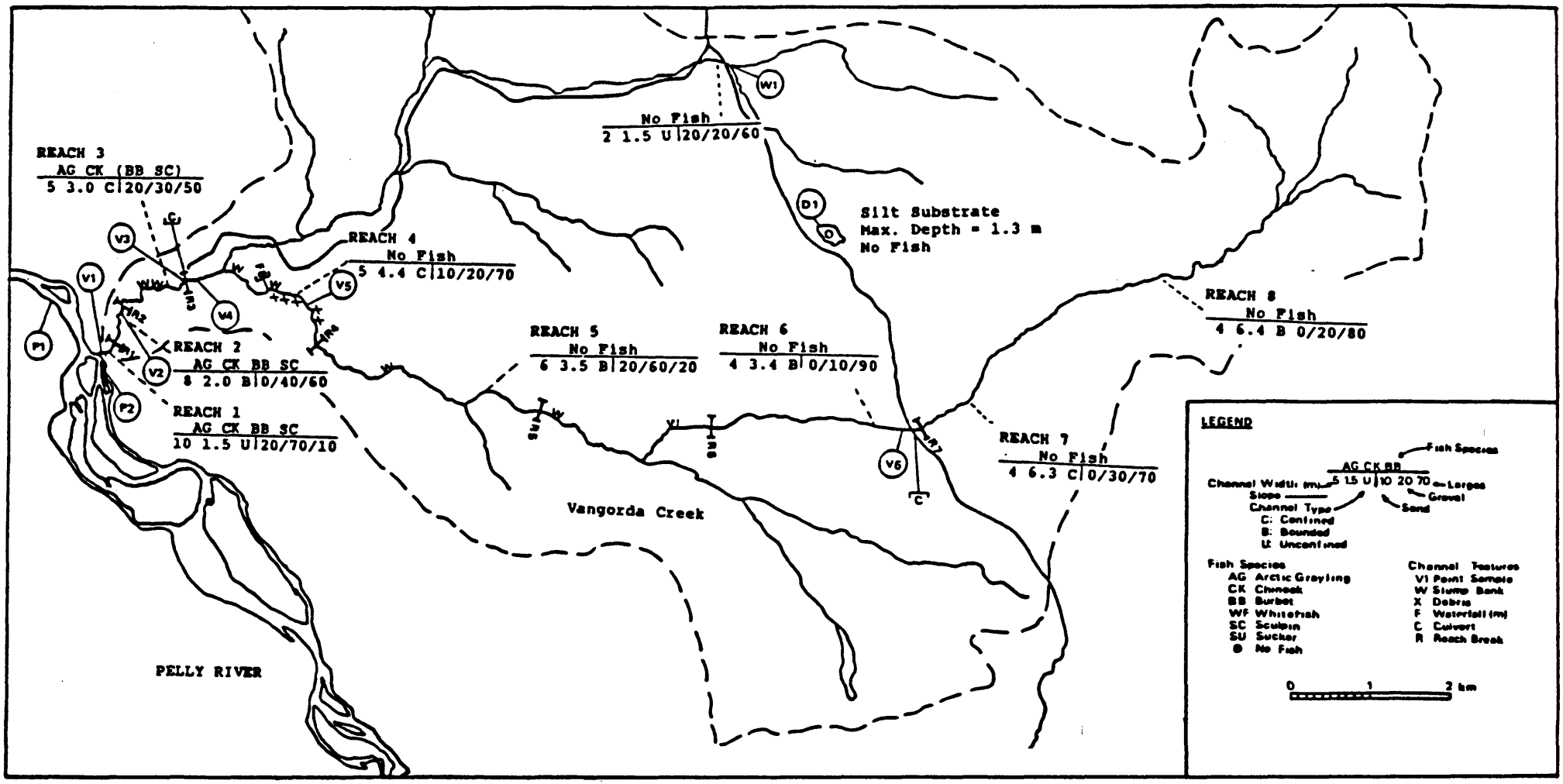


FIGURE 3.1

SCALE 1:50 000

CURRAGH RESOURCES INC.



FISH SAMPLING SITE LOCATIONS & BIO-PHYSICAL DATA SUMMARY

(From P.A. HARDER & ASSOC. 1987)

FIGURE 3.2

the acid water has the ability to leach heavy metals in the pit walls, such as Zinc which would remain in solution and eventually be transported into Vangorda Creek. From the results of the rock testing program discussed in Section 2.4.5.2, there are clear indications that the sulphide bearing rock found in the Vangorda Pit has a high potential for acid generation. The current abandonment plan for the Vangorda pit provides for the salvaging of the temporary culvert around the perimeter of the pit and the removal of the upstream diversion dam. Vangorda Creek would then discharge directly into the pit, eventually creating a lake. The ultimate elevation of the lake would be controlled by the spillway outlet in the northwest corner of the pit. The invert elevation of the spillway would be El. 1122.5 metres. As a result of the pit flooding, exposed, potentially acid generating rock below El. 1122.5 would be underwater. Based on current technology on abatement measures for Acid Mine Drainage, it is anticipated that the pit wall rock below the water level will not generate acid. The southeast and southwest pit walls at the south end of the pit, however, will have some acid-generating rock that will be above the water level.

During operation of the mine, the extent and geometry of this sulphide rock will be more clearly defined. Also during the operation, seepage along the southeast pit walls will be monitored for water quality and flow data. This data will provide information on the degree of acid generation and the levels of metal concentrations in the pit wall seepage. Further analyses will be completed to assess the impact of the pit wall seepage on Vangorda Creek and to determine the level of effort required to control the acid generation following abandonment. Anticipated "worst case" scenarios of the impact on Vangorda Creek from AMD have been modelled based on estimated infiltration rates of till covers, runoff, pit and groundwater seepage and Zn/Cu concentrations from the Humidity Cell Tests. The model attempts to predict the impact of AMD on Vangorda Creek and downstream receiving waters, as well as the need and effectiveness of proposed protective measures. A discussion of the model is presented in Section 5. Based on the conditions

experienced at the Faro pit and on preliminary results from the Humidity Cell Tests, the model indicates that pit wall seepage could contribute to the levels of metal concentrations in Vangorda Creek and some protective measures may be required. As more data is collected during the operation of the mines and input into the model, a more realistic assessment of the degree of contamination and the need and effectiveness of any protective measures, would be developed.

Abandonment plans for the Vangorda pit will also include measures to reduce the flow velocity and avoid cascading of the creek into the pit. This would involve regrading the channel bottom to provide a grade not exceeding 15 percent. Riprap erosion protection will be provided if necessary. The lake outlet at the northwest edge of the pit will also be armored with riprap to provide erosion protection. A plan of the northern end of the pit at abandonment is presented in Figure 4.1.

4.4 VANGORDA DUMP

Results from the rock testing program have indicated that most of the Vangorda waste rock has the potential to generate acid. However, further testing is being completed to provide more data that would allow better predictions of the relative rates of acid production and consumption.

As discussed in Section 2.4.3, the Vangorda waste dump will consist of two separate cells to segregate the potentially high acid generating pyritic massive sulphides from the potentially low acid generating altered phyllites. The cells will be impounded on all sides by till berms and covers and internal drains will be provided to prevent buildup and concentrations of acid water within the dumps. An internal till layer will also be constructed within the sulphide cell to separate the small volume of phyllite that will be deposited in the base of this cell. There are currently no plans to deposit any waste rock back into the pit.

Abandonment plans for the Vangorda dumps involve the placement of a 3-metre thick till blanket over the waste rock to reduce oxygen transmission and water penetration. Although it is very difficult to totally exclude oxygen transmission through the rock, the blanket would provide an effective water barrier. Oxygen could still enter the dump through cracks and deformation which may occur during construction and changes in barometric pressure would allow the dumps to breathe. The till cover would be constructed in five lifts. The lower three lifts would be compacted to 93 percent of the Modified Proctor maximum dry density to form a relatively impervious drainage barrier layer. The total thickness of this layer would be one metre. The upper two layers would each be placed to a thickness of one metre and would be compacted by the haul trucks and bulldozers. The final surface of the dump would be contoured to improve drainage conditions and to increase runoff potential. The till cover will be contoured to provide three drainage swales that would direct runoff to a spillway located at the south end of the dump as shown on Figure 2.16. Sideslopes along each swale will have grades of about 3 percent.

The internal rock drains will be constructed to enable water to escape while inhibiting oxygen entry. The seepage from these drains will be collected by a ditch which is located along the downstream toe of the dump. During the mine operation this water will discharge into the AMD collection pond at the toe of the sulphide cell and be pumped to the water treatment plant for processing. Following abandonment, and with the till covers in place, the level of metal concentration in the effluent will be significantly reduced. However, as contaminant levels in the effluent may remain elevated for a period after abandonment, the monitoring program will continue and a scaled down water treatment facility will be constructed. This facility will be located below the waste dumps and will treat seepage from the Vangorda dump. As metal concentration fall below the acceptable limits established for Vangorda

Creek, the water treatment facility will be abandoned, as discussed in Section 4.7.

4.5 GRUM PIT

Results of the acid/base accounting tests completed on drill core samples from the Grum deposit indicate that the pit walls will contain a high percentage of acid consuming calcareous phyllite. As less than 2 percent of the rock will be sulphide bearing, the potential for acid generation in the Grum pit is lower than at Vangorda. Similarly to Vangorda, the diversion ditches above the pit will not be maintained following abandonment and Grum Creek will be directed back into the pit. A lake will gradually build to an ultimate level of El. 1265 m. The geology of the Grum deposit indicates that all potentially acid generating rock will be located below water. Consequently, till covers for the pit wall above the ultimate lake level will not be required. An outlet spillway will be constructed along the western perimeter of the pit to provide controlled discharge to Grum Creek.

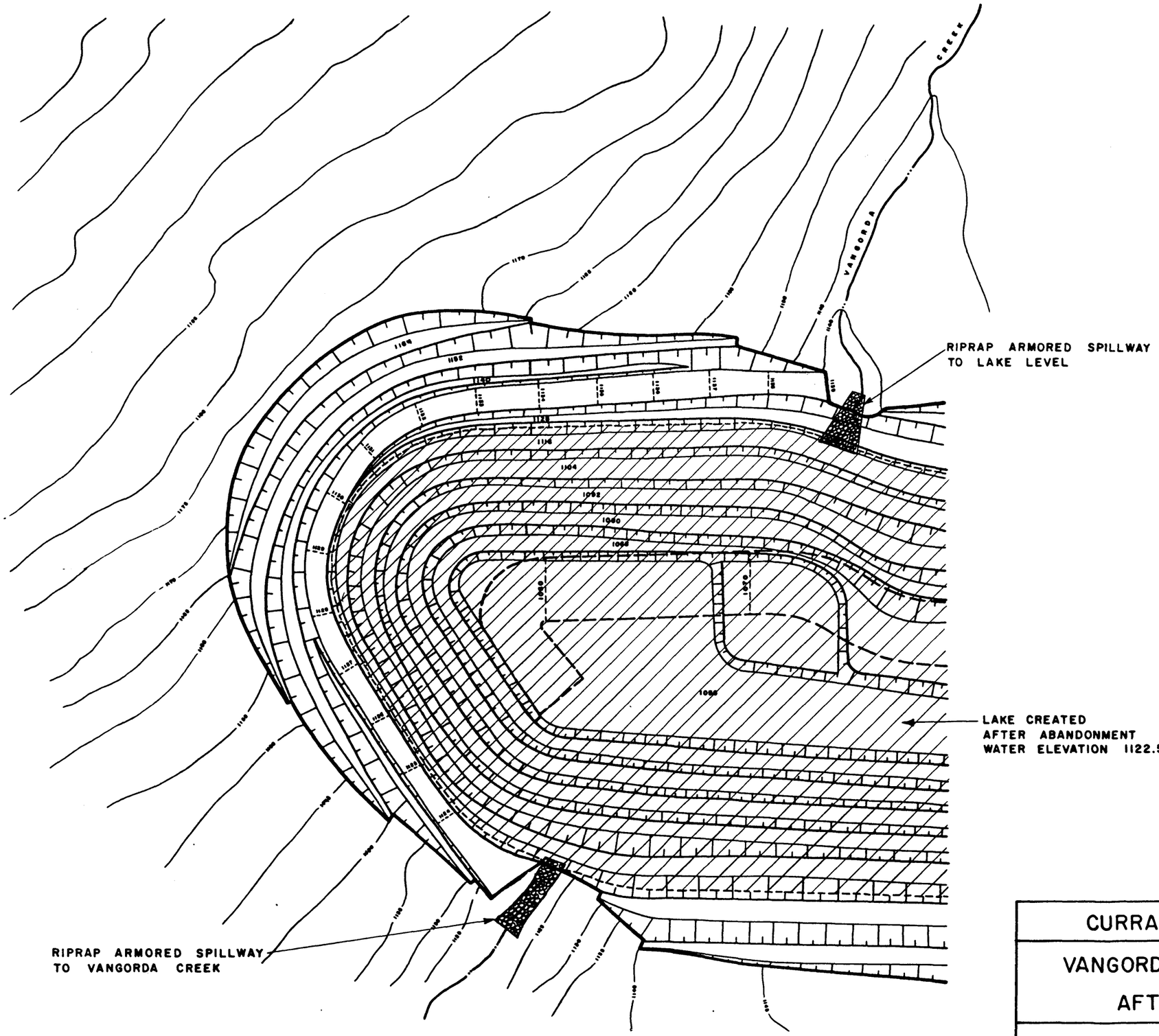
4.6 GRUM DUMPS

The waste dumps at Grum will consist of about two percent of the acid generating sulphide-bearing rock. The acid-consuming calcareous phyllite will represent in excess of 50 percent of the rock deposited in the dumps. The sulphide rock will be deposited in a separate cell and encapsulated with glacial till using methods similar to the Vangorda dumps. Consequently, acid generation from the waste rock dump at Grum is not anticipated and till covers will not be required. During the mining operation, however, the water quality of the seepage along the toe of the dumps will be monitored. In the event that metal levels do exceed acceptable limits, the seepage will be intercepted by a diversion ditch along the toe of the main dump. The seepage will be collected in a sump and pumped to the AMD treatment plant. If metal

concentrations remain high following abandonment, the seepage will b treated prior to discharge into the creek.

4.7 WATER TREATMENT PLANT

The sludge stored in the ponds at abandonment would undergo a fina decant and freeze and thaw cycle to ensure effective dewatering of th upper layers of sludge. A 1.5 to 2 metre cover of till would then b placed over the sludge. As dewatered unfrozen sludge has a relativel low compressive strength and has a tendency to liquefy, covering of th sludge will be completed during the winter months. The dykes aroun the ponds at abandonment, would be collapsed and the surface contoure to provide satisfactory drainage conditions.



CURRAGH RESOURCES INC.		
VANGORDA CREEK REHABILITATION AFTER ABANDONMENT		
	1:2000	FIGURE 4.5

SECTION 5

ENVIRONMENTAL IMPACTS

5.1 AQUATIC ENVIRONMENT

5.1.1 Hydrology

The proposed construction of open pits, waste dumps, roads and water treatment facilities would take place in the middle reaches of the Vangorda Creek watershed. It is anticipated that the project would have minimal adverse effects on the overall hydrology of the area.

The area to be disturbed occupies about 11.25 square kilometres. This represents one-eighth of the total Vangorda Creek catchment; which is about 90.8 square kilometres. Existing surface runoff from the catchment will be diverted around the proposed minesite, during the mine operation, using a series of open channel ditches. The catchment affected by the diversion system has a total area of about 4.1 square kilometres. Above the Vangorda pit the runoff is diverted to Shrimp Creek and eventually back into Vangorda Creek. Above the Grum pit the diversion will involve only a realignment of the existing channel and flow will continue to discharge directly into Vangorda Creek. During mining of Vangorda pit, Vangorda Creek will be diverted around the perimeter of the pit, discharging back into the creek on the west side. The proposed Vangorda haul road will involve the installation of culverts at major stream crossings to accommodate the surface drainage. It is concluded that during operation of the mine, the proposed construction will have minimal impact on the existing drainage patterns.

At abandonment, the ditch diversions would be removed and drainage patterns restored to their original configuration. It is also planned to allow the pits to flood, creating permanent lakes. As a result, Vangorda Creek would discharge into the lake created in Vangorda pit. It is estimated that it will require 8 to 12 months for the water level to reach the ultimate lake elevation. Consequently, flows in Vangorda Creek will be decreased until the ultimate lake level is reached. As the catchment above the pit represents only 20 percent of the total Vangorda Creek watershed, the impact on the streamflow at the townsite during lake filling, will be minimal. The temporary reduction in flow would be within the range of natural yield fluctuations and would not seriously impact on the watershed hydrology and fish habitat. The small reach of Vangorda Creek between the minesite and the confluence with Shrimp Creek will experience significant reduction in flow but this will not seriously impact on the watershed hydrology.

The Grum pit will require several years to fill, however, the catchment above the pit represents less than two percent of the total watershed area. Consequently the filling process would not have a significant impact on area hydrology.

As the area of the ultimate lake is less than one percent of the total catchment area, the newly formed lake is not expected to have any significant impact on the hydrology of the area.

5.1.2 Water Quality

5.1.2.1 General

The impact of the mine development on surface water quality is divided into three categories: construction, operation and abandonment. Each phase has its own concerns and mitigative

measures needed to maintain acceptable water quality in the area of the development.

5.1.2.2 Mine Construction

The major potential impact on surface water in the area during construction is siltation resulting from erosion during earthwork activities, road building and movement of heavy equipment. Although there would be some increase in runoff sediment from the ditches beside the Vangorda haul road, the major contribution would come from movement of equipment along the roadway. Results from daily Clarity Wedge readings and suspended solid tests conducted in May 1988 during a period of high runoff, indicated that although levels of suspended solids were initially high, the turbidity was short-lived and was indistinguishable from natural levels recorded in Vangorda Creek at Faro and in the Pelly River.

Regular monitoring of suspended solids would be conducted during periods of construction and high runoff, as discussed in Section 3.0.

5.1.2.3 Mine Operation

Water quality management would be required during mine operation to minimize the impacts of acid mine drainage on Vangorda Creek. Based on the Faro operation and the rock testing program, it is anticipated that seepage from the pit walls and the waste dumps will contain elevated concentration levels of heavy metals such as zinc and copper. In an attempt to predict the water quality in Vangorda Creek and the Pelly River during operation of the mine, a water balance/metal concentration model was developed. The model analyzes anticipated scenarios of the impact on Vangorda Creek, based on estimated infiltration rates of till covers and founda-

tion soils, runoff, pit and groundwater seepage and metal concentrations from Humidity Cell tests and the Faro operation.

In the Faro pit, water is pumped at rates varying from 40 litres per second during the winter months to 75 litres per second in the summer. It is estimated that seepage from the Faro pit walls which contributes to the pit water, varies from 25 to 50 litres per second over a 12-month period. The level of zinc concentration in the pit water averages about 29 mg/l and has been recorded at certain seeps as high as 300 mg/l.

As discussed in Section 2.4.5.2, Humidity Cell test results are being completed on representative samples of both the sulphide and phyllite rock types. Leachate from the sulphide rock sample tested under normal conditions presently shows zinc levels varying from 17.7 to 35.8 mg/l. Under accelerated or highly weathered conditions, zinc levels were recorded as high as 350 mg/l. Leachate from phyllite rock, under normal conditions, has zinc levels ranging from 0.99 to 15.7 mg/l. Although the test is still in progress, results to date are in the same order of magnitude as water quality observed in the Faro pit. For the purposes of predicting the impact on the water quality in Vangorda Creek and the Pelly River, during the mine operation, assumed levels of zinc concentration, based on the above results, were used in the Water Balance Model. The assumed mean monthly zinc concentration in seepage from the sulphide cells and the walls in the Vangorda Pit used in the model was 40 mg/l. The assumed mean monthly zinc level in the seepage from the phyllite cell at the Vangorda waste dump, used in the model was 20 mg/l. These assumed levels are only estimates and will be revised as further testing is completed and improved prediction techniques are developed.

The seepage flow estimate for the walls in the Vangorda Pit are based on the seepage flow rates at the Faro pit. During the mine

operation it is estimated that seepage from the pit walls over the winter would range from 6 to 8 l/s. During the spring freshet and summer months pit wall seepage could be as high as 25 l/s.

Rainfall and snowmelt on the pit walls would also contribute to the contaminant loading in pit water during mine operation. For purposes of the water balance model, the contribution from runoff and snowmelt is based on the monthly precipitation and the total projected area of the pit.

Seepage flows from the Vangorda waste dumps during mine operation have been calculated based on the mean monthly precipitation and evapo-transpiration estimates. As till covers will not be constructed until after abandonment, runoff is not factored into the calculation. A summary of the assumed design parameters used in the Water Balance Model, for conditions anticipated during mining operation, is shown in Table 5.1.

TABLE 5.1

WATER BALANCE MODEL - ASSUMED DESIGN PARAMETERS DURING OPERATION

Description	Vangorda Sulphide Cell	Vangorda Phyllite Cell	Vangorda Pit Walls
Zn Conc. (mg/l)	40	20	40
Pit Wall Seepage (l/s)	-	-	6 to 25
Pit Wall Runoff* (%)	-	-	100
Cell Runoff* (%)	0	0	-
Cell Evaporation* (%)	40	40	-
Cell Seepage* (%) in Drains	59	59	-
Cell Percolation* (%) through Foundation	1	1	-

* Percent of Total Precipitation

Under the assumed conditions, the model indicates that without treatment of the dump seepage and pit water during operation of the mine, zinc levels in Vangorda Creek at the minesite could range from 2.0 mg/l to as high as 17 mg/l over a normal 12-month period. Assuming a dilution factor equal to the ratio of the flow at the minesite to the flow at the Faro townsite, it was estimated that zinc levels in Vangorda Creek below the townsite could range from 0.4 mg/l to 7 mg/l. A summary of the results is presented in Table 5.2. A printout of the complete Water Balance is presented in the Appendix in Tables A-41A to A-41D.

TABLE 5.2

SUMMARY OF PRELIMINARY WATER QUALITY PREDICTIONS DURING MINING

STATION	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	TOTAL
Vangorda creek	cu.m/sec	0.02	0.02	0.02	0.02	0.34	0.44	0.23	0.19	0.16	0.11	0.05	0.04	0.14	1.64
at Diversion	dam³	70	70	75	75	978	1232	670	562	455	321	161	134	400.20	4802
	Zn mg/l	14.96	14.56	17.02	16.93	3.22	2.12	4.05	4.75	3.29	4.72	9.00	10.91	8.79	
	Zn kg	1042	1014	1277	1270	3146	2610	2713	2669	1498	1517	1446	1461	1805	21662
Vangorda Creek	cu.m/sec	0.09	0.09	0.09	0.09	1.73	2.27	1.18	1.00	0.82	0.54	0.27	0.08	0.69	8.25
at Faro	dam³	241	241	241	241	4634	6080	3161	2678	2196	1446	723	214	1841	22097
	Zn mg/l	4.3223	4.2074	5.2961	5.2665	0.6790	0.4293	0.8583	0.9966	0.6820	1.0486	2.0001	6.8161	2.72	
	Zn kg	1042	1014	1277	1270	3146	2610	2713	2669	1498	1517	1446	1461	1805	21662
Pelly River	cu.m/sec	26.30	21.80	19.50	23.10	412.00	715.00	387.00	250.00	209.00	157.00	68.70	38.70	194.01	2328.10
below Vangorda	dam³	70442	58389	52229	61871	1103501	1915056	1036541	669600	559786	420509	184006	103654	519632	6235583
	Zn mg/l	0.0148	0.0174	0.0244	0.0205	0.0029	0.0014	0.0026	0.0040	0.0027	0.0036	0.0079	0.0141	0.01	
	Zn kg	1042	1014	1277	1270	3146	2610	2713	2669	1498	1517	1446	1461	1805	21662

Note: dam³ = 1000 cu.m

5.1.2.4 Abandonment

The water quality concerns associated with the abandonment of the minesite, are the effects of long-term seepage and drainage from the pit and the waste dumps. The proposed abandonment plan involves flooding of the pits and the placement of till covers over the Vangorda waste dumps. The Grum waste dumps, with the exception of the sulphide rock cell, will not have till covers.

The abandonment of the Vangorda pit will consist of three phases namely:

1. Pit flooding with reduced flow in Vangorda Creek
2. The initial spill from Vangorda Lake to the creek
3. The steady state condition with the lake at ultimate level and the return of normal flows in Vangorda Creek.

During the first phase of the abandonment consideration would be given to balancing the water quality in the lake against either an uncontrolled lake filling or a controlled filling with partial diversion of the creek. A final decision on which procedure to adopt will be based on results of water quality analysis of the lake water during filling. Monitoring of seepage from the dump and pit walls will also be completed during filling of the lake.

The second phase of the Vangorda pit abandonment would occur as the lake level approaches the spillway invert. It is currently planned to maintain the in-pit diversion of Vangorda Creek for a period after abandonment, in the event that re-diversion of the creek is required, if containment levels in the lake are considered unacceptable. The option for treatment of the lake water would be examined at that time. However, perpetual diversion and treatment is not considered an option.

The final phase of abandonment occurs when the lake is at its ultimate level, and a steady state condition exists in Vangorda Creek. The Water Balance model was used to evaluate the impact on the water quality in Vangorda Creek under these long-term conditions. Estimates of runoff, infiltration and evapo-transpiration were developed by using the "Hydrologic Evaluation of Landfill Performance" (HELP, Version II) computer program. Details of the HELP model are in the Appendix. Assumed Seepage flows for the pit walls were estimated to range from 0.75 to 4 litres per second.

A summary of the design parameters used in the Water Balance model, for conditions anticipated following abandonment, is shown in Table 5.3.

TABLE 5.3

WATER BALANCE MODEL - ASSUMED DESIGN PARAMETERS AT ABANDONMENT

Description	Vangorda Sulphide Cell	Vangorda Phyllite Cell	Vangorda Pit Walls
Zn Conc. (mg/l)	40	20	40
Pit Wall Seepage (l/s)	-	-	.75 to 4
Pit Wall Runoff* (%)	-	-	100
Cell Runoff* (%)	34	34	-
Cell Evaporation* (%)	55	55	-
Cell Seepage* (%) in drain	10	10	-
Cell Percolation* (%) through foundation	1	1	-

* Percent of Total Precipitation

The water quality prediction for the assumed conditions is presented, by month, on Table 5.4. A complete list of the water

balance and water quality predictions is presented in the Appendix on Tables A-42A to A-42D.

Predicted zinc levels in Vangorda Creek at the townsite during the low-flow winter season range from .6 to .95 mg/l. During the summer months the zinc concentrations are much less, ranging from .08 to .2 mg/l.

Copper levels are not persistent in effluent from the Faro operations and as copper generally precipitates out at pH levels lower that the anticipated level at Vangorda, contamination from copper has not been considered.

TABLE 5.4

SUMMARY OF PRELIMINARY WATER QUALITY PREDICTIONS AFTER ABANDONMENT

STATION	UNITS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	TOTAL
Vangorda creek	cu.m/sec	0.02	0.02	0.02	0.02	0.34	0.44	0.23	0.19	0.16	0.11	0.05	0.04	0.14	1.64
at Diversion	dam^3	56	56	58	58	921	1189	624	517	434	300	138	110	371.68	4460
	Zn mg/l	2.63	3.00	4.00	3.98	0.55	0.43	0.67	0.79	0.66	0.96	1.61	1.56	1.74	
	Zn kg	146.40	168.67	230.26	229.20	506.74	506.85	417.99	410.25	285.42	288.68	222.73	171.51	298.72	3584.70
Vangorda Creek	cu.m/sec	0.09	0.09	0.09	0.09	1.73	2.27	1.18	1.00	0.82	0.54	0.27	0.08	0.69	8.25
at Faro	dam^3	241	241	241	241	4634	6080	3161	2678	2196	1446	723	214	1841	22097
	Zn mg/l	0.6073	0.6997	0.9552	0.9508	0.1094	0.0834	0.1323	0.1532	0.1300	0.1996	0.3080	0.8004	0.43	
	Zn kg	146.40	168.67	230.26	229.20	506.74	506.85	417.99	410.25	285.42	288.68	222.73	171.51	298.72	3584.70
Pelly River	cu.m/sec	26.30	21.80	19.50	23.10	412.00	715.00	387.00	250.00	209.00	157.00	68.70	38.70	194.01	2328.10
below Vangorda	dam^3	70442	58389	52229	61871	1103501	1915056	1036541	669600	559786	420509	184006	103654	519632	6235583
	Zn mg/l	0.0021	0.0029	0.0044	0.0037	0.0005	0.0003	0.0004	0.0006	0.0005	0.0007	0.0012	0.0017	0.00	
	Zn kg	146.40	168.67	230.26	229.20	506.74	506.85	417.99	410.25	285.42	288.68	222.73	171.51	298.72	3584.70

Note: dam^3 = 1000 cu.m

5.1.3 Fisheries Resources

5.1.3.1 Potential Impact

The potential impacts on the fish of lower Vangorda Creek are:

- Degradation of habitat through sedimentation. The addition of suspended solids to the creek could occur during stripping and during construction of culvert crossings, ditches and diversions. Monitoring of the stream during site preparation and ditch construction, as discussed in Section 3.2.2.3., has indicated there has been no impact on Vangorda Creek to date. Care will be taken to minimize the addition of suspended solids to the water course during the pre-mining period. The most critical period would be during construction of the haul road crossing and the culvert installation at Vangorda Creek. These activities are very likely to generate high levels of suspended solids and turbidity. Efforts will be made to avoid construction during periods of high runoff and measures would be adopted to control levels of suspended solids.

- Deterioration in water quality during operations. Metals, sulphate and ammonia are the parameters most likely to be affected. Effluent standards designed to protect downstream water quality will be maintained through treatment of the pit water and of any water contaminated during dump construction.

- Deterioration in water quality following abandonment. Seepage from the dumps and pit walls could contribute metals (principally zinc), sulphate and acidity to the creek. The abandonment measures described in Section 4.0 are designed to minimize this impact. Recommended Canadian standards for the protection of freshwater aquatic life for the parameters in question are

listed below (Canadian Council of Resource and Environment Ministers 1987):

Zinc	0.03 mg/L
Copper	0.002 to 0.006 mg/L, depending on hardness
Iron	0.3 mg/L
pH	range of 6.5 to 9.0 pH units

Juvenile chinook salmon and juvenile Arctic grayling are known to utilize the lower section of Vangorda Creek during summer and autumn. P.A. Harder and Associates (1987) suggested that the creek may receive little or no use as a wintering habitat. Sampling during the late fall, just before freeze-up could confirm this. Concentrations of contaminants in the creek are expected to be most severe during the late winter low flow period. The Water Balance Model indicates that after abandonment of the minesite zinc concentrations during this period could be as high as 0.95 mg/l in the lower reaches of Vangorda adjacent to the town of Faro. During the spring and early summer the preliminary figures indicate that zinc levels could vary from .08 to.2 mg/l.

5.1.3.1 Monitoring

Water quality monitoring of the effluent and the receiving waters will provide warning of any problems that may affect fish and fish habitat. There is a good data base of background water quality with which to compare water quality during operations.

On a long term basis, monitoring of the benthic invertebrate communities in the fish habitat section of the creek will act as an indicator of habitat quality. Curragh began benthic invertebrate monitoring in Vangorda Creek in 1988. Three basket samplers were placed in a uniform riffle section of the creek upstream of

the lower bridge, following the methodology described in Curragh's Rose Creek water licence. Results are not yet available.

5.1.4 Potential for Impact on the Town of Faro Water Supply

5.1.4.1 General

The Town of Faro obtains its water supply from wells located near the confluence of Vangorda Creek and the Pelly River. Curragh Resources Inc. has completed an investigation of the potential impact on the town water supply. This investigation included a study on the potential for a hydraulic connection between the creek and the aquifer(s) in which the town's wells are completed. The results of this study are contained in the following report, which is available from the RERC, Curragh Resources' Whitehorse office or the Town of Faro office:

Carefoot, E.I. 1988 Assessment of the Potential for a Hydraulic Link between Vangorda Creek and the Faro Town Wells. Prepared jointly with Hydrogeological Consultants Ltd. for Curragh Resources Inc.

The report, which was prepared by an engineer and a hydrologist who were involved in the design of the town's water system, is summarized below.

5.1.4.2 Summary of Consultant's Report (Carefoot 1988)

A test program was conducted in 1968 by International Water Supply Limited to locate and develop a groundwater supply. Eleven test holes were drilled, water levels were recorded and pump tests were conducted. Test results indicate that the main direction of groundwater flow within the sand and gravel aquifer is from east to west (Vangorda Creek is to the west of the town water wells).

The sediments in the Vangorda Creek bed are described as relatively impermeable. In western Canada, rockflour, created by glacial action, tends to seal the beds of most rivers. During periods of high flow, however, fine-grained sediment could be removed, allowing hydraulic continuity between a stream and an underlying aquifer.

The report concluded that, under normal conditions, it is unlikely that there is direct hydraulic continuity between Vangorda Creek and the aquifer in which the Town of Faro water wells are completed. However, during high flows, the fine-grained material may be removed from the creek bed and water from Vangorda Creek could enter the aquifer. At the present time, the main source of recharge to the aquifer is the Pelly River system.

The limited water quality data available indicate that water from the Pelly River, Vangorda Creek and groundwater from the town wells are all characterized as calcium-magnesium-bicarbonate type waters with low total dissolved solids. However, the concentration of zinc in the groundwater was five to ten times higher than the concentration in the surface waters. In order to establish background data and to enable a comparison to be made between creek and well water, the report recommended that water quality analyses be carried out on water samples. The location of these samples would be a) Vangorda Creek where it exits from the escarpment below the townsite; and b) No. 1 Well Pumphouse. It was recommended that samples be taken at different seasons (March, June, September and December) and be analyzed as for the Standard Municipal Analysis used in Alberta, with the addition of tests for lead and zinc.

The report also recommended consideration be given to equipping one observation water well with a continuous water-level recorder

for at least one year to record the water-level fluctuations in the aquifer.

The appendices in the consultant's report contain details of Water Wells 1, 2 and 3 and well water quality data.

5.1.4.3 Creek-Well Sampling Program

A water quality sampling program was initiated in March, 1988, following the recommendations of Carefoot (1988) as described above. The following alterations were made to the program:

1. Samples will be taken to represent winter, freshet and summer-fall conditions (March, May or June and September, respectively). An additional sample in December is not considered necessary.
2. Copper was added to the list of parameters.

Results from the first two sets of analyses are presented in Table 5.5.

TABLE 5.5

PRELIMINARY RESULTS OF VANGORDA CREEK AND TOWN WATER WELL WATER QUALITY SAMPLING PROGRAM

PARAMETER	March 10[3]		May 27[4]	
	Creek[1]	Well[2]	Creek	Well
pH	8.0[L]	7.7[L]	8.16[F]	7.74[F]
temperature (degrees C)	-	-	5.4	6.2
alkalinity ($mgCaCO_3/L$)	211[L]	199[L]	79.8[F]	175.4[F]
bicarbonate alkalinity ($mgCaCO_3/L$)	100[L]	95[L]		
suspended solids (mg/L)	1	<1	3	<1
total diss solids (mg/L)	380	363	127	325
hardness ($mgCaCO_3/L$)	381	341	102	246
ammonia (mg N/L)	0.060	0.012	0.017	0.014
nitrate (mg N/L)	0.206	0.204	0.012	0.146
sulphate (mg/L)	118	102	23	82
chloride	1.9	1.9	0.46	1.94
calcium (mg/L)	95	90	26	59
magnesium (mg/L)	35	29	9.1	24
sodium (mg/L)	4.05	3.63	1.5	3.0
potassium (mg/L)	1.24	1.04	0.50	0.77
total Cu (mg/L)	0.0014	0.028	0.0030	0.014
total Fe (mg/L)	0.041	0.008	0.17	0.024
total Mn (mg/L)	0.035	<0.001	0.0092	<0.001
total Pb (mg/L)	<0.001	<0.001	<0.001	<0.001
total Zn (mg/L)	0.010	0.0033	0.0040	0.0048

Notes:

[L] = Laboratory measurement
[F] = Field measurement
[1] = Vangorda Creek above Foot Bridge
[2] = Town Water Well No. 1
[3] = Low flow, 0.6 m ice at sampling point
[4] = High flow associated with spring melt.

5.1.4.4 Conclusion

The report commissioned by Curragh Resources indicated that there is a low probability of Vangorda Creek water being a major source of recharge for the Town of Faro water supply wells. A water sampling program was initiated by Curragh in March, 1988, to compare creek and well water quality and to obtain background data on seasonal fluctuations in levels of metals and major ions. It was not considered necessary to initiate further studies on the aquifer in which the wells are completed at this time.

It is considered that, in the event that a significant hydraulic connection were to exist between Vangorda Creek and the town wells, the potential for contamination of the water supply is low. The dissolved substances most liable to increase in concentration in the creek through mining are sulphate and zinc. These substances would only present a threat to human health at very high levels. The drinking water standard for zinc is 5.0 mg/l, and is based on the taste threshold. This is ten times greater than the effluent standard for the Faro mine. The standard for sulphate in drinking water is 500 mg/l and is related to taste and the potential for diarrhea in children consuming water with high levels of magnesium sulphate. Background sulphate levels in lower Vangorda Creek averaged 30 mg/L in 1987 and sulphate concentration in the effluent from the Faro mine averaged about 517 mg/L in 1987. It is unlikely that concentrations of either zinc or sulphate would ever approach the drinking water standards in lower Vangorda Creek.

5.2 THIN-HORNED (FANNIN) SHEEP

5.2.1 Potential for Impact

In the study by Horejsi (1988) there is a full discussion of the potential for impact from the Vangorda Plateau development on the sheep population. Horejsi concluded that the population is already under stress from hunting, harassment and exposure to disturbance on the winter range. He considered the disruption of the migration route by the two pits, the waste dumps and the haul road, along with the increase in human activity on the Plateau to pose additional serious threats to the survival of the population.

The potential impact is related to the operational phase of the mine only. Following abandonment, the cleared areas and the waste dumps will provide habitat that is likely to be more attractive to migrating sheep than is the Plateau in its present state. The area through which the sheep currently migrate is densely vegetated and there are few vantage points.

5.2.2 Mitigative Measures

A plan for mitigation of the impact on the sheep has been developed by Curragh in consultation with Renewable Resources, YTG. This plan has recently been incorporated into a broader management plan developed by Renewable Resources and aimed at protecting this sheep population throughout its range in draft form and is being circulated within government.

The mitigative measures consist of:

- A corridor of undisturbed ground 550 m wide at the narrowest point will be maintained between the pits, along the northwest bank of Vangorda Creek. This route is currently used by some of the

migrating sheep. Mine plans have been altered to maintain this corridor. Originally an overburden dump for the Vangorda pit was planned for the area as it represents the shortest haul from the pit. The water treatment plant was moved uphill to its present site to avoid the corridor.

- In the fall of 1987, two sections of trail (T1 and T2 on Figure 5.1) were cut to encourage use of this route. T2 was an enhancement of an existing sheep trail; T1 is a new trail leading from what appears to be the main traditional migration route to the migration corridor.

- In the area of the sheep corridor the haul road is actually cut into the hillside with minimal fill placement (Figure 2.16). This will allow the sheep to have a clear unimpeded view of the road before crossing. In areas where fill is required, ramps will be built along the haul road in this corridor to allow the sheep to safely approach the road and view the other side.

- Truck drivers will be instructed to stop traffic on the haul road when sheep are spotted in the vicinity. This section of the haul road will be in use during 1989, when site preparation and stripping will be underway. From 1990 to 1992, during mining of the Vangorda pit, a haul truck will pass any point on the road approximately every 10 minutes, day and night. Following this period, the road will not be in frequent use.

- An alternate migration trail (T3 on Figure 5.1) has been constructed to the southeast of the development. This trail starts near the mouth of Shrimp Creek, the area where the sheep descend Sheep Mountain. The trail is cut along the side of the Shrimp Creek valley, maximizing visibility. An uphill brush barrier is placed to discourage sheep from wandering off the trail. It will make use of a high berm along a drainage ditch to the east of the

Vangorda Pit and will extend over the current mine road to the lower slopes of Mount Mye.

5.2.3 Monitoring

Monitoring of the success of these mitigative measures forms part of the cooperative project being undertaken with Renewable Resources, YTG. Ten radio collars were purchased and attempts were made to trap ewes on Sheep Mountain during the spring of 1988. Unfortunately, this effort was not successful. Other methods of capture on the winter range were rejected as being too stress-inducing and it was decided to postpone the trapping until the following winter.

The box trap on Sheep Mountain has been reconstructed and a biologist has been hired by Renewable Resources YTG to trap and radio collar 10 ewes, habituate the sheep to bait (probably hay), attempt to encourage the use of the alternate migration trail through the use of bait and observe the sheep from late October through the 1989 spring migration. As of early 1989, the sheep were beginning to congregate in the trap and habituate quite well. Therefore the monitoring phase is expected to be successful.

A program for further monitoring will be developed jointly with Renewable Resources following a review of the study described above.

5.3 SOCIO-ECONOMIC CONSIDERATIONS

The development and operation of the Vangorda minesite would have minimal socio-economic impact on the town of Faro. The development will not require a change in the level of staff and consequently enlarging the facilities in Faro would not be required. It is estimated, however, that the project, by extending the life of the Faro minesite, will provide an additional 2500 man-years of employment to the area.

The proposed minesite at Vangorda lies within Ross River Group Trapping Area, and would have adverse effect on wildlife harvesting, both native and non-native since hunting on the minesite would be prohibited. It is known, however, that hunting on the Vangorda Plateau is part of the threat to the Fannin Sheep and a decline in hunting in this area would provide the sheep with better protection. The adverse effects on the trapping area have already occurred due to the Faro minesite development, and any additional impacts would be minimal.

Access is provided to highland areas northeast of the Vangorda Plateau, thus, the impact on hunting and trapping in that area will be minimal.

The impact of not proceeding with the development at Vangorda is also an important consideration. During the 1982 to 1985 closure of the Faro mine, the population of the Yukon Territory was reduced by as much as 5000 people. This resulted in a significant decline in the general level of business activity, house prices and employment. Without development of the Vangorda Plateau, operations at Faro would most likely be shut down by 1993 with significant decline in employment starting in 1991 when open pit mining ceases.

Curragh Resources Inc.

SHEEP MIGRATION ROUTES

— MIGRATION ROUTES (AFTER McLEOD 1981 AND HORESJI 1988)

— ALTERNATIVE & ENHANCED MIGRATION TRAILS

Scale: 1:24000	Drawn by: TP
Date: 88-08-10	FIGURE 5.1

SUMMER RANGE

4500

T1

T2

T3

POWERLINE

HAUL ROAD

FARO MINE

GRUM PIT

O.B. DUMP

VANGORDA PIT

S.W. WASTE DUMP

MAIN WASTE DUMP

WASTE DUMP

MINE ACCESS ROAD

4000

3500

FARO

VANGORDA CREEK

WINTER RANGE

SHEEP MTN.

4500

4000