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January 14, 1992
Project Number 60642

Curragh Resources
117, Range Road
Whitehorse, Yukon
Y1A 2T8

Attention: Mr G Acott

Dear Gerry

RE: FURTHER REVIEW OF THE POTENTIAL FOR SEEPAGE FROM THE FARO PIT AND CONTAMINATION OF THE NORTH FORK OF ROSE CREEK

In Appendix A of Kilborn Report #350928, Steffen, Robertson and Kirsten (SRK) presented a report on water quality issues related to the proposal to deposit tailings in the Main Pit at Faro. In the report, estimates of seepage from the Main Pit were made, primarily to enable a water-balance to be generated for the pit in order to estimate water recycle rates and pond water elevations. The report has been reviewed by federal agencies, and Environmental Protection (EP) has indicated that they intend to intervene at the Public Hearing on January 15, 1992, on the subject of seepage from the Main Pit, amongst other subjects. EP's intervention on the seepage question will be based on a review performed on their behalf by Kevin Morin. In the review, which is dated January 1, 1992, it was recommended that an extensive investigation and surveillance program be instigated to provide additional data and monitoring capacity for potential seepage from the Main Pit.

On your request, SRK has performed a further review of the potential for seepage from the Faro Pit and contamination of the North Fork of Rose Creek. The protection of water quality in the North Fork is the primary focus and, for this reason, the scope of this review has been expanded to consider all potential sources of contaminant discharge to the North Fork. The point of this is that specific contaminant source potentials, and the investigation thereof, should be considered in the context of the overall problem. It would be inappropriate to expend a great amount of effort investigating just one element of the problem when other elements perhaps have a larger potential for impact.

The following is a list of potential sources of contamination of the North Fork:

- seepage from the Main Pit
- seepage from the Zone II Pit
- run-off from waste rock dumps along the western side of the creek
- leaching of metal-rich natural soils and alluvial material adjacent to and within the creek valley

Each of these sources is considered below. Comment on the review performed by Kevin Morin will be given under seepage from the Main Pit. The significance of the sources of contamination will then be summarized. Following this, an investigation and surveillance program is recommended that should provide the data necessary to quantify contaminant sources, and the means to monitor ground and surface water quality.

Seepage from the Main Pit

It has been suggested that an extensive investigation program should be undertaken to determine the potential for seepage loss from the Main Pit through the east wall. This is because EP believe there is a risk of poor quality water migration to the North Fork. Potential water quality is addressed below. The nature of the program recommended is similar to the study performed by Piteau and Associates, presented in their report 86-804 of October 1986. The Piteau report has been further reviewed and has been correlated with Curragh's geological data and opinions supplied by Dr Lee Pigage, senior geologist at Curragh. This has enabled a classification of the Faro rock types in terms of their ability to transmit seepage. The rock types are illustrated on geological section A-A' drawn through the Main Pit and extended to the North Fork (see Figure 1A). The locations of the section and the Piteau boreholes are shown on Figure 2.

The borehole installations, tests and results provided by Piteau in 1986 are described below.

86-1 - This hole was drilled in phyllite to an elevation of 4075 feet mine datum. The elevation of the base of the Main Pit at the eastern end is now approximately 3500 feet mine datum. Three piezometers were installed adjacent to fractures generating the seepage. The remainder of the borehole was considered to be much less permeable. Piezometer intervals totalled 7.4 m out of a borehole length of 30.5 m. Piezometer tests returned an average hydraulic conductivity of approximately $1x10^{-5}$ cm/sec. However, weighting this value to account for the very low permeability of the remainder of the borehole, a value of roughly $5x10^{-6}$ cm/sec would likely be relevant for the total borehole profile. The hole is quite shallow, and test results show a permeability decrease with depth.

86-2/2A - These holes were drilled to elevations of 3738 and 3918 feet respectively. Four piezometers were installed in this location in phyllite in proximity to a diorite intrusive. Tests returned an average hydraulic conductivity of $1x10^{-6}$ cm/sec. While this value is low, it would probably be lower in the absence of the influence of the dike contact zone.

86-3/3A - These holes were drilled to elevations of 4068 and 4158 feet respectively. Schist and dike rocks at this location were tested at $2x10^{-7}$ and $5x10^{-7}$ cm/sec respectively. Higher values were recorded in the dike contact zones. Dikes mostly strike in the 060 - 070 direction, roughly parallel to the North Fork. Dikes would therefore tend to form a barrier to flow towards the North Fork. The dike contact zones are also thought to be truncated by later intrusives.

86-4/5 - These holes were drilled to elevations of 3607 and 3563 feet respectively. Two piezometers were located in 86-4 in fractured massive sulphides below a phyllite cap.

A pump test in adjacent borehole 86-5 enabled transmissivity values to be calculated in the piezometers. Assuming a fracture zone thickness of 12.5 m, the approximate hydraulic conductivity is $6x10^{-4}$ cm/sec. A value for the piezometer in the overlying phyllite was not given, perhaps because the piezometer did not respond to pumping.

86-6 - This hole was drilled to elevation 3583 feet, and is located in close proximity to the haulroad connecting the Main and Zone II Pits. The hole was drilled in phyllite and was dry. Uniform low permeability was assumed.

Competent rocks are generally massive and may host open fractures. Incompetent rocks generally will not sustain fractures. Dr Pigage classifies the calc-silicate, sulphide, quartzite and dike rocks at Faro as falling into the competent category, while the schists and phyllites fall into the incompetent category. Figure 1A shows that, east of the Main Pit, the rocks are predominantly schists or phyllites, and therefore the lower of the hydraulic conductivity values given above are relevant. Dike intrusives can be found between the pit and the North Fork. The dyke rock was found to be massive and low in permeability, with some permeability along the contacts. In conclusion, it would appear that the more permeable rock units identified above (although these are by no means high in permeability) are restricted to the vicinity of the pit, while the units east of the pit are low in permeability even accounting for the occurrence of fractures. The values are also only relevant to the immediate area of the test. The extent and connectivity of fractures is also expected to be low, thus further lowering the bulk permeability for a long flowpath.

Comment has been made regarding the presence of major faults between the Main Pit and the North Fork. Certainly the Big Indian fault system consists of a series of significant faults. However, these have been found to be mostly healed with either mineral deposits or fault gouge (Dr Pigage). The Piteau study was conducted in order to assess the potential for dewatering in the vicinity of the fault zones for pressure relief. Apart from the massive sulphides, very little water was found. Also, the southern extension of the fault zone strikes towards the Zone II Pit (see Figure 4.2in Appendix A of Kilborn report #350928). Any significant flow along the faults would be expected to flow through the Zone II area.

To put the Main Pit seepage potential into perspective, one can calculate an approximate seepage rate by applying Darcy's Law. If we assume a pit wall dimension of 150 m deep by 300 m long, a hydraulic conductivity of $1x10^{-6}$ cm/sec, and a relatively high hydraulic gradient of 0.5 (1 is vertical, 0 horizontal), we obtain a seepage rate of 19 m^3/day. For this volume to migrate from the pit to the North Fork, the individual fractures responsible for the permeability must be interconnected and extensive. This seepage estimate should therefore be considered conservative.

In essence, Kevin Morin's review focuses on:

- the potential for pit wallrocks to generate the products of acid generation;

- the possibility that sufficient alkalinity may not be available to neutralize the products; and,
- the potential for flow paths to carry the products via the groundwater to the North Fork.

Contaminated run-off from the pit walls is at present being pumped into the Down Valley system. Provided this water is blended with the tailings stream, effective neutralization occurs. Tailings discharged from the mill to the Down Valley impoundment had an average pH of 9.5 in 1990, and dissolved zinc concentration of 0.03 mg/L. The greatest contribution to this zinc loading came from pit dewatering whose concentration averaged 63 mg/L. Ponded water behind the Intermediate Dam averages less than 0.4 mg/L zinc annually, and water in the Cross Valley pond averages less than 0.25 mg/L zinc. When filling of the Main Pit commences, it is expected that acid products in wallrocks will be leached and neutralized. As these wallrocks will be progressively covered, the acid generation process will be stopped. Pit water is expected to be of better quality compared with the Down Valley system owing to the improved tailings settling characteristics. This would be subject to verification by monitoring. We believe that the majority of the pit wallrocks are sufficiently smooth that the amount of stored acid products is quite low, and would be rapidly neutralized. Where localized slope failures have occurred, and where waste has been left on benches, there is a greater potential for product storage. If the products are not leached and neutralized, we would expect them to remain in storage as a result of the low wallrock permeability. Morin refers to a permeable "skin" around the pit caused by blasting. This may be true, although the skin is not likely to be very thick given the incompetent nature of the wallrocks.

Based on the geological and hydrogeological data described above, it should be apparent that the pit wallrocks and seepage potential are reasonably well understood, and that significant seepage from the Main Pit to the North Fork is not expected. As a result, the investigation program recommended by Kevin Morin is considered to be excessive. In our opinion, a more balanced and appropriate program is contained in the section appearing below.

Seepage from the Zone II Pit

The Zone II Pit currently contains water of poor quality which is being pumped and treated. It has also been proposed that the pit be used as a storage facility for contaminated waste dump seepage. Water would be pumped to an underground treatment system, and the pit water level would fluctuate in response to seasonal variations in drainage inflows. Potential exists for the seepage of poor quality water to the North Fork. In contrast to the Main Pit wallrocks, the Zone II Pit wallrocks have not been investigated for seepage potential.

Figure 1B shows geological section B-B' drawn through the pit to the North Fork. The wallrocks on the down-gradient side of the pit are schists or phyllites, and these extend east below the North Fork. Phyllite bedrock was intersected at between 15 - 20 feet in the BH series holes adjacent to the North Fork. These same boreholes recorded groundwater at the base of a silty profile resting on bedrock, with water-levels below the elevation of the adjacent creek. The seepage potential of the schists/phyllites is expected to be low based on the study and interpretation described above. However, the condition of the wallrocks around the rim of the Zone II Pit is not known. Given that the rim is 700 m from the creek, and that the pit is to be used for contaminated drainage storage, it would be prudent to investigate wallrock conditions and provide monitoring facilities.

Run-off from Waste Rock Dumps

Waste rock dumps line the western side of the North Fork valley, which includes the filling of the Zone II Pit. Figure 2 shows the natural topography below the waste rock. Precipitation is infiltrating through these dumps, and has the potential for leaching soluble salts. Once this infiltration reaches the base of the dumps, part will infiltrate into the natural soils, and part will run-off through the dump and probably flow onto and infiltrate into the alluvial silty sediments of the North Fork valley. This is probably significant to the north of the Zone II Pit, although the waste rock deposited over the rim of the pit also has potential for contributing run-off. The unit mean annual run-off calculated for the Faro site is 260 mm (SRK report 60635). An estimate of infiltration through the North Fork dumps and subsequent run-off can be made by assuming a dump area of 360,000m^2, and infiltration rate of 150 mm. This derives a flow of approximately 150 m^3/day, greater than an order of magnitude larger than the Main Pit seepage estimate. The water quality of this flow is not easily estimated. Visible seeps have not been recorded at the toe of the dumps. However, the seepage is probably migrating into the valley sediments just below the surface. A shallow groundwater survey conducted by Curragh personnel in 1990 in the valley area provided a number of water samples. These had sulphate concentrations indicative of neutralized acid drainage (up to between 1200 and 2250 mg/L), although metal concentrations were low with an average zinc concentration of 0.07 mg/L, and a peak of 0.4 mg/L.

Leaching of Metal-rich Soils and Alluvial Sediments

Exploration overburden drilling, sampling and testing was conducted by Cyprus Anvil in 1971 across the Faro site. Elevated metal levels were detected in the natural soils in many of the holes. A hole located close to the location of the Zone II Pit returned a zinc concentration of 960 ppm for the top 10 feet of the profile. It is clear that the natural soils in this area, including the foot of the slope down to the valley bottom, have a high metal content. It would also be expected that the alluvial sediments occupying the North Fork valley would at least in part be derived from the erosion and deposition of adjacent soils, and that therefore these sediments may also have elevated metal levels.

Prior to the development of the Zone II Pit, and at a time when water was being diverted around the Main Pit, a small creek flowed over the Zone II area, discharging into the North Fork. Due to the diversions and periodic flooding, the creek cut a deeper channel through the overburden and washed-out soils, carrying them into the North Fork valley. The BH series boreholes are located in this area of the North Fork. The sediment profile is much deeper in this area compared with sections of the valley up and down-stream. The shallow groundwater survey conducted in 1990 in these latter areas found groundwater at a depth of approximately 5 feet on average, much shallower than in the BH series boreholes. The BH series boreholes have provided water samples with zinc concentrations ranging from 2.4 - 139 mg/L, while the shallow groundwater concentrations are less than 0.4 mg/L. It would appear that the area of the BH series boreholes has a thicker sediment profile owing to the washing-out of adjacent soil profiles and deposition in the North Fork valley. The naturally high metal levels of these soils, now sediments, may have an influence on the quality of groundwater which they now host.

Ranking of Sources of Contamination

The sources of contamination described above should be prioritized in terms of their potential for causing contamination of the North Fork. In summary, it appears that the Zone II Pit wallrocks should first be investigated given the proximity to the creek and the intention to store contaminated drainage in the pit. Contaminated dump infiltration should be ranked second owing to the potential for a significant volume of contaminated water to be generated. The metal content and leachability of natural soils and sediments should be considered next as these are in close proximity to creek water.

Seepage from the Main Pit should be considered a lower priority compared with the other sources. This seepage potential appears to be low in terms of both flow and quality by comparison.

Investigation and Surveillance Program

An investigation and surveillance program has been developed to provide the data necessary to further quantify the contaminant sources described above, and to provide monitoring systems to confirm assumptions (see Figure 3). The program is described according to the contaminant source targeted.

Zone II Pit - The wallrocks of the pit require investigation. This will not be an easy task given the waste rock cover which will make borehole location and drilling difficult. Three rotary drilled boreholes should be inserted around the down-gradient rim to a depth of approximately 150 feet, roughly equal to the elevation of the rock surface below the North Fork. The holes should be packer tested and then equipped with two monitoring piezometers each. Hydraulic and water quality data will form the basis for an assessment of seepage potential.

In addition to the BH series boreholes and shallow groundwater piezometers installed in 1990, four further monitoring boreholes should be installed adjacent to the North Fork, one immediately north-west of BH 4 which previously recorded the highest zinc concentration, two further south but in this same area, and one centred on the location of the creek which previously flowed over the Zone II area. Both the surficial sediments and the underlying bedrock would be investigated.

For pit water-level control, we recommend that a water-level inspection tube be installed in the existing pumping well, and that the observation well be refurbished or replaced. This should enable adequate water-level monitoring. Provided the pumping well is functional and quickly serviceable, we believe that the well alone has sufficient capacity to control the pit water-level. However, if this capacity diminishes or the well is not serviceable, immediate arrangements to replace the well should be instituted.

Run-off from Waste Rock - Seep surveys and waste rock characterization studies are part of Schedule D studies in progress. Also, plans for drainage collection and feed to an underground treatment system have been developed. Additional requirements are not considered necessary.

Leaching of metal-rich soils - Sediment samples should be collected when the three additional boreholes are installed adjacent to the North Fork. The samples should be tested to determine metal content and leachability.

Main Pit - In order to confirm the low potential for seepage from the pit, and to provide an indication of groundwater levels and quality when the pit is flooded, two monitoring boreholes should be strategically located in the area east of the pit but west of a large waste rock dump, one between the Main and Zone II Pits, and one further north. Borehole depths of approximately 200 feet should be adequate as the rock at this depth has been shown to be very low in permeability. It would be prudent to perform packer tests prior to piezometer installation in order to verify previous results. In addition, three further boreholes should be inserted around the toe of the large dump to investigate conditions towards the discharge end of potential seepage flowpaths. In these latter holes north of the BH series holes, both the surficial colluvium and underlying bedrock would be investigated.

In addition to the above, in recognition of historical instances of North Fork water quality variations, and uncertainty regarding the entry point of any contaminant discharges, the three additional monitoring stations on the North Fork between R7 and X2 recommended in EP's intervention statement should be adopted. It would be appropriate to monitor all 5 stations on a monthly frequency, with samples being collected from the west bank of the creek. Monitoring piezometers should only be sampled quarterly given the much less rapid changes in groundwater quality as a result of groundwater flow rates being orders of magnitude slower. Figure 3 shows the approximate location of the monitoring stations proposed. Precise locations should be selected in the field to enable efficient borehole drilling and surface water monitoring.

We trust the above meets your present requirements, and we will be happy to respond to any comments.

Yours truly,
STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.

Dave P. Harpley
Senior Hydrogeologist

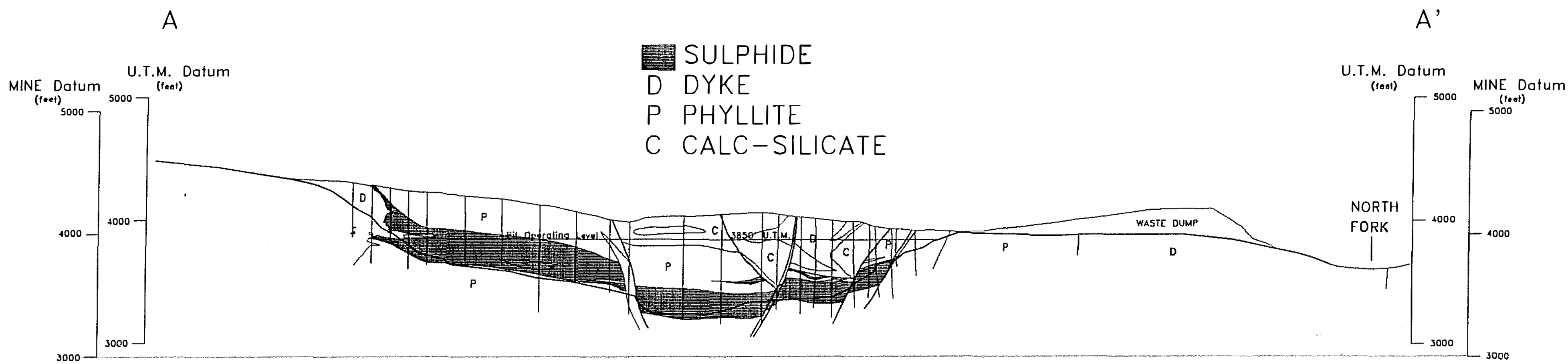

Figure 1A: Cross-Section through Main Pit to North Fork

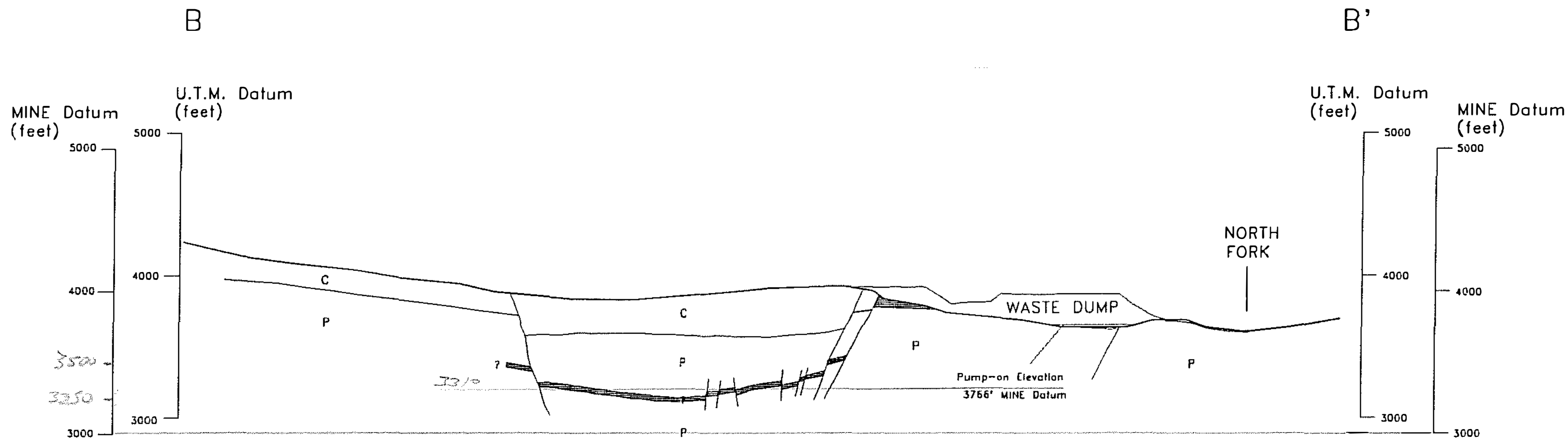

Figure 1B: Cross-Section through Zone II Pit to North Fork

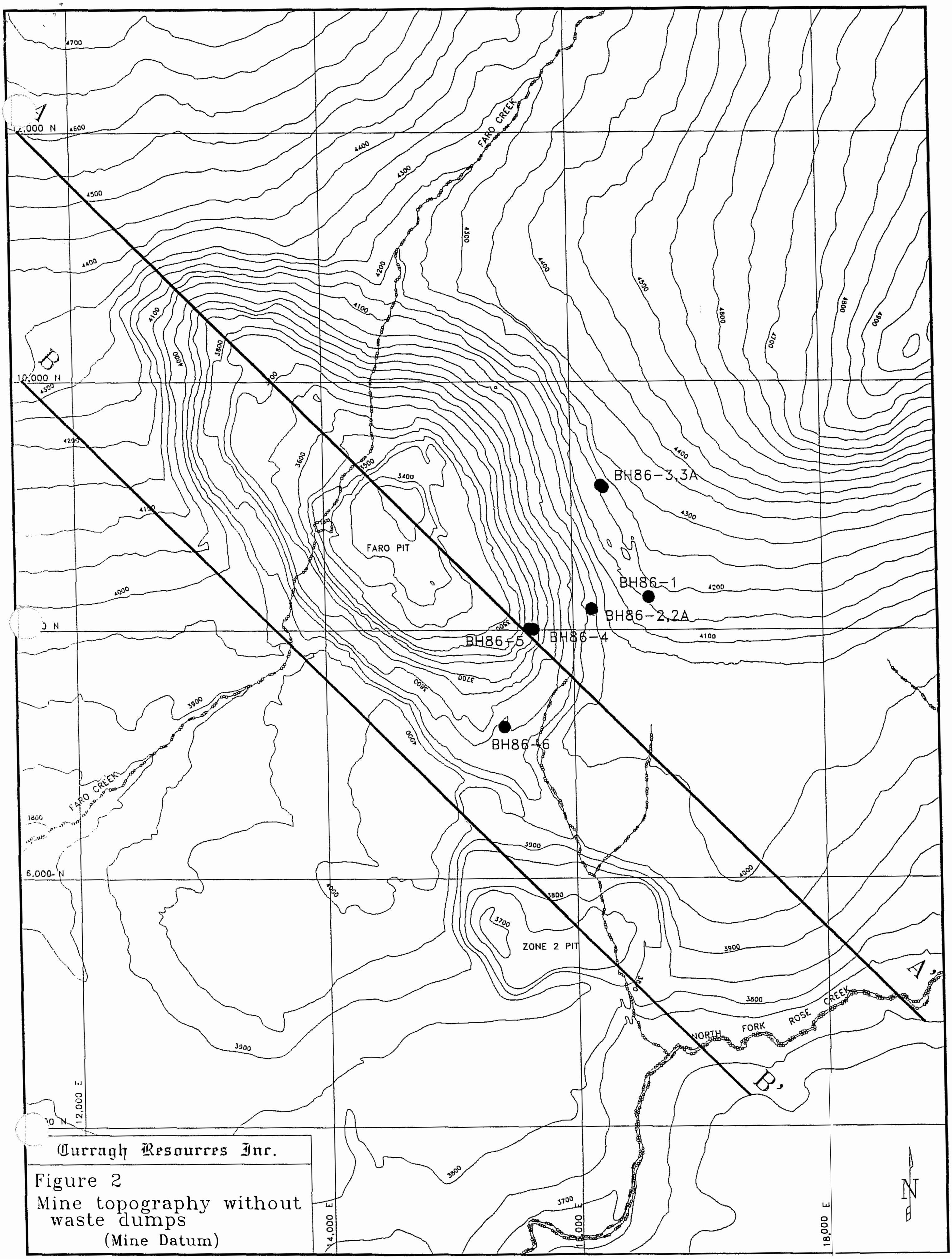

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Figure 2
Mine topography without waste dumps
(Mine Datum)

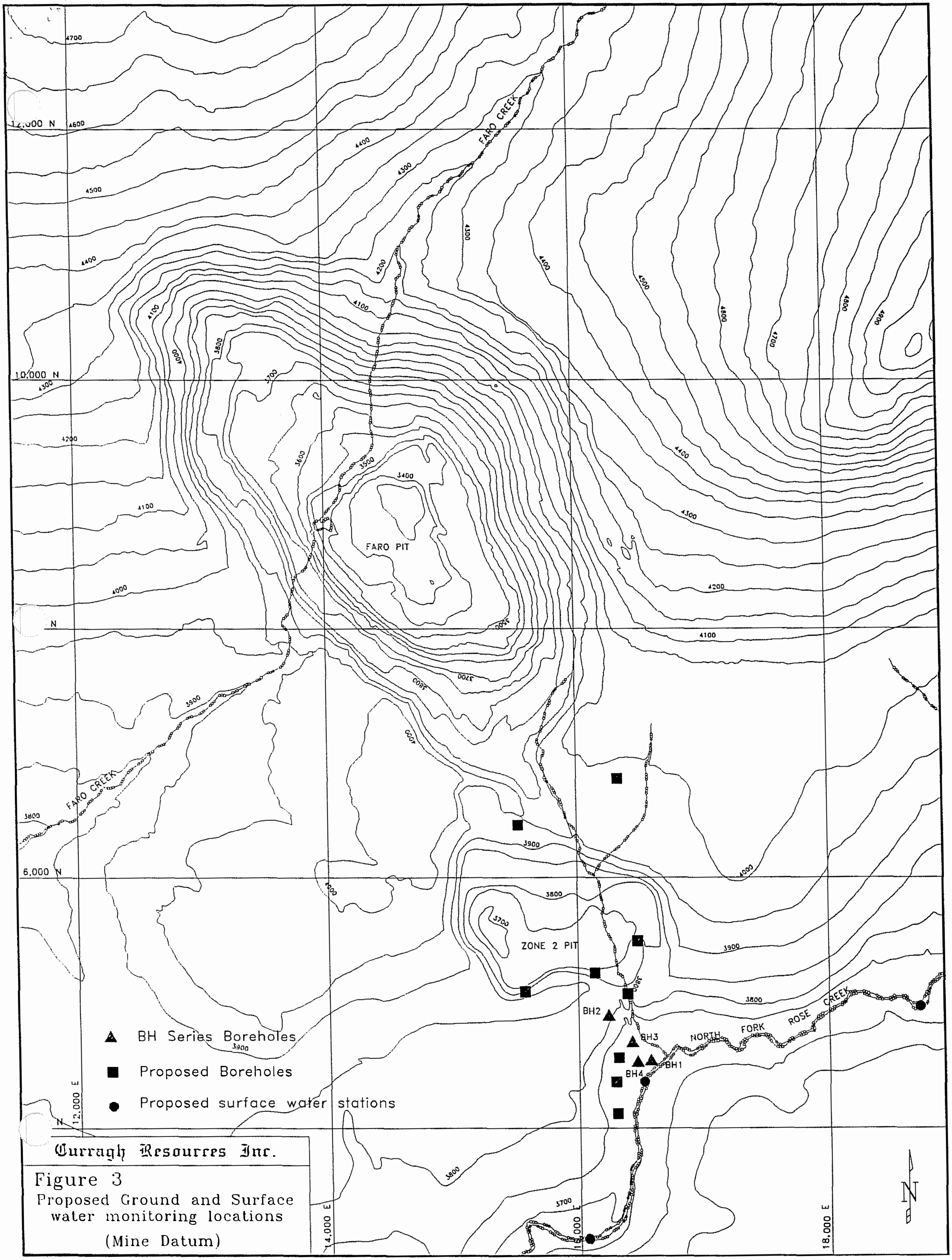

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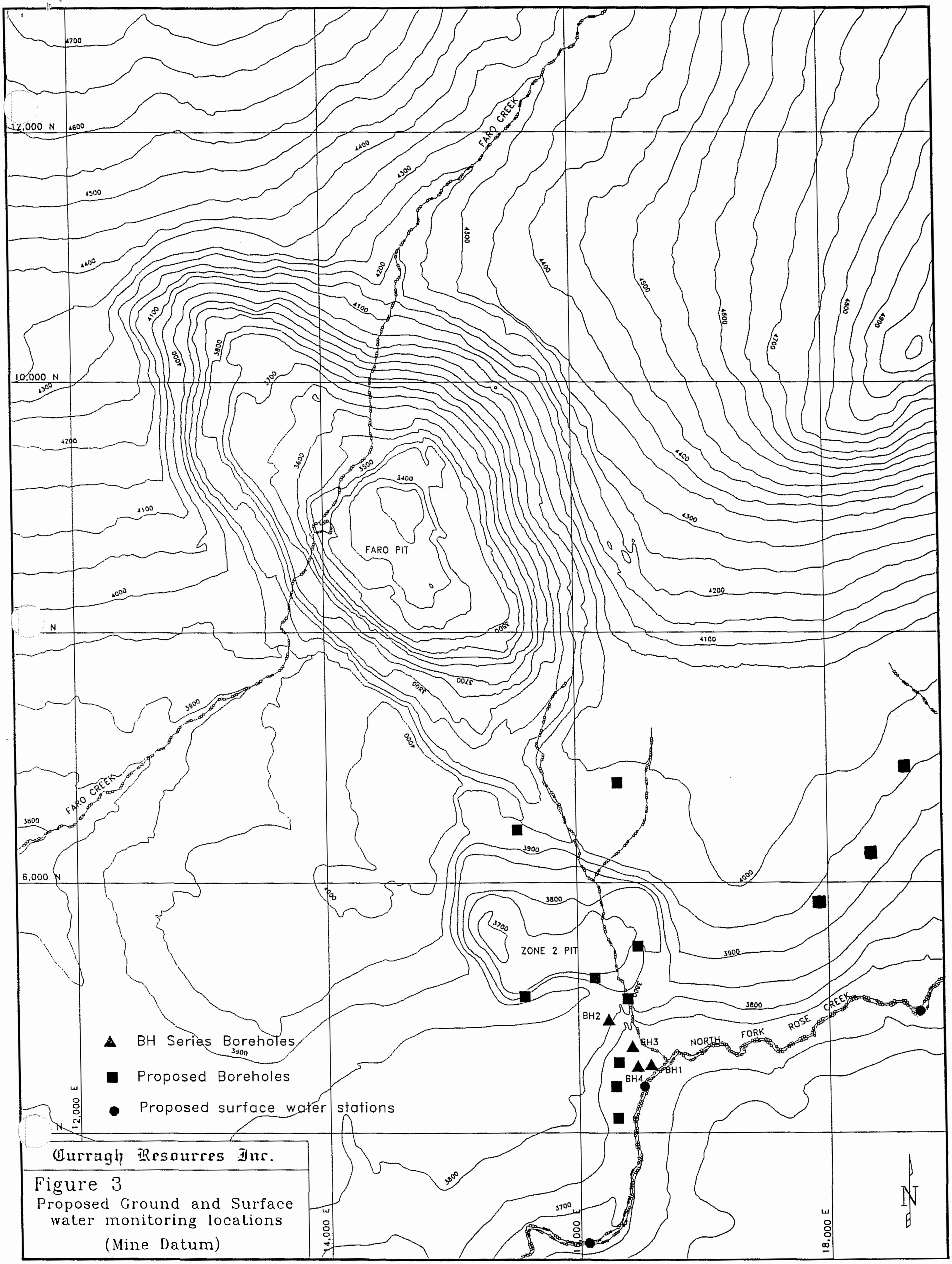
Figure 3
Proposed Ground and Surface water monitoring locations
(Mine Datum)



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