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# CURRAGH RESOURCES INC.

# FARO MINE ABANDONMENT PLAN

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## SUMMARY

This report describes the abandonment plan developed by Curragh Resources Inc. for the Faro open pit and area. The objective of the plan is to abandon the Faro minesite with no long term maintenance requirements. Until it can be demonstrated that the plan will achieve this objective, Curragh will provide maintenance, including water treatment where required, to limit the abandoned minesite's impact on Rose Creek to an acceptable level.

The report consists of plans for abandonment of the Faro pit and area and details of an ongoing monitoring/research program designed to assess these plans. Cost estimates and implementation schedules are included. The major elements of the plans and of the monitoring/research program are summarized below.

i. The Zone I/III Open Pit

The Zone I/III open pit will be partly backfilled with potentially acid-generating rock and will be flooded to the 3920 ft elevation by diverting Faro Creek flow into the pit in 1994. The water cover will inhibit acid generation by preventing further oxidation of submerged sulphides.

Two dykes will be constructed in the western and southern pit exits while flooding is in progress. This flooding will require approximately 8 years. When the water level reaches the overflow elevation, Faro Creek will be diverted back into the Faro Creek diversion channel for 2 years.

During the period required to flood the pit, and the 2 following years, physical stability of pit walls will be observed and water chemistry of Faro Creek water, pit water, and groundwater will be monitored and evaluated. Particular emphasis will be given to acid generation and metal contaminant loading rates, buffering capacities, flow volumes and concentration gradients within the pit water column. Mechanical mixing actions and the possibility of water column inversions occurring will be assessed. Any overflow from this pit will be pumped and treated.

At the end of this 2 year period, a final evaluation will be made as to the probable long term water quality which will be discharged from the Zone I/III pit. If this assessment determines that water quality will be acceptable, an overflow spillway and lined ditch will be constructed at the southern pit exit. Zone I/III overflow water will then be directed into North Fork Rose Creek.

If water quality is determined to be unacceptable, Faro Creek will be diverted to North Fork Rose Creek through an upgraded diversion channel. This will minimize water discharge from the Zone I/III open pit. All overflow from the Zone I/III pit will then be pumped and treated until such time as acceptable water quality can be demonstrated. During the life of the mill, treatment will be through the tailings system. Following this period, a separate treatment facility would have to be constructed. Initial research indicates that treatment with lime would be the most cost-effective method.

ii. The Zone II Open Pit

The Zone II open pit will be utilized as a dump site for non-acid-generating or net acid-consuming waste rock. Major water recharge sources are being diverted away from this pit by establishing a network of interceptor ditches. The purpose of these ditches is to limit flow through known sources of leachable zinc, thereby reducing metal loading rates to Zone II pit water. The reduction of water inflow to the pit will also reduce pit water discharge.

The Zone II open pit will, over a period of approximately 8 years, fill with water to the 3800 ft. elevation. This water cover will inhibit acid generation by preventing further oxidation of any potentially acid-generating rock below this elevation.

During the period required to flood the pit, pit water and groundwater discharge will be monitored and evaluated. Particular emphasis will be given to acid generation and metal contaminant loading rates, buffering capacities, flow volumes, and concentration gradients within the pit water column. When water reaches the 3800 ft elevation in the backfilled pit, the overflow will be pumped and treated as for the Zone I/III pit overflow, until such time as acceptable water quality can be demonstrated. The results from the monitoring program will provide a basis for assessment. If acceptable discharge is demonstrated, the overflow from Zone II will be routed into North Fork Rose Creek.

iii. Waste Rock Dumps

Abandonment objectives for the waste dumps have been incorporated into the Waste Rock Management Plan, which is included in this report (Section 5.5).

Potentially acid-generating waste, termed sulphide waste, is separated from non-acid-producing and net acid-consuming waste rock. The sulphide waste has been and will continue to be deposited in a special dump until 1990.

The abandonment plan for the sulphide waste dump is based on the minimization of inflow water to the dump and the subsequent minimization of metal leaching and transport. The dump has been designed so that its base is above the original ground surface. This minimizes the risk of groundwater flow leaching and transporting metal contaminants from the dump. At abandonment, the dump will be capped with a low-permeability phyllite seal and the surface will be sloped towards the Zone I/III open pit. The low-permeability cap and the sloped surface will promote rapid runoff of rain and snowmelt and reduce water infiltration to the dump.

After 1990, potentially acid-generating waste rock will be deposited in the bottom of the Zone I/III open pit. This rock will be covered by water which will inhibit further oxidation and acid generation.

All other waste rock that is not designated as potentially acid-producing rock is being and will continue to be deposited in the Zone II dump, the Intermediate Dump, the East Dump, and on the Vangorda haul road.

A seepage water and groundwater monitoring program is being implemented to assess the chemical stability of all the waste rock dumps. The physical characteristics of the dumps will be surveyed and further tests to more fully determine acid-generating potential will be conducted. Rock durability will be assessed and tests will also be conducted to determine the permeability and durability of the phyllitic capping material.

The physical stability of waste rock dump slopes will also be reviewed prior to abandonment in 1994. Field observations indicate that these slopes in their present configuration are stable. However, an assessment of these slope stabilities by a geotechnical engineer will be undertaken. In particular, slope stabilities of rock dump faces paralleling North Fork Rose Creek and upstream of the rock drain causeway will be analysed. If serious stability problems are detected, these problems will be addressed prior to abandonment.

Low grade ore stock piles will be sent to the concentrator for processing prior to abandonment.

iv. Creeks and Diversions

The creeks and diversions addressed in this abandonment plan are: Faro Creek, the Faro Creek diversion channel, North Fork Rose Creek, North Fork Rose Creek diversion channel, and the North Valley Wall interceptor ditch.

The preferred abandonment plan for Faro Creek is to permanently divert the creek into the Zone I/III open pit. This will involve the excavation of the Faro Valley waste dump and the redirection of Faro Creek into its former channel. The alternative, and less desirable, option is to divert the creek permanently into the Faro Creek diversion channel. An engineering evaluation will be undertaken to determine feasibility and design.

North Fork Rose Creek will be restored to its original channel at abandonment. The North Valley Wall interceptor ditch will be upgraded to meet abandonment objectives.

v. Other Structures

Other structures addressed in this report are: the North Fork rock drain causeway, the Rose Creek pumphouse reservoir and dam and the freshwater reservoir and dam.

The North Fork rock drain causeway will be breached at an intermediate elevation and a cascade spillway will be constructed at abandonment to provide controlled discharge in the event of a high flood. The downstream slope of the structure will be prepared to minimize erosion. Prior to abandonment, an assessment of sediment loading to North Fork Rose Creek will be conducted. The rock drain will then be assessed with respect to its long term performance capability.

The pumphouse dam will be breached and the concrete spillway broken up, removed, and buried.

At abandonment, the freshwater reservoir dam will be upgraded and left intact. The downstream face of the embankment will be flattened, the crest widened and the upstream face armoured for erosion protection. The conduit will be permanently plugged and the valve house removed. The spillway channel capacity will be upgraded and the spillway elevation lowered. At final abandonment, the reservoir elevation will be lower than the water level maintained during mining operations. The reservoir will not be abandoned until after the concentrator is shut down. By current mine plans, reservoir abandonment will not occur for at least 15 years.

The monitoring and research program is an integral part of this abandonment plan, and is discussed in detail in Section 8 of this report. Results of the program will be reviewed annually and adjustments will be made where required. The components of this program and the tentative implementation and evaluation dates, are:

i. Assessment of the loss of flow from Faro Creek at and below the point of diversion.

| | |
|---|---|
| Components | : Flow measurements |
| Implementation | : 1988 |
| Duration | : While the Faro Creek diversion channel is operational |
| Preliminary evaluation | : Fall, 1988 |

ii. Faro pit and area seep surveys and assessment of background water quality conditions.

| | |
|---|---|
| Components | : Seep surveys and background water quality sampling |
| Implementation | : Fall, 1987 |
| Duration | : Until final abandonment. |
| Preliminary evaluation | : Fall, 1988 |
| Major evaluation date | : a) Two years after Zone II flooded<br>b) Two years after Zone I/III flooded |

iii. Waste dump assessment.

| | |
|---|---|
| Implementation | : Spring, 1988 |
| Components | : Acid-base accounting of waste rock, characterization of the old dumps, stability analyses of dump slopes and permeability testing of compacted phyllite |
| Duration | : Stability monitoring will continue until final abandonment |
| Preliminary evaluation | : Fall, 1988 |
| Major evaluation date | : Fall, 1989 |

iv. Groundwater studies in the Faro pit area.

| | |
|---|---|
| Implementation | : Summer, 1988 |
| Components | : Piezometer readings and groundwater quality sampling, groundwater modelling |
| Duration | : Until final abandonment |
| Preliminary evaluation | : Fall, 1988 |
| Major evaluation date | : a) Two years after Zone II flooded<br>b) Two years after Zone I/III flooded |

v. Assessment of water quality in Zone II pit
Implementation : 1988
Components : Water samples from sampling wells and from overflow rock drain
Duration : Until final abandonment
Preliminary evaluation : Fall, 1988
Major evaluation date : One year after Zone II flooded

vi. Assessment of water quality in Zone I/III pit
Implementation : 1994
Components : Samples of pit water from different depths and from overflow
Duration : Until final abandonment
Preliminary evaluation : 1994
Major evaluation date : Two years after Zone I/III flooded

vii. Monitoring and impact assessment of the North Fork rock drain and measurement of stream flow in North Fork Rose Creek.
Implementation : Spring, 1988
Components : Stability and performance assessment of causeway, stream flow measurements, water quality assessment, record of extent of impoundment, fisheries study
Duration : Until final abandonment
Preliminary evaluation : Fall, 1988

viii. Assessment of upgrading and maintenance requirements for the Faro diversion channel
Implementation : 1989
Components : Assessment and monitoring
Duration : As long as the diversion is in place
Preliminary evaluation : Fall, 1989

ix. Freshwater reservoir assessment
Implementation : 1988
Components : Assessment and monitoring, fisheries capability study.
Duration : Stability monitoring until final abandonment
Preliminary evaluation : Fall, 1988

In addition to the monitoring and research program, Curragh Resources Inc. has developed a tentative abandonment project implementation schedule. This schedule, described in Sections 11 and 12 of this report, identifies some of the projects which can be undertaken during the active mining life at Faro and provides implementation dates. Cost estimates are included for these major abandonment items. The projects included in the implementation schedule are summarized below.

<u>1988</u>

i. Installation of piezometer nets and water gauging instruments.
ii. Construction of lower east wall interceptor ditch (Zone II).

<u>1989</u>

i. Upgrading of freshwater reservoir dam.
ii. Construction of access road to north valley wall interceptor.

<u>1990</u>

i. Maintenance and upgrading of Faro Creek diversion channel.
ii. Upgrading of North Valley Wall interceptor ditch.

<u>1994</u>

i. Construction of temporary diversion of Faro Creek.

<u>2000</u>

i. Construction of Faro pit south dyke and spillway.
ii. Construction of Faro pit west dyke.

<u>2004</u>

i. Removal of portions of the Faro Valley waste dump.

## 1. INTRODUCTION

Curragh Resources Inc. (Curragh) is required in its Water Licence No. Y-IN85-05A (Part D, Section 4 (a) i)) to apply for an amendment to:

> "Provide details of the proposed abandonment plan for the Faro pit and area."

The Licence specifies that (Part D, Section 4):

> "Each proposal...should specify the method of stabilization or modification which will be employed upon final abandonment and include a cost estimate of the measure."

and (Part D, Section 5):

> "The application...shall be accompanied by detailed and complete supporting documentation."

Curragh's on-site personnel developed the plans for abandonment of the Faro pit and area, with specialized input from Steffen, Robertson and Kirsten (B.C.) Inc. and Golder Associates. This report presents these plans along with supporting documentation and fulfils the above requirements of the Water Licence.

Included in this report are conceptual plans for abandonment of the Faro Zone I/III and Faro Zone II open pits, the non-acid-generating waste rock dumps, the potentially acid-generating waste rock dumps, the freshwater reservoir and dam, the pumphouse reservoir and dam, the north wall interceptor ditch, the Faro Creek diversion channel, and the North Fork diversion channel. Also included are details of the monitoring and research programs designed to evaluate these plans. Abandonment plans for the tailings facilities are being developed in accordance with Curragh's Water Licence requirements (Part D, Section 6) and are not dealt with in this report.

It should be noted that the timing of the implementation of this plan is dependent upon the timing of actual abandonment of the Faro Pit and of the milling facilities. These factors are subject to change with changes in Curragh's mine plan. It is also anticipated that refinements and changes will be made to the abandonment plan as information is acquired.

Curragh's objective is to abandon the Faro minesite with no long term maintenance requirements. This abandonment plan outlines the measures Curragh intends to implement to achieve this objective while satisfying the abandonment requirements for:

i. acid generation abatement and control;
ii. metal contaminant transport control;
iii. erosion control to prevent particulate transport into Rose Creek;
iv. protection of downstream water quality of Rose Creek;
v. long term stability of dumps and structures;
vi. restoration or enhancement of fish habitat.

The various components of the Faro open pit area have been investigated and methods and procedures for abandonment have been designed. A comprehensive monitoring and research program has therefore been developed to demonstrate that the plan provides for low-impact abandonment without maintenance. Collection and treatment systems will, however, be maintained as environmental protection measures while the remedial measures described in this plan are being implemented, monitored and evaluated. Water treatment will continue until it has been demonstrated that the impact on Rose Creek of the abandoned Faro pit area is acceptable. Curragh anticipates that during the next 15 years of mine operations, as planned for the Faro, Vangorda and Grum deposits, low-impact, maintenance-free abandonment can be demonstrated.

## 2. SITE DESCRIPTION

### 2.1 Location

The Faro Mine, owned and operated by Curragh Resources Inc, is located approximately 20 km northwest of the town of Faro, Yukon, (Figure 1). The town of Faro provides services for the mine and provides housing facilities and other community services for the mine workers.

### 2.2 Mine Facilities

The Faro Mine currently consists of: the Faro open pit and waste dumps; the concentrating facilities; the offices, service and maintenance buildings; the tailings impoundment structures; the freshwater reservoir; the pumphouse reservoir; and access roads (Figure 2).

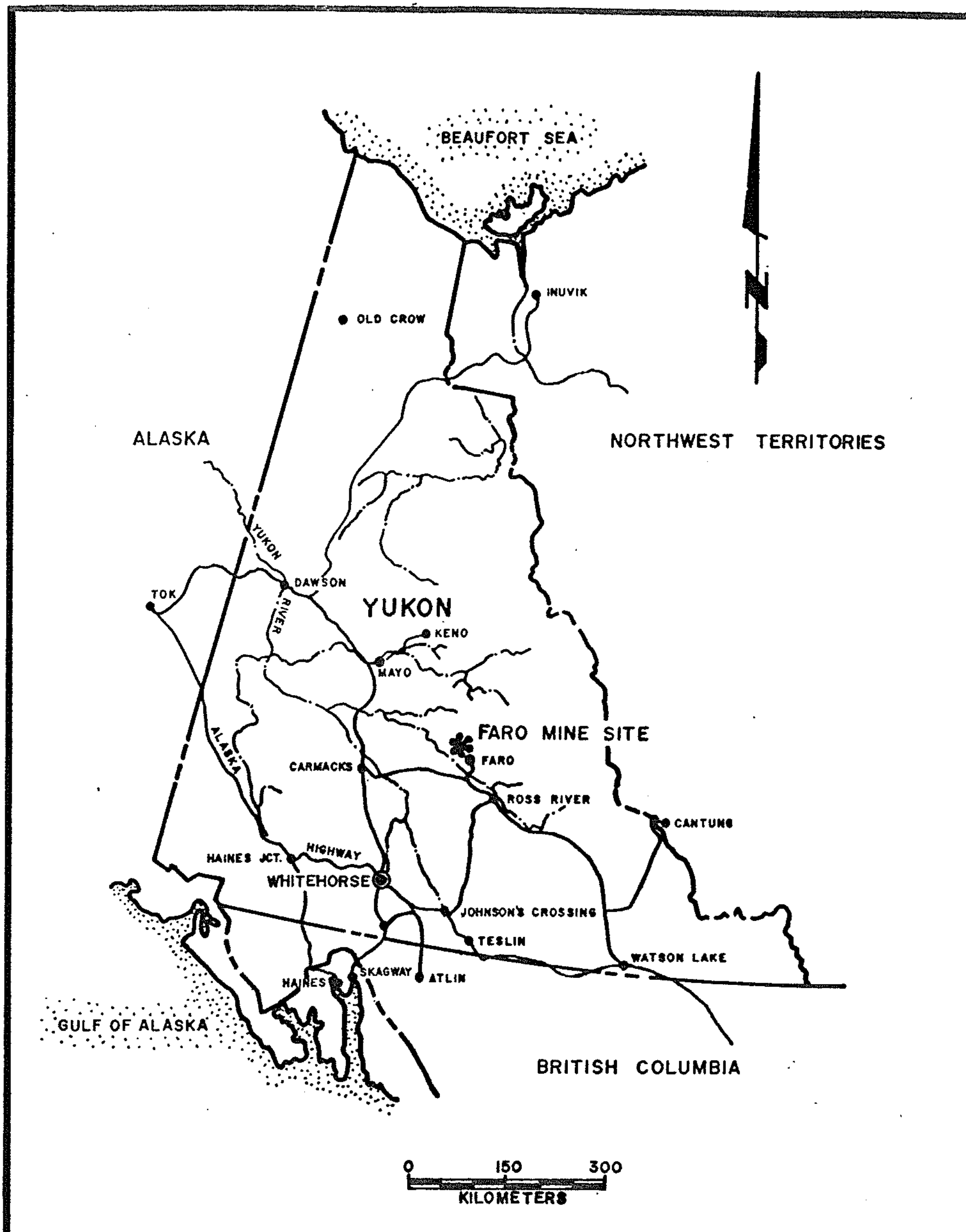
Mining operations in the Faro open pit will decrease beginning in 1989 and cease in 1993, during which time operations will commence and be expanded in the Vangorda and Grum open pits, 14 km by haul road from the concentrator. Ore from these and other soon-to-be-planned pits will maintain concentrator operations until into the 21st century.

### 2.3 Geological Description of Ore and Waste

Ore at the Faro deposit occurs in a elongate lens of sulphide bearing rock. Before mining the sulphide lens was 2000 m (6500 ft) long, 800 m (2600 ft) wide and from a few metres to 90 m (300 ft) thick. The long dimension of the lens trends northwest and the lens dips approximately 20 degrees toward the southwest. The sulphide lens is markedly asymmetric both in shape and rock type distribution. The northeast edge of the deposit is thick, relatively low in total sulphide mineral content and low in lead-zinc content. At the southwest limit the lens is thinner, tapering to a zero edge; total sulphide content is very high and the lead-zinc content is also high (Figure 13).

The sulphide lens occurs in a sequence of metamorphosed sedimentary rocks of Cambrian age (550 million years old). The sulphides are strongly layered. This layering is complexly contorted in detail but overall the ore layering follows the layering of the host sequence. All the metamorphic rocks have a pronounced platiness parallel to this layering.

Several important faults disrupted the nearly flat-lying sulphide lens into three separate ore bodies. The Big Indian-North Fork fault system (Figure 10) trends north south and dips steeply west;




| | | |
|---|---|---|
| CURRAGH RESOURCES INC. | DRAWN BY: B.C. BOORSE<br>DATE: MAR. 9, 1988 | SCALE: |
| LOCATION PLAN | FIGURE I | FILE No. |

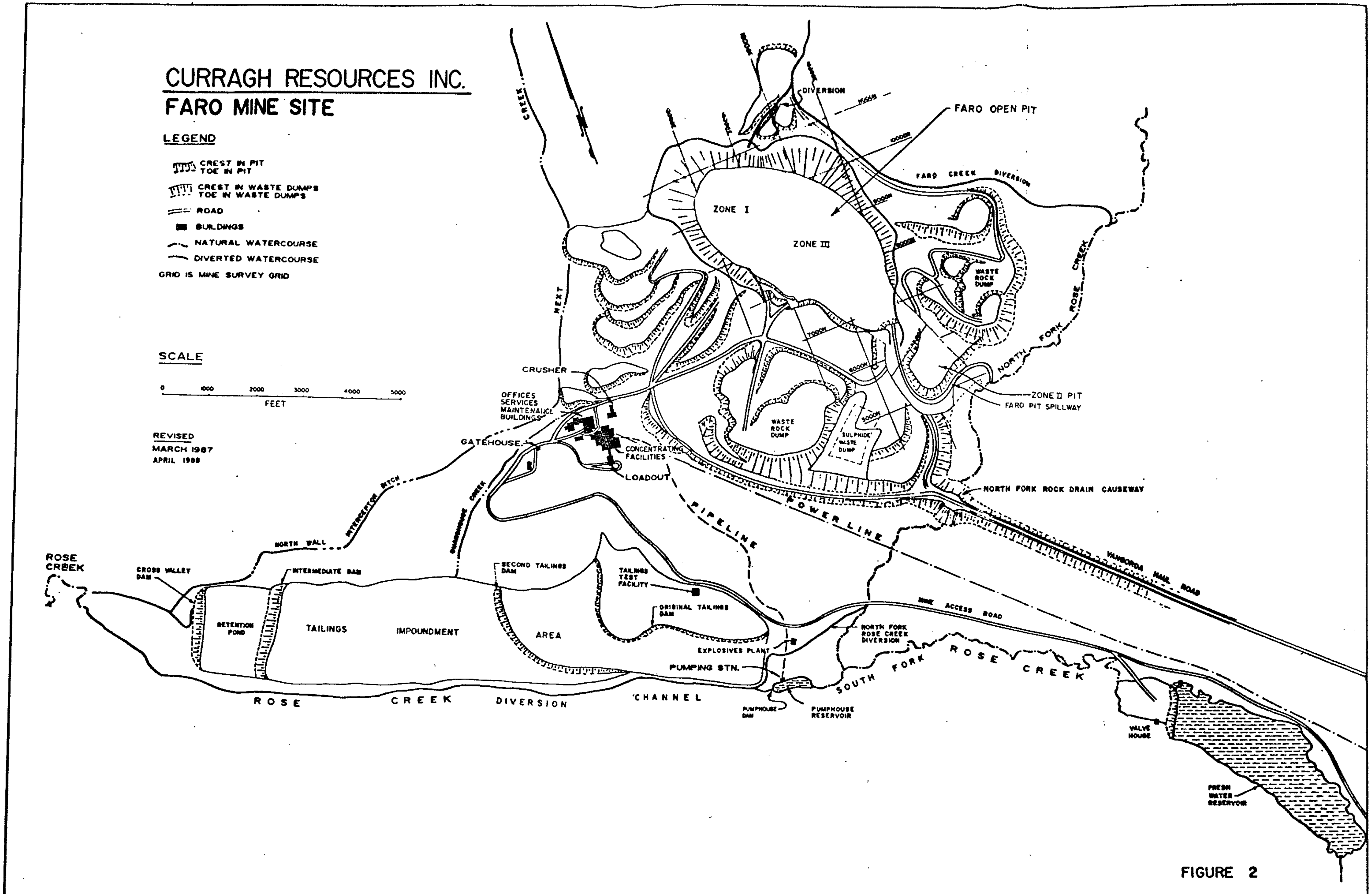

CURRAGH RESOURCES INC.
FARO MINE SITE
LEGEND
CREST IN PIT
TOE IN PIT
CREST IN WASTE DUMPS
TOE IN WASTE DUMPS
ROAD
BUILDINGS
NATURAL WATERCOURSE
DIVERTED WATERCOURSE
GRID IS MINE SURVEY GRID
SCALE
0
1000
2000
3000
4000
5000
FEET
REVISED
MARCH 1987
APRIL 1988
FARO OPEN PIT
DIVERSION
FARO CREEK DIVERSION
ZONE I
ZONE III
WASTE ROCK DUMP
NORTH FORK ROSE CREEK
ZONE II PIT
FARO PIT SPILLWAY
SULPHIDE WASTE DUMP
CRUSHER
OFFICES
SERVICES
MAINTENANCE
BUILDINGS
GATEHOUSE
CONCENTRATING FACILITIES
LOADOUT
NORTH FORK ROCK DRAIN CAUSEWAY
PIPELINE
POWER LINE
VANGORDA HAUL ROAD
NEXT CREEK
INTERCEPTOR DITCH
NORTH WALL
ROSE CREEK
CROSS VALLEY DAM
INTERMEDIATE DAM
SECOND TAILINGS DAM
TAILINGS TEST FACILITY
ORIGINAL TAILINGS DAM
RETENTION POND
TAILINGS
IMPOUNDMENT
AREA
MINE ACCESS ROAD
NORTH FORK ROSE CREEK DIVERSION
EXPLOSIVES PLANT
PUMPING STN.
ROSE CREEK DIVERSION CHANNEL
PUMPHOUSE DAM
PUMPHOUSE RESERVOIR
SOUTH FORK ROSE CREEK
VALVE HOUSE
FRESH WATER RESERVOIR

FIGURE 2

it downdrops the ore approximately 60 m (200 ft) on its west side and separated Zone II from Zone III. Between Zone I and Zone III is another major fault system that trends east to northeast, dips steeply and downdrops its southeast side 50 to 60 m (160 to 200 ft). Zones I and III are actually mined from the same overall pit; Zone II was sufficiently displaced from the other zones that it was mined from a separate pit, now largely backfilled. There are a myriad of lesser faults present in the Faro pit. The faults are manifested by zones of broken rock and/or clay gouge from centimetres to tens of metres thick and can exert strong and markedly anisotropic influence on water flow in the rock mass.

The immediate host rock of the sulphide deposit is a non-calcareous quartz-mica-feldspar schist (metamorphosed shale). Two major variants of this rock are present. Overlying the sulphide deposit the schist is fine grained (so that it is informally referred to as a phyllite in this report) and medium grey with local andalusite porpyhroblasts [unit 1DO]. Beneath the sulphide deposit the schist is coarser grained, richer in biotite and commonly contains andalusite rich bands as well as garnet and staurolite porphyroblasts [unit 1CD]; locally the biotite is retro-graded to chlorite giving the rock a pale green colour. The schist is overlain by a calc-silicate gneiss [unit 3D] (a metamorphosed calcareous or dolomitic shale). This rock consists of thin bands of quartz, biotite and feldspar alternating with thin bands of quartz, diopside, epidote, feldspar, and calcite. The calc- silicate is hard and dense, making it a desirable construction material.

The metamorphic sequence has been intruded by a suite of dykes which generally can be classified as either a hornblende diorite to quartz diorite [unit 10E] or a quartz, feldspar, biotite porphyry [unit 10F]. The dykes are not abundant at Faro. The largest diorite is at the northwest end of the pit, a smaller diorite dyke follows the fault zone that separated the Zone I and Zone III orebodies. All other occurrences of diorite are relatively insignificant. The porphyry occurs as a series of irregularly shaped bodies around the northeast and east edges of Zone III, overall the porphyry was less abundant than the diorite and neither constitutes a major component of the waste dumps.

At the north east edge of the Zone I-III pit in association with diorite dykes and sills and the intersection of major fault sets the calc-silicate is brecciated and strongly silicified so that it is very hard and resistant [unit 3Dbx]. Much of this material has been used for the North Fork rock drain.

There are two main ore types at Faro; massive sulphide ore and quartzite ore with disseminated sulphides. The massive sulphide ore [unit 2E and 2F] consists of over 80% sulphide minerals, dominantly pyrite (iron sulphide) with lesser sphalerite (zinc sulphide), galena (lead sulphide) and chalcopyrite (a copper-iron sulphide). Pyrrhotite (also an iron sulphide) is locally important with one variant of the massive sulphides consisting of massive pyrrhotite [unit 2H]. Magnetite (iron oxide) is locally an important accessory mineral. Gangue is largely quartz and minor carbonate though one variant of the massive ores contains up to 50% barite [unit 2G]. The quartzite ores contain 10 to 50% total sulphides in a quartz plus lesser mica gangue. The quartzite ores are commonly strongly banded with sulphide and quartz rich bands alternating on a centimetre scale. The sulphide assemblages of the quartzites [units 2B, 2C and 2D] are more varied than the massive ores but generally the most abundant sulphide is pyrite with lesser galena, sphalerite and chalcopyrite; pyrrhotite occurs sparingly. Locally the quartzites are dark grey due to the presence of abundant fine disseminated carbon [unit 2A].

The massive and disseminated ores are inter-layered on all scales but the overall distribution is not random. The massive ores tend to be the more central and uppermost ore type in the deposit while the quartzites are more peripheral and tend to underlie the massive ores. The massive ores also tend to be higher grade in lead and zinc than the quartzites.

Not all of the rocks that comprise the Faro sulphide lens is ore. A substantial portion of the sulphide lens contains so little lead and zinc that it is not economic to send this material to the mill and the rock is classified as sulphide waste. The concept of sulphide waste carries with it an economic, hence time dependent, factor. At times of high revenue (high metal prices, low exchange rates) and / or low costs (low power costs, labor rates, fuel costs, taxes etc.) sulphide waste becomes ore; at less beneficial times ore becomes waste. Non- sulphide waste on the other hand is always waste since it has no potential to generate revenue under any conditions. Because of the geographic zoning of sulphide content, ore type and thickness mentioned previously as well as the relation of lead-zinc grade to ore type implied above, the northeast part of the sulphide lens contains a higher proportion of this sulphide waste than the remainder of the lens. Consequently the northeast limit of the orebody is highly dependent on economics. This phenomenon is not unique to Faro but because of the superposition of a number of factors this limit is more sensitive than most ore body limits to economics. The implications of this geometry, zoning and the sulphide waste phenomena for abandonment are several: (1.) inherently it is inevitable that some sulphide will remain in the northeast wall (2.) there will be large quantities of sulphide waste to dispose of in the waste piles (3.) the abandonment measures should not sterilize potential ore that remains in the northeast wall (4.) the time of abandonment is not fixed but carries an economic determinant.

The upper and lower limits of the sulphide lens are sharp and physically distinct. The distinction between sulphide bearing waste and non-sulphide waste is not however that clear cut. The sulphide lens is enveloped by an easily recognized alteration zone within which the host schist is bleached to a white, quartz-muscovite schist [unit 1D4] containing minor marcasite (an iron sulphide). The enveloping alteration zone can be 5 m (15 ft) to 15 m (50 ft) thick. This material, though containing no valuable components, is treated as sulphide waste because of its potential for acid generation.

## 2.4 Simplified Description of the Mining and Concentrating Operations

Rock containing ore and waste rock are blasted in the pit and selectively loaded into large haul trucks. The waste rock is hauled and dumped into permanent waste dumps, while the ore is hauled to the concentrator for processing or to temporary stockpiles.

At the concentrator the ore mineral is upgraded or "concentrated", but in no way chemically altered, from the feed ore containing approximately 8% metals content to concentrates containing approximately 55% metals content by crushing, grinding, differential flotation and drying. The concentrates are trucked to Skagway for shipment to overseas markets. At the Faro mine two concentrates are produced: zinc concentrate and lead concentrate.

Water required in the concentrating process is stored in a freshwater reservoir and spilled on a controlled basis to a freshwater pumphouse reservoir located just upstream of the tailings pond system, from where it is pumped.

Finely ground gangue and non-economic sulphides ("tailings") are separated from the ore in the concentrating process. Tailings are mixed with water and pumped to an impoundment area where they are settled out and stored.

Water accumulating in the Faro pits and seepage from the waste dumps in the Faro watershed are also directed into the tailings system. The decant from the final tailings pond flows into Rose Creek.

## 2.5 History

Cyprus Anvil Mining Corporation (CAMC) began mining of the Faro lead-zinc deposit in 1969 and mined at a rate of approximately 9200 tonnes of ore per day. Mining was confined to Zones I and II of the Faro open pit until June of 1982, at which time CAMC terminated its mining and milling operations. Up to the point of closure CAMC had mined approximately 35 million tonnes of ore, generated 10 million $m^3$ of tailings, and stripped 62 million $m^3$ of waste rock which was stored in the Faro open pit waste dumps.

Curragh restarted the Faro mining and milling operation in June, 1986 and currently mines Zone I and III of the Faro open pit at a rate of approximately 13,500 tonnes of ore per day. Ore from the Faro pit will provide ore to the concentrator until 1993. From 1986 through 1993, Curragh will mine 22 million tonnes of ore, generate 6 million $m^3$ of tailings, and strip 30 million $m^3$ of waste rock in the Faro open pit which will be stored in the waste dumps and the Vangorda haul road. By the end of 1993, waste material in the Faro open pit waste dumps and the Vangorda road will total 92 million $m^3$.

## 2.6 Streams and Diversions

The Faro Mine is located at the confluence of three creeks: Faro Creek, North Fork Rose Creek, and Rose Creek.

The Faro ore body is located in the original Faro Creek valley. In order to develop the pit, Faro Creek, which originally joined Rose Creek downstream of the confluence of the North Fork with Rose Creek, was diverted to the east to flow directly into North Fork Rose Creek.

The freshwater reservoir is located on Rose Creek upstream of its confluence with the North Fork. Water is spilled on a controlled basis from the freshwater reservoir and ponded in a small pumphouse reservoir for pumping to the concentrator.

The tailings impoundment area is also located in the Rose Creek valley immediately downstream of the confluence with the North Fork. A diversion channel, named the Rose Creek diversion channel, has been constructed to direct Rose Creek along the south wall of the Rose Creek valley, around the stored tailings.

## 3. FARO ZONE I/III OPEN PIT

### 3.1 Site Description

The Faro Zone I/III open pit is the present site of active mining at Faro (Figure 3). Current plans indicate that open pit mining will be conducted until 1990, after which time underground mining will continue until 1993. By the end of 1993, 92 million $m^3$ of waste rock will have been excavated and placed in waste dumps and the Vangorda Road. The Faro open pit will measure 5500 ft (1675 m) long by 3200 ft (975 m) wide. The lowest elevation within the pit will be at 3300 ft (1006 m), 1100 ft (335 m) below the highest point on the western pit wall, at 4400 ft (1341 m).

### 3.2 Site Assessment

Abandonment measures related to the Faro Zone I/III open pit will be undertaken primarily to ensure discharge water is of acceptable quality. Assessment of water quality is thus of prime importance.

The assessment of the water quality aspects of the open pit site outlined in this section has been based on water sampling surveys conducted in June, 1984 and September, 1987, (Table 1) and the average pit water quality as determined from on-site records for the years 1982 and 1987 (Table 2). Sampling locations are shown on Figure 3.

Both the 1984 and the 1987 water sampling surveys indicate elevated zinc concentrations in some of the seepage water exiting from the northwestern, northeastern, and eastern pit walls. In particular, zinc concentrations from the northeastern wall were 84.0 and 5.4 mg/l for 1984 and 1987, respectively, and zinc loadings were 2102.8 and 83.2 mg/s for 1984 and 1987, respectively. It should be noted that the two surveys are not strictly comparable. They were conducted at different seasons and much of the metals loading in the June, 1984 survey may have been in particulate form as water flowing down the northeastern wall is typically very turbid in the spring. The report on this survey (Dome, 1984) does not indicate the type of metal analyses conducted, but it is assumed that samples were tested for total or extractable metals.

Elevated zinc concentrations were also recorded in the pit water: in 1982, the average zinc concentration was 26.3 mg/l; and in 1987, the average zinc concentration was 28.8 mg/l. With an average pit dewatering pumping rate of 0.04 $m^3/s$, average zinc loadings of 1052 to 1152 mg/s were indicated.

The water quality surveys and the pit water sample records also provide evidence that some acid is being generated from walls and floors of the pit. In June, 1984, samples #7 and #8, located in the northeastern wall, had slightly acidic pH's of 5.2 and 6.8,

**TABLE 1 ZONE I/III : SEEP SOURCES AND ESTIMATED LOADINGS**

| | LEAD (mg/l) | ZINC (mg/l) | IRON (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | MAGNESIUM (mg/l) | CALCIUM (mg/l) | SODIUM (mg/l) | SULPHATE (mg/l) | pH | FLOW (l/s) | TEMP (deg C) | COND. (umhos/cm) | ALKALINITY (mg/l) | Zn LOAD (mg/s) | Cu LOAD (mg/s) | SO4 LOAD (mg/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SEPTEMBER 1987** | | | | | | | | | | | | | | | | | |
| NORTH EAST WALL: | | | | | | | | | | | | | | | | | |
| A30 | | 5.400 | | 0.003 | | | | | 197.0 | 7.64 | 15.40 | 2.9 | 764 | | 83.2 | 0.05 | 3034 |
| A31 | | 0.145 | | -0.002 | | | | | 72.0 | 7.29 | 0.05 | 3.2 | 395 | | 0.0 | 0.00 | 4 |
| NORTH WEST WALL: | | | | | | | | | | | | | | | | | |
| A25 | | 5.060 | | 0.003 | | | | | 115.0 | 7.99 | 0.05 | 3.8 | 684 | | 0.3 | 0.00 | 6 |
| A26 | | 0.007 | | -0.002 | | | | | 35.0 | 8.28 | 1.00 | 4.3 | 597 | | 0.0 | 0.00 | 35 |
| A28 | | 0.385 | | -0.002 | | | | | 49.0 | 7.95 | 0.50 | 5.9 | 702 | | 0.2 | 0.00 | 25 |
| EAST WALL: | | | | | | | | | | | | | | | | | |
| A14 | | 0.061 | | -0.002 | | | | | 13.0 | 8.44 | 0.40 | 5.6 | 211 | | 0.0 | 0.00 | 5 |
| A15 | | 1.100 | | 0.002 | | | | | 84.0 | 8.26 | 0.10 | 3.9 | 608 | | 0.1 | 0.00 | 8 |
| A16 | | 2.200 | | 0.003 | | | | | 97.0 | 8.32 | 0.05 | - | 468 | | 0.1 | 0.00 | 5 |
| A18 | | 62.500 | | 0.002 | | | | | 1,035.0 | 7.59 | 0.05 | 5.0 | 1999 | | 3.1 | 0.00 | 52 |
| A19 | | 3.040 | | 0.008 | | | | | 118.0 | 8.30 | 0.50 | 4.9 | 775 | | 1.5 | 0.00 | 59 |
| A21 | | 180.000 | | 0.011 | | | | | 1,640.0 | 7.44 | 0.10 | 4.9 | 2620 | | 18.0 | 0.00 | 164 |
| TOTAL LOADING | | | | | | | | | | | | | | | 106.5 | | |
| **JUNE 1984** | | | | | | | | | | | | | | | | | |
| NORTH EAST WALL: | | | | | | | | | | | | | | | | | |
| 7 | 0.08 | 84.000 | 3.59 | 0.790 | 5.51 | 32.0 | 33.0 | 5.0 | 609.0 | 5.20 | 25.0 | | 660 | 4.9 | 2102.8 | 10.00 | 8374 |
| 8 | 0.08 | 0.110 | 0.85 | 0.010 | 0.49 | 19.1 | 26.0 | 6.0 | 60.9 | 6.80 | | | 220 | 94.8 | | | |
| NORTH WEST WALL: | | | | | | | | | | | | | | | | | |
| 1 | 0.08 | 40.500 | 0.21 | 0.010 | 4.52 | 34.5 | 40.0 | 33.0 | 505.3 | 7.40 | 6.5 | | 700 | 119.5 | 27.90 | 0.13 | 2294 |
| 2 | 0.08 | 29.800 | 0.04 | 0.010 | 4.12 | 32.3 | 47.0 | 7.0 | 593.8 | 7.60 | | | 740 | 83.0 | | | |
| 3 | 0.10 | 17.100 | 0.11 | 0.020 | 1.15 | 21.0 | 35.0 | 4.0 | 244.0 | 7.50 | | | 400 | 52.4 | | | |
| 9 | 0.07 | 0.040 | 0.01 | 0.040 | 0.41 | 11.5 | 22.0 | 2.0 | 68.3 | 7.10 | | | 150 | 54.3 | | | |
| EAST WALL: | | | | | | | | | | | | | | | | | |
| 5 | 0.08 | 0.050 | 0.10 | 0.010 | 0.43 | 51.6 | 38.0 | 25.0 | 224.3 | 8.10 | 1.0 | | 590 | 223.3 | 0.10 | 0.01 | 224 |
| TOTAL LOADING | | | | | | | | | | | | | | | 2130.8 | | |

* - DENOTES LESS THAN

TABLE 2. ZONE I/III PIT WATER QUALITY SITE X22 (Pump Water)

| | LEAD (mg/l) | ZINC (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | SODIUM (mg/l) | SULPHATE (mg/l) | pH | SUSP SOLIDS (mg/l) | FLOW RATE (l/s) | TEMP (deg C) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1987 YEAR MIN | 0.00 | 1.28 | 0.00 | 0.02 | 3.20 | 182 | 6.68 | 1 | 22.8 | 1 |
| 1987 YEAR MAX | 0.49 | 110.50 | 0.93 | 8.35 | 47.50 | 1485 | 7.92 | 1670 | 128.8 | 10 |
| 1987 NO. ANALYSES | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| 1987 YEAR AVG | 0.12 | 28.04 | 0.04 | 2.24 | 20.30 | 457 | 7.27 | 75 | 62.4 | 4 |
| 1987 YEAR STD DEV | 0.11 | 21.14 | 0.14 | 1.91 | 11.90 | 245 | 0.28 | 250 | 39.4 | 3 |
| | | | | | | | | | | |
| 1982 YEAR MIN | 0.02 | 0.03 | 0.01 | 0.50 | 10.00 | | 6.20 | 0 | - | 0 |
| 1982 YEAR MAX | 0.67 | 56.20 | 0.03 | 7.36 | 49.00 | | 7.00 | 3885 | - | 10 |
| 1982 NO. ANALYSES | 31 | 31 | 30 | 31 | 29 | | 31 | 31 | | 31 |
| 1982 YEAR AVG | 0.13 | 26.34 | 0.02 | 2.85 | 31.45 | | 6.52 | 171 | - | 3.8 |
| 1982 YEAR STD DEV | 0.14 | 15.54 | 0.01 | 1.65 | 12.89 | | 0.22 | 697 | - | 3.3 |

respectively. In September, 1987, samples taken from the same area had alkaline pH's of 7.64 and 7.29. The 1982 pit water average for pH was also acidic, being 6.52, but the 1987 pit water average for pH was alkaline at 7.27. These results may indicate some reduction in the rate of acid generation; however, the differences may just be due to seasonal variations. Further seep surveys will provide an improved understanding of pit water quality.

The water quality survey and pit water sampling results provide evidence that, through the mining of the Zone I/III pit, potentially acid-generating rock has been exposed in the pit walls and pit floor. The degree of acid generation is indicated to be variable however and, for the most part, alkaline seepage exists. Leaching of contaminant metals such as zinc is also indicated, and zinc loading appears to be variable depending on the location, the season, and the seepage flow rate.

In conclusion, the present assessment of the water quality aspects of the Zone I/III pit indicates that mitigation measures to prevent or reduce acid generation and metal contaminant migration are necessary for low-impact Faro open pit abandonment. Further water quality surveys are also required to determine whether or not acid generation is increasing or is remaining relatively constant, and to determine the total loading of metal contaminants to the pit water. Seasonal variations must also be determined. A water quality survey program is outlined in Section 10.

### 3.3 Remedial Measures

The primary objective upon abandonment of the Zone I/III pit will be to ensure that the water discharged to the environment is of acceptable pH and metals loading. Curragh will establish a water cover to the 3920 ft elevation to prevent further oxidation of the sulphides. Upon the cessation of all mining operations in the Faro pit, Faro Creek will be temporarily redirected into Zone I/III open pit and, together with local groundwater inflows, will fill the pit with water. This water will cover sulphides exposed in the pit walls below the 3920 ft elevation, the pit bottom, and the high acid generating waste rock dumped back into the pit during the later stages of mining.

Pit recharge will exceed pit groundwater discharge. Yearly average inflows are estimated to be 0.17 to 0.22 $m^3/s$ while average outflows are estimated to be 0.01 $m^3/s$ (Section 3.4) . With a pit volume of 52.6 x $10^6$ $m^3$, the water level in these pits will rise to the 3920 ft elevation in approximately 8 to 11 years. The pit area that would be affected is shown in Figure 3.

The natural pit water elevation would be determined by two bedrock elevation lows of 3910 ft located in the western and southern sections of the pit. (Locations shown on Figure 4). A pit water elevation of 3920 ft, however, will significantly reduce the amount of excavation required for the construction of an overflow spillway. Thus, two compacted till plugs (dykes) will be installed in the west and south elevation lows (as shown in Figure 3) prior to year 2001. Design details for both the west dyke and the south dyke are shown in Figures 5 and 6. As indicated, each plug will be keyed into the bedrock to act as a low permeability barrier.

The southern exit will be the favoured overflow spillway route in that less excavation will be required for ditch construction. The western exit would not only require more excavation for ditch construction, but would also require dyking to the 3955 ft elevation. Building dykes to this elevation is not considered feasible in that the probability of leakage around the plugs is increased. The southern exit overflow spillway for the Faro Zone I/III open pit will be constructed in the year 2000 at the 3920 ft elevation. A conceptual design for the overflow spillway ditch is presented in Figure 7. The ditch will have a capacity to handle a 1-in-500 year instantaneous peak flood event, and will be lined with a high-density polyethylene liner to minimize leakage. Spillway discharge would be directed into the North Fork of Rose Creek, upstream of the North Fork rock drain.

The water level in the Faro Zone I/III pit, based on average yearly flow rates, is expected to rise to the 3920 overflow spillway elevation by the year 2001. This level may be reached earlier if annual precipitation is greater than average and construction schedules will be altered accordingly. Once the water level reaches the spillway elevation, Faro Creek will be redirected into the existing Faro Creek diversion channel for a period of 2 years.

Evaluation of the water cover and assessment of metal contaminant loadings will be conducted throughout the initial flooding of the pit. Any water overflow which does occur during this testing period and which is considered to be of unsuitable quality will be collected and pumped to the tailings impoundment area (the Faro concentrator will still be operating at that time and thus the water will be treated through the tailings system).

During and, particularly, upon the completion of this test period, the effectiveness of a water cover as an abandonment measure for the Zone I/III pit will be evaluated. In the event that surface water quality from the Faro Zone I/III open pit proves satisfactory, Faro Creek will be permanently directed into Faro Zone I/III pit. Discharge from the Faro Zone I/III pit would then be routed into North Fork Rose Creek via the southern exit overflow spillway. This would be the preferred solution.

If the conclusion drawn from this evaluation is that unacceptable contaminant loadings in the surface water will result, Faro Creek will be permanently diverted around the Faro pits and active treatment of pit overflow water will be implemented. Treatment will continue until such time as discharge from the Faro Zone I/III pit is considered acceptable with respect to its effect on the water quality of Rose Creek downstream of the Faro minesite. Water treatment is discussed in Section 8.

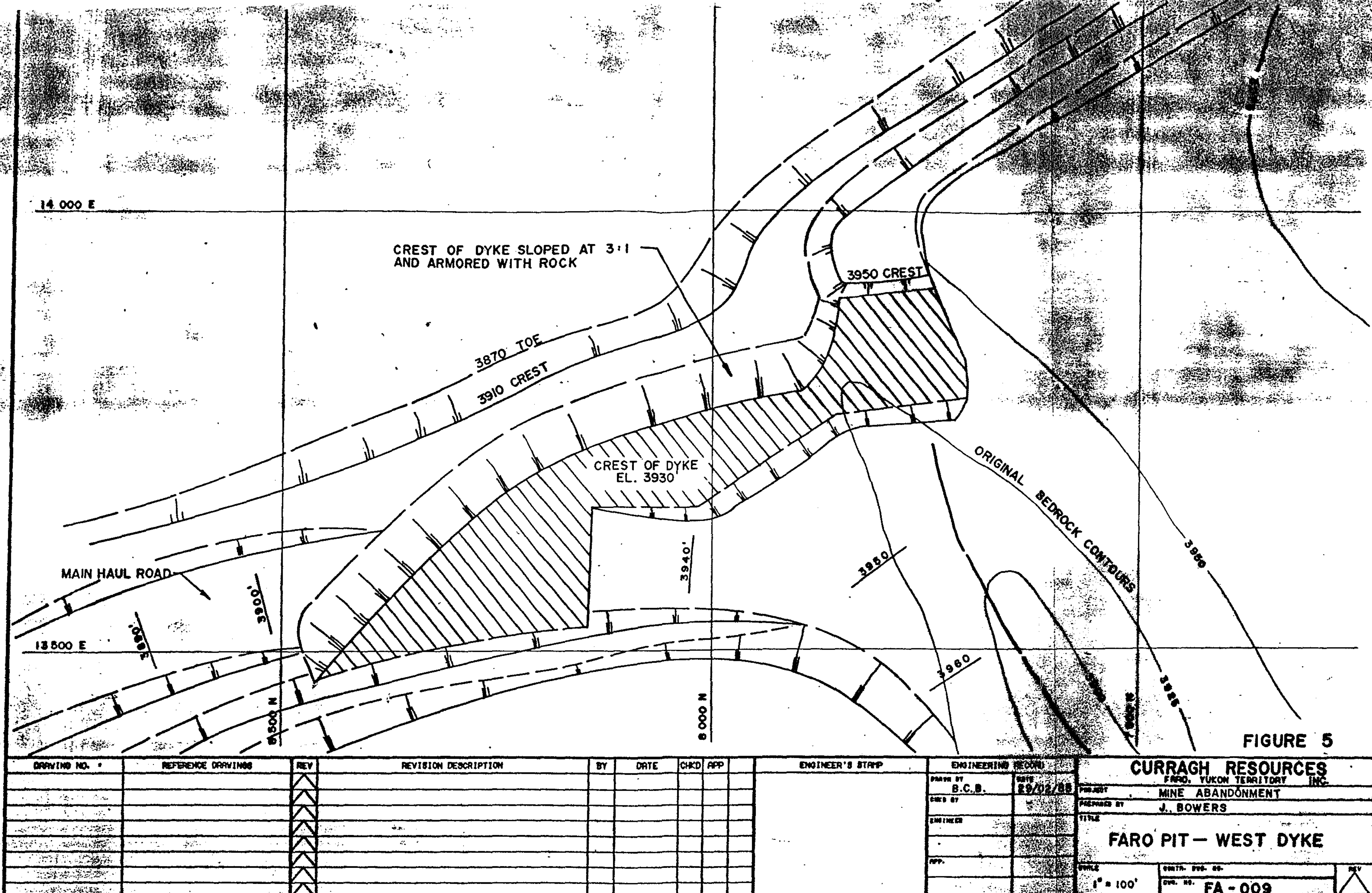

14 000 E
13 500 E
5500 N
6000 N
CREST OF DYKE SLOPED AT 3:1
AND ARMORED WITH ROCK
3950 CREST
3870 TOE
3910 CREST
CREST OF DYKE
EL. 3930
MAIN HAUL ROAD
3900'
3890'
3940'
3950
3960
ORIGINAL BEDROCK CONTOURS
DRAWING NO.
REFERENCE DRAWINGS
REV
REVISION DESCRIPTION
BY
DATE
CHKD
APP
ENGINEER'S STAMP
ENGINEERING RECORD
B.C.B.
29/02/88
CURRAGH RESOURCES INC.
FARO, YUKON TERRITORY
MINE ABANDONMENT
J. BOWERS
FARO PIT — WEST DYKE
1" = 100'
FA - 009

FIGURE 5

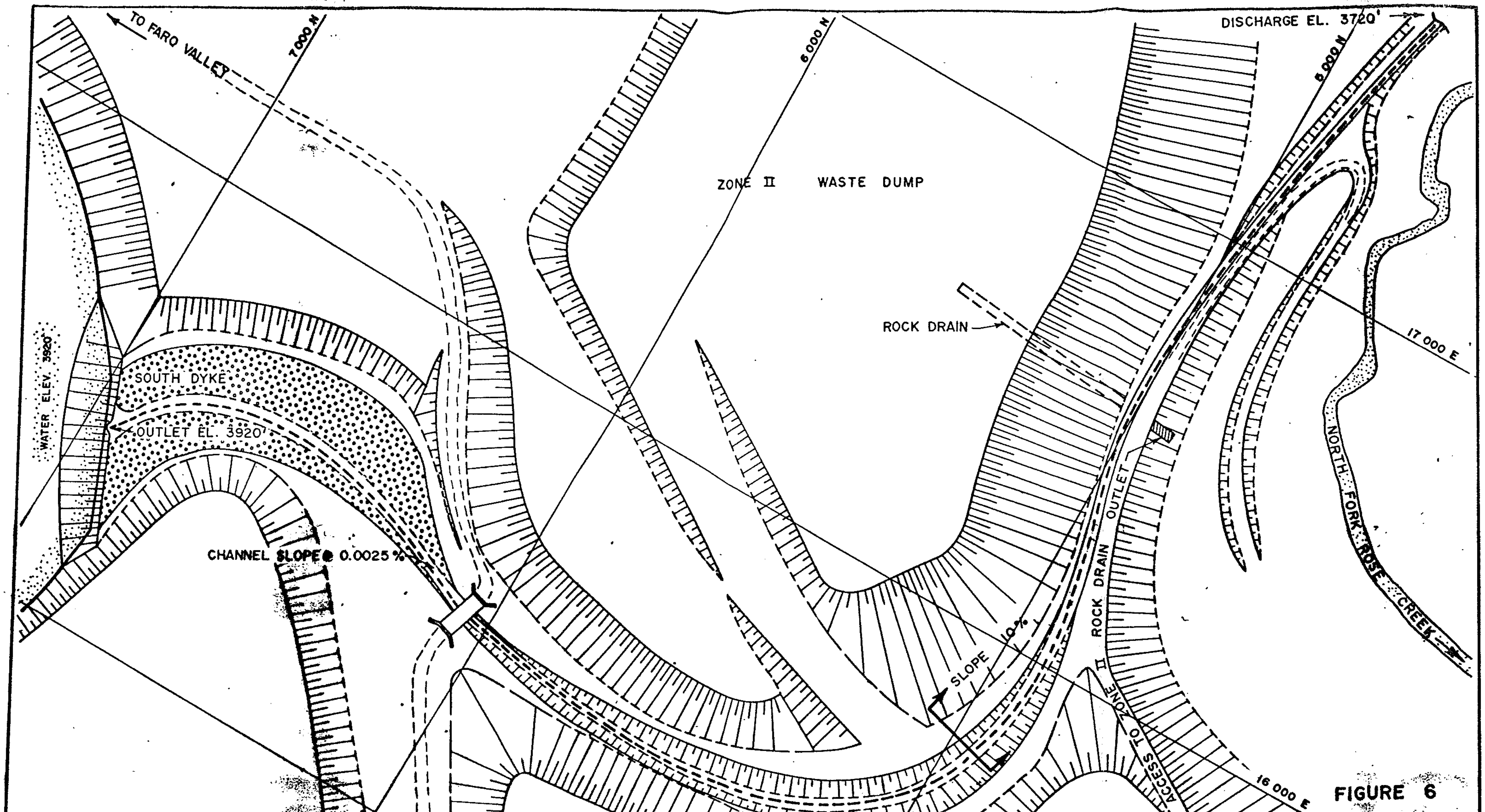



FIGURE 6

| DRAWING NO. | REFERENCE DRAWINGS | REV | REVISION DESCRIPTION | BY | DATE | CHKD | APP |
|---|---|---|---|---|---|---|---|

ENGINEER'S STAMP

ENGINEERING RECORD

DRAWN BY: B.C.B. DATE: 05/03/88

CHKD BY:

ENGINEER:

APP.:

CURRAGH RESOURCES INC.
FARO, YUKON TERRITORY

PROJECT: MINE ABANDONMENT

PREPARED BY: J. BOWERS

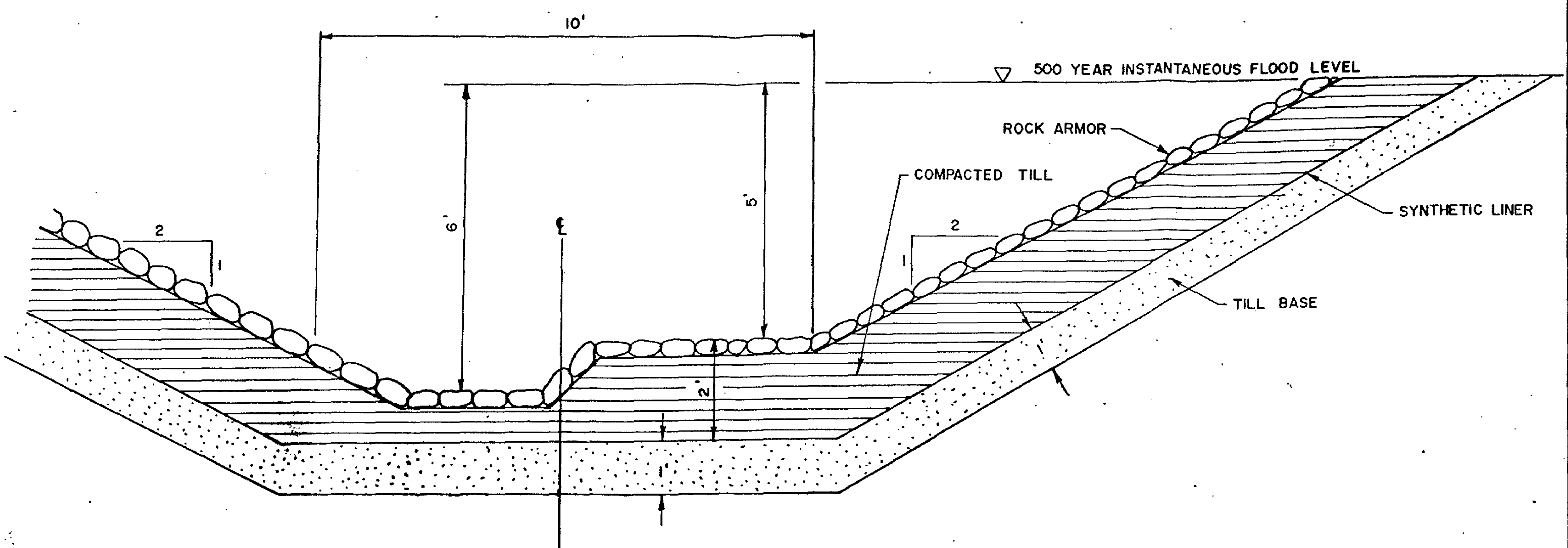
TITLE: SOUTH DYKE & SPILLWAY ROUTE PLAN VIEW

SCALE: 1" = 200'

CONTR. DWG. NO.:

DWG. NO.: FA-006

REV




FARO SPILLWAY DESIGN

1" = 2'

FIGURE 7

| DRAWING NO. | REFERENCE DRAWINGS | REV | REVISION DESCRIPTION | BY | DATE | CHKD | APP |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

ENGINEER'S STAMP

ENGINEERING RECORD
DRAWN BY: B.C.B. DATE: 28/02/88
CHKD BY:
ENGINEER:
APP.

CURRAGH RESOURCES INC.
FARO, YUKON TERRITORY
PROJECT: MINE ABANDONMENT
PREPARED BY: J. BOWERS
TITLE: FARO SPILLWAY DESIGN TYPICAL CROSS-SECTION
SCALE: 1" = 2'
DWG. NO. FA-004

## 3.4 Hydrology and Hydrogeology

The hydrological and hydrogeological flow regime affecting the Faro Zone I/III open pit can be summarized in two categories: pit recharge sources; and pit discharge sources. Both categories can be further sub-divided into flow types:

i. surface flow;
ii. interflow; and
iii. groundwater flow.

Flow components are illustrated in Figure 8.

Surface flow is represented by open channel flow or by sheet flow. Sheet flow is associated with intense periods of precipitation and steep topography. Faro Creek is the major surface flow affecting Zone I/III pits.

Interflow, by definition, has a short ground residence time and involves flow through the unsaturated zone. High hydraulic conductivity and steep slope gradients are required. Waste rock dumps are potential locations for the generation of interflows affecting the Faro Zone I/III open pit.

Groundwater flow refers to flows beneath the water table in soils and geologic formations that are fully saturated. In the Faro mine area, groundwater flows are located within the overburden composed mostly of glacial tills, along the weathered rock zone located at the overburden/bedrock interface, and in the geological formations composed of both ore and waste rock.

The overburden or glacial tills are relatively homogeneous and isotropic. These tills generally exhibit hydraulic conductivities in the order of $10^{-5}$ to $10^{-6}$ m/s (Ripley, Klohn and Leonoff, 1967). Drilling records indicate the existence of a weathered zone located at the overburden/bedrock interface, and its conductivity is estimated to be in the $10^{-5}$ m/s range. Idealized flow nets for these materials are presented in Figure 9.

The hydrogeological regime within the bedrock can be divided into two major components: a semi-confined or confined aquifer represented by the relatively high permeability ore rock and a low-permeability aquitard represented by the waste rock. The estimated hydraulic conductivity for the ore rock is $10^{-5}$ m/s and for the in-situ waste rock is $10^{-6}$ to $10^{-7}$ m/s (CAMC, 1982).

The host schist and phyllite is typical of regional metamorphic terrains thus, in absence of site specific data, the hydraulic conductivity can be assumed to be similar to averages for such rocks. This type of rock mass generally has low permeability, and the limited conductivity that does exist is associated with fractures and weathered zones. Such permeability is depth-dependent and should decrease with depth. Because permeability is associated with structural features, the permeability of the waste rock can be considered anisotropic or strongly directional.

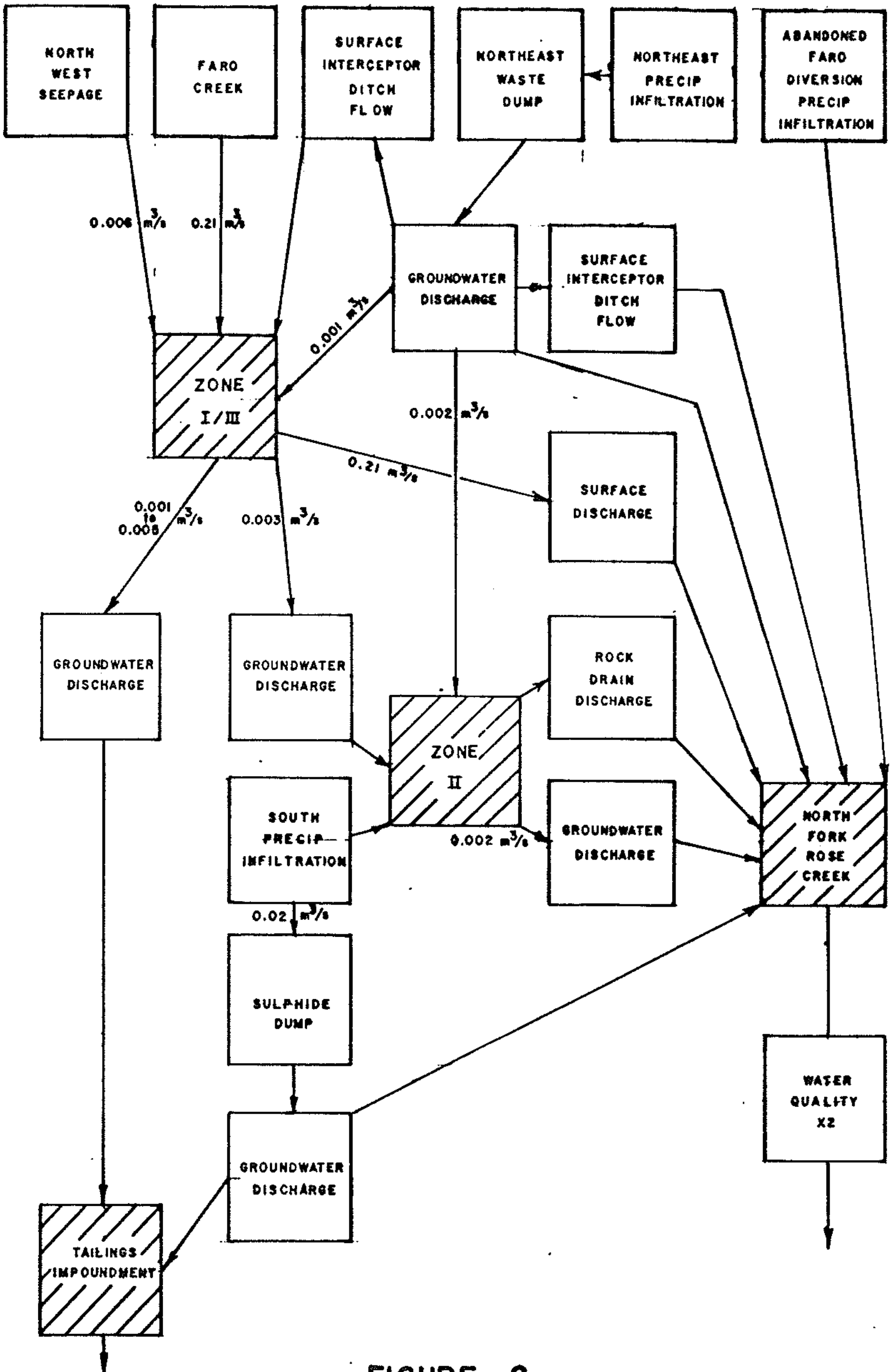
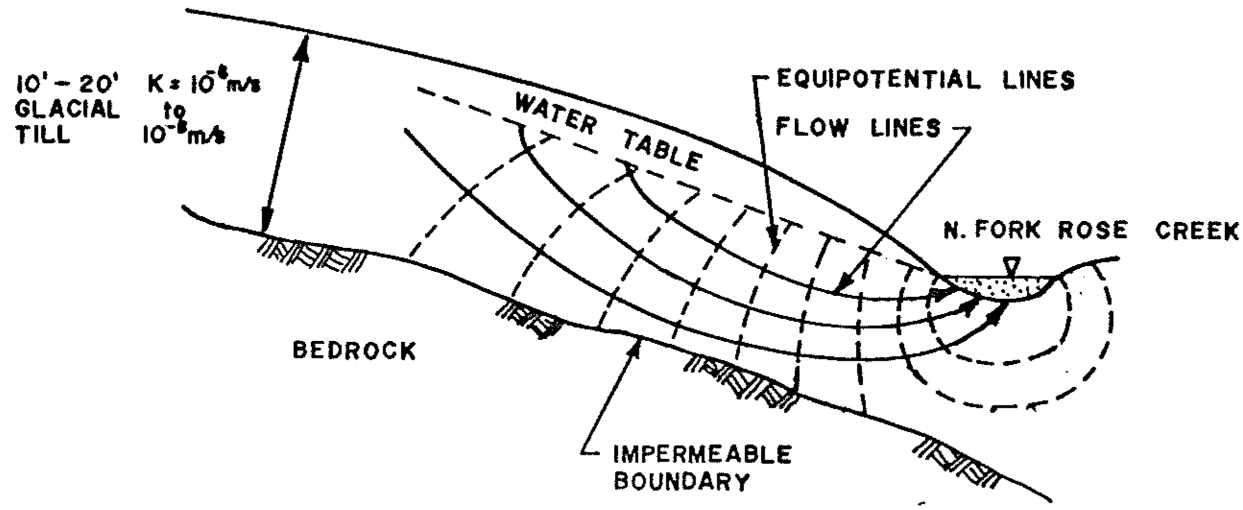


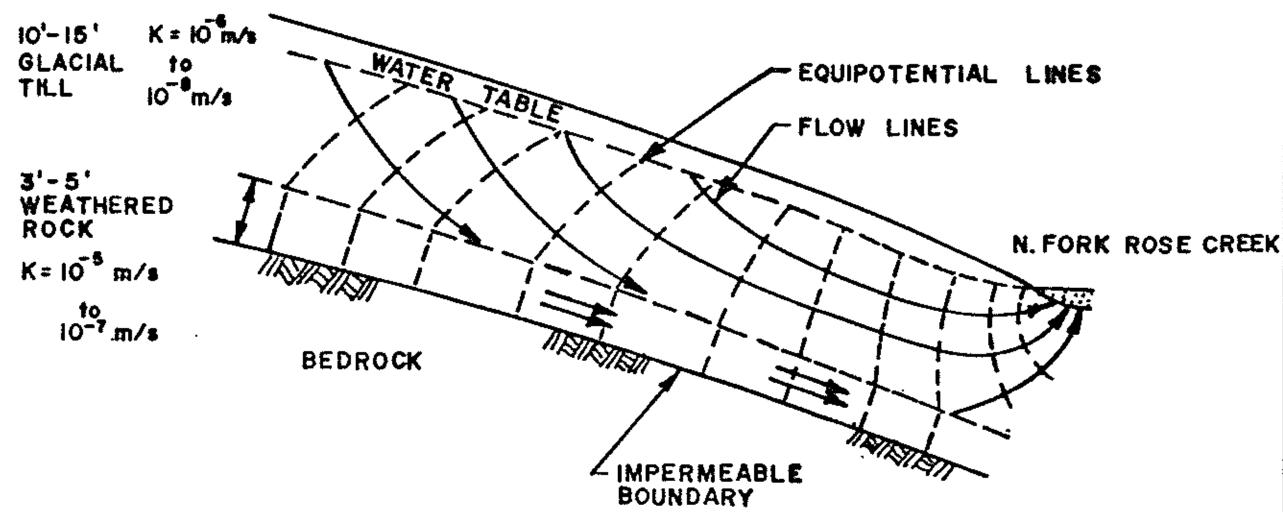

FIGURE 8

FARO PIT ABANDONMENT AREA · FLOW COMPONENTS

# IDEALIZED FLOW NETS




## Ⓐ OVERBURDEN ZONE




## Ⓑ OVERBURDEN AND WEATHERED ROCK ZONE

**FIGURE 9**

At Faro, groundwater flow in bedrock should therefore be closely associated with major fault zones, joints and minor fault sets, permeable contacts between diorite dykes and host rock, and bedrock foliations (Dome, 1984). An understanding of the structural geology of the Faro pits is therefore critical to understanding the hydrogeological flow regime of this area. The geology of the Faro Zone I/III pit area is presented in Figure 10.

Major structural features pertaining to Faro Zone I/III pit are:

i. the overburden/ bedrock interface which generally trends with the original surface topography but is deeper beneath the original Faro Creek Valley;

ii. a diorite dyke in the northwest pit wall of Zone I, a similar dyke along the fault separating Zone I and II and quartz feldspar porphyry dykes along and west of the Big Indian Fault;

iii. rock foliations (platiness) which generally dip 20 to 30 degrees towards the southwest; and,

iv. the Big Indian-North Fork Fault zone which transects the southeastern portion of the Zone III pit and has associated joint and fault sets.

Major Faro Zone I/III pit water recharge sources are summarized below. A summary of the methods used to calculate recharge and discharge volumes is presented in Table 3.

i. Faro Creek which acts as the major surface recharge source. Average annual flows are estimated at between 0.16 and 0.21 $m^3/s$;

ii. seepage under or through the Faro Valley waste dump. This source, estimated at 0.02 to 0.04 $m^3/s$ from pit de-watering pump records, is considered a part of Faro Creek recharge. Flow estimates are average annual flows.

iii. seepage from wall rocks:

- northwestern corner of Zone I (associated with diorite dyke);
- northeastern corner of Zone III (associated with the Big Indian Fault and leakage from Faro Diversion Channel);
- southwestern corner of Zone I.

The total average annual flow from these sources has been estimated at 0.01 $m^3/s$. (Dome, 1984).

The total average annual inflows have been estimated between 0.17 to 0.22 $m^3/s$.

**TABLE 3: ZONE I/III: RECHARGE/DISCHARGE SUMMARY**

| 1. RECHARGE | $m^3/s$ |
|---|---|
| A. Surface Flows | |
| i. Faro Creek | 0.16 - 0.21 |
| B. Groundwater Flows | |
| i. *Seepage from SW corner of pit | 0.005 |
| ii. *Seepage from W wall of pit | 0.002 |
| iii. *Faro Creek Valley seepage | 0.025 |
| iv. *Seepage from S-SE corner | 0.001 |
| | ----- |
| (*Dome, 1984) | 0.033 |
| (Note: Pit De-watering = 0.04 $m^3/s$) | ----- |
| TOTAL RECHARGE ............................ | 0.17 - 0.22 |

| 2. DISCHARGE | |
|---|---|
| A. Surface flows | |
| i. Overflow spillway (after pit reservoir established) | 0.210 |
| B. Groundwater flows (after pit reservoir established) | |
| i. Southwest wall<br>Q = Aki    A = (762 x 180) $m^2$<br>i = 0.039<br>k = $10^{-6}$m/s | 0.005 |
| ii. Southeast wall<br>Q = Aki    A = (245 x 34) $m^2$<br>i = 0.370<br>k = $10^{-6}$m/s | 0.003 |
| TOTAL DISCHARGE IN RESERVOIR FILLING YEARS ....... | 0.008 |

Major Zone I/III discharge sources are:

i. through the southwestern walls of Zone I/III pit. With a maximum pit reservoir head of 3920 ft, outflow has been estimated at between 0.001 and 0.005 $m^3/s$.

ii. through the southeastern walls of Zone III. With a maximum pit reservoir head of 3920 ft, outflow has been estimated at 0.003 $m^3/s$.

The total average annual outflows have been estimated at 0.01 $m^3/s$.

The water balance for Faro Zone I/III open pit, as calculated, represents an accumulated net recharge of 0.16 to 0.21 $m^3/s$. The total pit volume to the 3920 ft elevation will be 52.6 million $m^3$. Therefore, the Zone I/III ultimate reservoir level of 3920 ft would be attained in 8 to 11 years.

## 3.5 Abandonment Assessment

Curragh proposes to abandon the Faro Zone I/III open pit by establishing a water cover to the 3920 ft elevation. In the absence of convective transport, water is a poor oxygen transfer medium. Thus it is expected that a 1 m minimum water cover would prevent further oxidation of the sulphides exposed through mining operations. This measure should have two effects: acid generation from the majority of potentially acid-generating rocks within the Faro Zone I/III pit would be inhibited, and acid leaching of metal contaminants from these same rocks would be reduced.

Some potentially acid-generating rock, however, will remain exposed above the 3920 ft (pit water) elevation and would continue to oxidize. The locations of these potential acid generators are shown on Figure 10. Seepage waters penetrating these exposures of acid generating rock are known to have elevated contaminant concentrations, the most notable being elevated concentrations of zinc. The water pH, however, is only slightly acidic to alkaline (refer to Tables 2 and 3). Thus, the buffering capacity of the flow regime is presently sufficient to neutralize most of the acid produced. The leaching of metals into solution, though, is not prevented. Once dissolved, metals such as zinc remain in solution over a wide pH range, as indicated by results taken from the 1984 and 1987 water quality surveys.

The filling of the Faro Zone I/III open pit with water will take 8 to 11 years. During this period the Faro Mine will continue to operate and on-site monitoring and testing will be conducted by Curragh personnel to ascertain the effectiveness of the water cover. The selection of the final abandonment scheme will be based on these results.

Evaluation of pit water quality will be complicated by time dependant chemical reactions. During the initial flooding period, the pit bottoms will have considerable amounts of exposed sulphides, and pit waters can be expected to mobilize metal contaminants such as zinc. Waste rock which has high acid generating potential will also have been placed in the pit bottom and, if allowed to oxidize before the establishment of the water cover, will contribute soluble contaminant loads to the pit water. Pit water quality results for 1982 and 1987 (Table 2) indicate these loadings could be large. Final pit water quality will be dependent on whether or not chemical and temperature gradients are established within the pit reservoir water column.

During the filling years, no surface water overflow can exit from the pit. Metal contaminants can only exit from the pit during this time (8-11 years) through groundwater transport. Transport of contaminants however could be inhibited during this period by the presence of carbonate minerals in the groundwater flow regime sufficient to reduce the mobility of heavy metals by the formation of solid phases. The capacity of the groundwater system, though, to neutralize acidity and to remove metal cations is finite. A groundwater investigation and monitoring program described later in this report is designed to characterize this groundwater flow regime.

During active mine life, a groundwater flow piezometer/ water quality monitoring network will be installed southwest of the Faro Zone I/III pit, a pit seep survey program will be implemented, and a Faro Creek characterization program will be implemented. Monitoring performed during the remaining active mine life will allow a more complete understanding of the chemistry of this system, and form the basis for more detailed predictions of long term water quality.

The final abandonment plan for the Faro Zone I/III open pit surface water system will be based on the ability of Faro Creek recharge to neutralize pit water and to dilute metal concentrations so that the water overflow quality meets acceptable standards. If the Faro Creek recharge is capable of accomplishing the foregoing, then Faro Creek will be permanently routed through the Faro Zone I/III open pit and no long term treatment of the pit overflow water will be undertaken. This is the preferred remedial solution.

Faro Creek has a slightly alkaline pH, and its bicarbonate content should provide some buffering capacity. The water quality of Faro Creek is discussed in a subsequent section of this report. At present, Faro Creek and groundwater seepage into the Faro Zone I/III pit has sufficient buffering capacity to maintain slightly alkaline pit water. Table 2 summarizes Zone I/III pit water quality. The pH is sufficiently high to maintain low copper concentrations; however, high zinc concentrations are evident. The same pH effect and elevated zinc concentrations are evident for Zone II pit water.

It is likely that the preferred remedial solution's success will also depend on the establishment of a stratification of contaminant concentrations within the water in the pit. At this time there is some expectation that this stratification will establish itself primarily through temperature and concentration gradients.

Stratification is important since this will have the effect of immobilizing the metal concentrations at the bottom of the water column. Faro Creek, in the preferred remedial plan, would only have to neutralize the acidity and dilute the metal concentrations generated from pit wall seeps (see Table 1) above the 3920 ft water level that drain to the top, mobile, layer of the water column.

The principle of stratification assumes that no inversion will occur within the Faro Zone I/III pit water column. The surface area of the pit water reservoir is small (700,000 $m^2$), and this small area, in combination with low average wind speeds (8 km/hr), makes the probability of seasonal inversions like those occurring in large lakes unlikely. However, the Faro Creek inflow could result in significant water column mixing or could even trigger inversions in the autumn season at the time of year when surface water temperatures are cooling at a faster rate than water at depth. The determination of the extent of stratification and inversion will be undertaken during the filling years.

The calculated zinc loadings from the seep surveys vary from a low of 107 mg/s to a high of 2131 mg/s. The average annual Faro Creek inflow available for dilution is 0.21 $m^3/s$ (Section 3.4). If the average annual zinc loading equals the lower estimate, then the dilution capacity of Faro Creek is sufficient to ensure that overflow discharge from the Faro Zone I/III pit will be within the zinc water quality standard of 0.5 mg/l. If the higher estimate more closely resembles the average, overflow water will have an average zinc concentration 20 times the acceptable limit. Seasonal fluctuations in both seep zinc loadings and in Faro Creek inflow are also important. High loadings during low inflow periods could result in highly contaminated pit outflow water. Sufficient data are currently not available to adequately predict metal contaminant loadings to the Faro Zone I/III open pit. Collection of this data will be part of the monitoring program to be undertaken over the filling years.

In summary, for the preferred remedial plan to work, Faro Creek will have to have enough alkalinity to neutralize acid generation to the Faro Zone I/III pit water, the seeps above the 3920 level will have to have metal contaminant loading rates sufficiently small as to be diluted by Faro Creek, and a stratification of metal concentrations , or a metal concentration gradient, will have to establish itself within the pit water column.

While maintaining collection and treatment as environmental protection measures during the years the pit is filling with water, the remedial measures for the Faro Zone I/III open pit will be finalized, implemented, monitored and evaluated. Curragh anticipates that during the next 15 years, while the concentrator is operating and during which treatment can be provided by normal operations, low-impact abandonment can be achieved and will be demonstrated.

# 4. FARO ZONE II OPEN PIT

## 4.1 Site Description

The Faro Zone II open pit is located 300 m immediately southeast of the Zone I/III open pit (Figure 2). Mining of this pit commenced in 1980 and was completed in 1982, during which time approximately 11 million $m^3$ of material was excavated. The pit has a surface area of 650,000 $m^3$ and is 280 ft (85 m) deep (3990 ft elevation to 3710 ft elevation). Currently about 80% of the Faro Zone II pit has been backfilled with waste rock and the water level is at the 3750 ft elevation.

The Zone II pit area is presently used as an active waste rock dump site for the storage of non-acid-generating waste. It has a remaining capacity of approximately 2 million $m^3$ and will be filled by 1990. Careful investigation and evaluation was conducted on this area to ensure abandonment options were not restricted at a later date (see Curragh Resources Inc., 1987). Preliminary abandonment measures and short-term safe guards are being implemented as a result of the studies. These include the construction of a rock drain and sump at the 3800 ft elevation, the re-routing of existing pit perimeter ditches to intercept and divert surface drainage away from the Faro Zone II open pit and the installation of water quality monitoring stations. These installations are indicated on Figure 3.

## 4.2 Site Assessment

Abandonment measures related to the Faro Zone II open pit will be undertaken to ensure discharge water is of acceptable quality. Assessment of water quality is thus of prime importance.

The Faro Zone II open pit site assessment is based on water samples taken from the Zone II pit in 1983, 1984, and August, 1987, and on the Zone II water quality survey conducted in September, 1987. Results from the pit samples and the seep survey are presented in Tables 4 and 5, respectively. Sample sites are shown on Figure 3.

The results of the sampling tests indicate that the Faro Zone II open pit water has elevated zinc concentrations. The average zinc concentrations for 1983 and 1984 were 6.91 and 7.65 mg/l, respectively. In August, 1987 and September, 1987, the zinc levels were 21.40 and 20.10 mg/l, respectively. These latter zinc concentrations were recorded at a slightly alkaline pH of 7.06, which demonstrates that solubilized zinc can remain in solution over a range of pH values. Copper levels in the pit water were low.

Seepage flowing into the Faro Zone II open pit was also sampled in September, 1987 and sample site 31 (Table 4) had a zinc concentration of 93.5 mg/l and a zinc loading of 9.4 mg/s. The

**TABLE 4: ZONE II : SEEP SOURCES AND ESTIMATED LOADINGS**

| | ZINC (mg/l) | COPPER (mg/l) | SULPHATE (mg/l) | pH | COND (umhos/cm) | TEMP (deg C) | FLOW (l/s) | Zn LOAD (mg/s) | Cu LOAD (mg/s) | SO4 LOAD (mg/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| SEPTEMBER 1987 | | | | | | | | | | |
| SITE: | | | | | | | | | | |
| 2 | 4.00 | 0.760 | 202 | 7.27 | 602 | 2.4 | 9.4 | 37.6 | 0.71 | 1899 |
| 31 | 93.50 | 9.300 | 860 | 3.06 | 1910 | 5.5 | 0.1 | 9.4 | 0.93 | 86 |
| 23 | 3.92 | 0.084 | 180 | 7.43 | 563 | 2.2 | 9.2 | 36.1 | 0.77 | 1656 |
| 3 | 2.65 | 0.145 | 93 | 7.54 | 380 | 2.1 | 8.4 | 22.3 | 1.22 | 781 |
| 4 | 1.15 | 0.002 | 139 | 7.71 | 475 | 1.9 | 0.4 | 0.5 | 0.00 | 56 |
| 5 | 5.86 | 0.480 | 315 | 7.49 | 725 | 1.8 | 0.7 | 4.1 | 0.03 | 221 |
| 6 | 5.60 | 0.400 | 278 | 7.00 | 762 | 1.7 | 3.5 | 19.6 | 0.14 | 973 |

**TABLE 5: ZONE II PIT: WATER QUALITY**

| | LEAD (mg/l) | ZINC (mg/l) | IRON (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | MAGNESIUM (mg/l) | CALCIUM (mg/l) | SODIUM (mg/l) | SULPHATE (mg/l) | pH | TEMP (deg C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SEPTEMBER 1987 | | 20.10 | | 0.028 | | | | | 444 | 7.06 | 2.4 |
| AUGUST 1987 | 0.04 | 21.40 | 4.08 | 0.025 | 2.55 | 47.20 | 133 | 11.20 | | | |
| 1984: | | | | | | | | | | | |
| AVERAGE | | 7.65 | | | | | | | | | |
| STD DEV | | 0.29 | | | | | | | | | |
| 1983: | | | | | | | | | | | |
| AVERAGE | | 6.91 | | | | | | | | | |
| STD DEV | | 1.48 | | | | | | | | | |

copper concentration and loading rate were also elevated, being 9.3 mg/l and 0.93 mg/s, respectively. This seep was acidic, having a pH of 3.06. For a more detailed analysis of the water quality of the Zone II open pit, refer to the 1987 Curragh Report, "Development of the Zone II Dump" previously forwarded to the Yukon Territory Water Board.

In summary, water quality records indicate that substantial zinc leaching is occurring in the pit walls and that zinc concentrations in the Faro Zone II open pit water currently do not meet the water quality discharge standard of 0.5 mg/l. In its present condition, Faro Zone II open pit water must be collected, pumped and treated before discharge.

## 4.3 Remedial Measures

Curragh Resources Inc. has already undertaken some abandonment measures with respect to Zone II. Interceptor ditches are being built north of the pit to reduce water inflows. These ditches discharge into the Faro Zone I/III open pit and are located as shown on Figures 3 and 11. The purpose of these ditches is to limit flow through known acid generating rock and to reduce Zone II pit discharge.

A rock drain and water collector sump has been installed at the 3800 ft elevation. The design for this drain is presented in Figure 12. The rock drain allows collection of overflow water from the pit. This water will be pumped and treated until such time as the water quality is considered acceptable for discharge to the environment.

The present water elevation, as previously stated, is at the 3750 ft elevation in the Zone II pit. Eighty percent of the open pit has already been backfilled with waste rock. The acid-generating potential of this rock is unknown. The remaining volume will be backfilled with non-acid-producing waste rock. Inflows and groundwater outflows have been calculated in a subsequent section. From these calculations, the water level is expected to rise to the 3810 ft overflow level in 5 to 8 years. Acid generation below this level will then be inhibited through the restriction of oxygen.

## 4.4 Hydrology and Hydrogeology

The hydrological and hydrogeological flow regimes affecting the Zone II pit have been categorized using the methods outlined for the Zone I/III pit. At present, recharge to the Zone II pit originates in the area north-northeast of the pit. Present discharge from Zone II pit is associated with groundwater flow through the south face. After abandonment, recharge from the Zone I/III pit will likely occur. Also, surface discharge through the rock drain could occur.

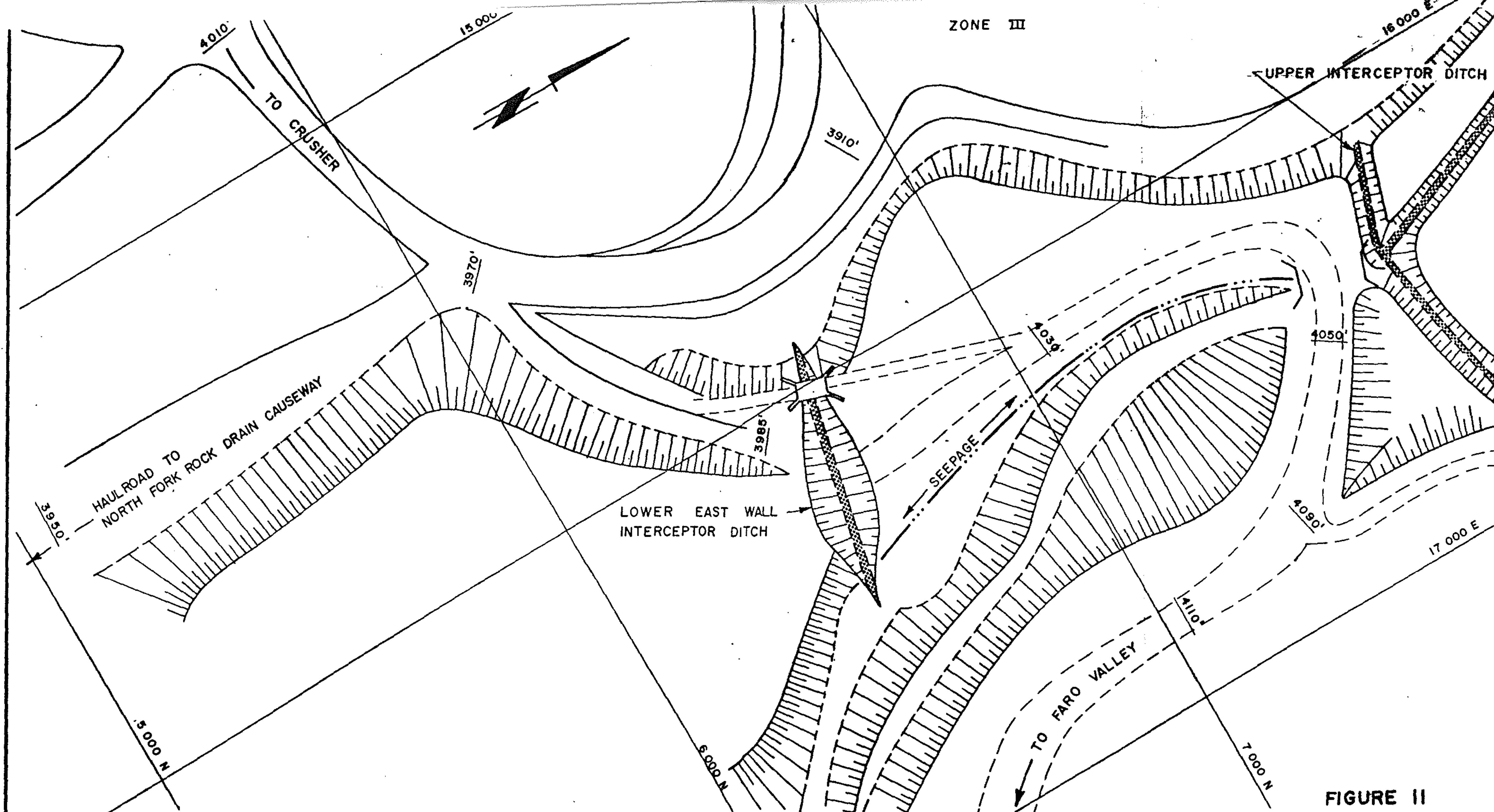


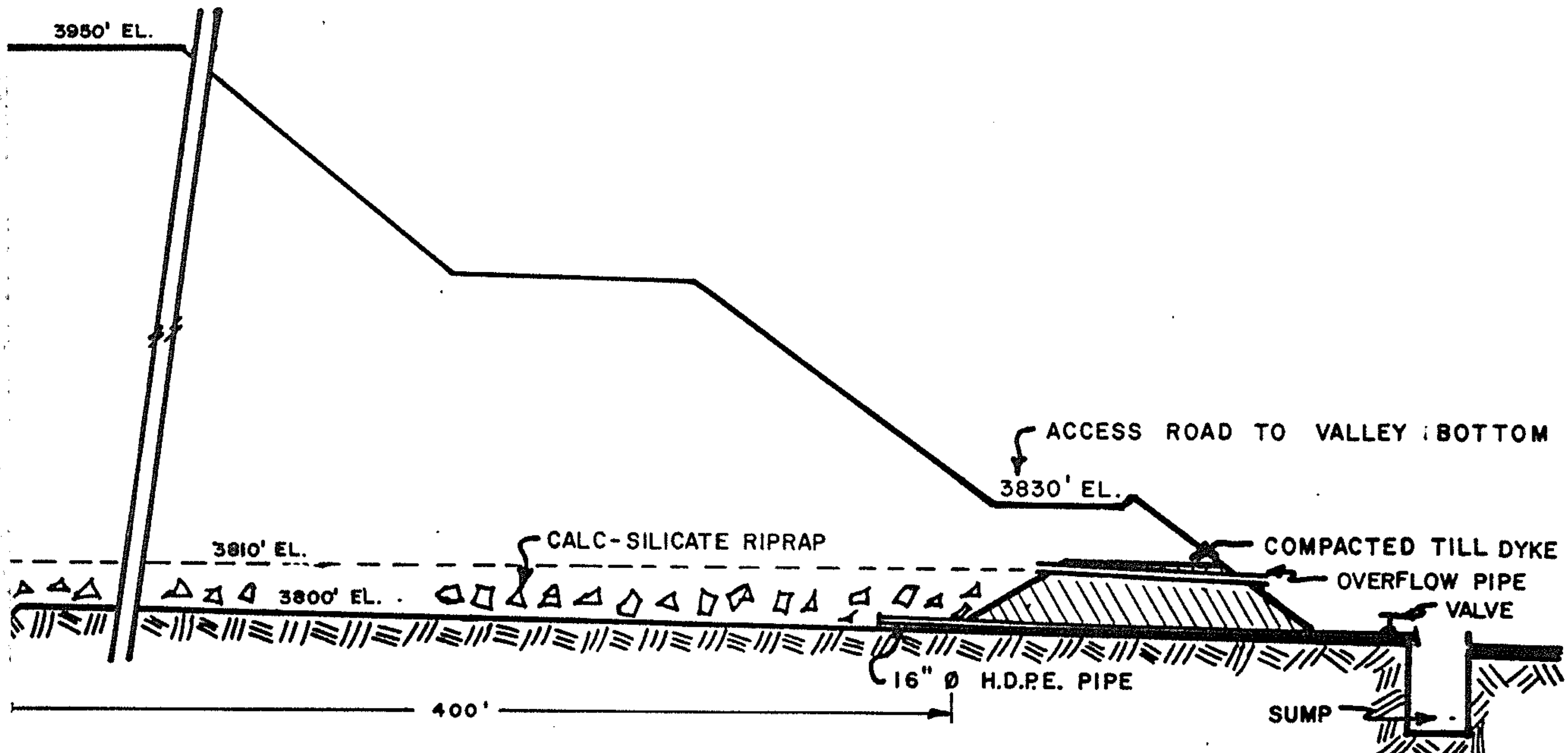

FIGURE 11

| DRAWING NO. | REFERENCE DRAWINGS | REV | REVISION DESCRIPTION | BY | DATE | CHKD | APP | ENGINEER'S STAMP |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

**ENGINEERING RECORD**
DRAWN BY: B.C.B. DATE: 05/03/88
CHKD BY:
ENGINEER:
APP.:

**CURRAGH RESOURCES INC.**
FARO, YUKON TERRITORY

PROJECT: MINE ABANDONMENT
PREPARED BY: J. BOWERS
TITLE: **FARO PIT INTERCEPTOR DITCHES**
SCALE: 1" = 200'
CONTR. DWG. NO.:
DWG. NO.: FA-011
REV:




IDEALIZED SECTION THROUGH INTERNAL ROCK DRAIN.

FIGURE 12 - ZONE II ROCK DRAIN DESIGN

At abandonment, the major Zone II pit recharge sources would be:

i. surface flows, interflows and groundwater flows originating north-northeast of Faro Zone II open pit:

surface flows and interflows:

- the ditch interception/flow control system could eliminate more than 50% of this recharge volume. The abandoned Faro diversion ditch, the 4030 bench ditch, and the northeastern Faro Zone II ditch will divert these flows away from Zone II.

- the abandonment of the Faro diversion ditch with the re-directing of Faro Creek should remove a major water recharge source. Dyke leakage, as measured during the September 1987 water quality survey, was in the range of 0.03 $m^3/s$. Although most of these losses flowed into the Zone I/III pit, there are indications that considerable leakage could also be occurring further downstream, affecting the Zone II pit area. These losses could be the major contribution to Zone II pit recharge.

groundwater flows:

- the groundwater flow is believed to be structurally controlled and closely related to faults, joint sets, and foliations. In this area, the foliations dip 20 to 30 degrees towards the southwest. The Big Indian Fault (see Figure 10) and associated splays also have high anisotropic hydraulic conductivity for flow from north to south but, being heavily gouge-filled, act as an impermeable barrier to flow from east to west. Thus, the Big Indian Fault could serve as a flow conduit from north to south, recharging intersecting faults and joint sets. The splays and joint sets , in turn, could be recharge sources for the Faro Zone II open pit. The hydraulic conductivity for the in-situ phyllite is estimated at between $10^{-6}$ and $10^{-8}$ m/s. (Dome, 1984; Piteau, 1986)

The total pit recharge from surface and groundwater flows from the north-northeast has been estimated at 0.002 $m^3/s$. This estimate assumes that Faro Creek flow is still within the Faro diversion channel and dyke leakages are occurring The re-routing of Faro Creek into the Zone I/III pit could reduce this flow to less than 0.001 $m^3/s$.

ii. groundwater flows originating from Faro Zone III open pit:

- The Zone II pit is isolated from the Zone III pit by approximately 90 m of in-situ waste rock. The bedrock-overburden contact intersects the Zone III pit above the 3920 ft water elevation and therefore will not act as a groundwater conduit between the Zone III pit and the Zone II pit. Structural orientation is also favourable, with foliation dipping southwest at 20 to 30 degrees. Thus, the hydraulic conductivity within this in-situ rock is attributable to joints and fractures and is estimated to be between $10^{-5}$ and $10^{-7}$ m/s.

- currently, groundwater flow in the region separating Zone III pit from Zone II pit is a function of precipitation recharge. The catchment area is small (0.60 $km^2$)and therefore surface infiltrate should be negligible. Surface infiltration is estimated to be 0.001 $m^3/s$ (a 10% infiltration factor has been used in the calculations) and is expected to move towards the Zone II pit as interflow or groundwater flow within the overburden horizon since the topography and overburden/bedrock contact trends towards the south-southeast.

- as is described elsewhere in this report, at final abandonment, approximately 8 to 11 years would be required to establish a water elevation of 3920 ft in the Faro Zone I/III pit. During the reservoir filling period, at the time when the Zone I/III reservoir approaches the 3710 ft elevation, groundwater will begin to move through the bedrock structures from Zone III towards Zone II. The hydraulic gradient from Zone III towards Zone II will continue to increase until the Zone I/III reservoir elevation of 3920 ft is attained. This flow, using the maximum gradient, has been conservatively estimated at 0.003 $m^3/s$.

At abandonment, the total recharge volume into Faro Zone II open pit has been estimated at 0.005 $m^3/s$.

At abandonment, the major Faro Zone II open pit discharge sources would be:

i. groundwater flow through the southern pit walls;

- Maximum groundwater discharge through the southern face has been estimated at 0.002 $m^3/s$.

ii. surface flow through the overflow rock drain discharge.

- the rock drain will not act as a discharge until the water level in the Zone II pit reaches an elevation of 3810 ft, following a period of approximately 8 years. The water level currently is at 3750 ft.

A summary of the methods used to calculate recharge and discharge volumes are presented in Table 6. Conceptual flow nets for the area are shown in Figure 9.

The water balance for Faro Zone II open pit, as calculated, represents a net recharge of 0.002 to 0.003 $m^3/s$. This estimate

**TABLE 6** ZONE II: RECHARGE/DISCHARGE SUMMARY

| 1. RECHARGE | | $m^3/s$ |
|---|---|---|
| A. Surface Flows | | |
| i. Interceptor ditches - diverted from from Zone III and surface infiltration | | 0.001 |
| B. Groundwater flows | | |
| i. Northeast dump area<br>Q = Aki | $A = 365 \times 27\ m^2$<br>$i = 0.175$<br>$k = 10^{-6} m/s$ | 0.002 |
| ii. Zone III/Zone II separation wall<br>Q = Aki | $A = 245 \times 27\ m^2$<br>$i = 0.400$<br>$k = 10^{-6} m/s$ | 0.003 |
| TOTAL RECHARGE.................................. | | 0.006 |
| **2. DISCHARGE** | | |
| A. Surface flows | | |
| i. Rock drain (after pit reservoir established) | | - |
| B. Groundwater flows | | |
| i. South wall<br>Q = Aki | $A = 490 \times 27\ m^2$<br>$i = 0.111$<br>$k = 10^{-6} m/s$ | 0.002 |
| TOTAL DISCHARGE .................................. | | 0.002 |

assumes that the interceptor ditches are successful in diverting part of the surface flow and interflow away from the Zone II pit. The total Zone II pit volume is 2 million $m^3$ below the 3810 ft elevation. Using a void ratio of 25% for neutral or net acid consuming waste rock, the reservoir capacity would be 500,000 $m^3$, requiring 5 to 8 years to fill.

## 4.5 Abandonment Assessment

The abandonment of the Faro Zone II open pit is based on the following premises: water recharge (and thus discharge) can be reduced, transport of leachable zinc can be reduced and a water cover to the 3810 ft elevation will inhibit the majority of acid generation within the pit.

Uncertainties exist with respect to:

i. the level of reduction of recharge which can be achieved;

ii. the level of acid generation which will occur;

iii. the total zinc loading which will occur;

iv. the buffering and dilution capacity of the groundwater; and,

v. the buffering and dilution capacity of North Fork Rose Creek.

This abandonment plan will implement a monitoring and characterization program to reduce these uncertainties. This program is described in Section 10.

During the operation life of the Faro mine and concentrator, Curragh will pump and treat all Zone II pit discharge that is not of acceptable quality. Pumping and treatment will be maintained until such time as Curragh can demonstrate that the impact of Zone II overflow on Rose Creek downstream of the Faro minesite is acceptable.

## 5. Waste Rock Dumps

### 5.1 Site Description

As described earlier in this report, significant quantities of waste rock must be mined to expose ore in the Faro open pit. At the end of Faro pit life, 1993, approximately 87 million m³ of waste will have been removed from the Faro open pits and stored in waste rock dumps. In addition, approximately 5 million m³ will have been used in the Vangorda haul road. The waste dumps, at the locations shown on Figure 3, are:

i. the Sulphide Waste Dump;

ii. the Zone II Dump;

iii. the Intermediate Dump;

iv. the Vangorda Haul Road;

v. the Pit Dumps;

vi. the Main Waste Dump;

vii. the East Waste Dump;

viii. the Northwest Waste Dump;

ix. the Faro Valley Waste Dump.

### 5.2 Site Assessment

From 1969 through to the time when Curragh restarted the Faro Mine in 1986, approximately 62 million m³ of waste rock were mined from the Faro Zone I and II open pits and stored in the Faro pit area waste rock dumps. By the end of the Faro pit mine life in 1993, Curragh Resources Inc. will have mined a further 30 million m³ of waste rock from Faro Zone I and III open pit, of which approximately 25 million m³ will be stored in waste rock dumps and approximately 5 million m³ will be used to construct the Vangorda haul road.

The abandonment of the Faro waste dumps will have to ensure discharge water of acceptable quality from the dumps to the environment, and therefore assessment of the acid-generating potential of the waste rocks and the manner of waste rock storage are of prime importance in the site assessment.

Chemically, the Faro pit waste rock types can be categorized as either potential acid generators, net acid consumers, or neutral rock. Ninety percent of the waste at Faro is either neutral or a net acid consumer and should not be acid generating. The remaining

10% of the waste, however, contains significant proportions of sulphide minerals and is potentially acid generating. The sulphide minerals are primarily pyrite, galena, sphalerite, and pyrrhotite.

Geologically, the waste rock at the Faro open pit mine can be divided into seven major types (greater than 1% by volume of all waste):

i. Quartzo-feldspathic, biotite-muscovite schist [1CD]:
   - Together with 1D0 this is the major component of the remaining waste. Non-acid producer.

ii. Calc Silicate Gneiss [3D]:
   - Comprises approximately 10% of remaining waste. Net acid consumer.

iii. Calc-Silicate Breccia:
   - Heavily silicified calc-silicates, silicification has removed much of carbonate thus generally a net acid consumer but highly variable (Table 7 and 16).

iv. Biotite-muscovite-andalusite schist to phyllite [1D0]:
   - Possible acid producer.

v. Altered schist, quartz muscovite schist [1D4]:
   - Possible acid producer.

vi. Sulphide Waste:
   - Together with altered schist represents 10% of remaining waste. Potential acid producer.

vii. Dyke rocks, mainly quartz diorite and diorite: - tests (Duncan, 1975) show these dyke rocks to be non acid-generating.

There are other waste rock types at the Faro pit, but in total these do not amount to more than 2 to 3% of the remaining waste.

Table 7 provides a summary of waste rock types and their net acid generation potential. Table 8 lists major dumps and summarizes their characteristics. Dump locations are presented in Figure 3.

### 5.2.1 Pre-1986 Waste Dump Accounting

Table 8B lists estimated volumes for dumps constructed prior to 1986. Where possible, the rock type composition has been estimated.

## TABLE 7: WASTE ROCK TYPES AND THEIR ACID GENERATION POTENTIAL

### 7-A: Acid Generation Potential of Curragh Samples

| Sample Description | Geol Code | S % | Max. Potential Acidity* | Paste pH | Neutralizion Potential* |
|---|---|---|---|---|---|
| BARREN MASSIVE SULPHIDE | 2E | 30.900 | 965.6 | 5.9 | 2.79 |
| MASSIVE BIOTITE-ANDALUSITE SCHIST | 1DO | 1.140 | 35.6 | 7.5 | 10.40 |
| WHITE MICA ENVELOPE-QUARTZ MUSCOVITE SCHIST | 1D4 | 4.090 | 127.8 | 7.2 | 18.30 |
| CALC SILICATE GNEISS | 3D | 0.423 | 13.2 | 8.9 | 212.70 |
| CALC SILICATE BRECCIA | 3DBx | 0.789 | 24.7 | 8.5 | 17.90 |

* Units: tons $CaCO_3$ equivalent/1000 tons material

Sampled: January 1987
Analysed by: Chemex Labs Ltd., North Vancouver, B.C.

**TABLE 7-B: ACID GENERATION POTENTIAL OF ANVIL SAMPLES**

| Sample Type | Sample | %Pb | %Zn | %Fe | %Cu | %Ba | %S | Natural pH | Acid Consumption (lb/ton) | Theoretical Acid Production (lb/ton) | Theoretical Acid Producer | Actual Acid Producer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ore | | | | | | | | | | | | |
| | yellow stockpile | 3.49 | 4.26 | 29.7 | 0.12 | - | 37.5 | 5.7 | 87 | 2250 | yes | yes |
| | red stockpile | 3.23 | 5.93 | 28.1 | 0.16 | - | 35.8 | 5.6 | 102 | 2148 | yes | yes |
| Tailings | | | | | | | | | | | | |
| | 16-h composite January 23 | 0.33 | 0.80 | 28.8 | 0.10 | - | 37.5 | 6.8 | 41 | 2250 | yes | yes |
| | 8:00 a.m. grab January 24 | 0.22 | 0.54 | 31.2 | 0.08 | - | 37.9 | 5.2 | 17 | 2274 | yes | yes |
| Waste Rock | | | | | | | | | | | | |
| [10E] | diorite dyke | 0.04 | 0.06 | 3.9 | 0.01 | 0.09 | 0.98 | 9.1 | 59 | 59 | ? | no |
| [10E] | diorite dyke A (unaltered) | - | 0.01 | 3.7 | 0.01 | - | 0.26 | 9.2 | 73 | 16 | no | |
| [10E] | diorite dyke B (unaltered) | - | 0.01 | 3.0 | 0.01 | - | 0.29 | 8.9 | 58 | 17 | no | |
| [10E] | diorite dyke C (altered) | - | 0.04 | 4.9 | 0.02 | - | 0.24 | 7.5 | 19 | 14 | no | |
| [10E] | diorite dyke D (altered) | - | 0.02 | 3.8 | 0.01 | - | 0.16 | 7.8 | 21 | 10 | no | |
| | biotite schist [1D0] | 0.01 | 0.01 | 4.9 | 0.01 | - | 0.09 | 9.2 | 30 | 5 | no | |
| | muscovite schist [1CD] | 0.01 | 0.02 | 4.9 | 0.01 | - | 0.09 | 7.9 | 40 | 5 | no | |
| | calc silicate [3D] | 0.06 | 0.08 | 4.6 | 0.01 | - | 0.46 | 9.4 | 145 | 28 | no | |
| | sandy pyrite [2E0] | 0.30 | 0.45 | 48.5 | 0.03 | - | 52.7 | 6.0 | 54 | 3162 | yes | yes |
| | drill cuttings in muscovite schist at ore contact [1D4] | 0.28 | 0.51 | 7.3 | 0.04 | 0.28 | 3.6 | 6.4 | 74 | 216 | yes | yes |

(D.W. Duncan, Leachability of Anvil Ore, Waste Rock & Tailings, 1975)

TABLE 8: FARO MINESITE - MAJOR WASTE DUMPS: CHARACTERIZATION SUMMARY

A. ULTIMATE WASTE DUMP CAPACITIES

| DUMP SITE LOCATION & DESCRIPTION | ULTIMATE DUMP SITE CUBIC METERS | CALC-SILICATE GNEISS 3D | BIOTITE MUSCOVITE ANDALUSITE SCHIST 1DO | BIOTITE MUSCOVITE SCHIST 1CD | GRANO-DIORITE & DIORITE 10E | POTENTIALLY ACID GENERATING WASTE ROCK |
|---|---|---|---|---|---|---|
| FARO MAIN DUMP SITES Includes: Main Dump, Intermediate Dump, "B" Stockpile & Oxide Ore Stockpile, Pad Locations, Encapsulated High Sulphides | 56,000,000 | 33% | 29% | 19% | 9% | 10% |
| UPPER NORTH WEST DUMP SITES Includes: Terraced Dump Levels North of Haulroad from Crusher to Lube Shop | 5,000,000 | 35% | 30% | 20% | 10% | 5% |
| EAST SIDE DUMP SITES Includes: Faro Valley, Zone II, S.E. Rock and till Dump Sites | 23,000,000 | 35% | 30% | 20% | 10% | 5% |
| VANGORDA HAUL ROAD | 5,000,000 | 40% | 30% | 20% | 10% | - |
| PIT DUMPS Includes: 4,200,000 tonnes of Sulphide Rock | 3,000,000 | 20% | 18% | 12% | 6% | 44% |
| | 92,000,000 | | | | | |

B. CYPRUS ANVIL: 1975 WASTE DUMP CHARACTERISTICS

| | Area ($m^2$) | Height (m) | Volume ($m^3$) | % |
|---|---|---|---|---|
| Granodiorite and Diorite [10E] | 218,500 | 38 | 8,303,000 | 10 |
| Biotite Muscovite Andalusite Schist [1DO] | 242,800 | 38 | 9,226,400 | 30 |
| Biotite-Muscovite Schist [1CD] | 242,800 | 38 | 9,226,400 | 20 |
| Calc Silicate Gneiss [3D] | 449,200 | 38 | 17,069,600 | 35 |
| Potential Acid Generating Rocks [Low Grade Sulphides and 1D4] | 60,700 | 38 | 2,306,600 | 5 |
| TOTAL | 1,214,000 | | 46,132,000 | |
| | (300 acres) approx. | | | |

### 5.2.2 Post-1986 Waste Dump Accounting

For the purpose of this report, waste rock is defined as either sulphide or non-sulphide waste according to its acid-generating potential, sulphide waste being acid generating. Sulphide waste consists of massive and disseminated sulphides as well as the altered phyllites. The distribution of the ore and waste types is schematically displayed on Figure 13. The "Waste Rock Management Plan" (Section 5.5) describes waste rock sources and final dump locations.

As of May, 1987, approximately 22 million $m^3$ of waste remained to be mined from the Faro open pit. Of this, it is estimated that approximately 20 million $m^3$ do not contain significant amounts of potentially acid-generating rock. Approximately 2 million $m^3$ of waste do contain significant amounts of acid-generating rock and require special consideration for permanent storage. Approximately 1 million $m^3$ of sulphide waste will be encapsulated within non-sulphide rock. Encapsulation segregates sulphide rock from both the atmosphere and the overburden. In addition, truck traffic induced compaction will cause the surfaces of the dumps to form seals which reduce water infiltration into the sulphide material.

The remaining 1 million $m^3$ of sulphide waste from the final pit phase will be dumped back into the Zone I/III open pit below 3975 ft elevation insuring that this waste will be covered by a minimum of 1 m of water at final abandonment. The water cover should inhibit oxidation and acid generation.

Seepage water quality data from waste dumps are not extensive. The September, 1987 water quality survey conducted by Curragh personnel indicated that zinc leaching occurs in the eastern waste dump. Weekly monitoring of the small stream flowing from the main waste dump indicates that zinc also leaches from this dump. Table 9 provides average data for 1982 and 1987 for this stream (sample site X23). The site is shown on Figure 3. In 1982, the average zinc concentration was 19.48 mg/l; in 1987, the average was 25.32 mg/l.

## 5.3 Remedial Measures

Curragh Resources Inc. operates with a waste rock management plan that is intended to minimize acid generation after abandonment of the Faro pit waste dumps. The waste rock management plan, presented below, utilizes the principle of isolation and encapsulation of sulphide wastes. Sulphide wastes are isolated in one location and drainage control measures are implemented to minimize the potential for contaminant migration. Prior to abandonment, a low- permeability cap will be placed on the dump surface. This cap, together with a high-elevation base, should effectively isolate the sulphide dump from the majority of water inflow sources. The aim is not to inhibit oxidation, but rather to restrict water flow and thus minimize contaminant transport.

# IDEALIZED CROSS SECTION – FARO PIT

NOT TO SCALE

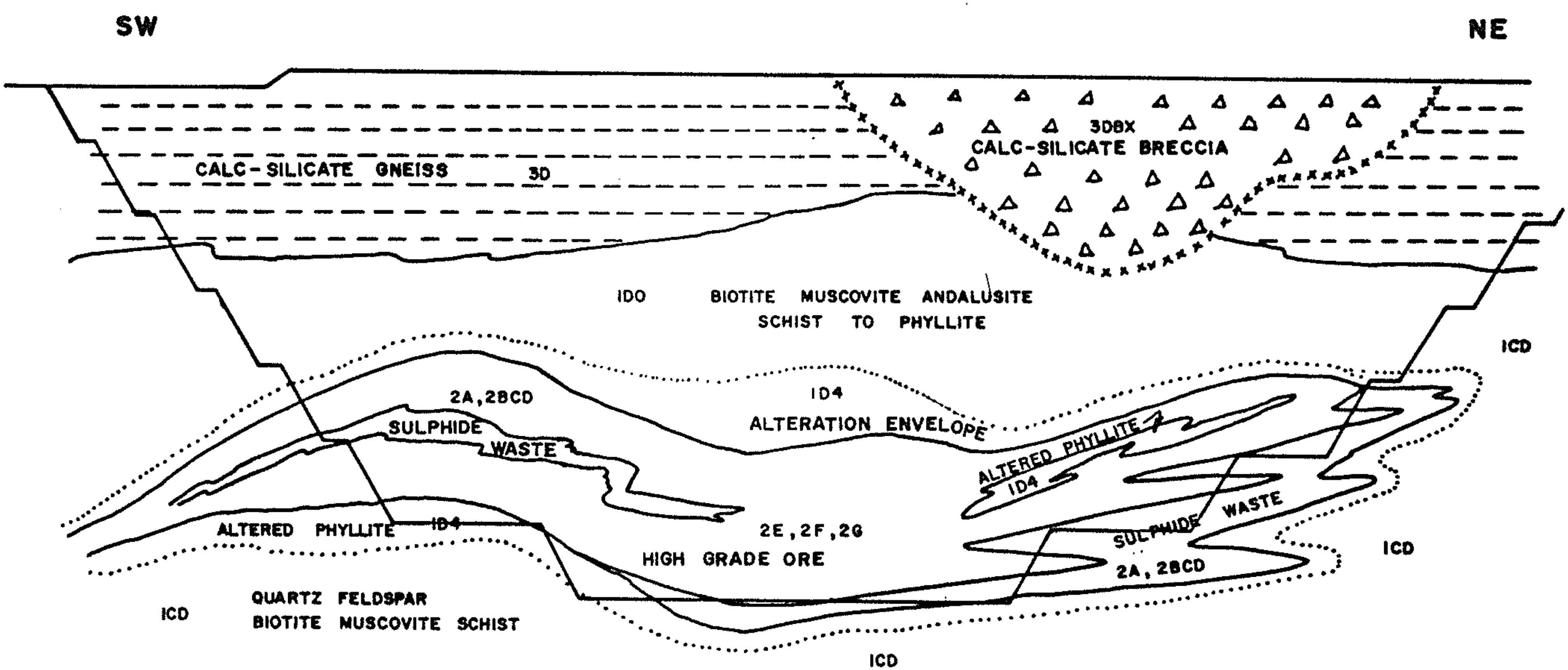



FIGURE 13

**TABLE 9: MAIN WASTE DUMP WATER QUALITY - SITE X23**

| | LEAD (mg/l) | ZINC (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | SODIUM (mg/l) | SULPHATE (mg/l) | pH | SUSP SOLIDS (mg/l) | TEMP (deg C) |
|---|---|---|---|---|---|---|---|---|---|
| **SAMPLE SITE X23** | | | | | | | | | |
| 1987 YEAR MIN | 0.00 | 8.50 | 0.00 | 1.98 | 14.40 | 415 | 6.11 | 0 | 1 |
| 1987 YEAR MAX | 0.20 | 44.90 | 0.11 | 15.30 | 43.00 | 1830 | 8.40 | 148 | 5 |
| 1987 NO. ANALYSES | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 51 |
| 1987 YEAR AVG | 0.04 | 25.32 | 0.02 | 9.17 | 30.60 | 1158 | 7.17 | 7 | 3 |
| 1987 YEAR STD DEV | 0.05 | 7.82 | 0.02 | 3.88 | 9.80 | 391 | 0.35 | 21 | 1 |
| 1982 YEAR MIN | 0.01 | 2.8 | 0.01 | 0.56 | 12 | | 6.2 | 0 | 0 |
| 1982 YEAR MAX | 0.26 | 41.6 | 0.07 | 6.4 | 50 | | 7.6 | 26 | 10 |
| 1982 NO. ANALYSES | 38 | 37 | 37 | 38 | 36 | | 38 | 38 | 38 |
| 1982 YEAR AVG | 0.08 | 19.48 | 0.02 | 3.1 | 28.8 | | 7.39 | 3.7 | 3 |
| 1982 YEAR STD DEV | 0.04 | 10.17 | 0.01 | 1.13 | 10.4 | | 0.87 | 4.3 | 3.1 |

Low grade ore stockpiles will be sent to the concentrator for processing prior to abandonment.

## 5.4 Abandonment Assessment

Of primary concern are the sulphide waste dumps. Construction and location of the dump outside the Faro Zone I/III open pit is being undertaken to minimize the water recharge and discharge fluxes through the dump. This will minimize metal contaminant migration. With the implementation of a surface cap, combined with the location of the sulphide dump, the only available recharge would be from surface water infiltration. The majority of the precipitation should be lost to evaporation or surface runoff. Thus, only small recharge flows should influence the sulphide waste rock dump. Given the acid-generating capacity of this waste rock, contaminant concentrations could be high; however, with small water fluxes, total discharge loading should be low. All infiltrate will eventually migrate into the overburden/weathered rock groundwater regime. The groundwater residence time and the buffering capacity of the flow regime must be determined, as well as actual infiltration rates and contaminant concentrations.

A monitoring program will be implemented to determine both groundwater flow characteristics and buffering capacity for the flow regime immediately south of the sulphide waste dump. The quality of the leachate will also be monitored. This program will consist of three double-nested piezometers and will be installed in the manner described for the Zone II piezometer net. Details of the monitoring program are described in Section 10.

The remaining dumps, although classified as non-acid-producing dumps, will also be investigated. Physical characteristics such as volume, area, and repose angles will be determined. Seep surveys will be undertaken to identify contaminated seeps. These programs are also detailed in the monitoring section of this report.

## 5.5 Waste Rock Management Plan

### 5.5.1 General

The current mining plan for the Faro deposit makes it possible to define in detail the timing and location of the deposition of waste rock. The primary objective of the waste rock management plan is to manage waste rock in a manner such that the waste dumps can be abandoned with little or no long term maintenance.

The final limits of the dump areas (Figure 3) show the limit to which each dump face will be developed under the current mine plan. The waste dump limits are subject to change should the mine plan change.

Up to 5 million m$^3$ of non-sulphide waste rock are needed to complete the haul road between the Faro and Vangorda deposits. This road is scheduled for completion by the end of June, 1989.

### 5.5.2 Design Parameters

The final dump slopes completed after January, 1986 will have overall slopes not greater than 2:1. Bench slopes will be at the angle of repose. Dump face/slope profiles are presented in Figure 14.

Beginning in the first quarter of 1989, all sulphide waste will be dumped back in the pit below the 3920 water elevation. Beginning in the third quarter of 1989, all waste will be dumped back in the pit. Backfilled waste will account for 2 million m$^3$ of waste rock.

The design limits of the dumps are constrained by the location of the North Fork of Rose Creek and the main power line supplying the mine. The toe of the dump parallel to the North Fork of Rose Creek will be a minimum of 125 m from the creek.

### 5.5.3 Active Dump Locations and Descriptions

There are three active dump faces to be used through the remaining life of the Faro deposit. The Vangorda haul road is not considered a dump face, but a haul road. Dump locations are shown on Figure 3. All dumps and the haul road are described below.

i. The Sulphide Waste Dump

This waste dump site was developed to segregate potentially acid-generating waste rock from non-acid-generating waste rock. It is located southeast of the highest level of the main waste rock dump and is located between the main and intermediate waste rock dump sites. The sulphide waste rock dump site was developed in 1986 by Curragh and was designed to accommodate up to 1 million m$^3$ of sulphide waste rock. As of January 1, 1988 approximately 0.5 million m$^3$ of sulphide waste rock had been deposited in this dump. This dump site is expected to be completed by December, 1988.

Potentially acid-generating wastes are stored in two specific locations (Figure 3): backfill in the Zone I/III pit and the sulphide waste dump. The sulphide waste dump location (Figure 15) was selected according to the following criteria:

i. drainage can be routed away from receiving waters;
ii. waste contact with the original ground surface can be avoided; and,

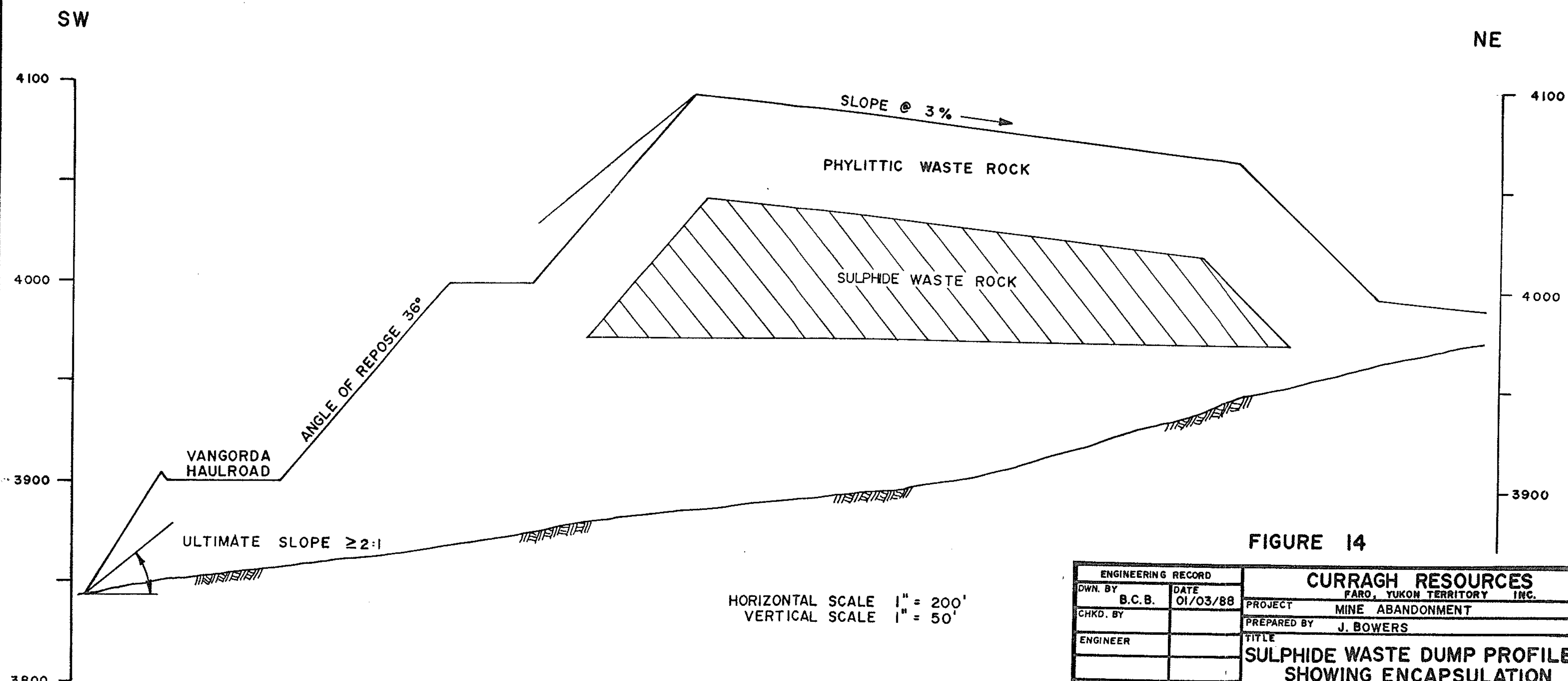



FIGURE 14

| ENGINEERING RECORD | | |
|---|---|---|
| DWN. BY B.C.B. | DATE 01/03/88 | |
| CHKD. BY | | |
| ENGINEER | | |
| APP. | | |

**CURRAGH RESOURCES INC.**
FARO, YUKON TERRITORY

PROJECT: MINE ABANDONMENT

PREPARED BY: J. BOWERS

TITLE: **SULPHIDE WASTE DUMP PROFILE SHOWING ENCAPSULATION**

SCALE: AS SHOWN | CONTR. DWG. NO. | DWG. NO. | REV

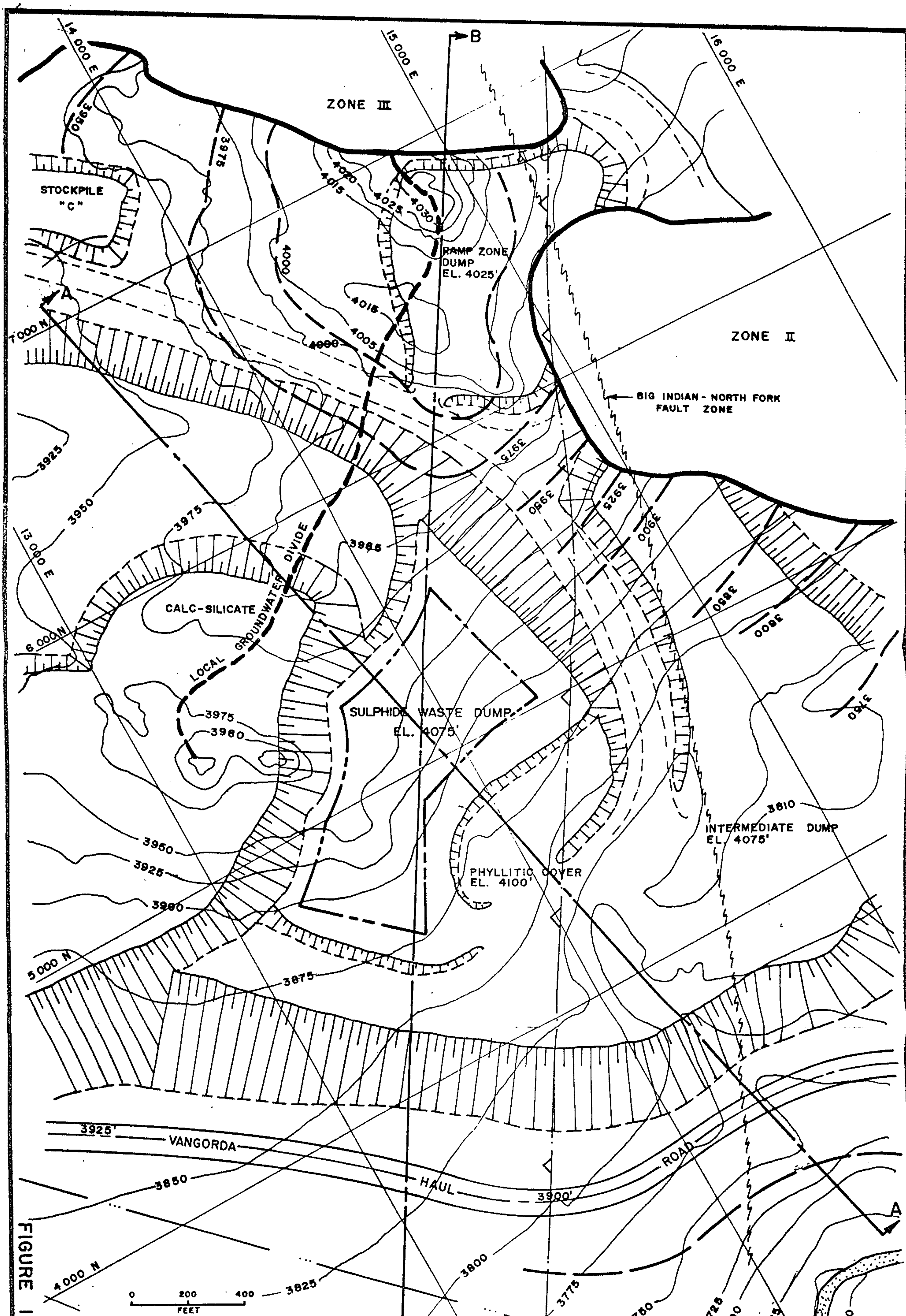



FIGURE 15

SULPHIDE WASTE DUMP - PLAN VIEW

iii. non-sulphide waste can be dumped on top of the sulphide waste to form a protective cap.

Two cross-sections through this dump are presented in Figure 16. As shown, this encapsulated cell of sulphides does not contact original ground and will later be capped by an inert, low-permeability rock.

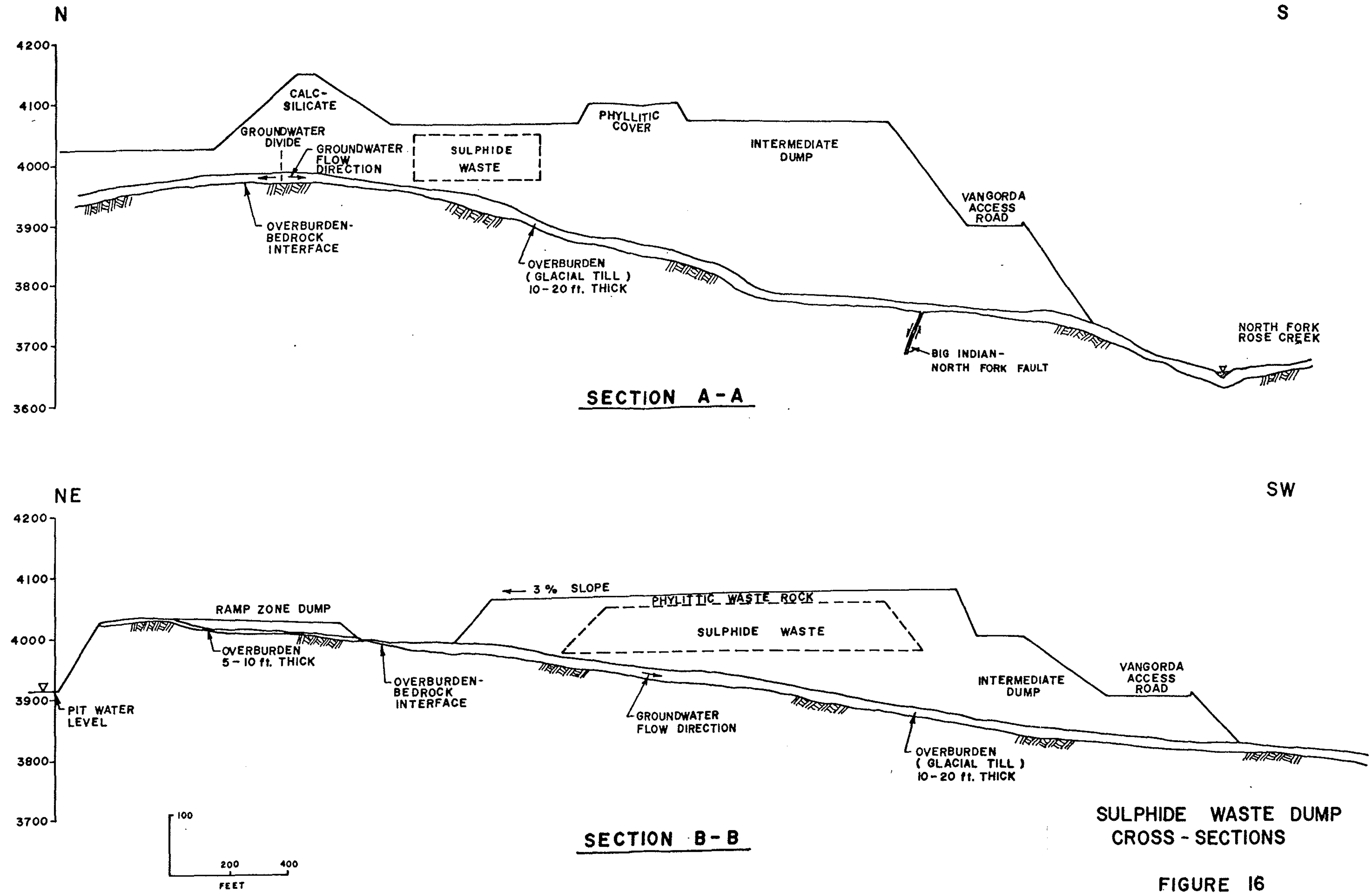
## Sulphide Waste Dump Hydrology and Hydrogeology

At abandonment, a low-permeability seal of compacted phyllitic waste will be placed on the surface of the sulphide waste dump. The phyllite will be tested to determine its permeability and weatherability prior to abandonment. The capping seal should minimize infiltration recharge due to local precipitation. Total precipitation recharge affecting this dump is estimated at 0.001 $m^3/s$. The catchment area of 0.1 $km^2$ is shown on Figure 15. Using a 10% infiltration rate, the recharge affecting this dump could be as low as 0.0001 $m^3/s$. The capping layer will be sloped towards the Zone I/III pit as shown on Figure 14 and, having low permeability, the majority of precipitation should run off.

Recharge waters should also be directed towards the Zone I/III pit by internal dump layers created during encapsulation. Cross-section B-B of Figure 16 indicates the slope and probable water flow direction. Both surface flow and dump infiltration water will be capable of infiltrating into the overburden groundwater regime immediately to the northeast of the sulphide dump. The groundwater flows towards the south, as indicated in cross-section A-A of Figure 16, but should remain below the sulphide dump capsule.

The sulphide dump is isolated from the overburden groundwater flow by a zone of phyllitic waste rock located immediately below sulphide waste. This zone was designed to raise the sulphide waste above original ground. Dumping procedures should also have resulted in compaction of this material, which in turn should have reduced its permeability. This zone is inclined towards the Zone I/III pit. Thus, this base seal zone should also direct sulphide dump infiltration water towards the northeast.

The groundwater flow regime below and in the immediate vicinity of the sulphide waste dump consists of 3 to 10 m of overburden with an approximate hydraulic conductivity of $10^{-6}$ to $10^{-8}$ m/s (EBA, 1987: till grain size analysis in North Fork Rose Creek Valley), underlain by 0.5 to 1.5 m of weathered rock with an estimated hydraulic conductivity of $10^{-5}$ m/s. These horizons, in turn, are underlain by bedrock. The bedrock hydraulic conductivity should be a function of geological structures and is estimated at $10^{-6}$ to $10^{-7}$ m/s.




SULPHIDE WASTE DUMP CROSS-SECTIONS

FIGURE 16

Regionally, the water table separating the unsaturated/saturated soil zones is located within the overburden (glacial till) layer. The weathered zone could be considered as a semi-confined aquifer, and the bedrock as an aquitard. Idealized flow nets in Figure 9 provide a conceptual view of this groundwater regime.

The overburden/bedrock contact trends generally with the local topography and slopes towards the south-southwest at approximately 6 degrees. The base of this overburden/bedrock contact intersects the Zone I/III pit above the 3920 ft elevation, as shown in cross-section B-B on Figure 16, and thus both the overburden and the weathered zones are isolated from regional recharge sources. Local precipitation and infiltration is, therefore, the only recharge source available to the overburden and weathered rock zones. The groundwater flow in the overburden and weathered rock horizons is estimated at 0.001 $m^3/s$. This small flow should be directed towards North Fork Rose Creek along the flow direction indicated by cross-section A-A of Figure 16.

Groundwater flow in the bedrock, as previously noted, will be structurally controlled. Foliations dip at 20 to 30 degrees towards the southwest. The Big Indian Fault - North Fork fault system transects this area immediately to the east of the waste dump, trending from northeast to southwest. The location of this fault is shown on Figure 15 and on cross-section A-A of Figure 16. Drill evidence indicates this fault to be gouge-filled with semi-impermeable material; thus, this fault should act as a barrier to groundwater flow in bedrock from west to east. Therefore, groundwater flow in the bedrock should trend along the flow direction indicated on cross-section B-B of Figure 16. Flow through the bedrock immediately underlying the waste dump is estimated to be less than 0.001 $m^3/s$. This flow could be recharged from the 3920 water reservoir in the Zone I/III pit but should not affect the waste dump.

ii. The Zone II Dump

This dump site development consists of backfilling the Zone II open pit, located 300 m southeast of the Zone I/III open pit. As of January 1, 1988 there were an additional 2 million $m^3$ of non-acid-generating waste rock scheduled for deposition in this location. This dump site is scheduled for completion by the end of 1989.

iii. The Intermediate Dump

The intermediate waste rock dump site is located southeast of the main waste rock dump site, bounded by the main powerline to the west and the Vangorda haul road to the east and south. This waste dump site is essentially completed except for 0.3 million $m^3$ of non-acid-generating waste rock scheduled for deposition in 1990.

iv. **The Vangorda Haul Road**

The Vangorda haul road connects the Faro minesite concentrating facility with the Vangorda Plateau ore deposits. The haul road begins west of the "B" ore stockpile and wraps around the west side of the main and intermediate waste rock dump sites at approximately the 3900 ft elevation. This haul road parallels the minesite access road to Vangorda for approximately 10 km, just east of the main powerline. It joins the Plateau haul road system east of the Grum open pit limits.

Approximately 5 million $m^3$ of pit-run waste rock, of which 1 million $m^3$ are currently in place, are required to construct 14.6 km of road. The road will be 23 m wide and averaging 1.5 m of fill. The first 1.6 km, the rock drain embankment crossing the North Fork of Rose Creek, requires 3 million $m^3$ or three-fifths of the total fill.

v. **Pit Dumps**

The "BZ" and "CD" Phases of the Faro Zone I/III open pit are ideally suited for back filling. Present mine plans call for mine waste rock from the "DZ" phase to be dumped along the west side of the pit at the 3700 ft elevation, beginning in 1989. Of a total of 2 million $m^3$ of waste that are scheduled to be dumped back into the pit, 1 million $m^3$ are sulphide waste rock.

vi. **The Main Waste Dump**

The main waste dump was developed by Cyprus Anvil Mining Corporation to the 4150 ft elevation and is the single largest dump. This dump is located southeast of the concentrating facility, bounded by the main powerline on the west and the intermediate waste dump on the south. A mine refuse dump, located on the 4075 ft elevation of the northwest level, was developed in 1987 by Curragh. A segregated waste calc-silicate waste dump area was developed by Cyprus Anvil on the northeast corner of the 4150 ft level and on the east side of the 4050 ft level.

vii. **The East Waste Dump**

This dump is located east of the Zone I/III pit and northeast of the Zone II pit, bounded by the Faro Creek Diversion Channel to the north. The east dump contains a high percentage of overburden in its upper levels. Curragh will utilize this dump site as a non-acid-generating waste dump for the upper levels of stripping of the "CD" Phase, currently underway. It is possible that this dump site may already contain acid-generating waste rock.

### viii. The Northwest Waste Dump

The northwest dump is located northwest of the Zone I/III open pit and is bounded by Next Creek to the west and the Crusher haul road to the south. This is an early Cyprus Anvil waste dump site and will not likely be used by Curragh. The explosives magazines, dispatch tower and fuel tank farm sites are currently located within this dump area.

### ix. The Faro Valley Waste Dump

The Faro Valley waste dump is located northeast of the Zone I/III open pit and is bounded by the Faro Creek Diversion Channel to the northeast. This dumpsite contains both overburden and waste rock, and is known to contain potentially acid-generating waste rock.

# 6. Creeks and Diversion Channels

## 6.1 Faro Creek and Faro Creek Diversion Channel

The major creeks and diversion channels in the Faro open pit area are: Faro Creek, the Faro Creek diversion channel, the North Fork of Rose Creek, the North Fork diversion channel and the North Valley Wall interceptor ditch. The Rose Creek diversion channel is associated with the tailings impoundment area and abandonment measures for this diversion will form part of the tailings abandonment plan.

### Site Description

Faro Creek is located to the north of the Zone I/III pit. Faro Creek was diverted in 1969 just to the north of the Faro pit into Faro Creek diversion channel to permit open pit mining of the Faro deposit. The diversion channel is routed to the North Fork of Rose Creek above the northeastern crest of the Faro Zone I/III open pit. The diversion channel and its confluence with North Fork of Rose Creek are shown on Figure 3.

### Faro Creek Hydrology and Hydrogeology

Faro Creek has an alpine catchment area of 14 $km^2$. An average of approximately 370 mm of precipitation falls on this area yearly (average derived from 1951-1980 precipitation records) , resulting in an estimated annual flow rate in Faro Creek of 0.17 $m^3/s$. Measured flow rates, typically in the range of 0.16 to 0.21 $m^3/s$, confirm this. Flow records, together with calculated flows based on catchment area and recorded precipitation are summarized in Table 10.

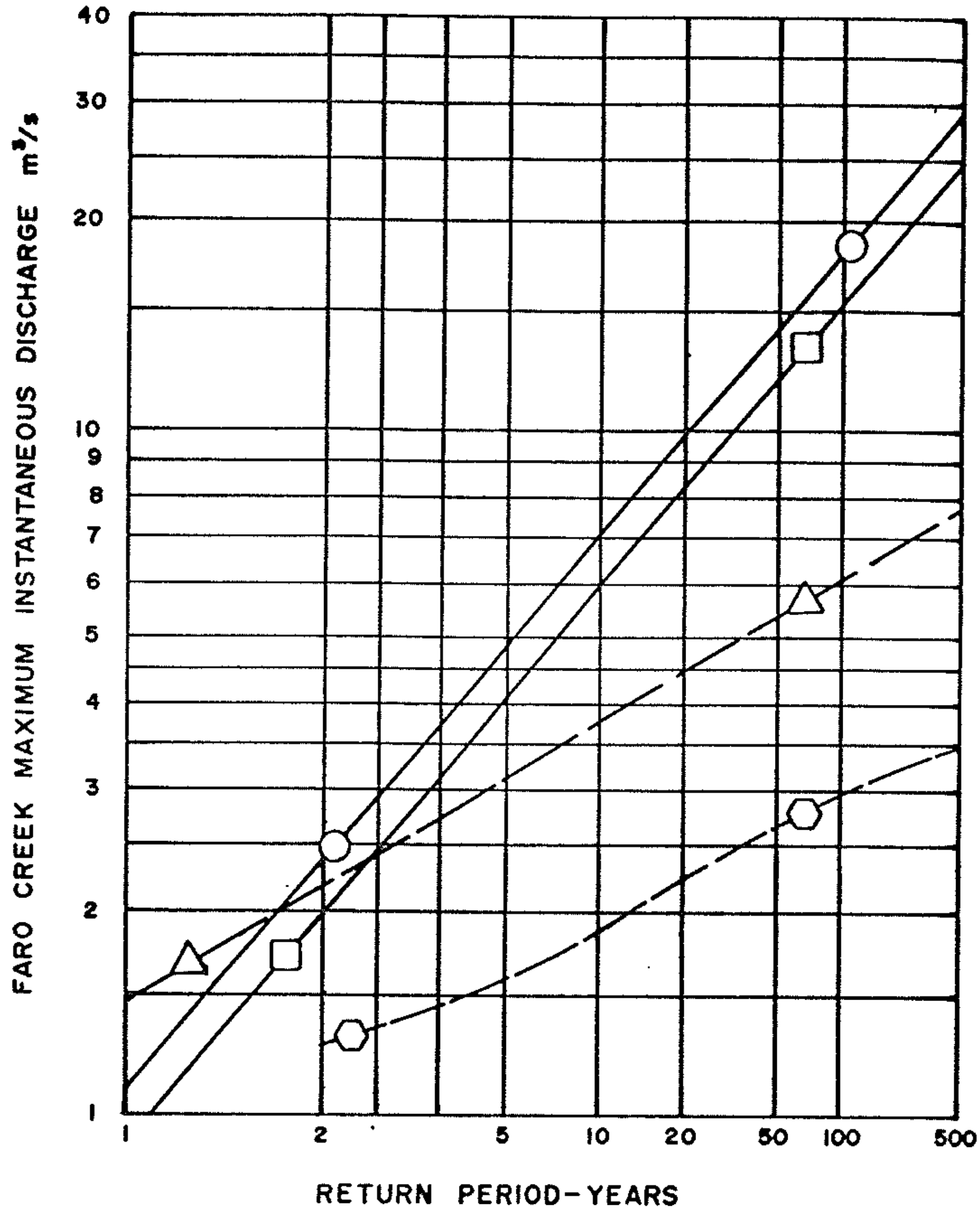
For the purposes of flood design for the Faro Creek diversion channel, a mean annual flood of 2.1 $m^3/s$ and a 500-year return period instantaneous discharge of 24.0 $m^3/s$ were used. This was derived from calculations for a 100-year return period instantaneous discharge, 15.6 $m^3/s$, based on catchment area. A flood frequency distribution is shown in Figure 17. The calculation coefficients for the Faro Creek catchment basin were based on those for the Rose Creek drainage basin, with a 25% safety margin (Hydrocon, 1980) to the calculated mean annual flood to account for physical differences in these watersheds. However, recent studies conducted by DIAND on potential flood discharge magnitudes for Yukon rivers (Janowicz, 1986) indicate that this safety margin may be high. Using DIAND methods, a mean annual flood of 2.2 $m^3/s$, a 100-year flood of 6.0 $m^3/s$, and a 500-year flood of 7.5 $m^3/s$ were calculated. Instantaneous flood magnitudes for selected return periods are presented in Table 11. Curragh is commissioning Golder Associates to review the hydrological data and provide recommendations on flood design parameters.

**TABLE 10:** SUMMARY OF FARO CREEK DISCHARGES

| SOURCE | YEAR | MONTH | METHOD | DISCHARGE ($m^3/s$) [under discharge] | NOTES |
|---|---|---|---|---|---|
| Sigma | 1975 | June | Meter | 1.56 | Peak flood flow |
| Klonn Leonoff | 1981 | * | * | 0.17 | |
| Dome Petroleum** | 1984 | June | Meter | 1.65 | |
| Water Resources | 1986 | July | Meter | 0.21 | |
| Curragh | 1987 | Sept. | Meter | 0.16 | |
| Calculations: | | | | | |
| Curragh | 1988 | - | Catchment/Precip. | 0.17 | No Evaporation |

* Unknown

** Dome (June, 1984, Meter) Faro Creek — At Peak Discharge
- upstream of diversion — 1.65 $m^3/s$
- downstream past dumps — 1.54 $m^3/s$
- diversion loss — 0.11 $m^3/s$




## FLOOD ESTIMATION METHODS

○ HYDROCON (1980) WITH 25% SAFETY FACTOR
□ HYDROCON (1980) WITHOUT SAFETY FACTOR
⬡ UNDERWOOD McLELLAN (1983)
△ JANOWICZ -(1986)

## FARO CREEK
## FLOOD FREQUENCY DISTRIBUTION

FIGURE 17

**TABLE 11:** INSTANTANEOUS FLOOD MAGNITUDE FOR SELECTED RETURN PERIODS FARO CREEK

| RETURN PERIOD | DISCHARGE ($m^3/s$) AREA 13.9 $km^2$ | DISCHARGE ($m^3/s$) AREA 17.4 $km^2$+25% | DISCHARGE ($m^3/s$) AREA 13.9 $km^2$ | DISCHARGE ($m^3/s$) AREA 13.9 $km^2$ |
|---|---|---|---|---|
| METHOD | Hydrocon 1980 | Hydrocon 1980 | UMA* 1983 | Janowicz 1986 |
| $Q_{MAF}$ | 2.1 | 2.5 | 1.04 | 2.20 |
| $Q_{100}$ | 15.6 | 18.2 | 2.4 | 6.0 |
| $Q_{500}$ | 24.0 | 28.0 | 3.0 | 7.5 |

METHODS

Hydrocon 1980
$Q_{MAF} = 0.22 \times A^{0.85}$ = Mean Annual Flood ($m^3/s$)
$Q_{100} = 2.47 \times A^{0.70}$ = 100 year Instantaneous Flood Magnitude ($m^3/s$) where A = Area in $km^2$

UMA* 1983
$Q_{MAF} = 0.085 \times A^{0.95} = 1.04$ ($m^3/s$)
$Q_{100} = Q_{MAF} \times 2.3 = 2.39$ ($m^3/s$)

Janowicz 1986
$Q_{MAF} = 0.226 \times A^{0.856} = 2.20$ ($m^3/s$)
$Q_{50} = 0.629 \times A^{0.811} = 5.32$ ($m^3/s$)

* UMA: Underwood McLellan Associates Ltd.

## Site Assessment

Under present operating conditions, Faro Creek is diverted along the northeastern wall of the Zone I/III pit into North Fork Rose Creek. A dyke north of the main pit, in Faro valley, diverts Faro Creek flow. Water quality data are presented in Table 12.

The existing dyke is permeable and seepage water collects in a small, marshy depression immediately to the north of the Faro Valley waste dump. Considerable volumes of water currently seep through this waste, and estimates provided from pit de-watering indicate a flow rate of approximately 0.02 to 0.04 $m^3/s$ (see Section 3.4).

Sampling of pit seepage in June, 1984 and September, 1987 indicated that seepage water passing through the Faro waste dump was high in zinc: (Table 13) 84.0 mg/l and 5.4 mg/l for the respective periods. Low pH was also noted in the 1984 sample.

## Remedial Measures

Faro Creek will be redirected into the Zone I/III pit, beginning in 1994. This diversion will be temporary. By 2002, the water level in the pit is expected to reach the overflow spillway elevation of 3920 ft; at that time, Faro Creek will be re-diverted into the existing Faro Creek diversion channel for a period of 2 years. These 2 years are required to evaluate the pit flooding abandonment method.

Provided water quality results are favourable, Faro Creek will be permanently diverted into the Zone I/III pit after the 2-year evaluation period. This will be accomplished either by excavating the acid-generating portion of the waste rock dump located between the point of diversion and the top of the open pit or by constructing a lined dyke and diverting the creek flow away from the dump site and into the Faro Zone I/III open pit. Any acid-generating waste removed from this dump will be dumped in the pit, beneath water (3920 elevation).

The existing Faro Creek diversion ditch will be isolated from the flow regime of Faro Creek, and left in place. This channel will intercept surface flows originating from the catchment area directly to the north-east, and will route this water towards North Fork Rose Creek. This channel will be an integral component of the water flow control plan for Zone II pit abandonment.

In the event that surface discharge water quality from the Zone I/III pit is not acceptable, Faro Creek will be permanently diverted into the diversion channel and routed into North Fork Rose Creek. This measure will be necessary to reduce treatment volume of Zone I/III pit overflow. The Faro Creek diversion channel, in

**TABLE 12: FARO CREEK WATER QUALITY**

| | LEAD (mg/l) | ZINC (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | CALCIUM (mg/l) | SODIUM (mg/l) | SULPHATE (mg/l) | pH | FLOW RATE (l/s) | TEMP (deg C) | COND. (umhos/cm) | ALKALINITY (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FARO CREEK SEPTEMBER, 1987 | | -0.002 | -0.002 | | | | 8 | 7.82 | | 2.8 | 27 | |
| FARO CREEK DIVERSION SEPTEMBER, 1987 | | 0.285 | 0.009 | | | | 14 | 7.8 | 81.4 | 2 | 41 | |
| FARO CREEK DIVERSION JUNE, 1984 | 0.07 | 0.05 | 0.02 | 0.41 | 1 | 1 | 3.7 | 6.6 | | | 20 | 9.9 |
| FARO CREEK SEEPAGE FROM DIVERSION IN FARO VALLEY: NORTH JUNE, 1984 | 0.08 | 0.01 | 0.01 | 0.41 | 1 | 1 | 4.1 | 5.6 | | | 20 | 5.9 |
| FARO CREEK SEEPAGE IN FARO VALLEY: SOUTH JUNE, 1984 | 0.08 | 0.07 | 0.01 | 0.41 | 34 | 1 | 10.3 | 8 | | | 170 | 131.4 |

- DENOTES LESS THAN

TABLE 13 FARO CREEK WASTE DUMP SEEPS

| | JUNE 1984 | | SEPTEMBER 1987 | |
|---|---|---|---|---|
| | SITE #7 | SITE #8 | SITE A30 | SITE A31 |
| Flow (l/s) | 25.0 | | 15.40 | 0.05 |
| Lead (mg/l) | 0.08 | 0.08 | | |
| Zinc (mg/l) | 84.00 | 0.11 | 5.40 | 0.145 |
| Iron (mg/l) | 3.59 | 0.85 | | |
| Copper (mg/l) | 0.79 | 0.01 | 0.003 | -0.002 |
| Manganese (mg/l) | 5.51 | 0.49 | | |
| Magnesium (mg/l) | 32.00 | 19.10 | | |
| Calcium (mg/l) | 33.00 | 26.00 | | |
| Sodium (mg/l) | 5.00 | 6.00 | | |
| pH | 5.20 | 6.80 | 7.64 | 7.29 |
| Sulphate (mg/l) | 609.00 | 60.90 | 197.00 | 72.00 |
| Cond. (umhos/cm) | 660.00 | 220.00 | 764.00 | 395.00 |
| Alkalinity (mg/l) | 4.90 | 94.80 | | |
| Temp (deg C) | | | 2.9 | 3.2 |
| Zinc Load (mg/s) | 1051 | | 83.2 | 0.01 |
| Copper Load (mg/s) | 10 | | 0.05 | 0.00 |
| Sulphite Load (mg/s) | 8374 | | 3034 | 3.6 |

* SITES #7 and #8 are in approximate vicinity of SITES A30 and A31. 1987 sites are indicated on Figure 3 and 1984 sites are in Dome, 1984

** Flows for sites #7 and #8 are combined. Zinc and copper loadings are calculated from the average zinc and copper concentrations for sites #7 and #8, and from the combined flow rate.

this event, will require substantial up-grading. Golder Associates will be commissioned in 1989 to review the present diversion design and make recommendations on routing and abandonment design requirements.

### Abandonment Assessment

The preferred option is that Faro Creek be permanently diverted into the Zone I/III pit. However, this option is dependent on the success of the open pit abandonment plan. If treatment of overflow from the Zone I/III pit is required, reduction of water discharge volume will be desirable.

Permanent diversion of Faro Creek into the Faro open pit eliminates the difficult requirement of maintaining a long term diversion channel above the northeastern highwall of the pit. Also, the creek water will provide buffering and diluting capacity to Faro Zone I/III open pit reservoir water. In this event, the discharge channel into the open pit will be designed to minimize erosion of the pit wall, and will incorporate an energy dissipation feature. These designs will be completed at the end of the Zone I/III pit abandonment evaluation.

## 6.2 North Fork Rose Creek and Diversion Channel

### Site Description

North Fork Rose Creek flows along the eastern boundary of the Faro open pit area, and is shown on Figure 3. The creek flows into Rose Creek through a diversion channel located to the west of the freshwater pumphouse reservoir.

### Hydrology and Hydrogeology

The creek has a watershed of approximately 118 $km^2$, an average annual flow of 1.4 $m^3/s$ (rainfall-catchment area calculation). At the present time, North Fork Rose Creek collects the discharges from the Faro Creek diversion channel, and the groundwater discharges originating from the Zone I/III and Zone II pits and from the waste rock dumps located immediately to the west of the creek's channel.

Hydrological characteristics of North Fork Rose Creek are presented in Table 14. Flood design analysis will be reviewed by engineering consultants as described for Faro Creek. A monitoring program will be initiated in 1988 to supplement the existing data set (Section 10).

TABLE 14: NORTH FORK ROSE CREEK HYDROLOGY

| RETURN PERIOD | DISCHARGE ($m^3/s$) AREA 118 $km^2$ | DISCHARGE ($m^3/s$) AREA 148 $km^2$+25% | DISCHARGE ($m^3/s$) AREA 118 $km^2$ | DISCHARGE ($m^3/s$) AREA 118 $km^2$ |
|---|---|---|---|---|
| METHOD | Hydrocon 1980 | Hydrocon 1980 | UMA* 1983 | Janowicz 1986 |
| $Q_{MAF}$ | 12.7 | 15.3 | 7.9 | 13.4 |
| $Q_{100}$ | 70.0 | 81.4 | 18.3 | 35.0 |
| $Q_{500}$ | 105.0 | 130.0 | 23.0 | 44.0 |

METHODS

Hydrocon 1980

$Q_{MAF} = 0.22 \times A^{0.85}$ = Mean Annual Flood ($m^3/s$)

$Q_{100} = 2.47 \times A^{0.70}$ = 100 year Instantaneous Flood Magnitude ($m^3/s$) where A = Area in $km^2$

UMA* 1983

$Q_{MAF} = 0.085 \times A^{0.95}$ = 7.9 ($m^3/s$)

$Q_{100} = Q_{MAF} \times 2.3$ = 18.3 ($m^3/s$)

Janowicz 1986

$Q_{MAF} = 0.226 \times A^{0.856}$ = 13.4 ($m^3/s$)

$Q_{50} = 0.629 \times A^{0.811}$ = 30.1 ($m^3/s$)

* UMA: Underwood McLellan Associates Ltd.

## Site Assessment

North Fork Rose Creek acts as a receiving water for seepages originating in the eastern side of the mine property. Water quality data are presented in Table 15. The November to December, 1983 sampling period should be noted. Average zinc concentrations of 0.68 mg/l were recorded, with the range being 0.33 to 1.21 mg/l. This sampling period corresponds with a discharge period from the Zone II pit when zinc concentrations in the Zone II pit water averaged 6.9 mg/l.

The toes of the east and intermediate waste rock dumps encroach on the North Fork Rose Creek Valley. The waste rock slopes to date have shown no evidence of instability in the region. The North Fork rock drain causeway may result in temporary ponding of water upstream from the crossing, and monitoring will be conducted. The potential for leaching must also be determined.

## Remedial Measures

Discharges originating from Zone I/III, and Zone II open pits and from waste rock dumps located along the eastern limits of the Faro mine property, flow into North Fork Rose Creek. Flow discharge characteristics and water chemistry of this creek are of importance to the abandonment plan, both in terms of the impact of contaminant loadings from pits and dumps and in terms of structural stability of the east-facing waste dump slopes and the North Fork rock drain causeway. Curragh will implement a program to supplement the understanding of this water course. This monitoring program is (Section 10).

The North Fork has been diverted westward at a point just downstream of the Faro mine access road. The natural channel of North Fork meets Rose Creek at a point upstream of the pumphouse dam; the diversion channel routes the North Fork past the BXL Explosives plant and along the toe of the tailings dam and into Rose Creek just downstream from the pumphouse reservoir dam.

At abandonment, Curragh will restore the North Fork to its original channel by constructing a thickly-armoured plug at the head end of the new channel and by removing the plug currently installed in the old channel.

## Abandonment Assessment

North Fork Rose Creek water quality will be influenced by discharges originating from the Zone I/III pit, the Zone II pit, and the east and intermediate waste dumps. Each discharge source has the potential to cause a deterioration in North Fork Rose Creek water quality. However, present records (Table 15) indicate that

**TABLE 15: NORTH FORK ROSE CREEK AND ZONE II SEEPAGE WATER QUALITY**

| SITE/YEAR* | LEAD (mg/l) | ZINC (mg/l) | IRON (mg/l) | COPPER (mg/l) | MANGANESE (mg/l) | SULPHATE (mg/l) | pH | TEMP (deg | TOTAL HARDNESS (mg/l) $CaCO_3$ | COND (umhos/cm) | TOTAL ALKALINITY (mg/l) $CaCO_3$ | SUSP SOLIDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987: | | | | | | | | | | | | |
| Avg. | 0.02 | 0.05 | | 0.01 | 0.08 | 12 | 7.55 | 2 | | | | 11 |
| Range | -0.01-0.17 | 0.02-0.10 | | -.01-0.03 | 0.02-0.14 | 3-19 | 7.2-8.21 | 0-7 | | | | 0-108 |
| 1986: | | | | | | | | | | | | |
| Avg. | 0.07 | | | | | 14 | | | | | | |
| Range | 0.04-0.11 | | | | | 8-15 | | | | | | |
| 1985: | | | | | | | | | | | | |
| Avg. | | 0.06 | | | | | | | | | | |
| Range | | 0.02-0.25 | | | | | | | | | | |
| 1984: | | | | | | | | | | | | |
| | 0.06 | 0.11 | 0.25 | 0.02 | 0.12 | 28 | 7.20 | 0 | | 127 | 94.9 | 7 |
| Range | 0.01-0.44 | 0.01-0.44 | | | | | | | | | 25.7-168.5 | |
| 1983 (Nov-Dec): | | | | | | | | | | | | |
| Avg. | | 0.68 | | | | | | | | | | |
| Range | | 0.33-1.21 | | | | | | | | | | |
| 1983 (Nov-Dec): (Zone II Seepage) | | | | | | | | | | | | |
| Avg. | | 6.9 | | | | | | | | | | |
| Range | | 5.09-9.26 | | | | | | | | | | |
| 1980: | 0.006 | 0.05 | 0.25 | 0.003 | 0.045 | 7 | 7.51 | 6.2 | 64 | 122 | 74.0 | 2 |
| 1979: | 0.01 | 0.08 | 0.58 | 0.020 | 1.06 | 82 | 7.73 | 4.0 | 92 | 390 | | 5 |
| 1973: | | | | | | | | | | | | |
| Total | -0.01 | 0.095 | 10.6 | 0.02 | 0.22 | | 8.1 | 5.0 | 88 | 167 | 58.6 | |
| Dissolved | -0.01 | -0.01 | -0.06 | -0.01 | 0.06 | | | | | | | |

* Site is North Fork Creek at minesite road ((X2) unless otherwise noted.
- Denotes less than.

the creek has significant buffering capacity and, through its volume of flow, significant dilution capacity. Curragh, through the implementation of a monitoring program (Section 10) will develop a more thorough understanding of this watercourse.

The North Fork rock drain causeway (Section 7.1) The crest of this causeway will be breached as a flood protection measure. The results from the sedimentation survey and performance monitoring (Section 10) will provide a basis from which to evaluate the long term performance of this structure.

## 6.3 North Valley Wall Interceptor Ditch

### Site Description

The north valley wall interceptor ditch diverts runoff from the north wall of the Rose Creek valley, beginning with Next creek, away from the tailings storage area (Figure 3). The water quality should be unaffected by mining/waste dump disturbance. The continuity of the interceptor is obtained by connecting natural gullies with an excavated channel and, in the downstream half, the flow is dyked across the sloping surface of the old borrow area "F", from which it falls into another natural gully. It is diverted from that gully past the north abutment of the Cross Valley Dam.

### Site Assessment

The interceptor ditch has performed well to date except for icing which is believed to be initiated by vehicles crossing above the Cross Valley Dam during winter.

### Remedial Measures

Abandonment measures for the interceptor ditch will consist of raising the capacity by 50% and then:

i. armouring the excavated and dyked section;
ii. widening the section of the channel across borrow area "F";
iii. strengthening the armouring of the natural channel diversion points along the ditch; and
iv. waste rock mantling of the outside of the dyke from the last diversion point to the crest of the Cross Valley Dam.

Armouring will involve application of a 0.6 m thickness of minus 300 mm non-reactive pit waste rock to the sideslopes of the channel. Freeboard will be increased by 0.6 m to counteract the loss of channel section and to provide increased capacity. Materials from the original excavation will be used for this work.

The Borrow Area "F" channel will be widened upslope by ripping. The ripped material will be cross-dozed to armour the existing dyke.

The natural channel diversion points will be strengthened using glacial till borrow and their faces, crests, and backslopes will be liberally armoured with minus 500 mm mine waste. Backslopes will be reduced to 4H:1V to provide for stability in the event of short-duration overtopping and the crests of diversions will be kept 0.6 m below the downstream dyke design crest to assure preferred release points.

The channel will be improved from the last diversion point to the Cross Valley dam to effect safety in the event that natural winter icing forces initial spring runoff over the top of the dyke. Well-graded, minus 1 m mine waste will be used and backslope inclinations of 4H:1V will be created from this waste material placement.

# 7. OTHER STRUCTURES

## 7.1 North Fork Rock Drain Causeway

### Site Description

The North Fork rock drain causeway was built across the North Fork of Rose Creek to develop an ore haulage route between the Vangorda and Grum open pits and the concentrator. It is constructed of mine waste selected such that clean, coarse, durable particles of large size provide a dependable flow path for conveyance of creek flows through the base of the embankment. The hydraulic capacity of the section is sized to conservatively pass a flow of approximately 70 $m^3/s$. The causeway location is shown on Figure 3.

### Site Assessment

The construction of the bulk of the causeway is by end dumping blasted waste rock from the top of the causeway in a longitudinal direction. Approximately 5 million $m^3$ of non-sulphide waste rock will be incorporated in the Vangorda haul road, including the causeway.

The material (approximately 4 million $m^3$) in the cross-valley fill, with the exception of the rock drain, is quartz-muscovite-biotite schist [1D0 and 1CD], the predominant waste types in the Faro pit. Table 16 shows that these rock types have a greater neutralization potential than acid generating potential (the tabulated results are a summary of ten samples sent to Chemex Labs Ltd. for analysis). The mean net neutralization potential is 50.9 tonnes of $CaCO_3$ equivalent per 1000 tonnes of material, with a mean paste pH of 8.3. Research indicates that such material will not be acid generating (Ferguson and Erickson, 1987).

The rock drain is constructed of large fragments of a resistant rock, calc-silicate breccia. Table 16 shows that the mean net neutralization potential of the calc-silicate breccia is 73.3 tonnes of $CaCO_3$ equivalent per 1000 tonnes of material, with a mean paste pH of 9.1. This material is incapable of generating acid.

Once sufficient material has been placed in the rock drain to bring the toe of the calc-silicate beyond the creek channel by approximately 60 m, the remainder of the cross-valley road will be constructed with non-sulphide waste. This waste will consist primarily of quartz-muscovite-biotite schists, with minor amounts of calc-silicate breccia and calc-silicate phyllites.

## TABLE 16

### MAXIMUM POTENTIAL ACIDITY AND NEUTRALIZATION POTENTIAL OF WASTE ROCK IN CAUSEWAY AND ROCK DRAIN

### 3DBx CALC-SILICATE BRECCIA (ROCK DRAIN)

| Sample | %S | Max Pot. Acidity | Paste pH | Neutral Pot. | Net Neutral. |
|---|---|---|---|---|---|
| 76-04 250' | 0.048 | 1.50 | 9.1 | 76.2 | 74.7 |
| 76-04 280' | 0.067 | 2.09 | 8.8 | 87.4 | 85.3 |
| 77-01 280' | 0.111 | 3.47 | 8.9 | 99.3 | 95.8 |
| 77-09 210' | 0.035 | 1.09 | 9.1 | 82.5 | 81.4 |
| 80-03 100' | 0.121 | 3.78 | 9.2 | 79.3 | 75.5 |
| 80-03 140' | 0.628 | 19.60 | 9.0 | 63.3 | 43.7 |
| 80-04 280' | 0.070 | 2.19 | 9.1 | 57.0 | 55.7 |
| 82F-01 270' | 0.791 | 24.70 | 9.2 | 95.0 | 70.3 |
| 82F-06 160' | 0.066 | 2.06 | 9.3 | 55.2 | 53.1 |
| 82F-06 180' | 0.026 | 0.81 | 9.3 | 98.1 | 97.3 |
| Mean | 0.196 | 6.13 | 9.1 | 79.4 | 73.3 |

### 1DO BIOTITE-MUSCOVITE-ANDALUSITE SCHIST (CAUSEWAY)

| Sample | %S | Max Pot. Acidity | Paste pH | Neutral Pot. | Net Neutral |
|---|---|---|---|---|---|
| 76-03 400' | 0.538 | 16.80 | 8.3 | 132.0 | 115.2 |
| 77-08 340' | 0.359 | 11.20 | 8.8 | 36.7 | 25.5 |
| 76-13 340' | 0.280 | 8.75 | 7.9 | 29.8 | 21.0 |
| 77-16 340' | 0.296 | 9.23 | 8.2 | 42.5 | 33.3 |
| 80-02 280' | 0.215 | 6.72 | 8.7 | 94.8 | 88.1 |
| 80-02 320' | 0.124 | 3.88 | 8.3 | 31.9 | 28.0 |
| 80-08 220' | 0.381 | 11.90 | 7.4 | 67.9 | 56.0 |
| 80-08 300' | 0.087 | 2.72 | 8.7 | 36.8 | 34.1 |
| 81-10 240' | 0.246 | 7.69 | 8.2 | 91.7 | 84.0 |
| 84F-24 240' | 0.354 | 11.10 | 8.2 | 34.4 | 23.3 |
| Mean | 0.288 | 9.00 | 8.3 | 59.9 | 50.9 |

* Units: tons Cu $Co_3$ equivalent/1000 tons material

Remedial Measures

It is proposed that the flow capacity of the rock drain be monitored and that creek bed load transport studies be conducted. Debris loading and the probability of blockage will also be investigated. These data will be used to determine the abandonment requirements.

Two abandonment alternatives are considered: extension of the underdrain zone to permit backslope flattening and gradual lowering of the crest to create a "flow through" rock spillway overflow structure, or breaching of the section plus construction of a cascade spillway. The required capacity will be dependent upon the observed performance of the existing facility. For the overflow alternative, a downstream slope of 3H:1V is envisaged because of the freely-draining nature of the causeway materials. A locally flatter toe section will be used to control surface stability below the point of seepage discharge. The crest elevation will be dictated by cut-fill balance (excluding imported calc silicate rock for the underdrain section). Conceptual designs are presented in Figure 18 and Figure 19. The arrangement will provide considerable flood control to North Fork flows and thus it will have a discernible effect on downstream Rose Creek peak flows. This flood reduction will contribute positively to the abandonment plan scenario for the Rose Creek diversion channel.

Abandonment Assessment

Through careful selection of construction material for the causeway, long term acid generation and metal contaminant loading potentials have been minimized.

The breaching of the causeway at abandonment is designed to provide additional flood discharge capacity in the event of a high flood.

The monitoring program is designed to increase the understanding of the performance of the rock drain, and, within the 15 operational years of the Faro mine and mill still remaining, provide the basis for a detailed abandonment plan. The probability of waste dump flooding upstream of the rock drain, the long term stability of waste rock slopes, and the probability of contaminants leaching from the waste rock during flood events will be investigated.

## 7.2 Rose Creek Pumphouse Reservoir Dam

This dam was constructed in the Rose Creek channel to provide a freshwater reservoir for pumping to the concentrator facility. The pumphouse and associated dam constituted part of the initial construction of the project and were rebuilt in about 1974. As a consequence of construction of the first tailings storage expansion in 1974, the tailwater elevation at the Pumphouse dam was raised to

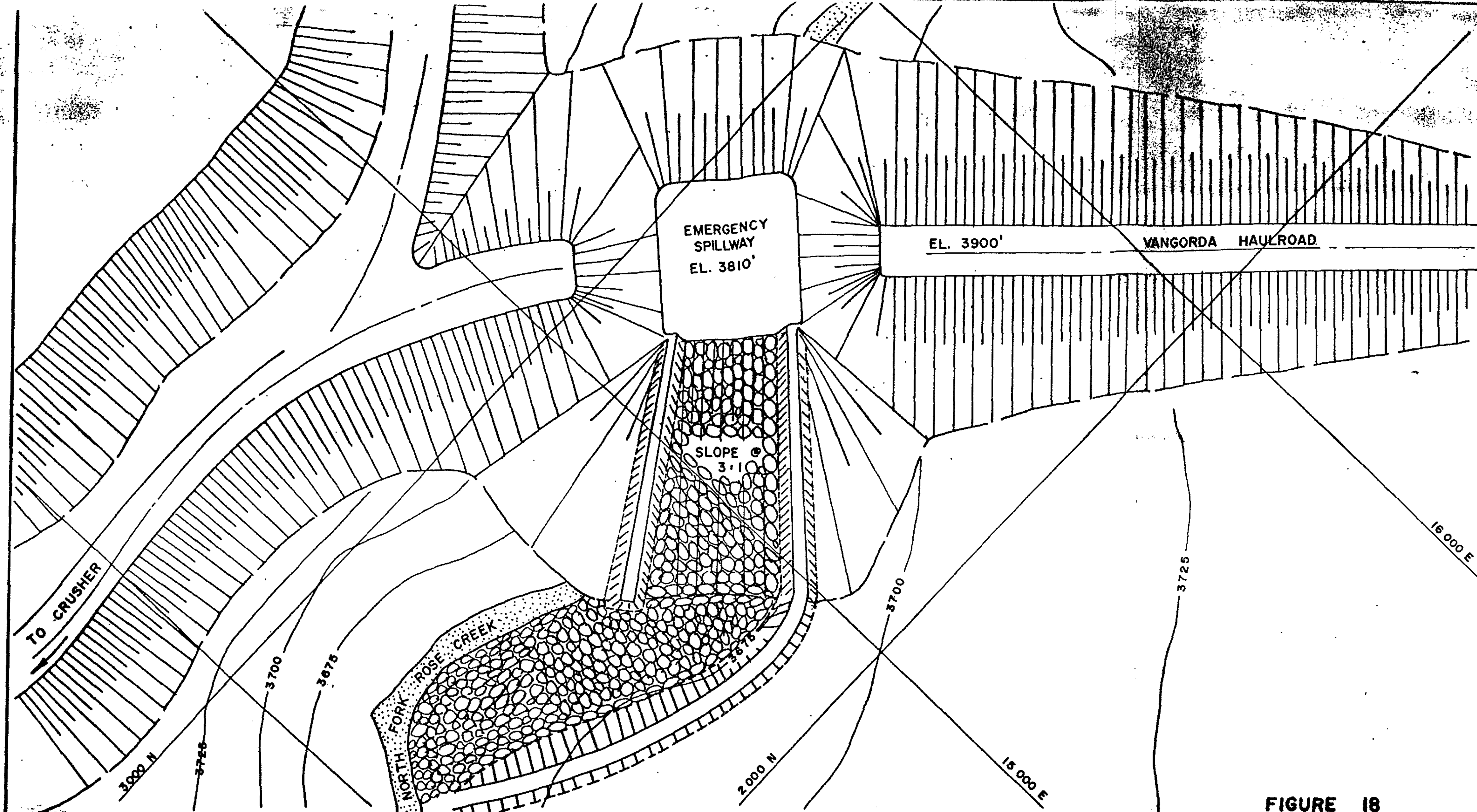



FIGURE 18

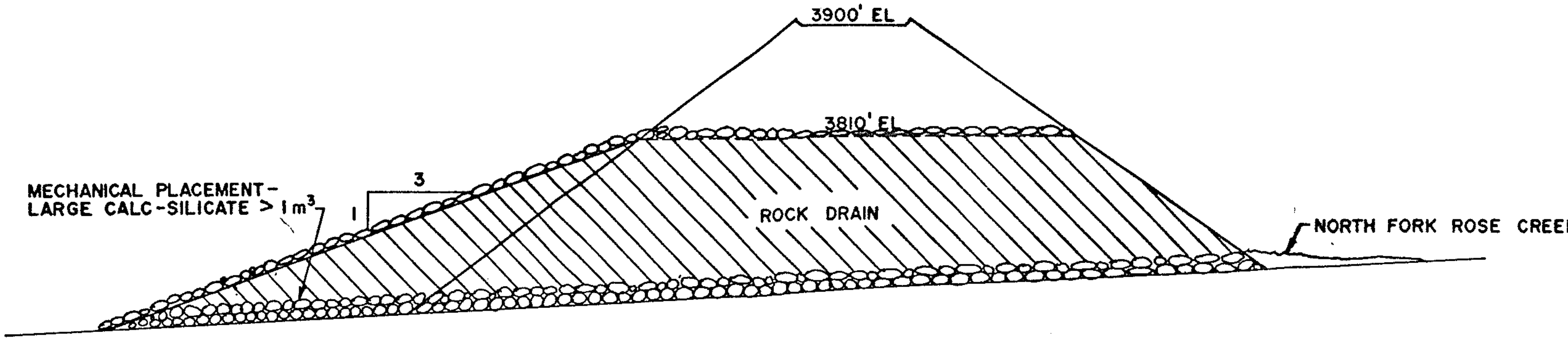
| DRAWING NO. | REFERENCE DRAWINGS | REV | REVISION DESCRIPTION | BY | DATE | CHKD | APP |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

ENGINEER'S STAMP

ENGINEERING RECORD
DRAWN BY: B.C.B — DATE: 28/02/88
CHKD BY:
ENGINEER:
APP.:

**CURRAGH RESOURCES INC.**
FARO, YUKON TERRITORY

PROJECT: MINE ABANDONMENT
PREPARED BY: J. BOWERS
TITLE: NORTH FORK ROCK DRAIN CAUSEWAY EMERGENCY SPILLWAY PLAN VIEW
SCALE: 1" = 200'
CONTR. DWG. NO.:
DWG. NO.: FA-007
REV:




**EMERGENCY SPILLWAY - NORTH FORK ROCK DRAIN CAUSEWAY**

**TYPICAL CROSS-SECTION**

SCALE 1" = 100'

FIGURE 19

| DRAWING NO. | REFERENCE DRAWINGS | REV | REVISION DESCRIPTION | BY | DATE | CHKD | APP | ENGINEER'S STAMP |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

ENGINEERING RECORD
DRAWN BY: B.C.B. DATE: 28/02/88
CHKD BY:
ENGINEER:
APP.:

**CURRAGH RESOURCES INC.**
FARO, YUKON TERRITORY

PROJECT: MINE ABANDONMENT
PREPARED BY: J. BOWERS
TITLE: NORTH FORK ROCK DRAIN CAUSEWAY EMERGENCY SPILLWAY CROSS-SECTION
SCALE: 1" = 100'
CONTR. DWG. NO.:
DWG. NO.: FA-008
REV

within 2 m of the crest of the Pumphouse dam. This raising was effected through diversion of Rose Creek from its natural channel into the excavated 1974 diversion channel. The diversion channel headpond is now filled with bedload material that has been delivered by North Fork flow and, as such, the Pumphouse dam no longer represents an abandonment challenge; it will simply be removed by upstream dozing and the now unused concrete spillway will be broken up, removed, and buried.

## 7.3 Freshwater Supply Reservoir and Dam

### Site Description

The freshwater reservoir is located 4 km south of the Faro property plant site (Figure 3). It was constructed in 1969 and is designed to hold 5,800,000 $m^3$ of water. The reservoir is positioned just west of this mine site access road and is 1400 m long by 400 m wide.

### Remedial Measures

The downstream face of the embankment will be flattened to 4H:1V using waste rock backhauled by the Vangorda orehaul fleet during the course of exploitation of that orebody. The valley bottom and abutment areas beneath the intended waste rock zone will be mantled with a 600 mm thick filter zone of clean sand and gravel alluvium (or minus 100 mm crushed calc-silicate rock). The crest of the embankment will be widened to 10 m. Filling against the west abutment will be delayed until abandonment to permit continued use of the low level conduit. At abandonment the conduit will be used to fully lower the reservoir; it will then be plugged with concrete and a welded cap installed over the inlet. The valve house will be removed, and the backside filling with mine waste completed.

Immediately after the reservoir is lowered the dam will be faced with a trapezoidal zone of calc-silicate rock designed to reduce the frontal slope to 3H:1V and to provide a minimum erosion protection thickness of 4 m of material (measured perpendicular to the slope).

In addition to the work noted above, the existing spillway concrete will be removed and the spillway channel widened to the right (south) and deepened by about 2 m. The discharge channel will be excavated to the same section and, where it is excavated in alluvium, the section will be substantially widened to reduce velocities and armoured with heavy rock. Alternatively, the discharge channel could be steepened to contain it in rock and a flat, graded channel constructed to connect it to the Rose Creek Channel. The latter alternative is preferred because the excavated materials could be of use in making the above-noted modifications to the embankment section.

## Abandonment Assessment

The abandonment measures planned for the reservoir dam are designed to maximize the stability of the dam structure. Detailed design work will be undertaken to achieve this objective.

Maintaining the freshwater reservoir has two advantages:

i. the reservoir could provide a post-abandonment fisheries resource;

ii. the reservoir could provide a peak flood buffer advantage for the Rose Creek diversion channel.

## 9. FISHERIES

A comprehensive fisheries study of the Rose Creek watershed is being undertaken by Curragh in 1988. The objectives of this study are to:

i. assess the impact of the North Fork rock drain on Arctic grayling;

ii. identify and develop preliminary designs for compensation options if required; and,

iii. provide information required to assess the options for tailings abandonment, as a component of the Tailings Abandonment Development Program, implemented in 1987.

This study includes habitat capability assessment of the creek (through reach descriptions and point sampling), with emphasis placed on the freshwater reservoir and the blockage to migration to North Fork Rose Creek. Compensation options in a nearby watershed will also be assessed.

The implementation of the final abandonment plan could impact the fisheries resource of Rose Creek in that:

- the fresh water reservoir dam will act as a barrier to Arctic grayling migration between the upper and lower reaches of Rose Creek;

- the tailings area, depending on which abandonment alternative is implemented, could act as a barrier to Arctic grayling migration between the upper and lower reaches of Rose Creek;

- the North Fork rock drain is a barrier to migration of Arctic grayling between Rose Creek and North Fork Rose Creek.

The retention of the freshwater reservoir dam and a portion of the existing freshwater reservoir could provide enhanced habitat for the fisheries resources of the upper reaches of Rose Creek.

## 10. MONITORING AND RESEARCH PROGRAM

The following program is designed to provide the information required by Curragh to evaluate the Faro Mine Abandonment Plan. It is expected that plans will be refined and major alterations may be proposed when the results of this program are evaluated.

The program is comprehensive and includes surface water quality and flow determinations, seep mapping, groundwater studies, assessments of stability, a reservoir depth survey and fisheries studies. Results will be reviewed as they come in and the program will be adjusted where necessary to obtain the information needed to assess and refine the abandonment plan. For each item proposed, monitoring will be continued for as long as is necessary to achieve the stated purpose.

### 10.1 Assessment of the Loss of Flow From Faro Creek at and Below the Point of Diversion

This information is required to estimate the seepage through the Faro Valley Waste Dump and the seepage to the pits from Faro Creek. The flow data will also be used to verify the flood estimates for Faro Creek.

Methods:

i. Discharges will be measured monthly (and more frequently during freshet and during high precipitation periods) at the two existing weirs in the Faro Creek diversion channel.

ii. If feasible, a weir will be established in Faro Creek above the point of diversion and measurements will be conducted at this site. If this is not feasible, a section of channel will be prepared for estimating flow using a current meter.

### 10.2 Faro Pit and Area Seep Surveys and Assessment of Background Water Quality Conditions

This information is considered critical to the assessment of the plan. The objective is to acquire an overall understanding of sources of contaminant loading in the pit and dump areas during different seasons. Analysis of these data will lead to a better understanding of the chemistry of the pit water, the extent of acid generation and metal leaching in the dumps and pit wall rock and the buffering capacity introduced to the system by the upstream waters.

This section of the program is a continuation of work initiated in 1987 and described in the report entitled "Development of the Zone 2 Waste Dump" (Curragh Resources Inc. 1987).

Methods:

i. Seep surveys will be carried out during 1988, with emphasis on the freshet period. Up to three surveys will be carried out during freshet, depending on the length of the melt period. At least one survey will be carried out during summer and one in the fall.

ii. All seeps will be sampled for at least one of these surveys and major and representative pit and dump seeps will be sampled for the remaining surveys. Water pumped from the pit (X22) and the main dump seep (X23) will be included in each survey.

iii. For each seep, flow will be estimated by the most appropriate method and field temperature, pH and specific conductance will be obtained. Samples will be collected for laboratory analysis of zinc, copper, iron, sulphate and total alkalinity (and acidity where pH conditions warrant). Dissolved and total metals will be compared during the freshet surveys.

iv. Each seep survey will include sampling of the following upstream and downstream sites:

- Faro Creek upstream of point of diversion
- Faro diversion channel at lower weir (2.2 km downstream of point of diversion)
- North Fork Rose Creek upstream of Faro Creek
- North Fork Rose Creek downstream of Faro Creek
- North Fork Rose Creek upstream of rock causeway
- North Fork Rose Creek downstream of rock causeway
- North Fork Rose Creek at mine road (site X2)

These sites have been chosen to assess the impact of seeps and of groundwater flow from the Faro pit and area.

v. Seep locations will be mapped and contaminant loadings calculated. After a full year's data have been assembled and reviewed, a seep monitoring program will be established. The objective of further monitoring will be to verify conclusions drawn from the 1987-88 seep surveys and to document changes in seep quality.

## 10.3 Waste Dump Assessment

There are, unfortunately, few records of waste rock deposition from the Cyprus Anvil mine days and the composition of the old waste dumps is poorly understood. Available seep data indicate that most of the old dumps are not acid generating. In order to gain an understanding of the chemical evolution within these dumps so that predictions of future seep quality may be made, the acid-base potential of rock from these dumps will be assessed.

This section of the research program also includes studies to assess the effectiveness of the compacted phyllite seal on the sulphide waste dump and to verify the physical stability of the waste dumps.

Methods:

i. During the summer of 1988, a set of rock samples will be taken from the old waste dumps. Samples will be taken by trenching the dumps (to avoid the zone of surface oxidation) and randomly choosing rocks to combine into composite samples. This method has been chosen to overcome problems associated with high variability of rock type in dumps. The composite samples will be logged, crushed, split and tested for acid-generating and acid-consuming potential.

ii. In conjunction with this sampling, a surface survey of the old dumps will be conducted by a geologist. Rock types on the dumps will be identified and a map will be produced.

iii. The old dumps will be surveyed for signs of instability and the angle of repose will be recorded.

iv. In the fall of 1988, a geotechnical engineer will be contracted to inspect the Faro dumps and provide an assessment of their stability.

v. In-situ permeability tests will be conducted on dumps with compacted phyllite covers. This will assist in estimating the infiltration rate of water to the dumps at abandonment.

## 10.4 Groundwater studies in the Faro Pit Area

Although surface water quality and flow patterns have been relatively well characterized, few studies have been conducted on the groundwater flow regime. Groundwater data are extremely expensive to collect and sites have been chosen carefully to obtain the maximum amount of information. Exact locations will be determined depending on results of early drilling. The need for further piezometers or sampling wells will also be determined from the results of the initial field studies. The objective of this study is to characterize the flow regime in critical areas and to obtain groundwater chemistry data. Once a network of groundwater sampling stations has been established, it will be possible to record changes that occur as the pits fill with water.

Methods:

i. A piezometer/groundwater sampling net will be established south of the Zone II pit. Three double-nested piezometers will be installed so that both vertical and horizontal groundwater gradients may be determined. Each nest will consist of:

- a piezometer/water sampler located in the weathered zone along the overburden-bedrock interface;
- a piezometer/water sampler located within the underlying bedrock.

ii. A piezometer/groundwater sampling net (as described above) will be established southwest of the sulphide waste dump.

iii. A sampling well/piezometer will be installed in the Zone II pit in order to monitor water level and water quality in the pit as it fills with water.

iv. Piezometric readings and water quality samples will be taken from all piezometers with sufficient frequency to characterize the hydrogeological flow regime and its associated chemistry.

v. A three-dimensional groundwater flow model will be developed for the Faro mine area, utilizing an appropriate groundwater modelling technique. Model calibration will be based on results from surface flow determinations, the 1982 pump test results and on information from the two piezometer nets described above.

## 10.5 Assessment of Water Quality in the Faro Pits

There is considerable uncertainty attached to any extrapolations that can be made from the current set of data to the quality of the water in the Faro pits when they reach the overflow point. The success of measures taken to limit contaminant loading (especially to the Zone II pit) and the extent of stratification that develops can be studied by monitoring water quality in the pits both while they are filling and after they reach the overflow points. This information will be useful in developing long term predictions of pit water quality.

Methods:

i. As Zone I/III pit fills with water, samples will be taken following standard lake-sampling methodology at regular depth intervals. Water will be analysed to determine if density stratification is occurring and to assess changes in water chemistry as the pit fills.

ii. As discussed above, water quality samples will be taken through the piezometer installed in the Zone II pit.

iii. After each pit is full, samples will be taken of the overflow. Samples at depth may also continue to be taken.

## 10.6 Monitoring and Assessing The Impact of The North Fork Rock Drain and Measuring Stream Flow in North Fork Rose Creek

In order to assess the performance of the rock drain and predict its performance at abandonment, data are required on the stability of the causeway, the degree of impoundment behind the drain, the degree of build-up of sediment behind the drain and the impact of the drain on North Fork Rose Creek water quality.

As the causeway is a barrier to fish passage on the North Fork, the extent of migration by Arctic grayling during the spawning period (spring) that has been blocked must be assessed.

More data on flow rates in North Fork Rose Creek is needed to verify flood design estimates that will be used in the final spillway design for the causeway and in assessing and upgrading structures located downstream. Flow data on the North Fork will also be used to calculate dilution rates when assessing downstream impact at abandonment.

Methods:

i. A geotechnical engineer will be contracted to inspect the drain annually and report on its performance. Following the 1988 inspection, the engineer will present recommendations for sedimentation sampling if, in his opinion, this is necessary.

ii. Water samples will continue to be taken above and below the drain in conjunction with seep surveys (see above). Suspended solids will be added to the suite of parameters for these sites.

iii. A photographic record will be maintained to depict the extent of impoundment behind the rock drain under different flow conditions.

iv. A fisheries study will be conducted by a consultant during the spring and summer of 1988 in order to assess the habitat lost through construction of the barrier to fish passage. Plans for this study have been approved by the Department of Fisheries and Oceans.

v. A continuous flow monitoring station will be installed in North Fork Rose Creek above the Faro Creek diversion channel. This station will be operated during the ice-free months and particular care will be taken to acquire the maximum instantaneous discharge each year.

## 10.7 Assessment of Upgrading and Maintenance Requirements for the Faro Diversion Channel

Faro Creek will be removed from the diversion channel in 1994 in order to fill the pit as quickly as possible. When the pit is full, the creek will be returned to the diversion channel for as long as treatment of the Faro pit overflow is necessary. Upgrading and maintenance work will be needed on the channel to ensure its stability over this period.

Methods:

i. A geotechnical engineer will be contracted to inspect the diversion channel in 1989 and recommend a schedule of maintenance and upgrading.

## 10.8 Freshwater Reservoir

In order to arrive at the final design for the abandonment of this dam at a lower level, the dam's stability must be fully assessed. The primary purpose for maintaining this structure is the capacity of the reservoir to provide overwintering habitat for Arctic grayling. The extent of this resource, therefore, must be assessed.

Methods:

i. A geotechnical engineer will be contracted to inspect the dam annually and report on its stability. This engineer will also develop or review plans for abandonment of the structure and assess them with respect to long-term stability.

ii. In the summer of 1988, a depth survey and a fisheries habitat assessment of the reservoir will be conducted by a consultant. Plans for this study have been approved by the Department of Fisheries and Oceans.

## 11.0 IMPLEMENTATION TIME-TABLE

Figure 20 graphically displays the tentative implementation schedule for major abandonment measures related to this plan.

FIGURE 20

## 12.0 ESTIMATED COSTS

Tables 17 and 18 present cost estimates of major abandonment measures related to this plan.

TABLE 17: FARO MINE ABANDONMENT - ESTIMATED COST SUMMARY

| PROJECT TITLE | ESTIMATED TOTAL COST | COST/m^m^m CUT &/OR FILL | PROJECT START/FINISH DATE | EQUIPMENT REQUIRED |
|---|---|---|---|---|
| 1. INSTALL PIEZOMETER NESTS WATER GAUGING INSTRUMENTS | $120,000.00 | - | July/88 to Aug/88 | Piezometer installed by contractor;water gauging instruments<br>1-Cat 235 Backhoe<br>1-Cat D8L Dozer |
| 2. LOWER EAST WALL INTERCEPTOR DITCH (ZONE II) | $30,000.00 | $3.63 | Aug/88 to Sept/88 | 1-Cat D8L Dozer<br>1-Cat 235 Backhoe |
| 3. FRESH WATER RESERVOIR | $369,000.00 | $3.14 | June/89 to Aug/89 | 1-Dart 600C FEL<br>3-Wabco 120C Trucks<br>2-Cat D8L Dozers<br>1-Cat 14G Grader<br>1-Cat 235 Backhoe |
| 6. CONSTRUCT ACCESS ROAD TO NORTH VALLEY WALL INTERCEPTOR | $97,000.00 | $1.86 | Aug/89 to Mar/90 | 3-Wabco 120C Trucks<br>1-Cat D8L Dozer<br>1-Cat 14G Grader |
| 5. FARO CREEK DIVERSION CHANNEL UPGRADING AND MAINTENANCE | $200,000.00 | - | Mar/90 to Jul/90 | 1-Cat 980 FEL<br>3-15t Tandum Dump Tr.<br>1-Cat 14G Grader<br>1-Cat 235 Backhoe |
| 6. NORTH VALLEY WALL INTERCEPTOR DITCH, UPGRADING | $101,000.00 | $6.48 | Jul/90 to Aug/90 | 1-Dart 600C FEL<br>3-Wabco 120C Trucks<br>1-Cat 14G Grader<br>1-Cat 235 Backhoe<br>1-Cat D8L Dozer |
| 7. TEMPORARY DIVERSION FARO CREEK | $50,000.00 | - | Jun/94 to Aug/94 | 1-Cat D8L Dozer<br>1-Cat 235 Backhoe |
| 8. FARO PIT - SOUTH DYKE AND SPILLWAY | $640,000.00 | $2.75 | Mar/2000 to Aug/2000 | |
| 9. FARO PIT WEST DYKE | $113,000.00 | $2.43 | Aug/2000 to Sept/2000 | |
| 10. FARO VALLEY REMOVE PORTION OF WASTE DUMP | $1,000,000.00 | $1.90 | Jun/2004 to Oct/2004 | |
| TOTAL | $2,720,000.00 | | | |

**TABLE 18: ANNUAL MINE ABANDONMENT COSTS**

| YEAR | ANNUAL COST | CUMMULATIVE COST |
|---|---|---|
| 1988 | $150,000 | $150,000 |
| 1989 | $466,000 | $616,000 |
| 1990 | $301,000 | $917,000 |
| 1994 | $50,000 | $967,000 |
| 2000 | $753,000 | $1,720,000 |
| 2004 | $1,000,000 | $2,720,000 |
| TOTAL COST | $2,720,000 | |

## REFERENCES AND BIBLIOGRAPHY

Acres Consulting Services Limited, 1985. Cyprus Anvil Mine Rose Creek Reservoir Hydrology Study.

CAMC, 1982. Deep-Well Dewatering Testing at the Faro Open Pit Mine.

Dome Petroleum Limited, 1984. Cyprus Anvil Mine Geotechnical Evaluation June, 1984 Field Trip. Report Berzins, B., No. 0400P/0039P.

Dome Petroleum Limited, 1984. Review of Cyprus Anvil Open Pit - Geotechnical and Hydrogeological Concerns. Report Berzins,. B., No. 0353P/0033P.

Driscoll, G. Fletcher. 1986. Groundwater and Wells. Johnson Division, St. Paul, Minnesota. 1089 p.

Duncan, D.W. 1975. Leachability of Anvil Ore, Waste Rock and Tailings. Report ALUR 1974-75 for Dept. of Indian and Northern Affairs.

Equity Silver Mines Ltd. 1987. Environmental & Reclamation Measures at Equity Silver Mines Ltd., Houston, British Columbia.

Ferguson, K.D. and P. M. Erickson. 1987. Will It Generate AMD? An Overview of Methods To Predict Acid Mine Drainage.

Freeze, R., John A. Cherry., 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, NJ 604 p.

Golder, 1982. Report to CAMC - Summarization Of The Down-Valley Tailings Containment Project. 1980-81 Construction. Report 802-2038.

Hydrocon Engineering, 1980. Hydrologic and Hydraulic Design of Down Valley Tailings Disposal Project, Cyprus Anvil Mining Corporation. Prepared for Golder Associates.

Janowicz, J.R., 1986. A Methodology for Estimating Design Peak Flows for Yukon Territory. in Cold Regions Hydrology Symposium, American Water Resources Association.

Kerr, Priestman & Associates, 1987. Report to Golder Associates Ltd. (For Curragh Resources Inc.) Alternatives For Abandonment of Rock Drain, North Fork Rose Creek.

Klohn Leonoff, 1981. Report to CAMC - Faro Mine Tailings Abandonment Plan, September 1981. VA2758.

Piteau Associates, 1985. Report on Phase 1. Geotechnical and Hydrogeological Assessment of the Northeast Wall of the Anvil Pit Report 85-804.

Piteau Associates, 1986. Assessment of Groundwater Conditions in Faro Pit, East Wall. Report 86-804.

Rescan Environmental Services, 1988. Vangorda Project, Preliminary Design: Effluent Treatment Plant. Prepared for Curragh Resources Inc.

Ripley, Klohn & Leonoff International Ltd., 1967. Foundation Report No. 2, Anvil Mines Millsite. Report R-969.

Senes Consultants Ltd. 1986. The Biogeochemistry of Acid Generation in Sulphide Tailings and Waste Rock.

Sigma Resource Consultants Ltd., 1975. Rose Creek Diversion Works. Observations and Measurements Made During Spring Runoff - 1975.

Steffen, Robertson & Kirsten, 1986. Studies Related to Evaluation of Alternative Abandonment Measures For Faro Mine Tailings for Curragh Resources Inc. Report 60601.

Underwood McLellan Ltd., 1983. Yukon River Basin Flood Risk Study. YRBS Hydrology Work Group Report No. 1, Environment Canada.