

**INITIAL ENVIRONMENTAL EVALUATION**

**VANGORDA PLATEAU DEVELOPMENT**

**Stage One: 1987 Program**

005046 EN-07-01

**submitted to the Regional Environmental Review Committee  
200 Range Road  
Whitehorse, Y.T.**

**by**

**Curragh Resources Inc.**

**September, 1987**

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REVIEW FOR THE PROPOSED VANGORDA AND GRUM OPEN PITS  
by Andrew T. Holmes and Alan F. Stewart, Piteau  
Associates, August, 1987.

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for:

Vangorda Plateau Development  
Initial Environmental Evaluation  
Stage 1: 1987 Program

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## 1. SUMMARY

Stage One of the Initial Environmental Evaluation presents Curragh Resources Inc.'s plans for the 1987 drilling/trenching/drainage program on the Vangorda Plateau. The program is set in the context of the overall development of the Vangorda and Grum open pits.

The 1987 program consists of:

- a. Test drilling to determine geotechnical and groundwater characteristics and to further define the ore bodies.
- b. Test trenching to assess stability and permeability of overburden.
- c. Construction of ditches to divert surface runoff and small streams around the pit areas, finger ditches to initiate overburden dewatering and a ditch and flow control structure to drain a small, shallow lake in the Grum Pit area.

Previous baseline studies of water quality, fisheries and thinhorn mountain sheep are outlined. Ongoing baseline, monitoring and investigative studies are described and preliminary data are presented. Results from this year's fish habitat assessment of Vangorda Creek indicate that there are no fish in the upper reaches of the system. Chinook salmon fry and Arctic grayling juveniles and adults utilize only the lower 2 km of the creek, over 10 km downstream from the proposed development.

Potential impacts of the 1987 program are assessed. It is concluded that the drilling and trenching programs will have no effect on water quality. The drainage of the small lake should have little impact as the drainage flow rate will be very low. Some increase in levels of suspended solids in Vangorda Creek is expected to be associated with the construction of the drainage ditches and with erosion at high flows until the channels stabilize. These increased suspended solids levels should be transitory. Settling and dilution by tributaries will further reduce suspended solids concentrations and there should be little effect on fish habitat in lower Vangorda Creek. Pelly River water quality and fish habitat will not be affected due to the river's high background levels of suspended solids and its far greater flow.

## 2. INTRODUCTION

### 2.1 The Initial Environmental Evaluation

The Initial Environmental Evaluation for Curragh Resources Inc.'s Vangorda Plateau Development will be submitted to the Regional Environmental Review Committee in two stages:

Stage One: 1987 Program (this report)

Stage Two: Overall Evaluation

This report provides information and environmental impact assessment for the 1987 program of drilling, trenching and drainage ditch construction on the Vangorda Plateau. The program is presented in the context of the overall Vangorda Plateau Development.

The report summarizes existing data and current studies on water quality, groundwater and geotechnical aspects. Previous information and current studies on the fish and sheep populations liable to be affected by the overall mine development are described. Possible impacts from the 1987 work are discussed along with measures being taken to mitigate these impacts.

Stage Two will include a more complete analysis of previous data and results from current studies. The report will contain plans of haul road and minesite development and an assessment of short and long term impact.

### 2.2 Overview of the Vangorda Plateau Development

#### 2.2.1 Description of the Development

Two open pits are to be developed on the Vangorda Plateau. The Vangorda pit will be relatively small, with a proposed depth of 70 m. The Grum pit, which contains greater ore reserves and has a greater depth of overburden, will be about 270 m deep. Pit locations are marked on Figure 1.

A haul road will be built to haul ore to the mill at the Faro minesite. A power line and maintenance facilities will be constructed. Dumps for overburden and waste will be located near each pit.

Vangorda Creek will be diverted around the Vangorda 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 indicated by its quantity and degree of contamination.

The proposed development involves only mining on the Vangorda Plateau. All processing and tailings storage will be located at the existing Faro minesite.

### 2.2.2 Timeframe

Table 1 outlines the main events in the startup of the two new open pits. Scheduling is centered around maintaining a continuous ore feed to the mill. We consider it essential to the orderly implementation of this development to initiate surface drainage now. The reasons are outlined in Section 3.1.

### 2.2.3 Environmental Concerns

Major aspects of the development that have potential environmental impacts are outlined below. These issues will be addressed in Stage Two of the Initial Environmental Evaluation. Several of these issues are discussed in the report on geotechnical and groundwater aspects of the 1987 program from Piteau Associates, Geotechnical and Hydrogeological Consultants, attached as Appendix A. The appendices of the report have not been included as they deal only with test procedures, but they are available from Curragh Resources Inc.'s Whitehorse office.

a. The diversion of Vangorda Creek. There are three alternatives under consideration for the diversion of Vangorda Creek: to the northwest of the pit (as proposed by Cyprus Anvil Mining Corporation), to the northeast of the pit (into Dixon Creek) and a shorter diversion through the pit area. These alternatives are described and evaluated in Appendix A, pages 5 to 8.

b. Location and design of the waste dumps. Concerns are physical stability, chemical stability (potential for acid mine drainage), and collection and treatment of runoff (see Appendix A, pages 11 and 17).

c. Control of surface and groundwater in the minesite and collection and treatment of contaminated water. This includes the water currently discharged from the old Grum adit and water in the Grum Dump Pond (see Appendix A, pages 14, 15 and 18 and Section 4 of this report).

d. The Vangorda haul road. Concerns include: the rock causeway at the North Fork of Rose Creek, potential for acid generation of construction materials, creek crossings.

e. Abandonment of the minesites.

Potential environmental impacts which are currently being evaluated

**Table 1: Vangorda Plateau Development Startup Schedule**

	<u>Vangorda</u>	<u>Grum</u>
1987 Late 3rd Quarter	-- Begin drainage of minesite areas -- in preparation for stripping	
	-- Test trenching and drilling -- to assess groundwater and soil characteristics	
1988 Late 2nd Quarter	Tree removal (possibly sooner)	
3rd Quarter	Start stripping	Extend finger ditches
1989 Late 1st Quarter	Vangorda Creek diversion complete (this may be delayed)	
2nd Quarter	Shovel moved to site *Power line must be completed.	Tree removal
3rd Quarter	First ore removed *Haul road must be completed.	Start stripping
1990	Mining	Stripping
1991	Last ore removed (possibly late 1990)	First ore removed (possibly late 1990)

and for which mitigation measures are being considered include:

- a. Disturbance to the thinhorn sheep population that utilizes the Plateau as a migration corridor between summer and winter ranges.
- b. Degradation of surface or groundwater quality.
- c. Degradation or loss of fish habitat in the lower part of Vangorda Creek and the North Fork of Rose Creek.

### 3. THE 1987 DRILLING/TRENCHING/DRAINAGE PROGRAM

#### 3.1 Objectives

The objectives of the 1987 program are:

- a. To initiate dewatering of the Vangorda and Grum pit areas.
- b. To collect data on groundwater and overburden characteristics that will aid in the finalization of mining plans.

Water control is vital in open pit mining, both from an operational and an environmental point of view. The objective is to divert uncontaminated water around the site, reducing the minesite water flow as much as possible. If water is intercepted before it enters the pit then no contamination will occur and environmental impact will be minimized.

##### 3.1.1 Surface Dewatering

The tills of the Vangorda Plateau are dense and impermeable (Montreal Engineering Company 1979), which means that drainage of groundwater will be slow.

Curragh Resources Inc.'s mine planning consultant (H.S. Clarke Mining Consultants of Calgary) who is currently reviewing all background data and plans for the Vangorda development, has advised that it is critical that drainage begin as soon as possible to avoid major problems and delays in stripping. It is standard practice in western Canada to initiate surface and groundwater drainage five to three years in advance of mining. Drainage at Vangorda will begin only one year in advance of stripping and two years in advance of first ore removal; drainage at Grum will begin two years in advance of stripping and three to four years in advance of first ore removal (see Table 1). We consider it critical to have the diversion and drainage ditches in place and functioning by spring runoff in 1988.

##### 3.1.2 Geotechnical and Groundwater Studies

The 1987 drilling/trenching/drainage program will in no way limit options for the final site plans. In fact, information from the program is required at this stage of planning. The 1987 work on Vangorda Plateau will provide the following information (see Appendix A for more detail):

Drilling: -Piezometers will be installed in drill holes.  
-A pumping test will be carried out if water quantities warrant.

Information on hydrogeology, particularly the degree of saturation of the overburden, will assist in planning dewatering strategy.

Trenching: -Standpipe piezometers will be installed in some trenches to monitor changes in groundwater after construction of finger ditches.  
-Samples will be collected for geotechnical analysis (to determine moisture content and plastic and liquid limits)  
-Percolation tests may be conducted in some of the trenches.

Geotechnical and hydrogeological data derived from the trenching will assist in locating and designing waste dumps and a stable creek diversion channel.

Ditching: -Ditches will be logged to obtain information on surficial soils.  
-Weirs may be constructed to estimate seepage loss in a diversion ditch.

The effectiveness of the finger ditches in draining surficial soils will assist in planning further dewatering measures.

### 3.2 Plans

The 1987 program will consist of drilling, test trenching and drainage of surface water from the pit areas. The drainage program has three components: drainage of a small, shallow lake in the Grum pit area, construction of two ditches to divert surface flow around the pits and construction of finger ditches in the Vangorda pit area to drain shallow surficial soils.

#### 3.2.1 Drilling

Forty-four holes are to be drilled in bedrock, totalling 4200 m (26 holes at Vangorda and 17 at Grum) and six piezometer holes in overburden, extending a short distance into rock.

Drilling fluid will be captured in a pond for settling before release.

The geotechnical drilling program is described in Appendix A, pages 23 to 24 and 26 to 28.

### 3.2.2 Trenching

Test trenches will be excavated along possible diversion alignments and in a potential waste dump area.

The trenching program is described fully in Appendix A, pages 20 to 26. Recommendations included in these pages will be followed wherever feasible, with the following exceptions. Testing of foundation conditions for the Grum waste dump will be postponed until next year. Test trenching in Dixon Creek will be postponed to avoid disturbance to the creek bed but should be done next year if the east diversion option is preferred.

### 3.2.3 Drainage of Doal Lake

#### 3.2.3.1 Volume of Water and Lake Sediment

A depth survey of the lake was conducted on August 22, 1987 (Figure 2). The lake is flat-bottomed and very shallow, with a maximum depth of 1.34 m and an average depth of 0.90 m, calculated from the grid of 18 depth soundings.

The volume of water was calculated to be approximately 40,000 m<sup>3</sup> from this depth survey. The volume of sediment on the lake bottom is estimated to be 60,000 to 70,000 m<sup>3</sup>.

#### 3.2.3.2 Drainage

Drainage of the lake will begin in late September and will take up to one month. Drainage will be via a trench 100 m long to the current outflow channel (west fork of Grum Creek). Outflow will be controlled by means of a gated culvert to be installed at the road crossing.

The flow through the system was estimated to be .015 m<sup>3</sup>/s in August, 1987. The flow during drainage is anticipated to be in the range of 0.05 to 0.08 m<sup>3</sup>/s. At the higher rate, the lake would be drained in approximately seven days. The suspended solids levels in Grum Creek will be monitored during drainage and the flow adjusted to minimize addition of sediment.

During the 1987-88 winter, the approximately 2 m thick layer of lake sediment will be removed and transported to a dump to the east of the lake (location marked on Figure 1). This will reduce the suspended sediment load in spring, 1988 and allow construction of finger ditches during the next phase of surface drainage.

### 3.2.4 Finger Ditches

Finger ditches will be excavated in the Vangorda Pit area only (location indicated on Figure 1). Test pits will be dug in this area and finger ditches constructed where there is sufficient groundwater seepage into the pits to make drainage worthwhile. Flow in most of the ditches is expected to be low and of short duration. However, preliminary testing has indicated that one or two of the ditches may initially release greater quantities of groundwater from a shallow, perched water table in a gravel seam. If test pits indicate that this is the case, ditches will be constructed so as to control the outflow to the creek. Small, temporary ponds may be constructed at the ends of ditches that do release large flows.

### 3.2.5 Diversion Ditches

#### 3.2.5.4 Location and Design of Ditches

Ditches will be constructed to divert surface water around the Grum and Vangorda pit areas. The locations, lengths and grades of the ditches are marked on Figure 1.

The Grum ditch will intercept water that formerly drained to Doal Lake and will divert it to Grum Creek. As recommended by Piteau Associates (Appendix A, pages 12 and 13), the portion of the diversion that directs water around the top of the Grum Pit will be constructed to accommodate the 50 year flood as estimated following the methodology developed by Hydrocon Engineering (Continental) Ltd (Golder Associates 1979). This methodology is described in Section 3.2.5.5. Flow will not be channelized once it has been directed around the pit area, but will flow overland to the top of the natural channel that forms the east fork of Grum Creek.

The Vangorda ditch will intercept runoff (along the section labelled Vangorda runoff ditch on Figure 1) and a small creek from the northeast of the pit (along the section labelled Vangorda SE diversion channel) and divert this water to a small tributary of Dixon Creek, which is in turn a tributary of Vangorda Creek. Note that this ditch is along the route of one of the proposed diversions for Vangorda Creek.

Ditches will be designed as follows:

- a. Grum NE diversion ditch: depth: 1 m  
width at bottom: 1 m  
width at top: 5 m  
slopes of walls: 2:1  
cross sectional area: 3.0 m<sup>2</sup>

- b. Vangorda run-off ditch:   depth: 0.5 m  
                                  width at bottom: 1 m  
                                  width at top: 2.5 m  
                                  slopes of walls: 1.5:1  
                                  cross sectional area: 0.88 m<sup>2</sup>
- c. Vangorda SE diversion channel:  
                                  depth: 1 m  
                                  width at bottom: 1 m  
                                  width at top: 4 m  
                                  slopes of walls: 1.5:1  
                                  cross sectional area: 2.5 m<sup>2</sup>

The Grum ditch's cross-sectional area of 3.0 m<sup>2</sup> provides storage for an instantaneous flow of 5.07 m<sup>3</sup>/s based on the 50 year flood design velocity of 1.69 m/s used for the proposed Vangorda diversion (based on a channel slope of 0.25 % and Manning's n value for channel condition of 0.35). The Grum diversion ditch will collect water from a catchment area of approximately 2.0 km<sup>2</sup>. The estimated 50 year flood level for this basin is 3.8 m<sup>3</sup>/s.

Similarly, the Vangorda SE diversion channel drains a catchment area of approximately 1.1 km<sup>2</sup> (including the area drained by the Vangorda runoff ditch), with a 50 year flood level of 1.9 m<sup>3</sup>/s. The cross sectional area of 2.5 m<sup>2</sup> provides storage for an instantaneous flow of 4.23 m<sup>3</sup>/s.

The diversion ditches are therefore adequate to contain the one in 50 year flood recurrence with a large safety margin allowed for the uncertainties involved in these calculations.

The effectiveness of the Grum NE diversion ditch in diverting flow around the Grum pit area will be evaluated in the spring of 1988 and the ditch will be extended if required.

#### 3.2.5.5 Estimation of Flows: 50 Year Flood

Fifty year flood levels were calculated to be 3.8 m<sup>3</sup>/s for the Doal Lake watershed and 1.9 m<sup>3</sup>/s for the drainage basin of the small creek being intercepted by the Vangorda SE diversion channel.

The methodology used was developed for design of a Vangorda Creek diversion ditch proposed by Cyprus Anvil Mining Corporation. Flood frequency analysis was conducted by Hydrocon Engineering (Continental) Ltd (Golder Associates 1979). Equations developed for the Dempster Lateral Pipeline river crossings were used with coefficients calculated using longterm data from the Pelly River at Pelly Crossing:

$$\begin{aligned} \text{and} \quad Q_{100} &= 2.47 (\text{D.A.})^{0.7} \\ Q_{\text{max}} &= 0.22 (\text{D.A.})^{0.85} \end{aligned}$$

where:  $Q_{100}$  = 100 year instantaneous flood magnitude in  $\text{m}^3/\text{s}$   
 $Q_{\text{max}}$  = mean annual instantaneous flood magnitude in  $\text{m}^3/\text{s}$   
and D.A. = drainage area in  $\text{km}^2$ .

The drainage area of the Doal Lake basin was estimated to be  $1.98 \text{ km}^2$  from the 1:5000 topographic map. In order to account for less vegetation and the steeper topography of the Vangorda Creek basin, in relation to the correlation basins, Hydrocon Engineering applied a 25 percent factor of safety to the base flood capacities derived for Vangorda Creek. Applying a 25 percent factor of safety would provide the following results for the Doal Lake drainage basin:

$$\begin{aligned} \text{and} \quad Q_{100} &= 5.0 \text{ m}^3/\text{s}, \\ Q_{\text{max}} &= 0.49 \text{ m}^3/\text{s}. \end{aligned}$$

Fifty year flood levels were estimated from these values by interpolation on a log-probability chart.

## 4. WATER QUALITY

### 4.1 Existing Data

#### 4.1.1 Surface Water Quality

Water quality sampling has been carried out since 1975 in the Vangorda basin by Montreal Engineering Company Limited (for Kerr-Addison Mines Limited), by Cyprus Anvil Mining Corporation and by the Federal Department of Indian and Northern Affairs. All water quality data will be presented and discussed in Stage Two of the Initial Environmental Evaluation.

Background data indicate that Vangorda Creek is characterized by:

a. Consistently high pH values throughout the system. The average pH of 18 samples collected near the mouth of the creek from 1975 to 1980 was 8.06 (range 7.6 to 8.38).

b. Clear water through most of the year. During the brief high flow periods, the suspended solids levels may increase substantially. The highest levels recorded at the mouth of the creek were during the spring runoff period. The suspended solids concentration at this site was 154 mg/L on June 10, 1976. This sampling date coincided with the peak flow for that year (Figure 3).

c. Extractable metals levels generally near or at the limit of detection. Occasionally higher levels may result from mineralized soil particles, as they appear to be correlated with high suspended solids (Montreal Engineering 1976, 1977 and 1978).

#### 4.1.2 Flow

An automatic water level recording station was in operation in the lower part of Vangorda Creek (near the town of Faro) from 1975 to 1977. The station was calibrated from a series of discharge measurements and mean daily flow rates were recorded. Data are presented in Figure 3.

Note that the peak levels for each year occurred during spring runoff, in late May to mid-June, and were of short duration. The peak flow for each of the three years was close to the 3.0 m<sup>3</sup>/s predicted as the mean annual flood by the methodology developed by Hydrocon Engineering and used to calculate 50 year flood levels for ditch design for the present study (see Section 3.2.5.5).

#### 4.1.3 Groundwater

Few data have been collected on uncontaminated groundwater quality. Two samples taken from the drinking water wells at the Grum camp (Montreal Engineering Company 1976) contained low levels of most metals. One of the samples, however, showed copper, cyanide and mercury levels slightly in excess of maximum allowable concentrations for any grab sample in Curragh Resources Inc.'s water licence.

#### 4.2 Ongoing Study

Curragh Resources Inc. initiated a monitoring program in June, 1987. The aim of the program is to: (1) update and augment the water quality data base for Vangorda Creek and (2) establish sampling sites that will allow monitoring of impact once the development is underway.

All sites may currently be regarded as background sites.

##### 4.2.1 Sites (see Figure 4 for locations)

#### **Vangorda Creek Drainage**

##### **Stream Sites**

- V1 Vangorda Creek above Vangorda Road crossing. (Background site.)
- V2 Grum Creek at mouth. (Assess impact of Grum development.)
- V3 Vangorda Creek 100 m downstream of Grum Creek. (Downstream of both mining areas.)
- V9 Dixon Creek (tributary to Shrimp Creek), above east diversion option. (Background.)
- V4 Shrimp Creek at mouth. (Background and influence of east diversion option.)
- V6A Creek entering West Fork Vangorda Creek from south above site V6. (Assess impact of possible disturbance in this small creek's drainage basin.)
- V6 West Fork Vangorda Creek at Vangorda Road crossing. (Background site on West Fork above influence of Mine Road.)
- V5 West Fork Vangorda Creek above Mine Road at km 1. (Influence of West Fork on downstream water quality.)

- V7 Vangorda Creek above Faro, east of rock cut on Mine Road.  
(Assess impact of entire development on East Fork.)
- V8 Vangorda Creek below Faro at pumphouse bridge. (Downstream  
site, effect on fish habitat.)

#### **Groundwater Sites**

- GA Grum adit water.
- RS Red spring (a natural spring), at ore outcrop near Vangorda Creek.
- DDH322 Flowing drill hole at Vangorda pit area.

These sites all represent groundwater which has been in contact with the ore body. Samples of uncontaminated groundwater will also be taken during this year's testing program in order to obtain data representing groundwater that will be released during minesite dewatering. Samples will be taken from drill holes and during pump tests (Appendix A, page 27) whenever it is possible to obtain a sample without contaminating it.

#### **Additional Water Quality Sites**

##### **Rose Creek**

- V14 Rose Creek below mine access road crossing. (Impact of haul  
road.)

##### **Blind Creek**

- V13 Blind Creek at bridge. (Background for long range development.)

#### **4.2.2 Procedures**

Samples are sent to commercial laboratories for analysis. Temperature is measured with a pocket thermometer in the field; pH is measured by meter in Curragh Resources Inc.'s assay lab, where acidification of samples for metal analyses is also carried out.

Sampling and analysis procedures are currently under review.

#### **4.2.3 Sampling Schedule**

Sites are being sampled monthly. With the exception of sites RS, V4, V9, V6A and DDH322 (which have been recently added), samples were taken June 3, July 8 to 9 and August 5 to 6, 1987.

Site V13 will be temporarily discontinued, as there are no plans for development in the Blind Creek drainage basin within the next few years.

Site V6A will be sampled less regularly: it will be used to determine if water quality in this small creek differs from that of the other headwater creek of the West Fork. Once background values are established, it will only be sampled if its drainage basin is to be impacted.

During and after the construction of the drainage ditches, sites V1, V2, V3 and V8 will be sampled at least weekly for suspended solids levels. Consideration is also being given to field estimation of suspended solids at these sites (using a clarity wedge) on a more frequent basis during critical periods of construction and high runoff. This will provide: (1) immediate feedback to onsite personnel and (2) a more complete record of the impact of the drainage works, as elevated suspended solids levels are likely to be transitory.

Flow in Grum Creek will be monitored frequently during the drainage of Doal Lake.

Once sufficient sampling has been done to establish background water quality, some sites may be discontinued or sampled less regularly. Sites may also be added to better define water quality or assess impact.

#### 4.2.4 Parameters

Parameters tested to date are those required for analyses of Rose Creek water in Curragh Resources' Water Licence (pH, temperature, suspended solids, flow, ammonia, copper, lead, zinc, cyanide, manganese, sodium and sulphate). The following changes will be made to the sample analyses:

(1) Analysis for sodium will be discontinued as sodium is added only during the milling process and no mill will operate in the Vangorda watershed.

(2) Flows will be measured at stream sample sites (beginning as soon as equipment is available). These data will assist in the design of drainage ditches and road crossings associated with the development.

(3) V1, V2, V3 and V8 samples will be analysed for arsenic and mercury to obtain background levels of these elements.

#### 4.2.5 Results to the end of August, 1987

Water quality data for Vangorda Creek sites are presented in Table 2.

Table 3 lists results from all analyses of water at Grum Camp, Doal Lake and drill hole DL 1. The latter site is located near Doal Lake. With the understanding that conclusions drawn from such a limited data set are preliminary, the following comments can be made:

- a. The quality of Doal Lake water is comparable to that of Vangorda Creek--it is similar in pH and has low metals content.
- b. The small quantity of water that drains from the Grum Adit, through a small pond and eventually to Grum Creek has no effect on downstream water quality.
- c. The series of samples taken June 29 indicates that the small Adit Pond is fairly effective in removal of zinc, reducing the level to about one-third of the adit water concentration. This is further discussed in Appendix A, page 18.
- d. The Grum Dump Pond, which is formed by rainwater and acquires its exceedingly high zinc level from the surrounding ore and waste rock piles, concentrated through evaporation, has no overflow and no evidence of seepage. There is no effect on downstream water quality (Grum Creek).
- e. Levels of sulphate and suspended solids appear to be higher in the lower West Fork than in the mainstem of Vangorda Creek. Possibly this is a result of road activity, as the West Fork flows near the Faro mine road between sites V6 and V5.
- f. The data from DL 1 indicate that groundwater metals levels may be slightly higher than those in surface water, but still well within effluent standards. The high pH may be influenced by cement in the drillhole and the higher zinc level on June 29 may result from sampling or analysis contamination, as the sample was taken and analysed in conjunction with the Grum Camp samples. As discussed above, more reliable sources of baseline groundwater samples are being investigated.

#### 4.3 Impact of the 1987 Program on Water Quality

##### 4.3.1 Drilling and Trenching

Drilling and trenching are not expected to have any impact on Vangorda Creek. Relatively small areas away from creek channels will be disturbed.

**TABLE 2: 1987 WATER QUALITY DATA: VANGORDA CREEK**  
 (see Figure 3 for location of sites)

Site	Date 1987	pH pH units	Temp x <sup>o</sup> C	Sus.Sol. mg/L	NH <sub>3</sub> mg/L	Cu mg/L	Pb mg/L	Zn mg/L	Mn mg/L	Na mg/L	SO <sub>4</sub> mg/L
V1	June 3		1	<1	.07	<.002	<.005	.002	.004	0.6	3.
	July 8	7.42	4	<1	.37	.002	.008	.022	.002	0.9	0.4
	Aug. 6	7.48	6	<1	.32	.002	.036	.007	.008	1.0	3.
V2	June 3		2	<1	.45	.002	<.005	.003	<.002	1.5	9.
	July 8	8.00	5	<1	.33	.002	.005	.008	.002	2.1	19.
	Aug. 6	8.13	5	<1	.31	.003	.037	.009	.008	2.3	20.
V3	June 3		2	1	.04	.002	<.005	.012	.004	0.8	3.
	July 8	7.47	5	<1	.25	.003	.008	.013	.003	1.0	6.
	Aug. 6	7.82	6	1	.44	.003	.037	.017	.009	1.2	4.
V5	June 3		3	15	.10	.003	.006	.003	.026	1.3	21.
	July 9	7.85	5	18	.45	.004	.008	.010	.023	1.8	36.
	Aug. 5	8.32	6	6	.46	.003	.031	.008	.017	2.1	48.
V6	June 3		2	2	.31	.002	<.005	.002	.004	0.7	2.
	July 8	7.67	4	1	.21	.002	.007	.008	.003	1.0	2.
	Aug. 5	7.81	6	<1	.36	.030	.034	.008	.009	1.2	4.
V7	June 3		2	3	.05	.003	<.005	.007	.006	0.9	8.
	July 9	7.97	5	16	.16	.003	.009	.014	.008	1.2	16.
	Aug. 5	8.19	8	7	.36	.003	.023	.011	.011	1.4	19.
V8	June 3		3	5	.08	.004	<.005	.007	.012	1.1	15.
	July 9	7.82	5	8	.57	.003	.008	.010	.009	1.6	23.
	Aug. 5	8.31	8	4	.33	.003	.016	.011	.009	1.7	26.

TABLE 3: 1987 WATER QUALITY DATA; GRUM CAMP, DRILL HOLE DL 1 AND DOAL LAKE

Site	Date 1987	pH pH units	Temp x <sup>c</sup>	Sus.Sol. mg/L	NH <sub>3</sub> mg/L	Cu mg/L	Pb mg/L	Zn mg/L	Mn mg/L	Na mg/L	SO <sub>4</sub> mg/L
Grum Adit	June 3		5	8	.27	<.002	<.005	2.32	.187	10.3	92.
	June 29		5	10		.002	.005	2.16	.182	11.6	98.
	July 8	8.01	5	9	.50	.002	.012	2.12	.174	11.9	99.
	Aug. 6	7.76	6	8	.41	.002	.029	2.13	.180	11.5	95.
Grum Adit Pond (flow 5 to 6 IGPM):											
Pond	June 29		18	3		.006	.007	.865	.135	11.3	111.
Overflow	June 29			2		.010	<.005	.785	.132	11.9	112.
Grum Dump Pond (no overflow)											
	June 29		16	5		.092	.047	120.	3.70	1.7	543.
DL 1	June 22	11.17				.012	.062	.079	.008	8.1	26.
	June 29			55		.016	.028	.268	.037	5.5	25.
	July 8	11.2			.15	.002	.009	.014	.009	5.3	21.
Doal Lake	June 22	7.5	15			.002	.007	.007	.005	1.0	2.

#### 4.3.2 Drainage of Doal Lake

Impact on Vangorda Creek water quality from the drainage of Doal Lake should be minimal. The lake's water quality is comparable to that of Grum and Vangorda Creeks. There should be little or no erosion of the outflow channel as the increased flow to Grum Creek during drainage will be well below the freshet level. (The mean annual flood estimate for the Doal Lake drainage is  $0.49 \text{ m}^3/\text{s}$ . The flow resulting from the lake drainage should not exceed  $0.15 \text{ m}^3/\text{s}$ , as described in Section 3.2.3.2.)

Removal of the lake sediments during winter will prevent leakage of mud into Grum Creek during spring runoff. The sediment dump is located in a flat, vegetated area--water from the sediment will percolate through vegetation and soil as it melts.

#### 4.3.3 Finger Ditches

The finger ditches are being constructed to drain groundwater from the overburden--they have essentially no catchment area. Rates of seepage into the ditches were expected to be very low (Appendix A, page 8) but recent preliminary testing has indicated that ditches in one area may release high flows of groundwater for a short period after construction. However, when high groundwater conditions are encountered, measures will be taken to control outflow from the ditches, as discussed in Section 3.2.4. There will be minor, short-term addition of suspended solids to Vangorda Creek resulting from ditch erosion following rainstorms.

#### 4.3.4 Vangorda Pit Area Diversion Ditch

The upper 550 m of this ditch (labelled Run-off Ditch in Figure 1) will carry little water, as it collects only surface runoff from the slope to its northeast. The small creek draining into the lower section of the ditch (labelled Vangorda SE Diversion Channel on Figure 1) is of low, intermittent flow, estimated at  $1 \text{ L/s}$  ( $.001 \text{ m}^3/\text{s}$ ) on July 30, 1987 (Appendix A, page 8).

The gradients will be low (0.25 % to 0.5 %) and erosion should be minimal at low flow. Some erosion of the ditch is to be expected during construction and at high flow until the channel stabilizes. The increased flow to the small tributary to Dixon Creek may increase erosion in its channel at high flow.

#### 4.3.5 Grum Pit Area Diversion Ditch

This ditch will carry the Doal Lake inflow, estimated at 0.015 m<sup>3</sup>/s in August, 1987. Gradients in the ditch will be low (0.25 % to 0.5%) and erosion should only occur during construction and at high flows.

Below the ditch, water will fan out and flow overland about 250 m to the east fork of Grum Creek. The gradient is relatively steep, averaging 8 % from the end of the ditch to the natural channel. Some gully erosion is expected to occur at high flow. However, test pits in this area have shown that a thin layer of organic material overlies gravelly sand (Appendix A, page 12). Stable channels should soon form in this gravelly sand layer.

Some settling is expected to occur in the low-gradient, marshy section at the top of the natural channel into which the water will flow. This channel has coarse deposits exposed along its length and should be capable of carrying the expected flows (Appendix A, page 12).

#### 4.3.6 Overall Impact on Water Quality

No groundwater that has been in contact with the ore body will be released to the creek and no impacts other than temporary increases in suspended solids levels to Vangorda Creek are anticipated. These elevated suspended solids levels will occur mainly during the brief flood periods following storms. There should be no impact after the drainage channels have stabilized.

Some of this suspended sediment load will settle out in the backwaters and low-gradient sections of the creek. Downstream water quality will be further protected by dilution from unaffected tributaries (the West Fork of Vangorda Creek and Shrimp Creek).

The finer fraction of the sediment load will be carried into the Pelly River. However, the dilution from the river is so great and the background levels of suspended solids in the Pelly River so high that no impact on Pelly River water quality is anticipated.

Flows and suspended solids concentrations in the Pelly River are summarized in Table 4. The mean maximum monthly flow for the Pelly River at Vangorda Creek was 685 m<sup>3</sup>/s, 1973 - 1985. The mean peak annual flow of Vangorda Creek for 1975 - 1977 was 2.89 m<sup>3</sup>/s (Figure 3). Thus Vangorda Creek is diluted about 240 times during periods of high flow, when suspended solids levels are likely to be highest.

Table 4: Flows and Suspended Sediment Loads in the Pelly River<sup>1</sup>

<u>Year</u>	<u>Suspended Sediment Load</u>			<u>Flow</u>	
	(Pelly R at Pelly Crossing)			(Pelly R below Vangorda Creek)	
	number of samples <sup>2</sup>	max. (mg/L)	min. (mg/L)	max. monthly mean (m <sup>3</sup> /s) (June except where noted)	min. monthly mean (m <sup>3</sup> /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		

<sup>1</sup>Flow data from Water Survey of Canada 1974 to 1985  
Sediment data from Water Survey of Canada 1987

<sup>2</sup>Each sample consists of several samples taken from fixed points  
along a vertical cross-section of the river.

## 5. FISHERIES

### 5.1 Existing Data

Fisheries work was carried out by Montreal Engineering Company on Vangorda Creek in the 1970's (Montreal Engineering Company 1976, 1977 and 1978). Sampling concentrated on the collection of fish for tissue analyses to establish background metals levels. Sampling methods, locations and fish species caught are as follows:

#### 1975

1. Location: Bridge to the pumphouse below Faro (site V8 on Figure ) and below the Vangorda Road crossing (downstream of site V1 on Figure ).  
Method: Electrofishing of 100 m<sup>2</sup> stream for 600 seconds  
Date: May  
Results: no fish were caught.
2. Location: Backwater of the Pelly River at the mouth of Vangorda Creek.  
Method: Electrofishing of 200 m<sup>2</sup> stream for 1200 seconds  
Date: May and August  
Results: In May sample, Arctic grayling, round whitefish, slimy sculpin, chinook salmon and longnose sucker.  
In August sample, Arctic grayling, round whitefish and slimy sculpin.

#### 1976

1. Location: Vangorda Creek at confluence with the Pelly River.  
Method: Electrofishing of 100 m of stream  
Date: August 10  
Results: Arctic grayling, round whitefish, slimy sculpin, burbot and chinook salmon were caught.
2. Location: Shrimp Lake  
Method: Monofilament nets (mesh sizes 2.5 cm, 5 cm and 6.2 cm) set two successive days and minnow traps set in shallows.  
Date: not given  
Results: no fish were caught.

#### 1977

1. Location: Vangorda Creek at confluence with the Pelly River.  
Method: Electrofishing of 100 m of stream  
Date: August  
Results: Arctic grayling, and slimy sculpin were caught.

These data indicate that several species, including chinook salmon and Arctic grayling, utilize the lower part of Vangorda Creek.

The one sample taken in the upper part of the creek indicated that no fish were present. However, this was not conclusive as sampling during the same period in the lower creek, where fish are known to be present, was unsuccessful.

The thorough sampling of Shrimp Lake indicates clearly that this lake does not contain fish.

## 5.2 Ongoing Studies

### 5.2.1 Description of Studies

A background fisheries habitat reconnaissance of Vangorda Creek is being conducted by a consultant (Paul Harder of P.A. Harder Associates of Victoria). The survey includes habitat mapping and point sampling to ascertain presence or absence of fish and to estimate fish densities in upper and lower Vangorda Creek. The consultant's report describing fish distribution and habitat in Vangorda Creek will be available on request from Curragh's Whitehorse office within a few weeks.

A preliminary study was conducted in the spring of 1987 in the North Fork of Rose Creek, also by P.A. Harder Associates. The purpose of this study was to assess impact of the North Fork rock drain (part of the Vangorda haul road) on Arctic grayling populations resident in or migrating to the North Fork of Rose Creek. An interim report is expected by the end of September and will be available on request from Curragh's Whitehorse office. Further assessment work on the North Fork of Rose Creek is being planned for 1988.

### 5.2.2 Preliminary Results of Vangorda Creek Study

Sampling was conducted at the following locations, August 27 to 30, 1987:

- Doal Lake
- Near water sampling sites V1, V6, V7, and V8 (see Figure 4) and Vangorda Creek both upstream and downstream of the Faro town culvert.
- Side channels of the Pelly River at the mouth of Vangorda Creek and downstream of the Pelly River bridge.

Electrofishing and minnow traps were used. A gill net and minnow traps were set overnight in Doal Lake.

Results indicate that there are no fish in the Vangorda Creek system

(including Doal Lake) upstream of the Faro town culvert. Chinook fry were found in the creek from the culvert to the confluence with the Pelly River. Arctic grayling were found in the lower part of this reach, as were sculpins, burbot and suckers.

### 5.3 Impact of the 1987 Program

The only potential impact on Vangorda Creek could be a temporary increase in suspended solids levels resulting from the construction of the drainage ditches, as discussed in Sections 4.3.4 and 4.3.5. This increase would occur sporadically during construction (late fall, 1987) and during high flows until drainage channels have stabilized.

The fish-bearing reaches of the creek are over 10 km downstream of the Vangorda Plateau Development. Suspended solids levels would be reduced by settling and dilution (see Section 4.3.6). No major impact on fish and no net loss of fish habitat is expected.

Potential impacts on fish habitat from the 1987 program are:

- a. Minor increases in suspended solids levels (and thus in turbidity) in late fall, 1987 and during high flow periods in 1988.
- b. Some settling of suspended solids in the low-velocity side channels and backwaters of the Vangorda and the Pelly at the mouth of Vangorda Creek. These sediments would be re-suspended during floods.

## 6. THINHORN SHEEP (Ovis dalli)

While it is recognized that the Vangorda Plateau Development as a whole could have considerable impact on the local population of thinhorn sheep, the level of disturbance involved in this year's work should not deter sheep movement across the plateau.

### 6.1 Existing Data

Previous studies of sheep population size and migration patterns on Vangorda Plateau are presented in Curragh Resources Inc. 1987. These data will be summarized in Stage Two of the Initial Environmental Evaluation.

### 6.2 Ongoing Study

Curragh has hired a consultant (Dr. Brian Horesji of Calgary) to advise on mitigative measures. He has reviewed previous studies, advised the company on current plans and will be conducting field work on the plateau in mid September.

Mine workers and contractors working on the plateau this fall will be asked to make note of sheep sightings, including location, numbers and composition of groups of sheep seen.

### 6.3 Impact from the 1987 work

The increase in activity during the fall migration period may have some impact on sheep movement. However, there will be less activity than during previous periods of exploration. There will continue to be only one resident at the Grum Camp. Work will be carried out partly by mine employees and partly by contractors. The number of workers on site at any one time should not exceed about ten.

Mitigative measures consist of:

a. Education: Mine employees involved in the Vangorda Development will be informed about the sheep and the importance of the plateau as a migration corridor between summer and winter ranges. It will be made clear that harrassment will not be tolerated and that disturbance should be kept to a minimum. A clause will be included in all contracts for work on the plateau requiring contractors to take steps to minimize disturbance to the sheep.

b. Line cutting around the surface lease boundary, originally scheduled for August, 1987, has been postponed on the advice of Dr. Horesji until we receive his recommendations. Plans are to:

i. Use the surface lease cut line as sheep trail whenever possible.

ii. Construct the cutline so as to increase access (by trucks or all-terrain vehicles) as little as possible.

## 7. REFERENCES

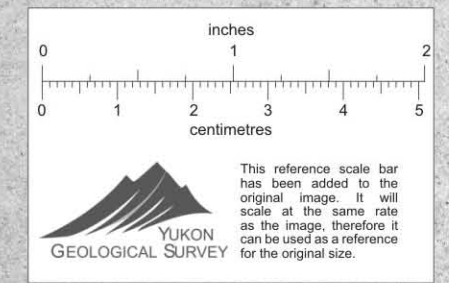
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- Water Survey of Canada, 1987. Sediment Data: Yukon and Northwest Territories, 1985. Water Resources Branch, Inland Waters/Lands Directorate.





Orthophoto map compiled from aerial photography taken in August, 1979 by North West Survey Corporation International Ltd.  
 Coordinates shown are U.T.M. coordinates based on Clarke's Spheroid of 1866 and are computed for Zone 8.  
 Elevations shown are Geodetic elevations based on the North American Datum, 1927.  
 Horizontal and vertical control survey was performed by Hosford, Impey, Welter & Associates Ltd. and North West Survey Corporation (Yukon) Ltd. in the summer of 1979 for Cyprus Anvil Mining Corporation and is included in a report of the same date.  
 Any conflict between contour numbers and planimetric detail is due to planimetric detail being added at a later date.

Sheet No. F-6-4 (W 1/2)



**CURRAGH RESOURCES INC.**

**ANVIL AREA**

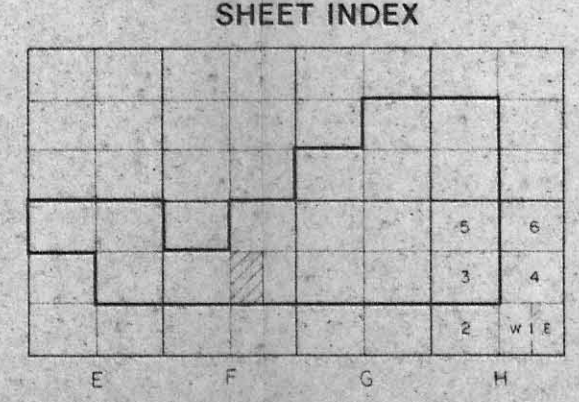
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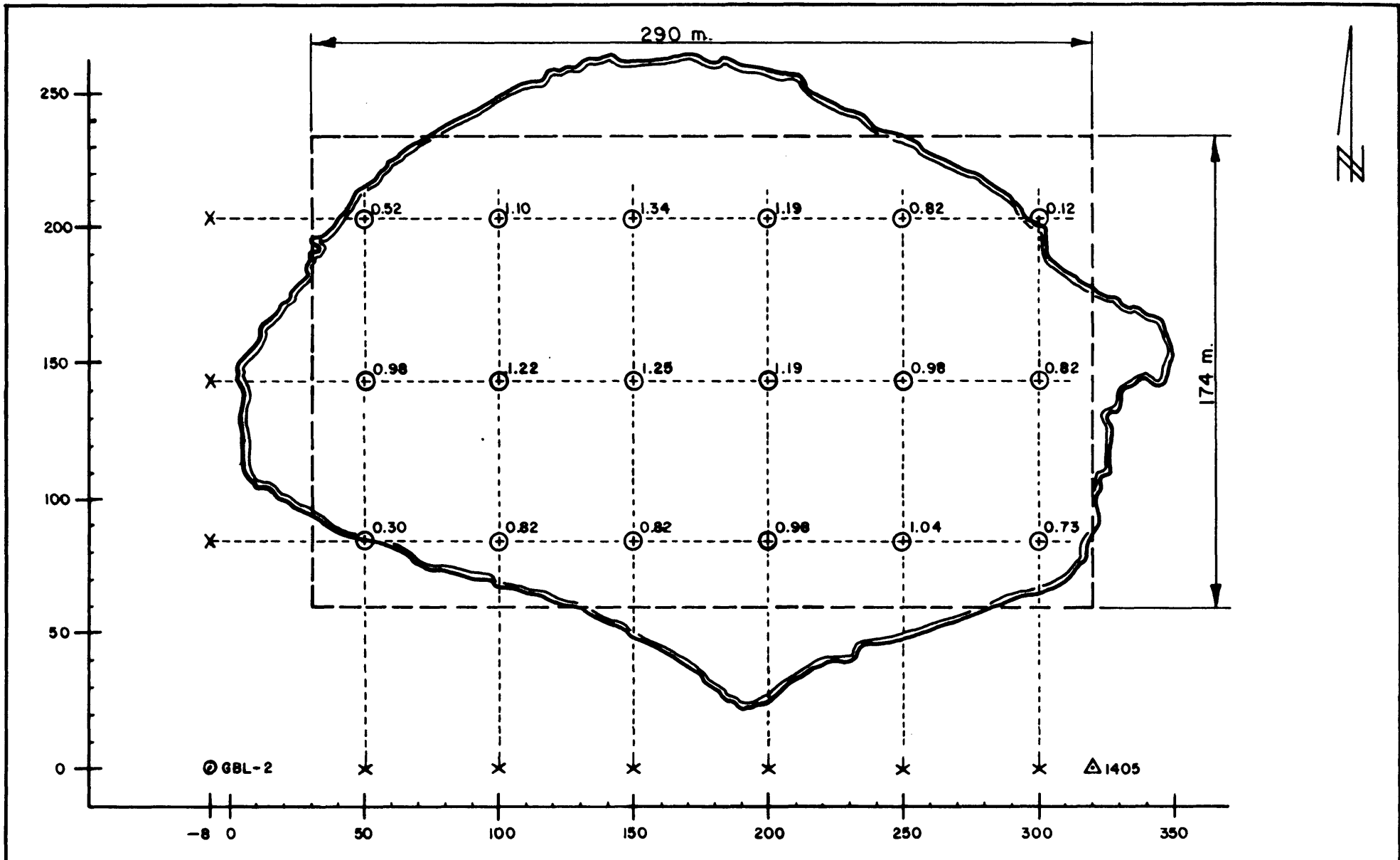
**VANAGORDA PLATEAU DEVELOPMENT**

**1987 PROGRAM**

Figure 1b

**NORTH WEST SURVEY CORPORATION INTERNATIONAL LTD.**





**LEGEND**

- ⊕ DEPTH STATION
- X GRID STATION
- LAKE PERIMETER from F-6-3 (E-3)
- - - AVERAGED OUTLINE

**DOAL LAKE SOUNDINGS**

AUGUST 21, 1987

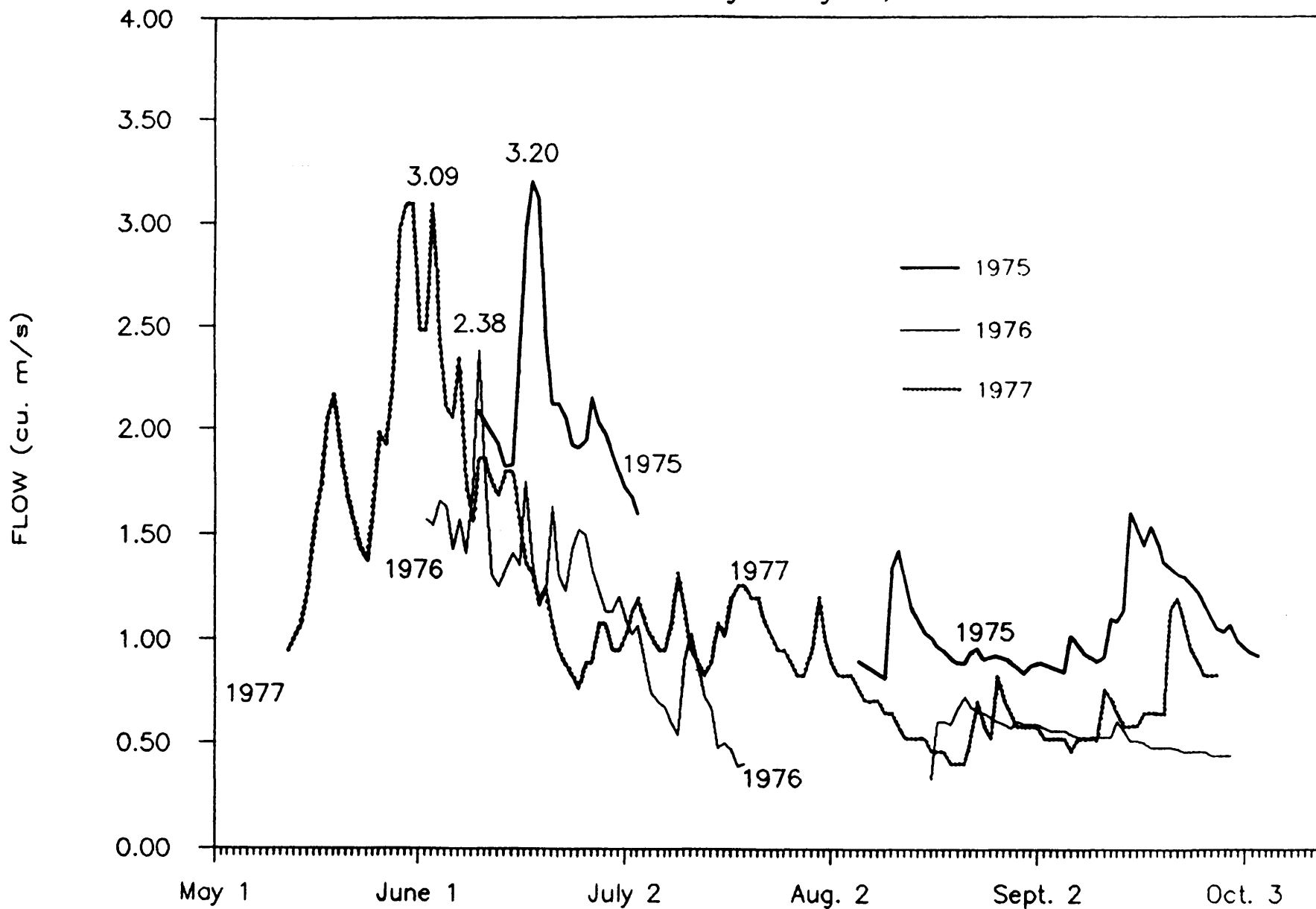
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**CURRAGH RESOURCES INC.**

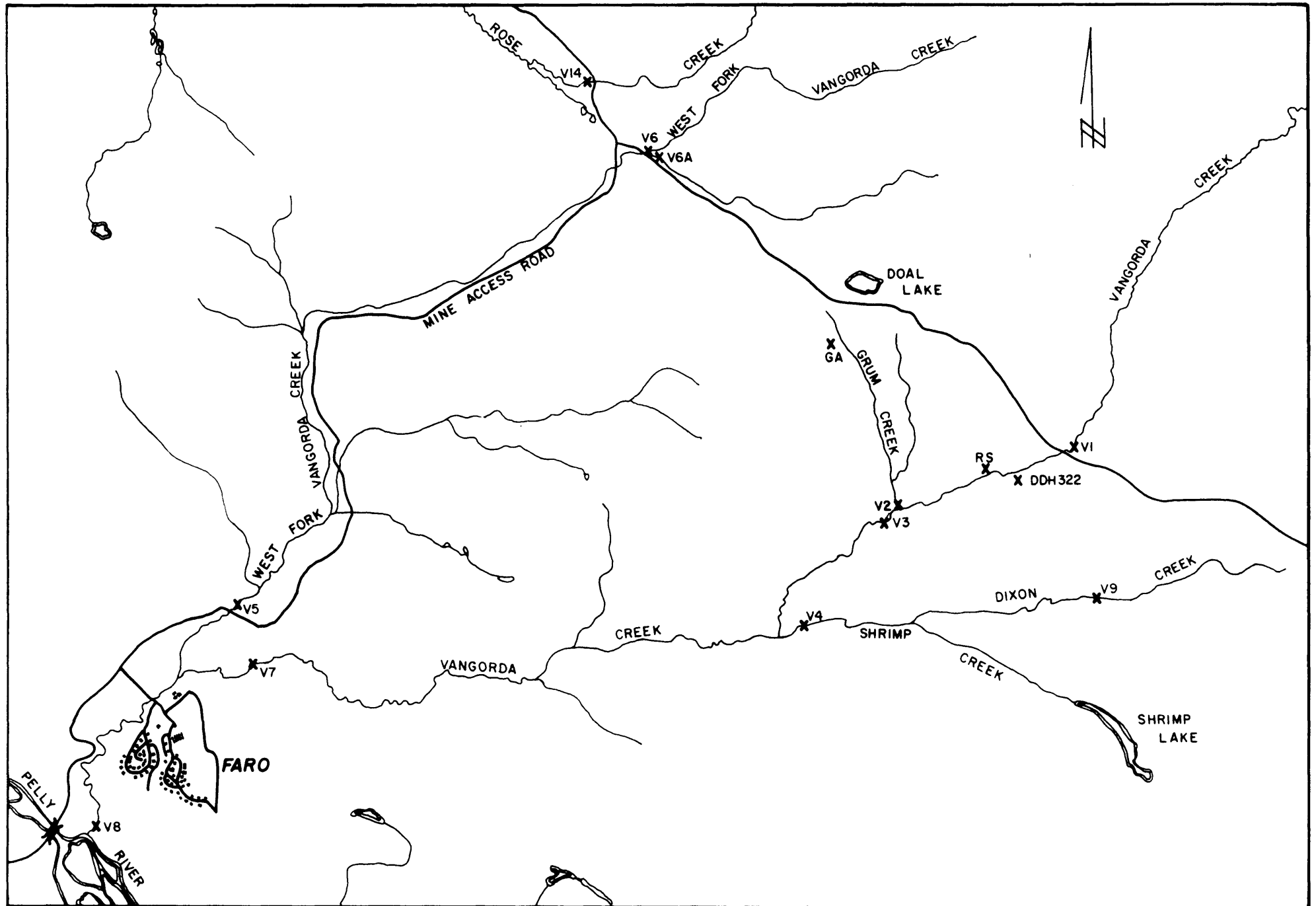
Figure 2

# VANGORDA CREEK FLOW 1975 - 1977

from Montreal Engineering Co., 1975 - 77



# WATER QUALITY MONITORING SITES



SCALE 1:50 000

CURRAGH RESOURCES INC.

Figure 4

**CURRAGH RESOURCES INC.**

**GEOTECHNICAL, HYDROLOGICAL AND HYDROGEOLOGICAL  
REVIEW FOR THE PROPOSED VANGORDA AND GRUM OPEN PITS**

**AUGUST, 1987**



**PITEAU ASSOCIATES**  
GEOTECHNICAL AND  
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APPENDIX A

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GEOTECHNICAL, HYDROLOGICAL AND HYDROGEOLOGICAL  
REVIEW FOR THE PROPOSED VANGORDA AND GRUM OPEN PITS

by  
Andrew T. Holmes  
and  
Alan F. Stewart

87-947

AUGUST, 1987



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APPENDIX A Soils Logging Information and Percolation Test Procedure

APPENDIX B Description of Rock Mechanics Core Logging Technique

APPENDIX C Falling Head Test Procedure



## FIGURES

- FIG. 1 Site Plan
- 2 Vangorda Pit Plan
- 3 Grum Pit Plan
- 4 Plan Showing Proposed Drilling Program
- 5 Hydrogeological Section A-A

## 1. INTRODUCTION

### 1.1 TERMS OF REFERENCE

As part of Curragh Resources' continuing work toward developing the Vangorda and Grum deposits over the next few years, Piteau Associates Engineering Ltd. was requested to review and comment on existing data and the proposed geological, geotechnical, hydrological and hydrogeological investigation programs for these deposits. The scope of this study was discussed in a series of telephone calls between Mr. A. Stewart of Piteau Associates and Messrs. M. Pelly and G. Jilson of Curragh Resources in mid-July, 1987. Specifically, Piteau Associates was to review: i) available reports prepared for Kerr Addison Explorations between 1975 and 1978; ii) reports prepared for Cyprus Anvil between 1979 and 1985; and iii) reports recently prepared for Curragh Resources. Other geological and exploration data relevant to geotechnical studies were also to be reviewed. All the above information was to be considered in the context of the proposed site work which is to be carried out later this summer and fall. As most of the proposed site work is related to dewatering the overburden, the emphasis of our review was to be on the hydrological and hydrogeological aspects of the project.

The field aspects of the review were undertaken by Mr. A.T. Holmes during the week of July 27 to 31, 1987. Initially, Mr. Holmes spent approximately three days in Curragh Resources' Whitehorse office, during which time he reviewed the available documents on file. Following this, approximately two days were spent at the site conducting a reconnaissance of field conditions. On returning to Vancouver, further review of relevant data, reports and the proposed field program was undertaken and a report summarizing our findings was prepared.

### 1.2 DESCRIPTION OF PROPOSED DEVELOPMENT

Two open pits are to be developed on the Vangorda Plateau (see Fig. 1). The Vangorda Pit, with open pit reserves of approximately 6.5 million tonnes, would

be the first developed. It is a relatively small pit with a proposed depth of about 70m. In order to mine this pit, Vangorda Creek will have to be diverted around the pit, and two small tributaries will have to be conveyed around the pit in interception trenches. The large diversion and small interception trenches could possibly be combined as one structure.

The Grum Pit, which would start producing ore shortly after Vangorda, is a much larger pit, having open pit reserves totalling 25 million tonnes, plus 1.7 million tonnes in the adjoining Champ Zone. Production from this pit would carry mining and milling operations through to the year 1999. Although there are no major diversions required for this pit, there may be water related problems due to the 270m depth of the pit, and the 100m plus depth of surficial soils identified on the proposed southeast wall.

### 1.3 DESCRIPTION OF CURRENTLY PROPOSED WORK

Drilling and excavation work are proposed for the Vangorda and Grum pit areas in the late summer and fall of 1987. Small diversion ditches and shallow finger ditches (i.e. trenches) are proposed in both pit areas to allow drainage of shallow surficial soils. Doal Lake is also to be drained. Trenching is to be carried out along possible diversion alignments and in potential waste dump areas. Drilling of about six holes in overburden, and extending a short distance into rock, is also proposed. Piezometers will be installed in these holes, and a pumping test is planned if sufficient quantities of water are encountered during drilling.

### 1.4 GEOLOGY

#### 1.4.1 Surficial Geology

There appears to be three basic surficial soils overlying the Grum/Vangorda area. The most widespread is a very dense, well graded (i.e. gravelly sandy silt with some clay) cohesive till-like material which appears to cover most of the Vangorda Pit area, and may be present

at thicknesses of greater than 100m over the southeast portion of the Grum orebody. This material also covers most of the potential waste dump areas for the Vangorda Pit, and some of the dump areas for the Grum Pit.

Sand and gravel (possibly deposited as a kame terrace with upper elevation at approximately 1305m) covers the portion of the Grum deposit south and west of the mine access road. It is present as a thin veneer near the proposed Vangorda diversion on the west side of Vangorda Creek, and underlies a portion of the potential waste dump area for the Grum Pit. This material is generally a well graded, very fine sand to fine gravel. Its thickness is not accurately known, but it probably overlies till in most areas.

Colluvium is present as a thin veneer on bedrock over much of the potential waste dump area for the Grum Pit. As this deposit is derived from phyllite, it is generally a silty material with platy gravel.

#### 1.4.2 Bedrock Geology

Calcareous and carbonaceous phyllites of the Vangorda formation will be the dominant rock types exposed in the walls of the proposed pits. Sulphide bearing quartzites and massive sulphides will primarily be mined as ore, but some of these lower grade ore rocks will be left in the walls. Altered Mt. Mye phyllites will be exposed near the base of the east wall in the Grum Pit.

The dominant plane of weakness present in the rock mass is the S2 foliation, which, in the Grum pit area, generally appears to dip shallowly (i.e. between about 10° to 35°) to the southwest (G. Jilson, March 29, 1985). However, relatively little detailed interpretation of foliation dip has been completed, and there is considerable evidence that both the strike and dip of the S2 foliation may vary considerably. In addition, there is concern that assumptions made regarding the dip of the S2

foliation during a previous geotechnical study (Montreal Engineering Company Limited, December, 1979) are sufficiently in error such that the results of this previous study must be seriously questioned. Little assessment of faulting in the proposed pit areas has been completed, although it is anticipated that a major fault zone, named the Bankruptcy Break (striking north/south and dipping about  $40^{\circ}$  west), will be encountered in the northeast wall of the Grum Pit.

## 2. VANGORDA PIT

The proposed Vangorda Pit is to cover an area approximately 900m x 400m (see Fig. 2). A maximum slope height of 120m will be developed in the north corner of the pit, with slopes on the east side of the pit averaging about 70 to 80m in height. Slopes in surficial soils will range in height from a few metres up to about 35m.

### 2.1 DIVERSION OF VANGORDA CREEK

Vangorda Creek must be diverted around the pit. The catchment area for the upper portion of the creek which must be diverted is approximately 22 Km<sup>2</sup>. A study of a proposed diversion dam and channel has already been conducted by Golder Geotechnical Consultants Ltd. (December, 1979), in conjunction with Hydrocon Engineering (Continental) Ltd. (flood frequency analysis and hydraulic design) and Atmex Geophysics Inc. (seismic survey).

A diversion dam site was identified on Vangorda Creek at the existing Vangorda Plateau access road (see Fig. 1). Based on seismic survey and test pit data, the proposed dam axis is underlain by till overlying bedrock, with some alluvium associated with the present creek channel. If an approximately 15m high diversion dam is to be constructed at this location, drilling will be required along the dam axis to determine foundation conditions to verify that low permeability till does exist down to bedrock, and to delineate the extent of alluvium present. Provided till does exist to bedrock, as is indicated by presently available data, an effective diversion dam, with minimal subsurface leakage, could be constructed at the proposed location.

An alternate diversion structure, located slightly upstream from the proposed dam, is also being considered (see Fig. 1). As this diversion would be located at a higher elevation on the creek, a much smaller structure would be required. This site was dismissed by Golder Associates due to the bedrock scarp on the west side of the creek, which would result in high construction costs for the

initial portion of the diversion channel. However, as the cost of constructing the proposed dam along the access road could be very high, it would be worthwhile to investigate the feasibility of locating a diversion structure at a narrower point in the valley. Mr. Holmes reconnoitred Vangorda Creek upstream of the mine access road on July 30, 1987, and a potential dam site, with a rock slope for an east abutment, was identified.

The diversion route initially recommended by Golder Associates follows the 1182m contour around the north end of the pit to an existing drainage channel which, in turn, flows into the existing Vangorda channel. Advantages and disadvantages to this route are:

#### Advantages

- Well away from the northeast and east walls of the proposed pit where seepage could cause stability problems.
- Diversion empties back into original Vangorda Creek channel.

#### Disadvantages

- Water is being diverted through area of mining activity, hence water quality could be affected by waste dumps, haulroads, etc.
- Much of the alignment will be constructed in shallow, weathered bedrock which, in highly fractured zones, could be more permeable than till.
- The outlet to the diversion is very steep; thus a carefully engineered channel would be required to prevent erosion.

An alternate diversion route around the southeast end of the pit is also being considered. This would require a diversion starting at about the same elevation, but would direct water to Dixon Creek, a tributary of Vangorda Creek which is located well outside the area of mining activity. Advantages and disadvantages of this route are:

## Advantages

- Diverted water is kept well away from area of mining activity.
- A much gentler grade could be achieved at the outlet end, such that a channel cut into phyllite would probably be all that is required.
- The diversion would intercept two small tributaries to Vangorda Creek that might otherwise flow into the pit.

## Disadvantages

- Channel is located above the east wall of the pit, hence seepage could cause stability problems on the east wall.
- Work may be required on small creek into which Vangorda Creek water is to be diverted. This could represent a large cost due to the length of the creek involved.

As will be discussed in Section 5.1.1, we recommend that the proposed trenching program along both of the potential diversion routes be carried out later this summer. Some minor trenching should also be performed in the upper tributary of Dixon Creek. If dense till exists along most of the alignment above the east wall, leakage is not likely to be a major problem and a channel along this route would warrant serious consideration.

A third diversion option, which is also being considered, involves the following procedure:

- i) Moving Vangorda Creek to the northern side of its present flood plain.
- ii) Mining the recoverable ore to the south of the relocated creek.
- iii) Establishing a final wall on the north side of the creek.
- iv) Rerouting Vangorda Creek along a bench on this final north wall.
- v) Complete mining in Vangorda Pit.
- vi) Flood or backfill pit with waste and re-establish creek in its original channel.

This diversion option would have the advantage of being a short diversion channel which would only convey the creek for a relatively short period of time. However, mill feed from the pit would be disrupted while the creek was being relocated on the north wall of the pit, and leakage from the diversion channel would recharge directly into the pit wall. The mill feed problem may be overcome by scheduling production in the Faro pit or Faro underground operations around the ore gap from the Vangorda pit. Leakage of the diversion may have to be prevented by lining the diversion channel along the north wall of the pit; however, for this relatively short diversion, the cost should not be prohibitive.

If the third diversion option is selected, it would have to be initiated at about the 1145m elevation. Some soils information should be collected along this proposed alignment. In order to obtain this information, two or three trenches should be excavated along the 1145m contour between the points where this contour intersects Vangorda Creek and the northeast wall of the proposed pit.

## 2.2 DRAINAGE OF SURFACE WATER FROM PIT AREA

A small diversion of a tributary creek above the east wall of the proposed pit, and some ditching in the pit area, are to be carried out later this year. As the flow in the tributary creek is very small (estimated at less than 1 L/s on July 30, 1986), there should be no problem diverting it to the Dixon Creek tributary.

A finger drain ditch system proposed for the pit area this year should drain the surficial soils quite well. Rates of seepage into these ditches are expected to be very small.

Once mining is underway, it would be desirable to collect local runoff plus any seepage from the Vangorda Creek diversion on a bench on the east wall of the pit. As this bench should be at or slightly below the bedrock/surficial soils contact, the 1130 or 1120 benches (see Fig. 2) are probably the most suitable. Pit planning should make provision for constructing small trenches on one of

these benches. As gravity drainage from the pit area would be impossible for a trench on the 1120 bench, and very difficult for one on the 1130 bench, a sump near the present location of Vangorda Creek would be required.

### 2.3 GROUNDWATER IN PIT SLOPES

Two piezometers installed in drillholes along Section 4E (in the Vangorda Valley), plus a flowing hole on Section 12, indicate that the water table is currently very high, being near or slightly above ground surface over the entire pit area.

Gravity drainage towards the pit is expected to result in partial dewatering of the slopes in surficial soils and in bedrock, but high groundwater conditions should be anticipated when assessing pit wall stability. While depressurization along specific structures, such as faults or shear zones, may be achieved with wells or drainholes, it is highly unlikely that measures to reduce pore pressures along foliation planes could be successfully implemented. A piezometer nest, outside the east limit of the pit, should be installed prior to mining, so that pore pressure can be monitored as the pit is excavated. This piezometer nest should be located such that pore pressure information can be obtained on either side of any major faults which may daylight in the northeast wall of the proposed pit.

### 2.4 SLOPE STABILITY ASSESSMENT

A report describing a preliminary geotechnical investigation and slope design for the Vangorda Pit was prepared by R. Lopaschuk of Cyprus Anvil on October 1, 1980. While the study was based on all data available at the time, and the recommended overall slope angles of  $40^{\circ}$  for the northeast wall (i.e. where the foliation dips out of the wall) and  $45^{\circ}$  for the southwest wall (i.e. where the foliation dips into the wall) do not seem unreasonable, it is noted that the analysis and design study had a number of limiting constraints. As discussed in the report, no drillhole information was available in the area of the proposed pit walls and none of the available core was oriented or mechanically logged.

In addition, no structural mapping data or groundwater information was available. However, the strength data that were used in the study, which were based on previous studies done for the Faro and Grum deposits, would seem to be reasonable.

As discussed in the Lopaschuk report, and has been seen at the Faro Pit, S2 foliation is considered to be the most prominent discontinuity affecting slope design. Thus, the determination of the orientation of this structural weakness on a few typical cross-sections through the Vangorda Pit, along with the determination of the mechanical properties of the rock, is considered important for rational slope design. The presence of high groundwater pressures in the slope can have a significant effect on slope stability. Information obtained to date (see Section 2.3, above) indicates that such groundwater conditions do exist and will, in all likelihood, be difficult to alter.

The overburden slopes in the Vangorda Pit are estimated to be up to about 35m high in glacial till. Preliminary design recommendations in the 1980 Lopaschuk report indicate that overall slope angles of  $37^{\circ}$  could be stable. Based on our brief review of the information provided, and considering the relatively low slope height (i.e. compared to Grum) of the surficial soils, such an overall slope angle is not unreasonable. However, further assessment of the overburden slope angle should be conducted.

Based on the above, it is recommended that further data collection, analysis and design is required for both the overburden and bedrock pit slopes. As will be discussed in more detail in Section 5.1.3, this work should initially involve obtaining oriented core to allow detailed structural interpretation of S2 foliation and other joints (particularly on the northeast wall) which, in turn, will allow a more rational slope design to be carried out. Sampling of the bedrock and overburden materials should also be completed to allow the mechanical and strength properties of these materials to be assessed, and to allow appropriate slope designs to be completed.

## 2.5 WASTE DUMPS

The most recent plan for the Vangorda pit waste is to create dumps on the slopes above Vangorda Creek or in the small tributary creek valley which exists immediately southwest of the pit. Curragh Resources' personnel will evaluate possible dump sites based on operational constraints, and select one or two potential sites which will have to be investigated in detail. As discussed in Section 3.5, it may be necessary to construct separate dumps for the soil and rock waste.

No waste dump site investigations have been carried out for the Vangorda Pit to date. However, once potential sites have been selected, field reconnaissance and test pitting should be conducted to determine foundation conditions, including type of surficial soils, strength and permeability, and position of the water table. Documentation of conditions in the Faro Pit waste dumps, at least some of which are expected to behave in a similar manner to those for the Vangorda Pit, is also recommended. Further comments and recommendations with regard to siting and investigating the waste dumps are given in Sections 3.5 and 5.1.4.

### 3. GRUM PIT

The Grum Pit is to be much larger than the Vangorda Pit. As currently planned, it extends over an area of about 1150m x 850m and is about 300m deep as measured from the highest point on the perimeter (see Fig. 3). Slopes in surficial soils will exceed 100m in height in the extreme east corner of the pit, and will average about 60m in height along the northeast and southeast walls.

#### 3.1 DIVERSIONS AND PIT DRAINAGE

There are no major diversions required for the Grum Pit. Two small creeks that feed Doal Lake are the only surface flows that must be diverted around the pit. Current plans are to divert both of these creeks to a small tributary of Vangorda Creek (see Fig. 1), although consideration is being given to diverting the more northerly of these two creeks into another Vangorda tributary further to the west.

The main creek that flows into the east end of Doal Lake is to be diverted later this summer to allow for drainage of Doal Lake. Based on test pits excavated for a foundation investigation (Montreal Engineering Company Limited, October, 1977), it is anticipated that the alignment of the proposed diversion will be underlain by a thin layer of organic material, over about 0.5 to 3.0m of gravelly sand. The gravelly sand overlies a silty sand or sandy silt till. If possible, the invert of the diversion trench should be excavated into the till along the entire length of the diversion alignment. However, this may not be a practicable recommendation for the diversion trench that is to be installed this summer, as it could involve trenching to a very great depth in some areas, making grading difficult. Therefore, the diversion ditch should be excavated to a nominal 1.5m depth, and should be graded as uniformly as possible to the point of discharge. If the ditch, which will be excavated this summer, is intended to be permanent for the life of the mine, the trench should be wide enough to ensure adequate cross-sectional area for the 50 year storm flow. This flow would have to be determined prior to construction. The flow frequency

relationship for the drainage basin could be determined using the same equations and procedure as was used for estimating flows in Vangorda Creek (Golder Associates, December, 1979).

Once stripping of overburden from the pit starts, a shallow trench could be located closer to the pit crest, in an area where most of the shallow gravelly sand will have been removed. This trench could intercept local surface runoff, plus any groundwater which seeps under the diversion trench, and convey it by gravity back into the diversion trench at some point further downstream. The tributary creek to Vangorda Creek, which is to receive the diverted water, has coarse channel deposits exposed along its length and should be capable of carrying the expected flows, provided Doal Lake is not drained too quickly.

An in-pit ditch may be required to intercept water on a bench at the base of the slope in surficial soils (see Fig. 5). This ditch would collect any seepage which enters the pit through the surficial soils or along the surficial soils/bedrock contact. A sump would have to be maintained at some point on the bench to enable the collected seepage to be pumped from the pit. Present indications are that this quantity of seepage will be small, as the bulk of the surficial soils are expected to be a dense silty till with low permeability. An investigation program, as discussed in Section 5.2, is to be carried out later this year to determine the nature of these soils.

### 3.2 GROUNDWATER IN PIT SLOPES

Four piezometers have been installed in the pit area by Montreal Engineering personnel (Montreal Engineering Company Ltd, December, 1979). Three of these were installed in bedrock, while the fourth was installed in overburden. Piezometric heads are all near ground surface and relative hydraulic heads measured between piezometers show 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 therefore expected to be worst on the northeast and east walls of the pit.

Some natural depressurization of the slopes in surficial soils is expected to occur due to gravity drainage towards the pit. However, based on observations in the Faro Pit, depressurization of the bedrock slopes is expected to be minimal, particularly on the recharge side of the pit (i.e. northeast and east). Some depressurization of fault structures (eg. Doal Lake Fault, Bankruptcy Break) could probably be achieved by drilling wells or drainholes to intersect them, but depressurization of the entire rock mass would be extremely difficult due to the low permeability of the rock mass and the height of the slopes. Stability analyses should be performed to assess the affect that the major structures may have on the slopes, so that the benefits of depressurizing the structures can be evaluated. Similar analyses should also be performed to determine the benefits of depressurizing foliation planes, although a 30% reduction in pore pressure should be considered as the best depressurization which could likely be achieved.

Results of falling head tests to be run in piezometers, and possibly results of a pump test in a bedrock well, will be available later this year. However, unless these results indicate that the rock mass is reasonably permeable, mine planning should realistically be based on high groundwater conditions in the pit slopes.

### 3.3 GROUNDWATER IN THE BASE OF THE PIT

An exploration decline was constructed in the Grum Pit area in the mid 1970's. The exploration adit developed from this decline extended down to about the 1130m elevation, with many drillholes fanning out into the ore. Based on a proposal from Canadian Mine Services to Kerr Addison Exploration regarding a pumping system, dated June, 1976, total seepage inflow to the adit during the exploration period was estimated to be about 3 to 5 L/s. Most of this flow evidently came from the ore (Montreal Engineering, December, 1979), which seems reasonable, based on our knowledge of groundwater in the Faro Pit.

The observed flows into the decline were apparently quite low, indicating that either the ore is of low permeability (which is doubtful) or the ore was not

being recharged quickly. If the latter is the case, the exploration adit would make an ideal drainage gallery to dewater the ore in the Stage I pit and early phases of the ultimate pit. Rehabilitation of the adit would not be required, as all that is needed is a means of installing a pump near the lowest point in the exploration adit. This could be achieved with a 150mm or 200mm diameter well drilled from ground surface or from a bench on the pit wall. Pilot holes could be drilled until one successfully intersected the adit, and then a larger diameter hole could be reamed out and cased. An initial pumping rate of about 15 to 20 L/s would be desirable to dewater the adit, but a pumping rate of between about 2.5 and 5 L/s would probably be sufficient to maintain a dewatered adit once initial dewatering is complete.

### 3.4 SLOPE STABILITY ASSESSMENT

The Grum Pit is to be developed in a number of phases or pushbacks. As for the Vangorda Pit, the regional geology in the area of the Grum Pit indicates that the S2 foliation generally dips moderately toward the southwest. Therefore, the design of the northeast wall of the pit will likely be controlled by the foliation. In a report to Cyprus Anvil Mining Corporation dated December, 1979, Montreal Engineering indicated that four diamond drillholes had been drilled and logged and that the S2 foliation dip had been found to dip to the west at between about 33° and 70°. Rock slope design recommendations given in the December, 1979 report for the eastern walls of the pit indicated that overall slope angles of about 30° to 40° would be required to ensure stability. Based on an apparent lack of adversely oriented throughgoing discontinuities on the western side of the proposed pit, it was recommended that the west pit slope be designed at an overall slope angle of 45°.

Subsequent to the studies by Montreal Engineering, a report was prepared by Mr. G. Jilson in March, 1985 that provides an updated assessment of the orientation of the critical S2 foliation planes. In this report, it is concluded that there is considerable doubt as to the validity of previous attempts at correctly defining the orientation of the foliation from drill core and that it is

possible that the S2 foliation may dip as flat as  $10^{\circ}$  to the west near the bottom of the proposed pit wall. In addition, in the upper portion of the pit wall, foliation may actually dip into the wall (i.e. to the east). Considering the concerns with respect to the orientation of the S2 foliation, the preliminary slope designs presented in the December, 1979 report must be questioned. Recommendations for further work, including obtaining and logging oriented core, mapping pit walls as they are developed, etc. are included in Section 5.

Recommendations concerning the stability of slopes excavated in surficial soils were included in a report by Montreal Engineering dated August, 1979. In this report, it was noted that three holes had been drilled into the deep overburden on the eastern side of the proposed pit and that the surficial soils consisted primarily of a gravelly sandy silt with some clay. This material, which was referred to as a till, was categorized as having a high density and low plasticity. Preliminary slope design recommendations for long term slopes cut in this material were: i)  $30^{\circ}$  overall angles for slopes where seepage is minimal; and ii)  $\leq 25^{\circ}$  overall slope angles where seepage is significant. While, in general terms, these overall slope angles do not appear unreasonable, the soil slopes should probably be benched with 5 to 10m berms at suitable intervals.

Revegetation of the slopes may also be desirable. In any event, further work is recommended to arrive at final slope design recommendations in the surficial soils. Such work should be focused on substantiating the findings of the August, 1979 report, investigating the possibility of encountering saturated sand and/or gravel zones in the overburden that might be subject to instability (and may have to be buttressed or otherwise protected), and obtaining accurate strength parameters for the surficial soils. During mining, assessment of the exposed first phase slopes in overburden should be undertaken to obtain further data that will help to optimize the overburden slope design. Further comments with regard to geotechnical work recommended for the surficial soil slopes are included in Section 5.

### 3.5 WASTE DUMPS

Waste dumps, as initially planned by Kerr Addison Mines, are addressed in the Montreal Engineering report dated August, 1979. While preliminary assessments of safe waste dump angles in the 1979 report indicate overall slope angles of  $28^{\circ}$  for rock waste, and  $23^{\circ}$  for surficial soil waste should be acceptable, it is difficult to comment precisely on the accuracy of these recommendations. Depending on the exact dump location and method of placement of dump materials, the above recommended dumping angles may be either too conservative or too optimistic.

It is our understanding that Curragh Resources has not made any final plans regarding waste dump locations and that the location shown on Fig. 1 is only tentative and likely to change. With regard to siting the waste dumps for the Grum area (and the Vangorda area for that matter), it is suggested that separate dumps for the rock and surficial soils will likely be required and that the best location for any dump material, particularly for the surficial waste, would be in a depression that is surrounded on all sides by sound rock or soil. A mined out pit would be ideal. If this cannot be done, consideration should then be given to a valley or draw that has confinement on at least two sides or, failing this, to locate the waste dumps on as flat topography as possible. While these siting considerations may seem rather extreme for most waste dumps, the generally poor quality of the soil and rock waste may rule out locating and building the waste dumps in a more conventional manner on somewhat steeper, more open terrain.

Depending on the selected locations for the waste dumps, and depending on the properties of the waste materials, consideration may have to be given to impounding and revegetating the dump material. This could be particularly relevant to the unusually large volume of surficial soils which may have a tendency to flow or otherwise fail if loose dumped and allowed to become saturated. Such problems could possibly be overcome by compacting the waste dump in lifts as the material is dumped, or at least by compacting a dam-like structure or buttress of waste, behind which the remaining waste could be loose dumped.

Recommendations regarding the investigation and design of waste dumps are given in Sections 5.1.4 and 5.2.4.

#### 4. ENVIRONMENTAL CONCERNS

The following discussion on environmental concerns is limited to potential impacts on water quality, as that is the main facet of the environment which is affected by mine drainage and waste dumps.

##### 4.1 SURFACE WATER QUALITY

Surface water quality is currently monitored at nine locations along creeks which drain the Vangorda Plateau area. One of the water quality monitoring stations is on a tributary of Rose Creek, while the rest are on Vangorda Creek or its tributaries. Discharge from the decline in the Grum deposit, from Doal Lake and from a flowing hole near Doal Lake are also monitored. It is recommended that one more station be added on Dixon Creek, just upstream of its confluence with Vangorda Creek, as Dixon Creek would receive the main Vangorda Creek flow if the easterly (i.e. alternate) diversion option is chosen.

Recent water quality data for the above monitoring network shows that all metal concentrations analyzed for are extremely low, with the exception of the 2.3 mg/L zinc concentration in the Grum decline. The 2.3 mg/L zinc concentration in the water from the Grum decline is above the 0.5 mg/L effluent regulation set by Indian and Northern Affairs; however, as the decline discharge settles and aerates in a pond before it flows into the Creek, zinc concentrations are generally near the allowable concentration where the flow reaches the creek. If the decline is pumped after mining starts, suspended solids and total metals concentrations are expected to increase. This would require close monitoring of the settling pond system to ensure effluent regulations are being met.

##### 4.2 ACID MINE DRAINAGE

Acid mine drainage from the exploration decline has not been a problem to date. This is probably due to the high alkalinity of the groundwater in the area.

However, if sulphide rich waste rock is placed in a dump through which unbuffered, well oxygenated water derived from precipitation can infiltrate, there is a good potential that acid drainage could develop. Waste dump planning and scheduling should consider the problem of acid generating waste. Possible solutions which should be investigated include sandwiching acid generating waste between calcareous phyllites to neutralize the sulphur, or placing it in the bottom of the Vangorda pit, and covering it with other wastes, to ensure that there is no supply of oxygen to the bacterial processes that are required to initiate acid mine drainage.

#### 4.3 GROUNDWATER QUALITY

A flowing hole in the Vangorda pit area (V-322), plus a spring near the discovery outcrop beside Vangorda Creek, should be sampled. These samples would provide some baseline groundwater quality data which could prove to be useful when assessing environmental impacts in the future.

## 5. RECOMMENDATIONS REGARDING THE UPCOMING FIELD INVESTIGATION AND POSSIBLE FUTURE INVESTIGATIONS

A program involving ditching, drilling and trenching is proposed for later this summer and continuing into the fall. The objectives of this program are to:

- i) Investigate possible diversion channel alignments around the Vangorda Pit.
- ii) Divert a small creek which flows through the Vangorda Pit area, and drain the shallow surficial soils in the pit area.
- iii) Divert a small creek which flows into Doal Lake and construct a ditch to drain the lake.
- iv) Drain the shallow surficial soils in the Grum Pit area.
- v) Determine the character and permeability of the surficial soils and shallow bedrock in the east area of the Grum Pit, and investigate the feasibility of dewatering these soils prior to mining.

Our recommendations regarding data that should be collected during this program are given in the following, along with our comments on the program as currently proposed. Also included are additional comments concerning anticipated geotechnical matters that will have to be addressed before final mine designs can be prepared.

### 5.1 VANGORDA PIT AREA

#### 5.1.1 Trenching and Diversion Works

It is recommended that the proposed test trenching program along the potential Vangorda Creek diversion routes be carried out this year. Some trenching should also be carried out to assess valley bottom soils in the

tributary of Dixon Creek which would receive diverted water if the eastern route is selected. Surficial soils exposed in the test trenches should be carefully logged, and the strength of the soils should be estimated (see descriptive terms in Appendix A). Two or three percolation tests should also be performed in each representative soil type encountered, to provide an indication of the in-situ permeability. These tests should be performed using the standard methods employed when evaluating effluent drain-field sites (see Appendix A). Some photographs of typical soils should be taken and a few samples should be selected for grain size analysis. Any bedrock exposed in the trenches should be described in terms of lithology and mechanical properties (rippability and fracturing).

The preparation of a limited number of typical cross sections through Dixon Creek should also be carried out to allow an assessment to be made of the capability of Dixon Creek to carry the flow from Vangorda Creek. In conjunction with this, if more recent stream flow data than that available for Hydrocon's assessment of Vangorda Creek in 1979 is available, a review of Hydrocon's study, and possible updating of the flood flows, should be completed.

Once the above information has been assessed, the Vangorda Creek diversion route should be selected and a preliminary design prepared. Following this, additional, more detailed work will be required to provide a better understanding of foundation conditions in critical areas, such as in the area of the proposed diversion structure across Vangorda Creek. If a large dam is to be constructed (as proposed by Golder Associates), and if bedrock is too deep to trench to, or groundwater seepage is too severe, drilling and soil sampling would likely be required to determine foundation conditions and delineate borrow material areas and properties. After the surficial sediment and bedrock characteristics along the chosen diversion route are accurately known, the proposed hydraulic design should be re-evaluated.

The diversion trench that is proposed to be excavated this summer to divert a small creek that flows through the Vangorda pit area should be carefully logged to obtain information on surficial soils. Consideration should also be given to constructing weirs on either end of this diversion to measure seepage losses. This information could prove to be very useful when planning the Vangorda Creek diversion and should be relatively simple to collect. However, this should only be done if little or no seepage into the trench is noted during construction. If too much seepage into the trench is occurring, it would be difficult to estimate true seepage losses between the weirs.

The finger drains that are proposed for the mine area should proceed as planned. While they should do an adequate job of draining the shallow surficial soils, it is expected that this will only involve very low rates of flow.

#### 5.1.2 Investigations for Assessment of Dewatering Requirements

It is understood that some diamond drilling is to be carried out for further ore evaluation in the Vangorda Pit area. If a hole is drilled near V-322 (flowing hole), and a similar water-bearing zone is encountered, a standpipe piezometer should be installed and sealed into the zone making water. If a piezometer is installed, Drillhole V-322 should be pumped and a mini pump test should be performed. Monitoring of the new piezometer would give some indication of the hydraulic connection along the structure which is making water. As this structure must extend well outside the pit area for the artesian head to be maintained, an interception well outside the pit perimeter should be considered when pit excavation begins.

#### 5.1.3 Investigations for Pit Slope Stability

As discussed in Section 2.4, further data collection (i.e. including structural and mechanical logging of oriented core and sampling of soil

overburden) should be undertaken before final pit slope designs are prepared for both the bedrock and surficial soils. With reference to the diamond drilling program referred to above in Section 5.1.2, it is recommended that soil sampling and testing of the overburden portion of a few of these holes be carried out to allow the character of the soils at depth to be determined. In this regard, it is suggested that standard penetration tests be performed at regular (i.e. at least every 15m) intervals and when a different soil type is encountered in the drillholes. Sampling of soils using a thick walled drive sampler or by coring should also be undertaken at the same intervals in the drillholes. Depending on the materials obtained, suitable laboratory tests (i.e. such as grain size analyses, Atterberg Limits, etc.) should then be carried out. If downhole geophysics is planned as a regular investigative tool, it is suggested that electrical resistivity (run in an open hole) or neutron porosity or natural gamma (run in a cased hole) could be utilized to delineate various stratigraphies in the surficial soils. These methods may be beneficial in locating saturated sandy, gravelly or cobbly layers which could be the source of stability problems on the soils portion of the pit slope. As a supplement to the above sampling and testing, it is suggested that the tills that seem to comprise much of the surficial material at the site be compared to the tills that are exposed along a portion of the Faro Pit wall. If these soils are considered to be similar, it would be advantageous to document the behaviour of the tills at the Faro Pit with a view toward extrapolating and/or estimating likely soils behaviour at the Vangorda Pit. By doing this, there may be some possible savings in the amount of testing required in the Vangorda area.

As discussed in Section 2.4, the drilling of oriented core is recommended to obtain a more accurate and detailed structural interpretation of the S2 foliation and other relevant structural discontinuities. All core should be mechanically logged as per the core logging techniques outlined in

Appendix B. Sufficient data should be obtained such that at least two or three "typical design sections" through the deposit can be constructed. At this time, it is anticipated that sufficient index and shear strength testing of the rock has been undertaken for a preliminary design of the pit walls and that further such testing may not be required.

#### 5.1.4 Investigations for Waste Dumps

As discussed in Section 2.5, once potential waste dump sites have been selected, field reconnaissance, test pitting and sampling should be conducted to determine foundation conditions. The surficial soils encountered should be classified in terms of soil type, strength and permeability, and the location of the water table, if known, should be recorded. Appropriate laboratory tests, such as grain size analyses and Atterberg Limits, should be conducted, as required.

With regard to investigating the properties and stability of the surficial soil dump materials for purposes of designing stable overburden waste dumps, it is recommended that representative samples of the appropriate soils be obtained and that grain size analyses and Atterberg Limit tests be conducted. Strength and permeability testing at various levels of compaction should also be conducted, the end result being the determination of a relationship between strength and density. If possible, it would also be desirable to develop a relationship between lift thickness and density for loose dumped material.

For the waste rock dump(s), freeze-thaw tests, slake durability tests and swelling tests may have to be conducted to attempt to evaluate the long term behaviour of the waste rock. It is further recommended that, because it is anticipated that the waste rock in the Vangorda and Grum rock dumps will behave in a similar manner to the Faro waste dumps that are predomi-

nantly comprised of schist, the relevant Faro waste dumps should be documented with respect to their behaviour and stability. In addition, it is suggested that the Faro waste dumps be test pitted and sampled, that grain size analyses be carried out and that percolation tests be performed in the test pits.

Following the above field and laboratory assessments of the soil and bedrock waste materials, appropriate stability analyses would be completed and design recommendations made for the waste dumps.

## 5.2 GRUM PIT AREA

### 5.2.1 Diversions and Ditching

Soils encountered while excavating the diversion and ditches proposed for the Grum area should be carefully logged, as discussed above in Section 5.1.1. A few shallow piezometers (i.e. simple standpipes installed with a backhoe) should be installed throughout the pit area so that the effect of the drains can be evaluated. Finger drains should be excavated from the drains currently proposed for this area to improve not only the rate at which drainage will occur, but also the amount of drainage which will occur.

As discussed in Section 3.1, the diversion ditch to intercept the creek flowing into Doal Lake should be excavated to a depth of about 1.5m. While this may not be sufficiently deep to fully penetrate the sand and gravel which overlies till throughout much of this area, it will be deep enough to cut off most of the seepage through the sand and gravel that flows towards the mine area. Seepage under this diversion could be picked up in another trench, located nearer to the pit crest, after stripping for the pit is underway. If this diversion is to be part of the permanent trench system around the northeast perimeter of the pit, it should be sufficiently wide to handle the 50 year storm flow.

The ditching and diversion works should proceed as soon as possible so that the effectiveness of the diversion and drainage ditches can be evaluated on both a long term and seasonal basis. If any problems are encountered with draining the area, they could then be addressed in a rational manner before mining commences, rather than having to contend with wet conditions during the early phases of stripping.

#### 5.2.2 Investigations for Assessment of Dewatering Requirements

Drilling in the deep surficial soils in the eastern area of the pit is to be carried out later this summer. This drilling is to be performed by a contractor with water well experience, as the main purpose of the program is to obtain hydrogeological data. The budget, as it currently stands, allows for six rotary holes to be completed with piezometers, plus one pumping well.

We recommend that five rotary holes for piezometer installations be drilled at the locations shown on Fig. 4. Each hole should be completed with one piezometer in bedrock, and two or three in surficial soils. All piezometers should be properly sealed with cement so that falling head tests can be performed to provide estimates of hydraulic conductivity. Procedures for conducting falling head tests in sealed standpipe piezometers are included in Appendix C.

The drillers or a supervising geologist should log the soils carefully and keep notes on water flows from the drill. If zones of coarse, clean sediments are encountered which appear fairly permeable, they should be developed briefly so that flow rates can be accurately measured (in a bucket) and recorded. Representative samples of the till and any sand and gravel should be bagged for future reference and possible laboratory testing (see Section 5.2.3 for further comments on sampling and testing).

Once the five piezometer holes have been completed, a decision can be made as to whether or not a pumping well should be constructed. It should only be constructed if significant water bearing zones are encountered during drilling, or if falling head tests indicate there are moderately to highly permeable zones in the till or in the bedrock. The most likely location for a successful pumping well is shown in Figs. 4 and 5. There is the possibility of encountering coarse sediments in the bedrock channel located here, or alternatively, encountering a fracture zone in bedrock associated with the Doal Lake Fault. While it is unlikely that a well, developed in either the bedrock channel or in a fractured zone in rock, would produce more than about 2 L/s, a pump test run at even a low pumping rate can provide valuable hydrogeological data. If a pumping test is performed, it should be continued for a period of a few days to a week, as there could be boundaries encountered many hours after testing begins, due to the expected low permeability of the sediments and rock. All piezometers should be monitored during any pumping tests which are performed.

Data from the drilling program should be evaluated so that an estimate of groundwater conditions which will be encountered when excavating the overburden in the Grum Pit can be made. Planning of groundwater control measures could then be carried out in conjunction with the detailed mine planning.

### 5.2.3 Investigations for Pit Slope Stability

Recommendations concerning the investigation and design of pit slopes in the Grum Pit are considered to be virtually identical to those discussed in Section 5.1.3 for the Vangorda Pit. However, the substantially increased slope heights in both the overburden and bedrock portions of the Grum Pit serve to increase the need for and the importance of such studies.

It is noteworthy that the phased approach to mining the pit will allow trial interim slopes to be mined and documented before final slope designs are prepared.

With regard to the rotary drilling program to be carried out this summer, it is recommended that, if possible, the driller be equipped to conduct soil sampling and penetration testing as discussed for the Vangorda Pit in Section 5.1.3. He should also be instructed to collect samples of the cuttings every 1.5m in the holes so that visual and laboratory classifications of the materials can be made by an experienced engineer. Such a sampling program, along with the recommended penetration tests, drive sampling (and possibly geophysical logging) and suitable laboratory testing, should give a good indication of the properties of the soils that will be encountered in the pit walls. However, it may still be necessary at some time in the future (i.e. before final slope designs are prepared) to drill and sample the soils using a conventional soil drilling rig. Although the need for downhole pressuremeter tests is uncertain, such testing cannot be ruled out at this time.

Previous recommendations for developing more accurate structural interpretations of the bedrock and developing "typical design sections" through the use of oriented core are also important for the Grum Pit. Such work will allow a more rational initial design for the high pit walls that eventually will be developed at Grum.

An additional source of data that should be utilized in the assessment and determination of final slope design recommendations (for both the rock and soil slopes) will be the exposed interim mining slopes. The phased approach to mining the Grum Pit should uncover a wealth of geotechnical information that should be recorded and analyzed for use in updating the final pit wall design.

#### 5.2.4 Investigations for Waste Dumps

Investigations for waste dumps for the Grum deposit should be carried out in an identical manner to that described in Section 5.1.4 for the Vangorda deposit. These investigations will be even more critical than that for the Vangorda area, due to the increased volume of material that will be mined and the larger size of the waste dumps that will be created.

Respectfully submitted,

PITEAU ASSOCIATES ENGINEERING LTD.



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per 

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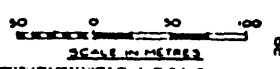
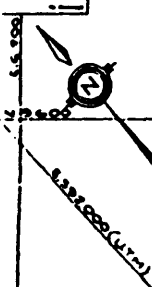
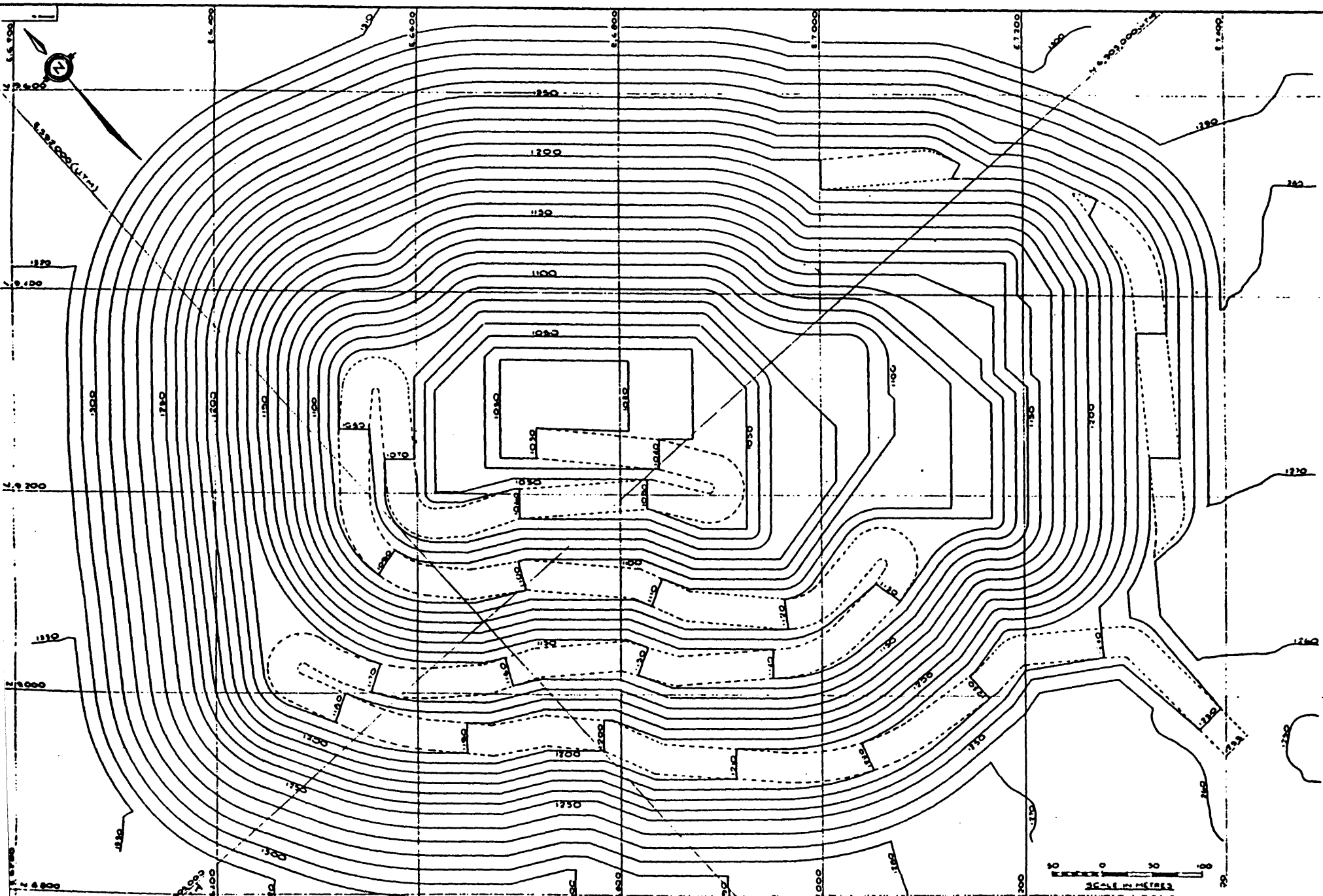
August 20, 1987

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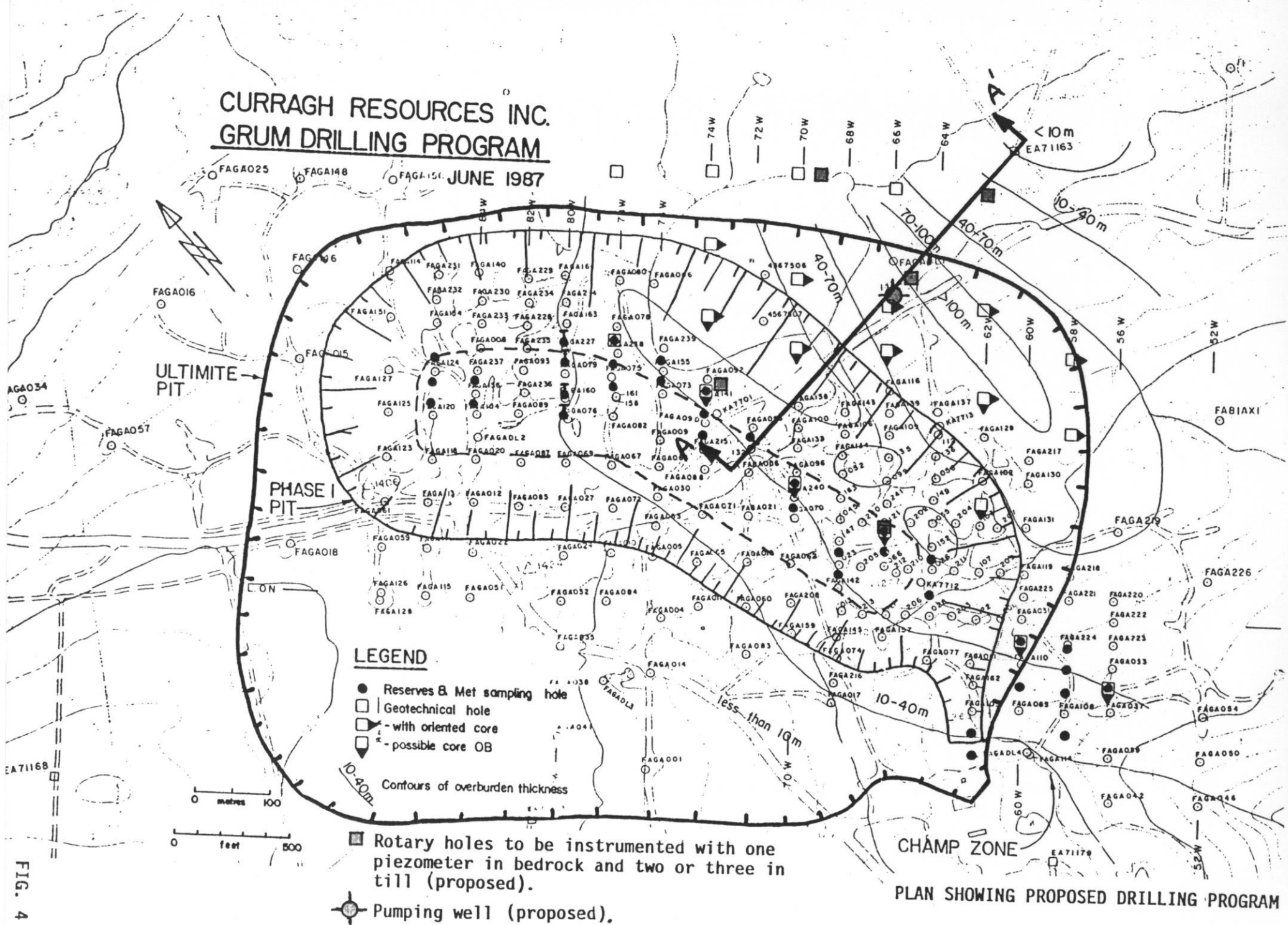


PROPERTY		OWNER		COURCH RESOURCES		KILBORN		GRUM PIT PLAN	
1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

GRUM PIT PLAN  
 GRUM DEPOSIT  
 OPEN PIT PLAN  
 DATE

# CURRAGH RESOURCES INC. GRUM DRILLING PROGRAM

JUNE 1987



## LEGEND

- Reserves & Met sampling hole
- Geotechnical hole
- ◻ with oriented core
- ◻ possible core OB
- Contours of overburden thickness

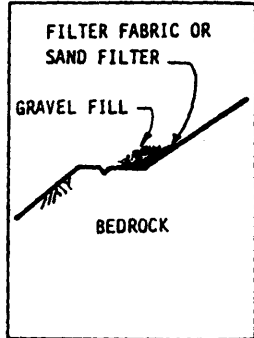
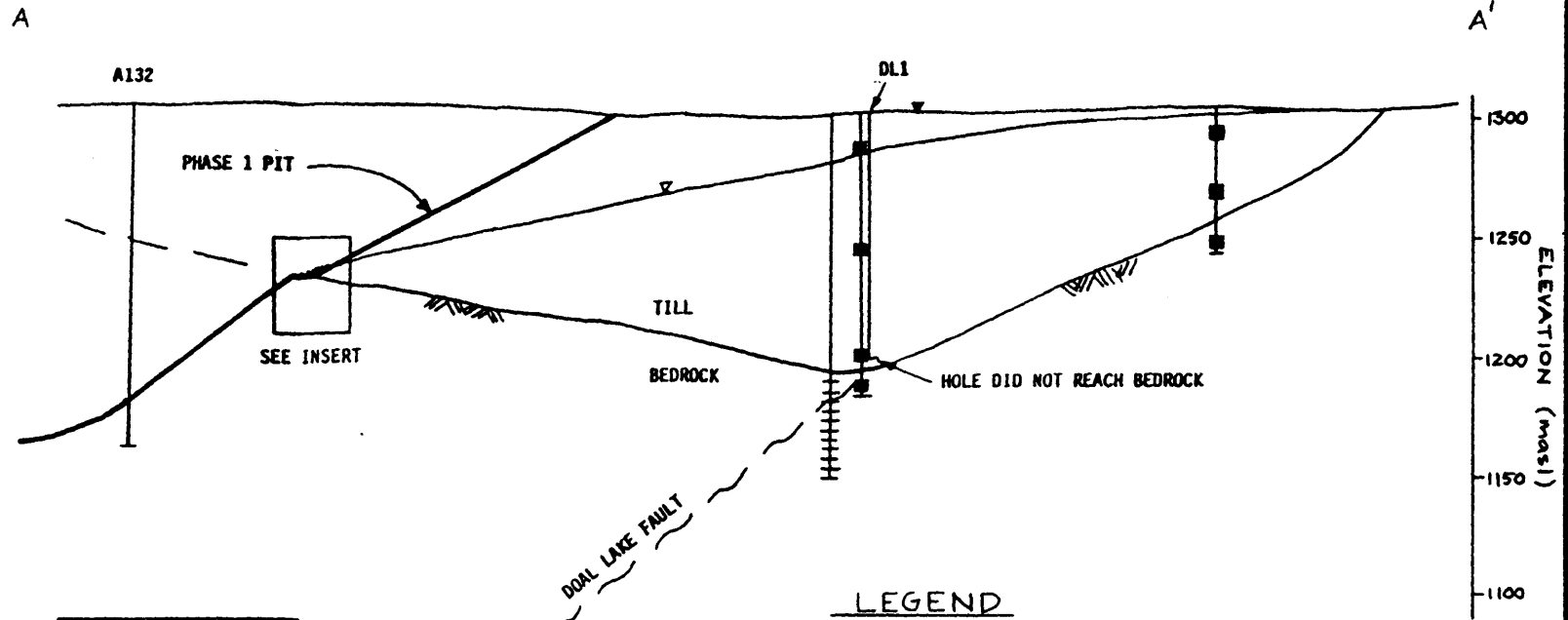
◻ Rotary holes to be instrumented with one piezometer in bedrock and two or three in till (proposed).

⊕ Pumping well (proposed).

CHAMP ZONE  
PLAN SHOWING PROPOSED DRILLING PROGRAM

FIG. 4

JOB NO 947



POSSIBLE DESIGN FOR TOE BERM TO STABILIZE TOE OF OVERBURDEN SLOPE

**LEGEND**

- PRESENT WATER TABLE
- ESTIMATED WATER TABLE WHEN PIT IS EXCAVATED
- EXISTING HOLES
- PROPOSED MONITORING HOLE SHOWING ONE STANDPIPE PIEZOMETER COMPLETED IN BEDROCK AND TWO OR THREE COMPLETED IN TILL
- PROPOSED PUMPING WELL-SCREEN TO BE INSTALLED IN WATER-BEARING ZONE WITHIN TILL UNIT, IF ENCOUNTERED. HOLE TO BE DRILLED INTO BEDROCK AFTER SHALLOW PUMP TEST. OPEN HOLE IN BEDROCK TO BE TESTED IF WATER ENCOUNTERED IN FAULT OR FRACTURE ZONE.

SCALE = 1:2000  
NO VERTICAL EXAGGERATION

FIG. 5

NOTE: For location of section see Fig. 4

<p>CURRAGH RESOURCES VANCOUVER/GRIM DEVELOPMENT</p>	<p>PITEAU ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY</p>	<p>BY: HWN</p>	<p>DATE: AUG '87</p>
		<p>HYDROGEOLOGICAL SECTION A-A'</p>	