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CURRAGH RESOURCES INC.

Report Number 60646

SULPHATE REDUCTION AT FARO
PRELIMINARY LABORATORY EVALUATION

STEFFEN ROBERTSON & KIRSTEN

Consulting Engineers

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August 25, 1992
Project Number 60646

Curragh Resources Inc.
117 Industrial Road
Whitehorse, YUKON
Y1A 2T8

Attention: Mr. G. Acott, P.Biol.
Manager, Environmental Affairs

Dear Gerry:

RE: SULPHATE REDUCTION LABORATORY EVALUATION

As requested, please find enclosed four bound copies and one unbound copy of our final report, Report Number 60646, on the preliminary laboratory evaluation of sulphate reduction for the Faro Mine.

The recovery and analysis of the sludge accumulated in the respective sulphate reduction reactors is currently under way. However, the laboratory indicated that the analytical data will not be available until early next week. That data is therefore not included in the report, but will be reported to you and discussed separately in a letter, when it becomes available.

Should you have any questions please do not hesitate to call me.

Yours truly,

STEFFEN, ROBERTSON AND KIRSTEN (CANADA) INC.

J.T. Chapman, M.Sc.(Eng.), P.Eng.
Project Manager

JTC/072

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September 16, 1992
Project Number 60646

Curragh Resources Inc.
117 Industrial Road
Whitehorse, YUKON
Y1A 2T8

Attention: Mr. G. Acott, P.Biol.
Manager, Environmental Affairs

Dear Mr. Acott;

RE: SULPHATE REDUCTION LABORATORY EVALUATION

As we discussed, to confirm the activity of sulphate reducing bacteria and the subsequent precipitation of zinc as a sulphide in the reactors, samples of accumulated sludges were recovered from each of the reactors and submitted for total zinc and sulphide zinc analysis. The results are as follows:

Sample	Zn (Total) (%)	Zn (as Sulphide) (%)	Fraction Zn as Sulphide (%)
Reactor 1	4.69	2.25	48.0
Reactor 2	4.78	2.41	50.4
Reactor 3	2.47	1.10	44.5

Proceeding from the understanding that the reactor systems were zinc free when initiated, it is clear that this metal was removed from the mine water. Further, approximately 45 to 50 % of the metal is present as the sulphide in each of the reactors. While the sludge from reactor 3 has a lower zinc content than either reactors 1 and 2, it should be noted that this reactor (reactor 3) was operated at the longest retention time, and thus received significantly less water (thus zinc metal) than either of the other two reactors.

Presence of the zinc as the sulphide mineral in all three reactors confirms the generation of hydrogen sulphide and the subsequent removal of zinc as a sulphide mineral. Therefore, the above test results substantiates the conclusions described in the preliminary laboratory test report, SRK Report Number 60646.

As stated in the report, we recommend that a pilot scale evaluation be completed on site at the Faro Mine to provide more exact estimates of:

- the substrate (sugar) requirement of the sulphate reducing bacteria to maintain zinc removal; and,
- sludge accumulation rates in the reactor system.

The pilot system would also ensure a continuous supply of sulphate reducing bacteria adapted to the Faro Mine rockpile water which may be introduced directly to the underground mine. This would accelerate the start-up process for the underground system.

Should you have any comments or questions please do not hesitate to call me.

Yours truly,

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.

J.T. Chapman, M.Sc.(Eng.), P.Eng.
Chemical Engineer

JTC/072

4 bound & 1 original
- original to our file
- 1 - office copy
- 1 - to Chantal @ Faro
2 - extra (on shelf downstairs)

Report Number 60646

SULPHATE REDUCTION AT FARO
PRELIMINARY LABORATORY EVALUATION

Prepared for:

Curragh Resources Inc.
117 Industrial Rd
Whitehorse, Yukon

Prepared by:

STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.
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AUGUST 1992

Report Number 60646

SULPHATE REDUCTION AT FARO
PRELIMINARY LABORATORY EVALUATION

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Report Number 60646

SULPHATE REDUCTION AT FARO
PRELIMINARY LABORATORY EVALUATION

1.0 INTRODUCTION

1.1 Terms of Reference

A conceptual evaluation for the implementation of sulphate reduction in the Faro underground mine, as a water treatment alternative, was completed by Steffen, Robertson and Kirsten (SRK) in October 1991. Subsequently, a preliminary laboratory scale evaluation of the process was completed to confirm the potential for the removal of dissolved metals from the Faro Mine mine rock drainage, and to establish preliminary reaction rates and efficiencies. The test program was completed at Min-En Laboratories, North Vancouver.

The objectives of the test program were to:

- establish the potential for adapting sulphate reducing bacteria to the mine rock drainage from the Faro Mine site;

- evaluate the potential for utilizing sugar as an organic substrate for the sulphate reducing bacteria;

- provide a preliminary estimate of sulphate reduction rates that may be achieved; and,

- evaluate the potential for utilizing the sulphate reduction process for the removal of zinc from the mine site runoff.

This report presents the results from this initial laboratory test program and summarises the findings.

1.2 Background

Various operating parameters contribute to the performance of sulphate reducing bacteria. These include temperature, reactor retention time, and, the type and availability of the organic substrate utilized by the bacteria.

In SRK Report Number 60643, October 1991, the concept of utilizing the underground mine section off the Faro Main Pit as a sulphate reduction reactor system to treat the drainage water from the mine rock piles on the site, is described. In that evaluation it was estimated that the drainage water will, on average, contain approximately 26 mg/L zinc. The preliminary assessment of the water temperature during its passage through the underground mine section suggested that the water temperature may increase to approximately 12°C. At this temperature a sulphate reduction rate of approximately 0.06 g SO_4^{2-} /L/day (or 2.5 mg/L/h) was estimated to be possible for the process.

Bacterial activity decreases with a decrease in temperature below the optimum, thus the rate of sulphate reduction reduces accordingly. As a general rule of thumb, the bacterial activity halves for every 10°C decrease in temperature ($Q_{10} = 2$). It is therefore important to conduct any experimental work at or close to the actual operating temperature that may be expected for the reactor system. Thus one of the objectives of the test program was to evaluate the sulphate reduction rate that may be achieved at the anticipated underground reactor system temperature.

The rate of sulphate reduction is a function of the concentration of active biomass present in the reactor system. The concentration of active biomass in turn is a function of the substrate availability and the efficiency with which the bacteria utilise it. In the conceptual evaluation it was established that sugar represents the most cost effective substrate for utilisation in the underground reactor system. Based on the performance data presented in the literature, the estimated water quality to be treated , and the estimated retention time for the underground system, it was estimated that a sugar addition rate of 0.325 g/L will be required to maintain a sufficiently elevated sulphate reduction rate in order to sustain dissolved metals (in particular zinc) removal from the contaminated drainage water. A substrate addition rate of 0.325 g/L was thus maintained for each of the reactors in the experimental program.

926 kg/day or 338 Tonnes/year
original rpt said 235 Tonnes/year

2.0 MATERIALS AND METHODS

2.1 Water Sample

Approximately 125 litres of discharge water from the Zone II Pit at the Faro Mine was received from Curragh Resources Inc. at Min-En Laboratories for the completion of the preliminary test program.

The as received solution analysis, summarised in Table 1, indicated a zinc concentration of approximately 60 mg/L. The objective of the test work however was to simulate the expected conditions for the underground mine sulphate reduction reactor system as closely as possible. These conditions are summarised in SRK Report Number 60643, "Sulphate Reduction as an Alternative Water Treatment Option at Faro". As the evaluation indicated an average zinc concentration of approximately 26 mg/L, it was necessary to dilute the 'as received' water with distilled water to achieve a similar zinc concentration. The analysis of the diluted water sample is also summarised in Table 1.

TABLE 1
Zone II Pit Discharge and Reactor Feed Solution Water Quality

Parameter	Zone II Discharge (mg/L)	Feed Stock (mg/L)
pH	6.25	6.45
SO_4^{2-}	920	478
As	0.04	0.03
Cd	0.051	0.031
Cu	0.016	0.032
Fe	2.12	1.23
Mn	5.260	2.775
Ni	0.520	0.280
Pb	0.208	0.132
Sn	0.480	0.298
Zn	61.327	32.086

2.2 Equipment

Three small scale reactors were constructed with PVC piping. Pipe sections were capped on each side as illustrated in Figure 1, providing a total reactor volume of approximately 5.0 litres. Granite rock, 25 to 75 mm in diameter, was used as an inert fixed bed material to provide attachment sites for the sulphate reducing bacteria. The effective reactor volumes (i.e. void space in the reactor) were determined by obtaining the total water displacement capacity of each reactor after the rock medium was in place. The [redacted]

The reactors were each equipped with an inlet and a discharge port. A peristaltic pump was used to transfer feed solution from the feed container to the reactor. Different feed rates to each of the reactors was ensured by activating the respective peristaltic feed pumps with intermittent timers to achieve the required volumetric throughput.

Each reactor was inclined at an angle of approximately 15° above horizontal, with the inlet elevated above the outlet, approximating the incline of the underground mine.

2.3 Methods

Drainage water in the feed container was maintained under anoxic conditions by continuously purging the head space with nitrogen. Solution from the sulphate reduction reactors was discharged directly into a product receiving vessel under anoxic conditions. To ensure anoxic conditions for the discharge, a water column in the discharge tube, as illustrated in Figure 1, was maintained and discharge occurred below the water level in the receiving vessel.

The concentration for sulphate in solution was determined using standard turbidity measurement techniques. Multi-element Inductively Coupled Plasma (ICP) scans were performed on the feed and discharge solutions to evaluate the metal content of the respective solutions. Standard techniques were employed to obtain solution pH values.

It was not possible within the scope and budget of the present test program to implement strict temperature control. Rather, as the operating temperature was below room temperature, [redacted] As temperature measurements were obtained in the late afternoon, it is considered that the reported temperatures are higher than the average daily operating temperature for the reactors. The results are therefore likely to be conservative, i.e. since the actual average temperature is likely to be lower than the reported air temperature, th[redacted]

The reactors were inoculated under anaerobic conditions with a mixed bacterial culture exhibiting sulphate reducing characteristics. These bacteria have previously been adapted to metal contaminated water with a high sulphate concentration. Prior to testing, the culture was maintained with water synthesized to simulate ARD, with elevated metal concentrations and a sulphate concentration of approximately 2,000 mg/L. Culture maintenance was at a temperature of 30 °C, which corresponds with the optimum bacterial activity observed for this sulphate reducing culture.

2.4 Substrates

It is anticipated that, for the temperature and retention time conditions applicable, a relatively low bacterial activity and sulphate reduction rate will be observed (SRK Report Number 60643). At this level of activity, it is also anticipated that the inorganic nutrient requirement will be minimal. The solution analysis has indicated a trace phosphorus content, and an abundance of potassium for the site water; nitrogen was not obtained. [redacted]

As discussed in SRK Report 60643, sugar is likely the most economical organic substrate that may be used for the process. Household sugar was therefore added directly to the feed solution to meet the estimated requirement of 0.325 gram per litre.

Since a constant feed concentration was utilised for all the tests, the actual substrate feed rate to each reactor was different because of the difference in the volumetric feed rates. Based on the volumetric throughput and the feed solution concentration, the actual organic substrate supply rates were calculated and are summarized in Table 2.

TABLE 2
Effective Organic Substrate Feed Rate

Reactor	Feed Rate (L/h)	Substrate (g/h)
1	0.032	0.0104
2	0.023	0.0075
3	0.016	0.0052

3.0 RESULTS AND DISCUSSION

The reactor parameters, including the temperature, feed rate, retention time and sulphate concentrations for the feed and discharge solutions are presented in Appendix A for reactor 1, Appendix B for reactor 2 and in Appendix C for reactor 3. Also provided in these appendices are the respective discharge water quality data for each of the reactors. The sulphate reduction rates were calculated based on the individual inlet and outlet sulphate concentrations for each reactor, and are included with the operating data. Sample calculations are included in Appendix A.

The [redacted] This transition period is evidenced in the change in pH observed for the system. The Zone II pit water pH is typically higher than 6.0 and falls within the optimum range of pH 6.0 to 8.0 for sulphate reducing bacteria. However, the pH values recorded for the systems show that the solution was below this optimum pH range, as a result of the effect of residual synthetic ARD in the system, for the initial 20 to 30 days of operation and therefore confirms the transient nature of this operating period. This transient period represents the time required by the bacteria to adapt to the changes in the operating temperature, pH conditions and the increase in metal content observed for the Faro water. [redacted]n. It should also be noted that reactors 2 and 3 required a significantly longer period of time to respond to changes in the operating parameters due to the longer operating retention times (i.e. time required to displace the water contained in the reactor).

3.1 Retention Time and Temperature Effects

[redacted] The target operating retention times and effective reactor volumes for each reactor are provided in Table 3.

TABLE 3
Reactor Void Space and Target Retention Time

Reactor	Void (L)	Retention (h)
1	3.03	90
2	3.25	130
3	3.23	180

The operating retention time data for the reactors are provided in their respective appendices. Retention time profiles for the respective reactors are illustrated in Figure 2. With the exception of days 11 and 44, when general power failures resulted in the timer setting memory loss of the intermittent timer controlling the pumps, the operating retention time profiles for the respective reactors closely approximated the target values.

The effect of retention time on the overall sulphate reduction rate, at corresponding temperatures, is illustrated in Figure 3. A sample calculation of the sulphate reduction rate, which is calculated based on the reactor volume and retention time, is provided in Appendix A. On this basis, consistent with expectation, the results show a decrease in the overall volumetric sulphate reduction rate as a function of the retention time. ?

Wouldn't one expect and an increase of rate as retention time increases?

The corresponding overall fraction sulphate in the feed that was reduced, as illustrated in Figure 4, are contrary to expectation up to approximately day 75. It was anticipated that the reactors would have emulated a plugflow system at the relatively low flow rates: i.e. no backmixing or shortcircuiting of the solution would occur as the solution passed through the reactor; and, sulphate reduction would occur continuously throughout the reactor so that the greatest conversion will occur for the reactor with the longest retention time. The results however indicated a lower effective fraction sulphate reduced in reactors 2 and 3 which were operated with the longer retention times than for reactor 1 during this period. However, subsequent to day 75 the fraction sulphate conversion achieved by reactors 2 and 3 exceed that observed for reactor 1. It should also be noted that the general trend in the fraction sulphate reduced for [redacted] This clearly indicates that, due to the fluctuations in temperature combined with the long retention times for these reactors, [redacted] The lag period in achieving optimum pH conditions also likely had a deleterious effect on the performance of these reactors.

It is therefore considered more probable that steady state conditions were achieved for reactor 1, and thus reactor 1 data are likely the most reliable. Therefore, further discussions will concentrate on the data for this reactor.

The operating temperature profile as a function of time is illustrated in Figure 5. Also shown in Figure 5 is the sulphate reduction rate for reactor 1. As a result of the fluctuation in the temperature profile, the sulphate reduction rate was affected. A decrease in the temperature resulted in a decrease of the sulphate reduction rate and, similarly an increase in temperature resulted in an increase in the sulphate reduction rate. While this temperature fluctuation was not intentional, it is possible to identify different time periods where an approximately constant temperature was observed for a period long enough to associate a specific sulphate reduction rate with that temperature regime. These time periods, average temperatures and associated sulphate reduction rates are summarised in Table 4. It is however important to recognize that there is a lag between the time a change in temperature is observed and the response of the bacteria to that change in temperature. This lag is further exaggerated by the retention time; the longer the retention time, the longer the lag time before the effect will be observed. [redacted]are [redacted]

TABLE 4
Temperature Effect on Sulphate Reduction Rate

Period (day)	Average Temperature (°C)	Sulphate Reduction Rate (g/L/day)		
		Reactor 1	Reactor 2	Reactor 3
1 - 24	12	0.027	0.015	0.008
25 - 34	4	0.021	0.008	0.005
25 - 58	15	0.043	0.016	0.008
58 - 71	19	0.110	0.018	0.014
71 - 90	14	0.059	0.017	0.010

The sulphate reduction rate data for reactor 1 as a function of temperature are illustrated in Figure 6. As indicated by the graphed data, the sulphate reduction rate approximately halves for each 10°C decrease in temperature, closely approximating the theoretical bacterial activity quotient (Q_{10}).

3.3 Substrate Utilization

The sugar content of the discharge solution was not measured, [redacted] The equivalent sulphate reduction achieved for the total quantity sugar added to the feed solution was calculated for the reactor 1 data, and presented in Table 5.

At the highest sulphate reduction rate observed, a sugar utilization of 0.748 g/g SO_4^{2-} was observed. This corresponds well with the sugar utilization rate of 0.694 g reported in the literature and used in the 1991 evaluation (SRK Report 60643). Based on the overall sugar addition rate, the apparent utilization rate increases for the lower sulphate reduction rates. However since sugar was added at a constant rate for the duration of the test program, and since the sulphate reduction rate varied with temperature, it is unlikely that all of the sugar was utilized at the lower rates (and temperatures). [redacted] but it is likely that at the lower rates the sugar passed through the reactor system unutilized. The sugar addition rate could have been reduced at the lower reduction rates to the theoretical utilization value without affecting the reduction rate. [redacted]

TABLE 5
Reactor 1 - Organic Substrate Utilization

Temperature (°C)	SO_4^{2-} Reduction (g/L/day)	Utilization (g sugar/gSO_4^{2-} reduced)
12	0.027	3.098
4	0.021	3.918
15	0.043	1.903
19	0.110	0.748
14	0.059	1.389

3.4 Metal Removal

3.4.1 Zinc

The zinc concentration in the feed solution ranged from 27 mg/L to 32 mg/L. However, within approximately 2 - 3 weeks from the start of the test program, precipitates were observed in the feed vessel. Subsequently samples of the feed solution was obtained directly from the pump line and analyzed for the dissolved metal content. [redacted] However, the operating procedures ensured that the total content of the feed vessel was transferred to the sulphate reduction reactor, including the precipitates. The solution retention time in the feed vessel ranged from approximately 90 hours for reactor 1 to approximately 180 hours for reactor 3.

As a result of the difference in the sulphate reduction rates observed for the three different retention times, and as a consequence of not achieving steady state operating conditions in reactors 2 and 3, a difference in the metal removal performance was observed. The highest metal removal rates were observed for reactor 1, correlating to the sulphate reduction rates observed for this reactor. The zinc concentrations in the feed, the dissolved content for the pumped solution and the discharge for reactor 1 are illustrated in Figure 7.

The effect of the anoxic conditions in the feed container on the dissolved zinc concentration is clearly evident. It is further evident from the discharge solution concentration profile that during the initial 20 to 30 days of operation zinc removal rates were marginal. However, once the stable sulphate reduction rates were established, the discharged solution concentrations decreased rapidly. During the final two weeks of operation discharge zinc concentrations well below 1 mg/L were achieved consistently.

In order to evaluate the effect rapidly changing water quality may have on the operating performance of the sulphate reduction system, the [redacted] As shown in Figure 7, following the increase in zinc in the feed solution, this [redacted]

The discharge solution concentration for zinc plotted against the sulphate reduction rate is illustrated in Figure 8, [redacted] The results also indicate that a sulphate reduction rate of approximately 0.06 g/L/day (2.5 mg/L/h) will be required to maintain a zinc concentration of less than 1 mg/L in the discharge. This rate corresponds well with the rate estimated in the 1991 evaluation (SRK Report Number 60643, Nov 1991).

3.4.2 Manganese

No significant decrease in the manganese concentration was achieved. The precipitation of this metal requires the formation of the carbonate mineral, as this metal does not form a stable sulphide compound. It is therefore evident that insufficient carbonate was formed through the generation of CO_2 to affect the solubility of manganese during the test period.

It was however [redacted]e enclosed system anticipated in the underground mine at the scale the test program was conducted. It is anticipated that in the underground reactor system, elevated pressures should lead to increased partial pressures for CO_2, which should lead to the removal of manganese.

3.4.4 Other Metals

While the feed solution concentration for cadmium ranged from 0.024 mg/L to 0.031 mg/L, a significant decrease for this metal was observed in the discharge of all the reactors. The cadmium concentration was decreased to less than 0.008 mg/L for all the reactors.

A reduction in the already low concentration of tin was also observed. On average, the tin concentration was reduced from 0.032 mg/L to 0.003 mg/L.

4.0 CONCLUSIONS

From the test work completed, it can be concluded that:

- Sulphate reducing bacteria have been successfully adapted to the Faro Mine rock pile runoff water;

- The test results confirmed that a sulphate reduction rate equal to 0.06 mg/L/day will be required to achieve removal of the zinc from solution in the underground reactor.

- The results indicate that the required sulphate reduction rate of 0.06 mg/L may be achieved at a temperature of approximately 14°C.

- Precipitation of metals occurred in the feed reservoir under anoxic conditions. While the decrease in the solution may have been advantageous to the sulphate reduction process, it is felt that a similar occurrence will prevail once the solution is pumped underground following the onset of anoxic conditions. In the case of the underground mine reactor system, the solution will be subjected to anoxic conditions while it is being 'pre-heated' (as described in SRK Report Number 60643) in the first section of its passage along the flowpath. This will likely result in the partial precipitation of the metals, followed by the complete precipitation as sulphides, once the active sulphate reduction zone is reached.

- A rapid change in the feed solution water quality (increased metal content) was readily absorbed by the sulphate reduction system and did not affect the metal removing performance.

- Sugar is a viable organic substrate that can be utilised by the sulphate reducing bacteria. However, while achieving zinc removal from the mine rock drainage, the sugar utilisation based on the overall addition rate is less efficient than that indicated at a higher reaction rate. At the reduced reduction rate it is expected that not all of the sugar was utilised, but rather that a portion of it passed through the reactor unused. This suggests that the sugar addition rate may potentially be decreased to correspond with the actual sulphate reduction rate for the system without affecting the sulphate reduction rate or the efficiency for metals removal.

- Manganese was not effectively removed under the laboratory conditions. However, the partial pressure for carbon dioxide in the underground mine under the elevated pressure head may prove sufficient to achieve manganese removal as the carbonate mineral.

5.0 RECOMMENDATIONS

It is recommended that a pilot scale facility be constructed on site at the Faro mine. The pilot facility will be used to provide:

- Confirmation of sulphate reduction and metal removal rates, as well as substrate utilization, at a larger and more reliable scale; and,

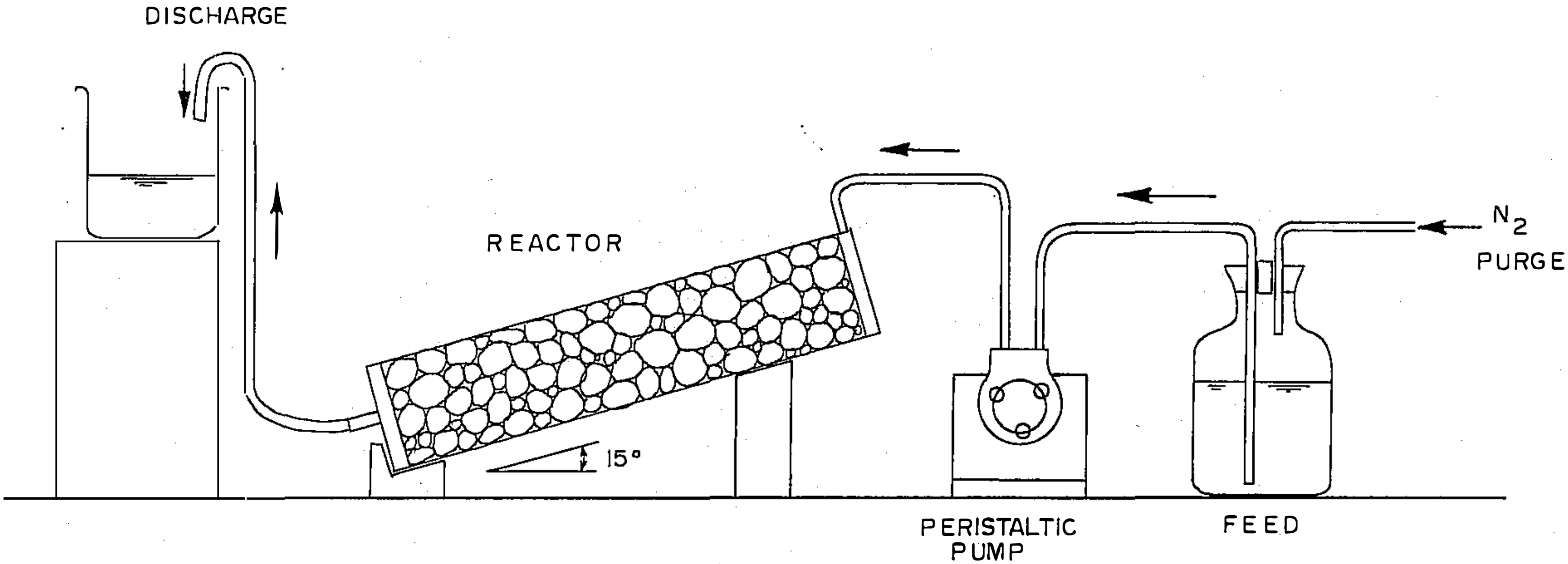
- Production of a sulphate reducing bacterial culture that may be used to inoculate the underground mine reactor system directly. This will insure an adequate supply of bacteria during the initial start-up of the system, which will minimise lag times before adequate sulphate reduction activity is achieved.

This report, 60646, Sulphate Reduction at Faro Preliminary Laboratory Evaluation, has been prepared by:

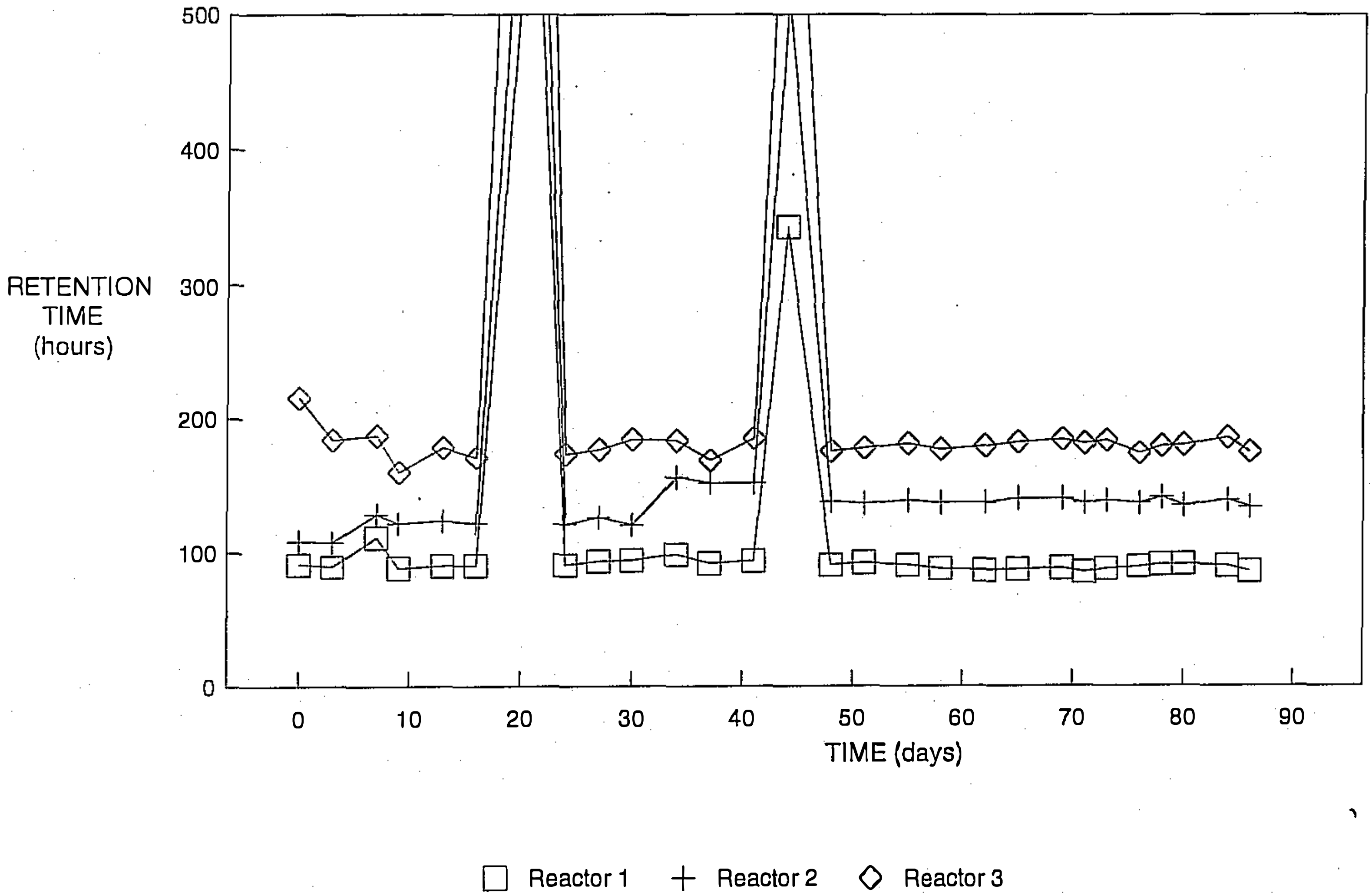
STEFFEN, ROBERTSON AND KIRSTEN (CANADA) INC.

J.T. Chapman, M.Sc.(Eng)., P.Eng.
Project Manager

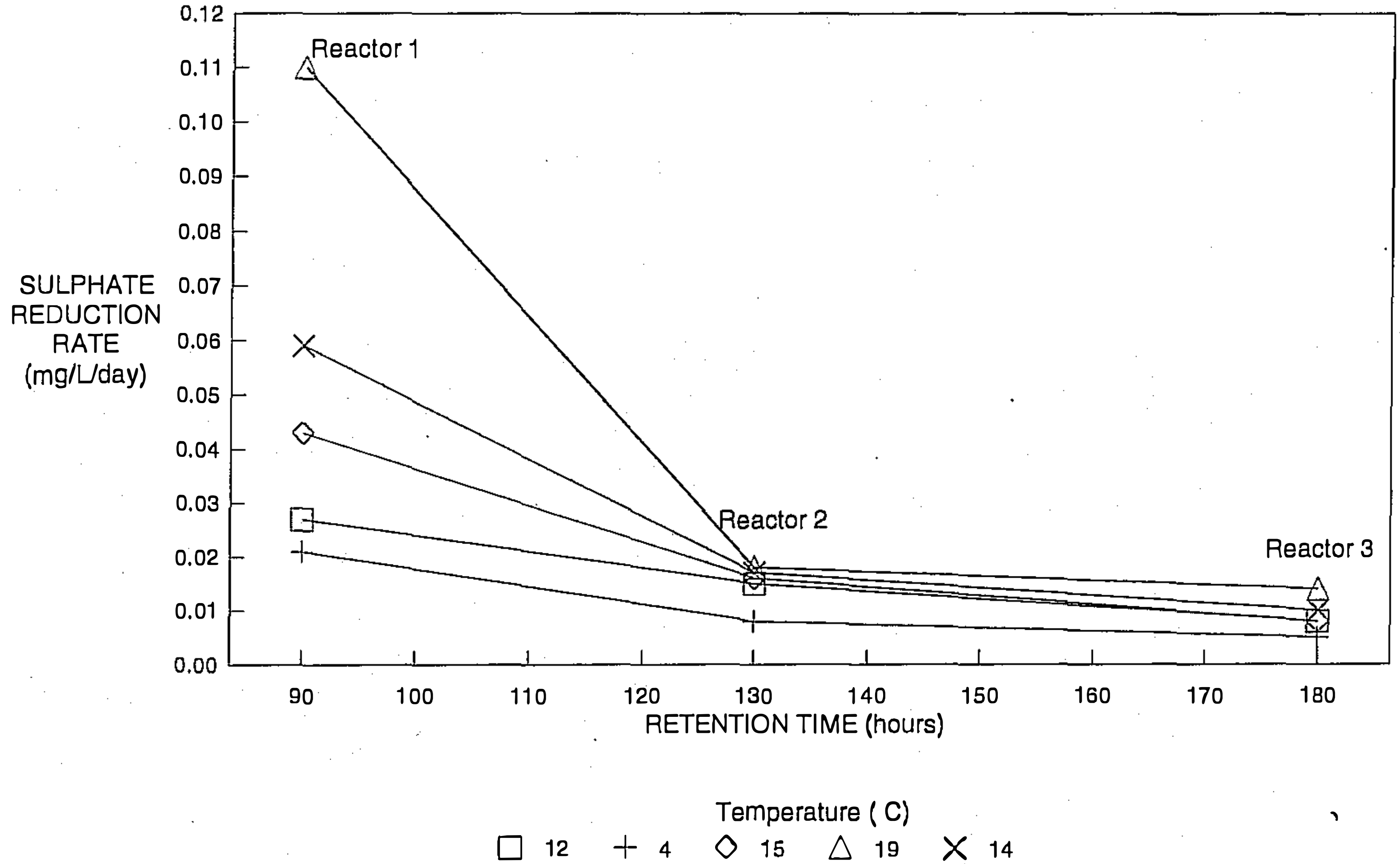
JTC/R-13



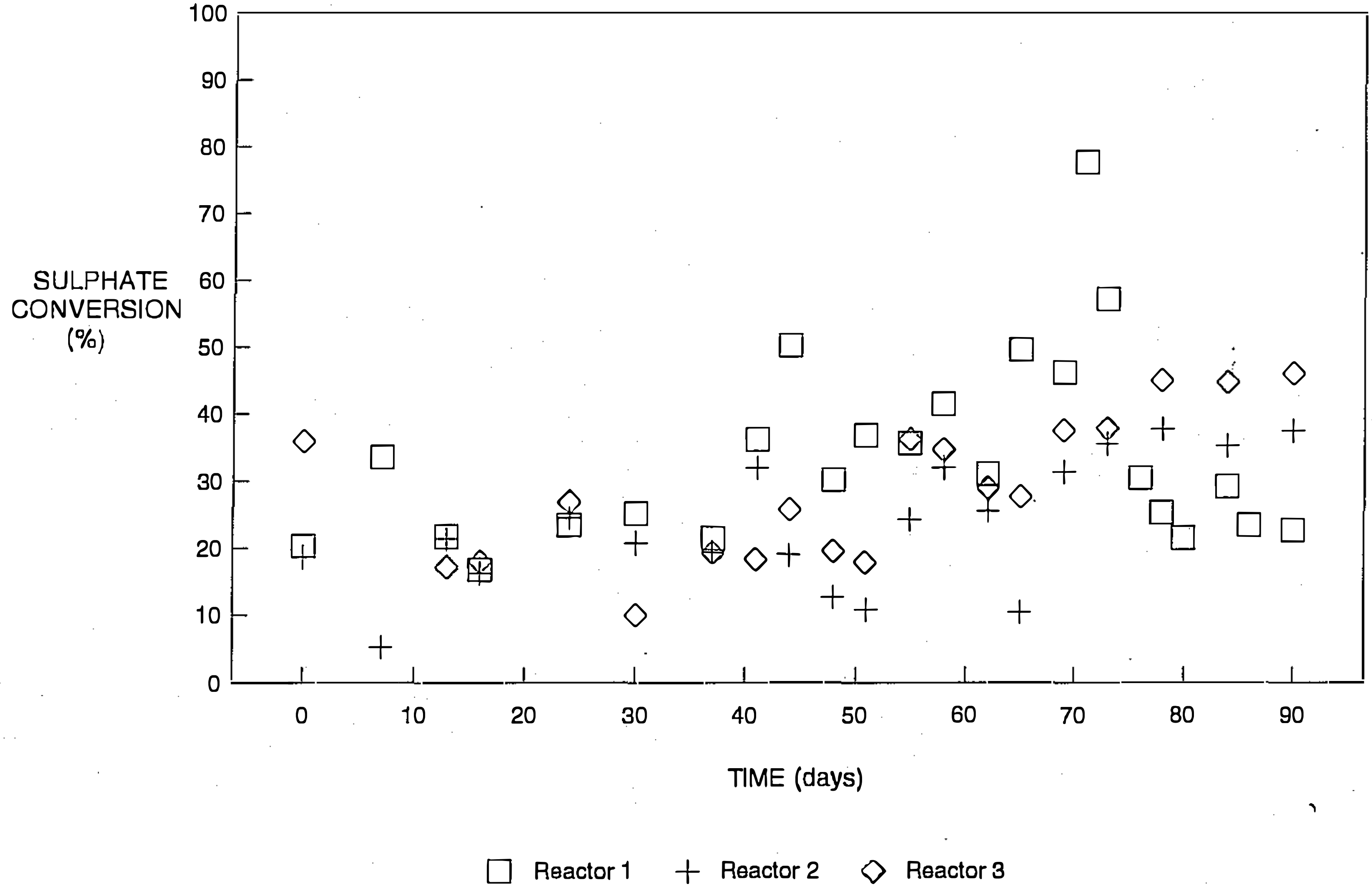
CURRAGH RESOURCES INC.	FARO MINE	DATE AUG. 1992
DIAGRAM OF LABORATORY EQUIPMENT		PROJ. NO. 60646
		APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		NO. 1



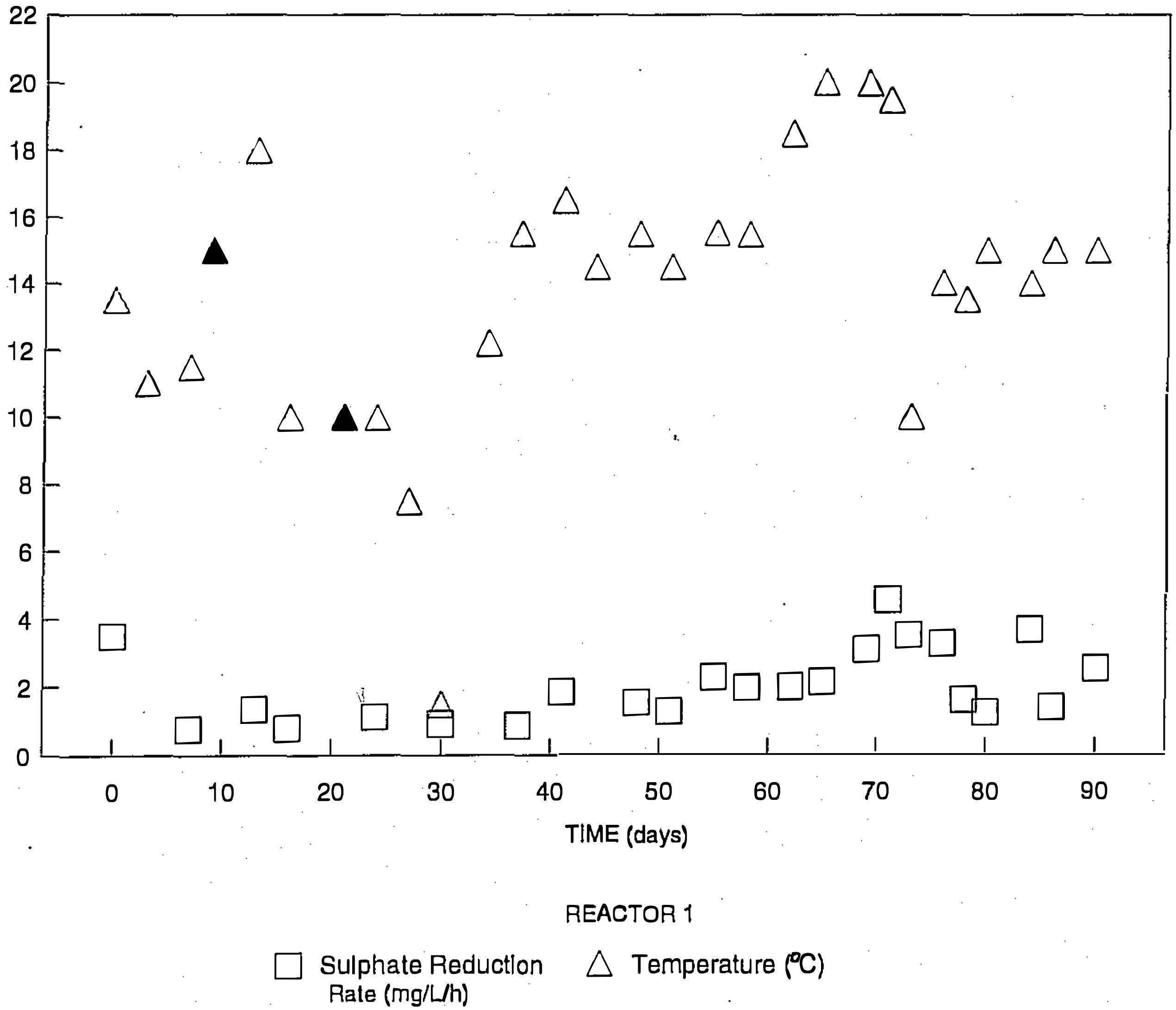
CURRAGH RESOURCES INC. FARO MINE	DATE AUG. 1992
	PROJ. NO. 60646
RETENTION TIME PROFILES FOR REACTORS 1,2, AND 3	APPROVED
	NO. 2
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers	



CURRAGH RESOURCES INC.	FARO MINE	DATE AUG. 1992
EFFECT OF RETENTION TIME ON SULPHATE REDUCTION RATE		PROJ. NO. 60646
		APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		NO. 3



CURRAGH RESOURCES INC.	FARO MINE	DATE AUG. 1992
		PROJ. NO. 60646
FRACTION SULPHATE REDUCTION ACHIEVED (AS A PERCENTAGE)		APPROVED
		NO. 4
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		



CURRAGH RESOURCES INC. FARO MINE

DATE AUG. 1992

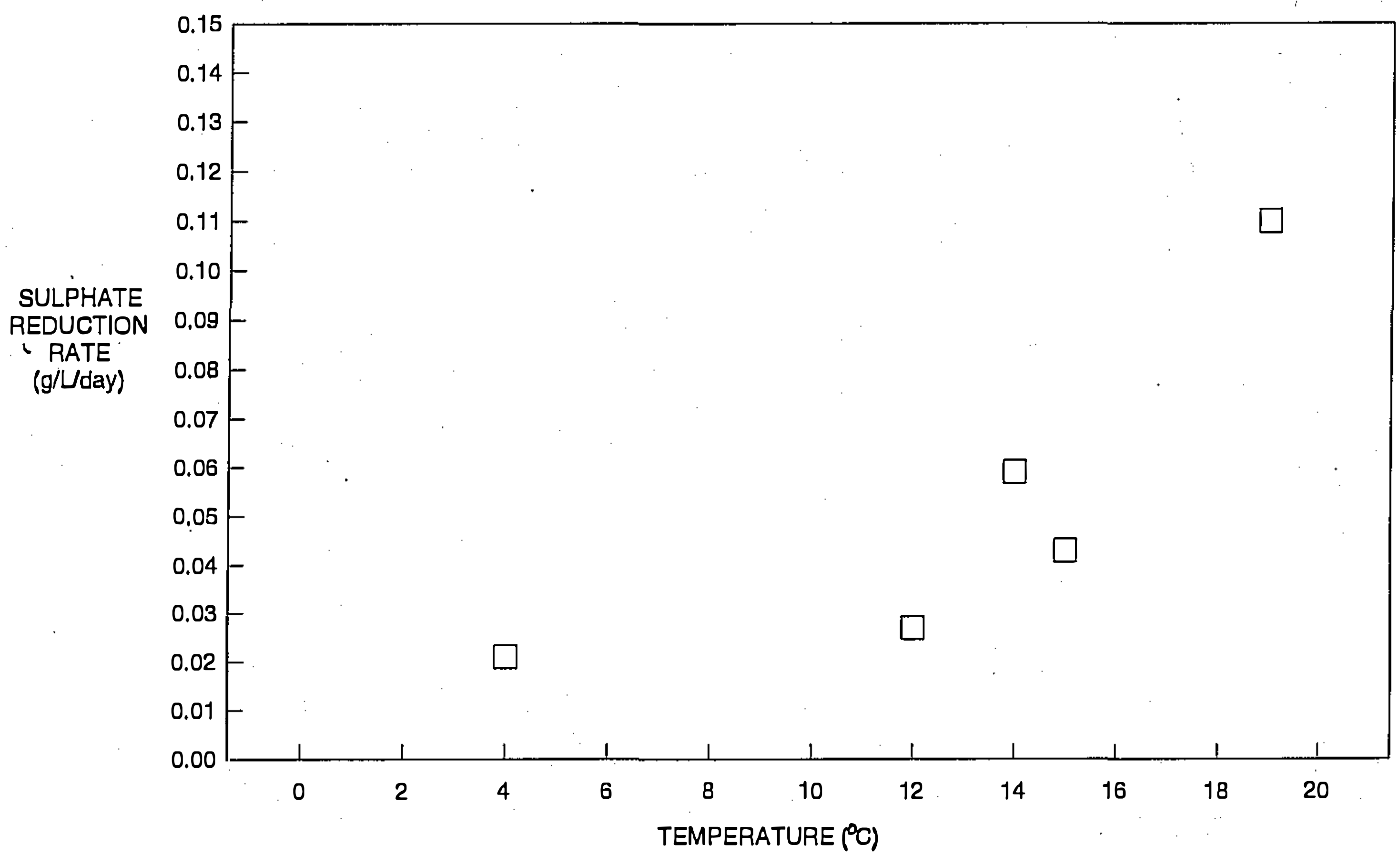
PROJ. NO. 60646

APPROVED

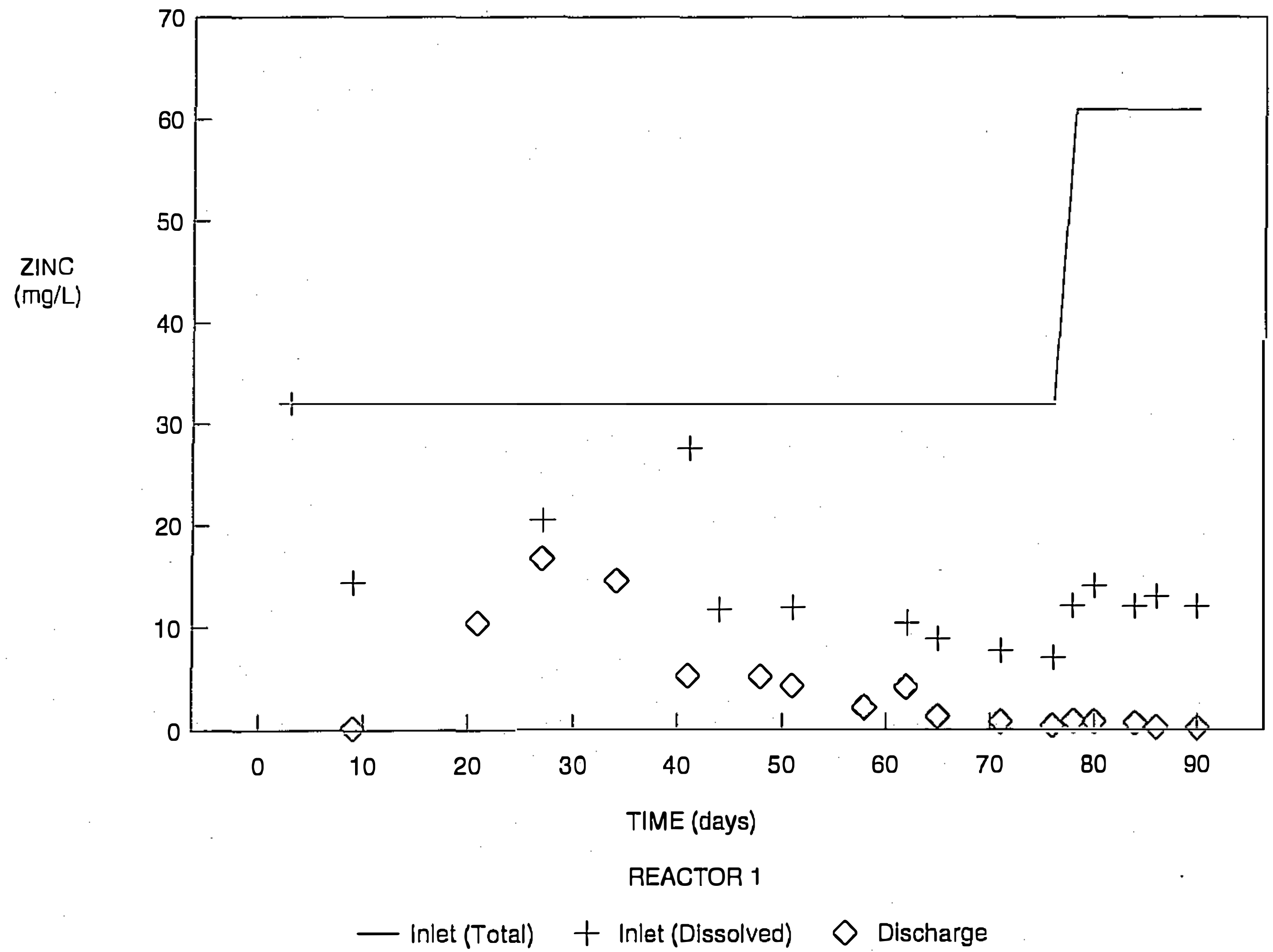
NO. 5

SULPHATE REDUCTION RATE AND OPERATING TEMPERATURE PROFILES FOR REACTOR 1

STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers



CURRAGH RESOURCES INC.	FARO MINE	DATE AUG. 1992
CORRELATION BETWEEN SULPHATE REDUCTION RATE AND TEMPERATURE		PROJ. NO. 60646
		APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		NO. 6



CURRAGH RESOURCES INC. FARO MINE

DATE AUG. 1992

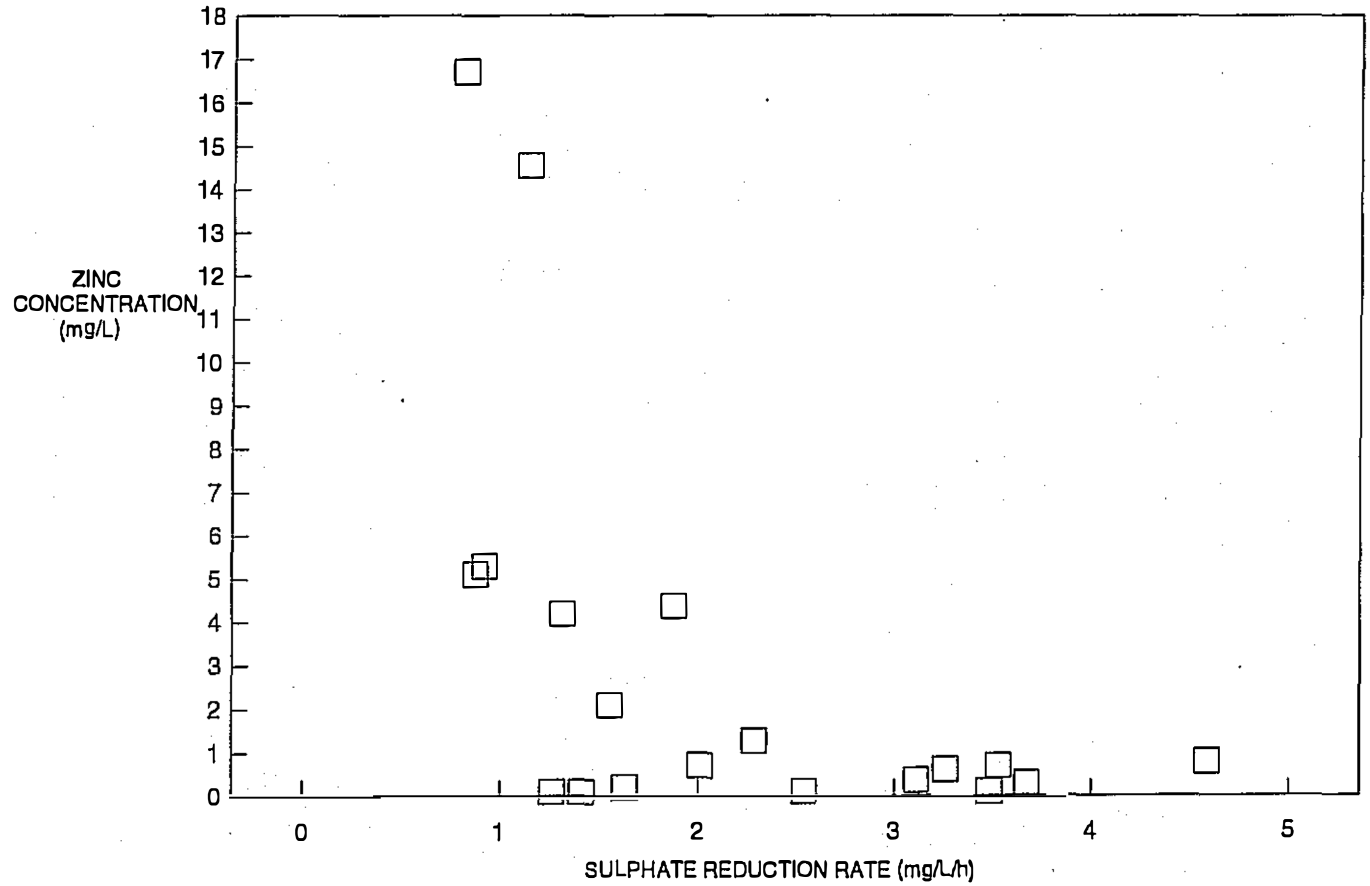
PROJ. NO. 60646

APPROVED

ZINC CONCENTRATIONS IN THE FEED (INLET) AND DISCHARGE SOLUTION TO REACTOR 1

NO. 7

STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers



CURRAGH RESOURCES INC. FARO MINE	DATE AUG. 1992
CORRELATION BETWEEN SULPHATE REDUCTION RATE AND DISCHARGE ZINC CONCENTRATION FOR REACTOR 1	PROJ. NO. 60646
	APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers	NO. 8

APPENDIX A

REACTOR 1 OPERATING DATA

FEED VESSEL WATER QUALITY DATA

Time	Days	Cd ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Sb ppm	Se ppm	Sn ppm	Zn (Dissolved) ppm	Zn (Total)
12.25	0	0.024	0.002	0.930	3.340	0.026	0.250	0.104	0.002	0.110	0.004	14.402	32.09
16.75	3												
12.50	7												
16.25	9												
13.17	13												
15.68	16	0.026	0.034	1.120	3.120	0.024	0.245	0.120	0.002	0.095	0.004	20.558	32.09
10.42	21												
12.83	24												
15.50	27												
13.43	30	0.027	0.034	1.220	2.930	0.022	0.250	0.124	0.002	0.080	0.002	27.649	32.09
14.93	34	0.025	0.030	0.900	2.985	0.022	0.225	0.100	0.006	0.100	0.002	11.706	32.09
13.08	37												
14.83	41	0.026	0.032	0.940	2.980	0.022	0.225	0.098	0.020	0.105	0.002	11.988	32.09
14.00	44												
13.75	48												
13.35	51	0.029	0.060	0.810	2.945	0.020	0.220	0.084	0.010	0.100	0.002	10.440	32.09
13.12	55	0.024	0.024	0.860	2.920	0.022	0.220	0.092	0.010	0.110	0.002	8.819	32.09
14.15	58												
12.37	62	0.027	0.036	0.910	2.965	0.018	0.205	0.106	0.016	0.100	0.002	7.640	32.09
13.83	65												
15.12	69	0.032	0.004	1.040	2.970	0.024	0.205	0.102	0.018	0.120	0.004	6.977	32.09
13.50	71											12.000	61.24
12.50	73											14.000	61.24
11.87	76											12.000	61.24
12.92	78											13.000	61.24
12.50	80											12.000	61.24
14.60	84											11.000	61.24
12.82	86											10.900	61.24
9.18	90											10.400	61.24

REACTOR 1 - OPERATING DATA

Time	Days	Temperature (oC)	Vol. Feed (L)	Feed Rate (L/h)	Retention Time (h)	Feed pH	Feed [SO4] (mg/L)	Discharge Vol (L)	pH	Discharge [SO4] (mg/L)	Sulphate Conversion (%)	Reduction Rate (mg/L/h)
12.25	0	13.5	3.10	0.033	90.9	5.50	1280	2.95	4.95	1020	20.3	3.5
16.75	3	11	2.60	0.034	89.2			2.44	5.00	612		
12.50	7	11.5	2.50	0.027	111.2	5.50	475	2.93	4.90	316	33.5	0.8
16.25	9	15	1.78	0.034	88.1			1.75		316		
13.17	13	18	3.13	0.034	90.0	5.70	455	2.95	5.25	356	21.8	1.4
15.68	16	10	2.50	0.034	90.3	5.50	430	2.38	5.25	358	16.7	0.8
10.42	21	10	0.54	0:005	643.8			0.58		375		
12.83	24	10	2.49	0.033	90.5	5.90	478	2.40	5.30	366	23.4	1.1
15.50	27	7.5	2.42	0.032	93.5			2.36	5.28	366		
13.43	30	1.5	2.25	0.032	94.2	6.40	465	2.25	5.29	348	25.2	0.9
14.93	34	12.2	3.00	0.031	98.5	6.39		2.92	5.72	368		
13.08	37	15.5	2.31	0.033	92.0	6.88	461	2.26	6.76	363	21.3	0.9
14.83	41	16.5	3.16	0.032	93.7	6.94	450	3.10	7.13	287	36.2	1.9
14.00	44	14.5	0.63	0.009	342.3	6.95	426	0.64	7.15	212	50.2	0.1
13.75	48	15.5	3.20	0.033	90.7	6.91	416	3.11	7.73	291	30.0	1.6
13.35	51	14.5	2.35	0.033	92.3	7.06	415	2.32	7.81	262	36.9	1.3
13.12	55	15.5	3.20	0.033	90.7	7.13	510	3.06	7.58	328	35.7	2.3
14.15	58	15.5	2.52	0.035	87.8	7.05	478	2.41	7.36	280	41.4	2.0
12.37	62	18.5	3.30	0.035	86.5	7.10	469	3.16	7.43	323	31.1	2.0
13.83	65	20	2.55	0.035	87.3		431	2.45	7.32	217	49.7	2.1
15.12	69	20	3.35	0.034	88.0		497	3.13	7.86	267	46.3	3.1
13.50	71	19.5	1.65	0.036	85.2	7.49	910	1.57	8.40	202	77.8	4.6
12.50	73	10	1.62	0.034	87.9	7.39	973	1.53	7.45	416	57.2	3.5
11.87	76	14	2.42	0.034	89.4	7.04	969	2.17	6.99	674	30.4	3.3
12.92	78	13.5	1.63	0.033	91.2	7.27	1000	1.58	6.85	747	25.3	1.6
12.50	80	15	1.58	0.033	91.2	7.40	898	1.52	6.64	704	21.6	1.3
14.60	84	14	3.30	0.034	90.1	7.38	955	3.18	6.85	676	29.2	3.7
12.82	86	15	1.63	0.035	85.9	7.31	875	1.58	6.72	670	23.4	1.4
9.18	90	15	3.00	0.032	93.3	7.35	948	2.90	6.65	733	22.7	2.5

REACTOR 1 - DISCHARGE WATER QUALITY DATA

Time	Days	Cd ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Sb ppm	Se ppm	Sn ppm	Zn ppm
12.25	0	0.007	0.002	1.050	2.825	0.012	0.120	0.102	0.002	0.150	0.020	0.109
16.75	3											
12.50	7											
16.25	9	0.013	0.002	1.290	3.095	0.018	0.275	0.110	0.002	0.090	0.002	10.397
13.17	13											
15.68	16	0.010	0.002	1.420	3.065	0.022	0.240	0.114	0.002	0.095	0.004	16.725
10.42	21											
12.83	24	0.015	0.024	1.790	2.990	0.022	0.200	0.120	0.008	0.095	0.002	14.557
15.50	27											
13.43	30	0.010	0.004	1.890	2.970	0.018	0.220	0.094	0.002	0.090	0.002	5.303
14.93	34											
13.08	37	0.016	0.006	1.420	2.930	0.022	0.065	0.106	0.006	0.095	0.002	5.118
14.83	41	0.022	0.016	1.010	2.715	0.016	0.045	0.088	0.002	0.095	0.002	4.363
14.00	44											
13.75	48	0.018	0.016	1.620	2.650	0.018	0.035	0.070	0.012	0.100	0.002	2.085
13.35	51	0.020	0.016	1.110	2.790	0.020	0.065	0.060	0.006	0.095	0.002	4.178
13.12	55	0.017	0.006	1.040	2.685	0.018	0.045	0.086	0.002	0.100	0.002	1.273
14.15	58											
12.37	62	0.012	0.012	1.050	2.845	0.016	0.065	0.100	0.008	0.100	0.002	0.712
13.83	65											
15.12	69	0.013	0.008	1.710	2.755	0.018	0.040	0.100	0.014	0.125	0.006	0.358
13.50	71											0.800
12.50	73											0.700
11.87	76											0.600
12.92	78											0.200
12.50	80											0.100
14.60	84											0.300
12.82	86											0.100
9.18	90											0.100

SAMPLE CALCULATIONS

Example: Reactor 1, day 7

Time elapsed from Day 3, 16.75H to day 7, 12.50H:

Time = 24 - 16.25 + (7-3-1)x24 +12.50 = 91.75 hours

Feed Rate = (feed volume) / (elapsed time)

Feed Rate = 2.50 L / 91.75 h = 0.027 L/h

why are these different?

Retention Time = (Effective reactor volume) / (feed rate)

Retention = 3.03 L / 0.0216 L/h = 111.2 hours

Sulphate in = Volume in x sulphate concentration in
= 2.50 L x 475 mg/L = 1187.5 mg

Sulphate out = volume out x concentration out
= 2.93 L x 316 mg/L = 925.9 mg

Sulphate Reduction Rate = (sulphate in - sulphate out) / (reactor volume x retention time)

Rate = (1187.5 - 925.9) / (3.03 x 111) = 0.776 mg sulphate / L / h
(or 0.8 mg/L/h)

APPENDIX B

REACTOR 2 OPERATING DATA

REACTOR 2 - OPERATING DATA

Time	Days	Temperature (oC)	Vol. Feed (L)	Feed Rate (L/h)	Retention Time (h)	Feed pH	Feed [SO4] (mg/L)	Discharge Vol (L)	pH	Discharge [SO4] (mg/L)	Sulphate Conversion (%)	Reduction Rate (mg/L/h)
12.25	0	13.5	2.80	0.030	108.3	5.50	1280	2.80	4.60	1040	18.8	2.0
16.75	3	11	2.31	0.030	107.6			2.22	4.45	766		
12.50	7	11.5	2.32	0.025	128.5	5.50	475	2.29	4.62	450	5.3	0.2
16.25	9	15	1.38	0.027	121.9			1.36		360		
13.17	13	18	2.44	0.026	123.8	5.70	455	2.32	5.00	358	21.3	0.7
15.68	16	10	1.98	0.027	122.3	5.50	430	1.86	5.10	360	16.3	0.5
10.42	21	10	0.48	0.004	776.9			0.46		378		
12.83	24	10	2.00	0.027	120.9	5.90	478	1.94	5.00	361	24.5	0.7
15.50	27	7.5	1.92	0.026	126.4			1.91	5.21	370		
13.43	30	1.5	1.88	0.027	120.9	6.40	465	1.81	5.32	368	20.9	0.6
14.93	34	12.2	2.03	0.021	156.1	6.39		1.98	5.15	373		
13.08	37	15.5	1.50	0.021	152.0	6.88	461	1.46	5.70	373	19.1	0.3
14.83	41	16.5	2.09	0.021	152.0	6.94	450	2.03	5.73	307	31.8	0.7
14.00	44	14.5	0.45	0.006	514.0	6.95	426	0.46	5.76	345	19.0	0.0
13.75	48	15.5	2.25	0.023	138.3	6.91	416	2.22	6.44	363	12.7	0.3
13.35	51	14.5	1.70	0.024	136.9	7.06	415	1.66	6.20	370	10.8	0.2
13.12	55	15.5	2.24	0.023	139.0	7.13	510	2.19	5.92	386	24.3	0.7
14.15	58	15.5	1.73	0.024	137.2	7.05	478	1.70	6.40	325	32.0	0.7
12.37	62	18.5	2.23	0.024	137.3	7.10	469	2.20	6.09	349	25.6	0.7
13.83	65	20	1.70	0.023	140.4		431	1.70	6.04	386	10.4	0.2
15.12	69	20	2.25	0.023	140.5		497	2.22	6.14	340	31.6	0.9
13.50	71	19.5	1.10	0.024	137.0	7.49	480	1.06				
12.50	73	10	1.10	0.023	138.9	7.39	477	1.06	6.50	308	35.4	0.5
11.87	76	14	1.69	0.024	137.1	7.04	498	1.65				
12.92	78	13.5	1.13	0.023	141.3	7.27	501	1.10	6.75	312	37.7	0.5
12.50	80	15	1.14	0.024	135.2	7.40	488	1.11				
14.60	84	14	2.29	0.023	139.4	7.38	485	2.22	6.60	314	35.3	1.0
12.82	86	15	1.12	0.024	134.1	7.31	490	1.08				
9.18	90	15	2.10	0.023	142.9	7.35	475	2.07	6.75	297	37.5	0.9

REACTOR 2 - DISCHARGE WATER QUALITY DATA

Time	Days	Cd ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Sb ppm	Se ppm	Sn ppm	Zn ppm
12.25	0	0.008	0.004	4.560	2.825	0.012	0.050	0.090	0.002	0.140	0.008	2.491
16.75	3											
12.50	7											
16.25	9	0.015	0.002	1.240	3.040	0.020	0.260	0.126	0.002	0.100	0.002	3.568
13.17	13											
15.68	16	0.016	0.002	1.560	3.070	0.018	0.255	0.074	0.002	0.085	0.008	16.676
10.42	21											
12.83	24	0.018	0.002	2.810	2.990	0.026	0.240	0.116	0.008	0.110	0.004	18.538
15.50	27											
13.43	30	0.017	0.004	2.240	2.840	0.022	0.215	0.110	0.002	0.105	0.002	15.240
14.93	34											
13.08	37	0.020	0.002	2.670	2.960	0.022	0.200	0.114	0.006	0.095	0.002	13.022
14.83	41	0.022	0.004	4.460	2.750	0.024	0.165	0.104	0.004	0.095	0.002	12.173
14.00	44											
13.75	48	0.012	0.002	3.620	2.955	0.018	0.145	0.092	0.008	0.090	0.002	1.838
13.35	51	0.020	0.002	3.990	2.800	0.018	0.150	0.080	0.002	0.105	0.002	12.214
13.12	55	0.012	0.002	3.070	2.950	0.022	0.125	0.104	0.010	0.105	0.002	3.635
14.15	58											
12.37	62	0.012	0.004	3.470	2.895	0.018	0.130	0.086	0.008	0.105	0.002	1.513
13.83	65											
15.12	69	0.016	0.002	3.280	2.905	0.020	0.085	0.102	0.018	0.125	0.006	4.321
13.50	71											
12.50	73											
11.87	76											
12.92	78											
12.50	80											
14.60	84											
12.82	86											
9.18	90											

APPENDIX C

REACTOR 3 OPERATING DATA

REACTOR 3 - OPERATING DATA

Time	Days	Temperature (oC)	Vol. Feed (L)	Feed Rate (L/h)	Retention Time (h)	Feed pH	Feed [SO4] (mg/L)	Discharge Vol (L)	pH	Discharge [SO4] (mg/L)	Sulphate Conversion (%)	Reduction Rate (mg/L/h)
12.25	0	13.5	1.40	0.015	215.3	5.50	1280	1.29	4.90	822	35.8	1.1
16.75	3	11	1.26	0.016	184.0			1.09	4.90	810		
12.50	7	11.5	1.49	0.016	186.6	5.50	475	1.48	4.85	630		-0.4
16.25	9	15	0.98	0.019	160.0			0.89		622		
13.17	13	18	1.58	0.017	178.2	5.70	455	1.47	5.40	377	17.1	0.3
15.68	16	10	1.32	0.018	171.0	5.50	430	1.19	5.50	353	17.9	0.3
10.42	21	10	0.32	0.003	1086.4			0.28		377		
12.83	24	10	1.30	0.017	173.4	5.90	478	1.25	5.55	350	26.8	0.3
15.50	27	7.5	1.28	0.017	176.8			1.21	5.70	353		
13.43	30	1.5	1.15	0.016	184.3	6.40	465	1.15	5.81	419	9.9	0.1
14.93	34	12.2	1.61	0.017	183.5	6.39		1.50	6.11	368		
13.08	37	15.5	1.26	0.018	168.7	6.88	461	1.15	6.67	373	19.1	0.3
14.83	41	16.5	1.60	0.016	185.1	6.94	450	1.57	6.65	368	18.2	0.3
14.00	44	14.5	0.30	0.004	718.8	6.95	426	0.30	6.75	316	25.8	0.0
13.75	48	15.5	1.65	0.017	175.8	6.91	416	1.54	6.87	334	19.7	0.3
13.35	51	14.5	1.22	0.017	177.8	7.06	415	1.16	7.32	340	18.1	0.2
13.12	55	15.5	1.60	0.017	181.4	7.13	510	1.50	6.92	325	36.3	0.6
14.15	58	15.5	1.25	0.017	177.0	7.05	478	1.17	7.30	312	34.7	0.4
12.37	62	18.5	1.59	0.017	179.6	7.10	469	1.48	6.87	333	29.0	0.5
13.83	65	20	1.22	0.017	182.4		431	1.15	6.64	312	27.6	0.3
15.12	69	20	1.60	0.016	184.2		497	1.48	6.90	311	37.4	0.6
13.50	71	19.5	0.78	0.017	181.3	7.49	480	0.72				
12.50	73	10	0.78	0.016	183.8	7.39	477	0.72	6.90	297	37.7	0.3
11.87	76	14	1.24	0.017	174.1	7.04	498	1.20				
12.92	78	13.5	0.83	0.017	179.5	7.27	501	0.80	7.20	275	45.1	0.4
12.50	80	15	0.80	0.017	180.2	7.40	488	0.74				
14.60	84	14	1.60	0.016	185.8	7.38	485	1.49	7.35	268	44.7	0.7
12.82	86	15	0.80	0.017	175.1	7.31	490	0.80				
9.18	90	15	1.50	0.016	186.6	7.35	475	1.45	7.25	256	46.1	0.6

REACTOR 3 - DISCHARGE WATER QUALITY DATA

Time	Days	Cd ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Sb ppm	Se ppm	Sn ppm	Zn ppm
12.25	0	0.008	0.002	2.080	2.490	0.010	0.020	0.056	0.002	0.135	0.002	0.122
16.75	3											
12.50	7											
16.25	9	0.014	0.006	3.320	2.825	0.012	0.130	0.050	0.002	0.110	0.002	6.510
13.17	13											
15.68	16	0.012	0.002	2.800	3.010	0.014	0.185	0.088	0.002	0.090	0.008	17.877
10.42	21											
12.83	24	0.012	0.008	3.940	3.015	0.026	0.160	0.118	0.008	0.115	0.002	20.184
15.50	27											
13.43	30	0.010	0.004	3.960	2.890	0.020	0.165	0.100	0.004	0.100	0.002	21.746
14.93	34											
13.08	37	0.013	0.002	3.730	2.900	0.022	0.145	0.098	0.002	0.095	0.002	21.896
14.83	41	0.013	0.008	3.610	2.885	0.022	0.155	0.086	0.012	0.100	0.002	17.458
14.00	44											
13.75	48	0.014	0.002	1.660	4.530	0.018	0.070	0.106	0.006	0.090	0.002	3.187
13.35	51	0.018	0.002	2.660	2.805	0.016	0.135	0.054	0.002	0.090	0.002	12.010
13.12	55	0.013	0.004	1.620	2.880	0.018	0.080	0.106	0.006	0.095	0.002	3.048
14.15	58											
12.37	62	0.008	0.022	1.620	2.930	0.018	0.100	0.098	0.008	0.095	0.002	1.222
13.83	65											
15.12	69	0.012	0.002	1.400	2.940	0.018	0.050	0.108	0.014	0.125	0.010	0.724
13.50	71											
12.50	73											
11.87	76											
12.92	78											
12.50	80											
14.60	84											
12.82	86											
9.18	90											

APPENDIX D

CHEMICAL ANALYSIS REPORTS

MIN-EN LABORATORIES
(DIVISION OF ASSAYERS CORP.)

SPECIALISTS IN MINERAL ENVIRONMENTS
CHEMISTS • ASSAYERS • ANALYSTS • GEOCHEMISTS

VANCOUVER OFFICE:
705 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
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FAX (604) 980-9621

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA1

Company: SRK
Project: C01 P.O. A004
Attn: JOHN CHAPMAN

Date: JAN-14-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 10 SOLUTION samples submitted JAN-13-92 by JOHN CHAPMAN.

Sample Number	SO4 mg/l
C01-1224-1	1240
C01-1224-2	1170
C01-1224-3	1200
C01-1230-1	1280
C01-1230-2	1180
C01-1230-3	1150
C01-0107-1	1170
C01-0107-2	1180
C01-0107-3	1110
C01-0108-1	920
C01-0108-2	420
C01-0108-3	
C01-0108-4	

Certified by ____________________

M -EN LABORATORIES

MIN • EN LABORATORIES
(DIVISION OF ASSAYERS CORP.)

SPECIALISTS IN MINERAL ENVIRONMENTS
CHEMISTS • ASSAYERS • ANALYSTS • GEOCHEMISTS

VANCOUVER OFFICE:
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SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA2

Company: SRK
Project: COL
Attn: JOHN CHAPMAN

Date: FEB-04-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 20 SOLUTION samples submitted JAN-13-92 by JOHN CHAPMAN.

Sample Number	*ALKAL.	SO4 mg/l
0113-1		1180
0113-2		1180
0113-3		1020
0117-1		1150
0117-2		1140
0117-3		978
0121-1		1020
0121-2		1040
0121-3		822
0121-4	50.00	
0124-1		612
0124-2		766
0124-3		810
0124-4		440
0128-1		316
0128-2		450
0128-3		630
0130-1		316
0130-2		360
0130-3		622

*$CaCO_3$ mg/l.

Certified by [signature]

MIN-EN LABORATORIES

MIN-EN ENVIRONMENTAL
LABORATORIES
(DIVISION OF ASSAYERS CORP.)

SPECIALISTS IN MINERAL ENVIRONMENTS
CHEMISTS • ASSAYERS • ANALYSTS • GEOCHEMISTS

VANCOUVER OFFICE:
705 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
TELEPHONE (604) 980-5814 OR (604) 988-4524
FAX (604) 980-9621

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA3

Company: SRK
Project: COL
Attn: JOHN CHAPMAN

Date: FEB-12-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 7 SOLUTION samples submitted FEB-03-92 by JOHN CHAPMAN.

Sample Number	SO4 mg/l
C01-0203-1	356
C01-0203-2	358
C01-0203-3	377
C01-0206-1	358
0206-2	360
0206-3	353
0206-4	430

Certified by ____________________

MIN-EN LABORATORIES

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(DIVISION OF ASSAYERS CORP.)

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VANCOUVER OFFICE:
?05 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
TELEPHONE (604) 980-5814 OR (604) 988-4524
FAX (604) 980-9621

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate 2V-0024-WA4

Company: SRK
Project: COL
Attn: JOHN CHAPMAN

Date: MAR-02-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 21 SOLUTION samples submitted FEB-03-92 by JOHN CHAPMAN.

Sample Number	SO4 mg/l
C01-0211-1	375
2	378
3	377
C01-0214-1	366
2	361
3	350
4	478
C01-0217-1	366
2	370
3	353
C01-0220-1	348
2	368
3	419
4	465
C01-0224-1	368
2	373
3	368
C01-0227-1	363
2	373
3	373
C01-0227-4	461

Certified by ____________

MIN-EN LABORATORIES

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VANCOUVER OFFICE:
705 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
TELEPHONE (604) 980-5814 OR (604) 988-4524
FAX (604) 980-9821

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA5

Company: SRK
Project: COL
Attn: JOHN CHAPMAN

Date: MAR-30-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 24 SOLUTION samples submitted FEB-03-92 by JOHN CHAPMAN.

Sample Number	SO4 mg/l
C01-302-1	287
2	307
3	368
4	450
305-1	212
2	345
3	316
4	426
309-1	291
2	363
3	334
4	416
312-1	262
2	370
3	340
4	415
316-1	328
2	386
3	325
4	510
319-1	280
2	325
3	312
4	478

Certified by ____________

MIN-EN LABORATORIES

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(DIVISION OF ASSAYERS CORP.)

SPECIALISTS IN MINERAL ENVIRONMENTS
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VANCOUVER OFFICE:
705 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
TELEPHONE (604) 980-5814 OR (604) 988-4524
FAX (604) 980-9621

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA6

Company: SRK
Project: COL
Attn: JOHN CHAPMAN

Date: MAR-30-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 8 SOLUTION samples submitted FEB-03-92 by JOHN CHAPMAN.

Sample Number	SO4 mg/l
COL-323-1	323
COL-323-2	349
COL-323-3	333
COL-323-4	468
COL-326-1	217
COL-326-2	386
COL-326-3	312
COL-326-4	431

Certified by ____________

MIN-EN LABORATORIES

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SPECIALISTS IN MINERAL ENVIRONMENTS
CHEMISTS • ASSAYERS • ANALYSTS • GEOCHEMISTS

VANCOUVER OFFICE:
705 WEST 15TH STREET
NORTH VANCOUVER, B.C. CANADA V7M 1T2
TELEPHONE (604) 980-5814 OR (604) 988-4524
FAX (604) 980-9621

SMITHERS LAB.:
3176 TATLOW ROAD
SMITHERS, B.C. CANADA V0J 2N0
TELEPHONE (604) 847-3004
FAX (604) 847-3005

Assay Certificate

2V-0024-WA5

Company: SRK
Project: C01
Attn: JOHN CHAPMAN

Date: APR-15-92
Copy 1. SRK, VANCOUVER, B.C.

We hereby certify the following Assay of 10 CONCENTRATE samples submitted JAN-08-92 by DOUG WARKENTIN.

Sample Number	SO4 mg/l
C01-330-1	267
C01-330-2	334
C01-330-3	340
C01-330-4	375
C01-403-1	455
C01-403-2	973
C01-406-1	969
C01-406-2	674
C01-408-1	747
C01-408-2	1000

Certified by ____________

COMP: SRK
PROJ: C01 P.O. A004
ATTN: JOHN CHAPMAN

MIN-EN LABS — ICP REPORT

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WJ1
DATE: 92/01/14
* SOLUTION * (ACT:WATER)

SAMPLE NUMBER	AG PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	BI PPM	CA PPM	CD PPM	CO PPM	CR PPM	CU PPM	FE PPM	K PPM	LI PPM	MG PPM	MN PPM	MO PPM	NA PPM	NB PPM	NI PPM	P PPM	PB PPM	SB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TH PPM	TI PPM	U PPM	V PPM
C01-0108-3	.011	.09	.04	.04	.055	.0361	.024	168.00	.051	.185	.025	.016	2.12	.74	.07	89.33	5.260	.052	8.77	.630	.520	.61	.208	.056	.265	3.88	.480	.766	.06	.024	.45	.024
C01-0108-4	.007	.12	.03	.02	.025	.0231	.016	89.00	.031	.100	.015	.032	1.23	.38	.04	46.49	2.775	.030	3.37	.455	.280	.35	.132	.026	.150	2.66	.298	.404	.06	.022	.35	.015

MIN-EN LABS — ICP REPORT

COMP: SRK
PROJ: C01 P.O. A004
ATTN: JOHN CHAPMAN

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WJ1
DATE: 92/01/14
* SOLUTION * (ACT:WATER)

SAMPLE NUMBER	W PPM	ZN PPM	ZR PPM
C01-0108-3	2.005	61.327	.002
C01-0108-4	1.095	32.086	.002

COMP: SRK
PROJ: C01
ATTN: JOHN CHAPMAN

MIN-EN LABS — ICP REPORT

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WF1
DATE: 92/02/12
* SOLUTIONS * (ACT:WATER)

SAMPLE NUMBER	AG PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	BI PPM	CA PPM	CD PPM	CO PPM	CR PPM	CU PPM	FE PPM	K PPM	LI PPM
0121-1	.001	.01	.02	.01	.015	.0009	.002	154.05	.007	.065	.025	.002	1.05	8.88	.03
0121-2	.006	1.23	.01	.01	.045	.0006	.002	176.52	.008	.015	.060	.004	4.56	7.44	.01
0121-3	.001	.05	.01	.01	.065	.0004	.002	194.44	.008	.005	.030	.002	2.08	9.68	.01
0121-4	.001	.01	.01	.01	.015	.0011	.002	88.66	.024	.085	.015	.002	.93	5.49	.04
0130-1	.001	.28	.01	.01	.015	.0011	.002	86.28	.013	.075	.015	.002	1.29	4.30	.03
0130-2	.001	.21	.01	.01	.010	.0008	.002	87.09	.015	.085	.020	.002	1.24	4.74	.03
0130-3	.001	.18	.01	.01	.045	.0008	.002	145.77	.014	.035	.025	.006	3.32	6.61	.01
0206-1	.001	.17	.01	.01	.015	.0010	.002	85.71	.010	.040	.005	.002	1.42	4.10	.02
0206-2	.001	.16	.01	.01	.010	.0007	.002	85.69	.016	.035	.005	.002	1.56	4.20	.02
0206-3	.001	.10	.01	.01	.010	.0011	.002	86.41	.012	.045	.005	.002	2.80	3.62	.02
0206-4	.001	.10	.01	.01	.010	.0011	.002	83.86	.026	.090	.015	.034	1.12	4.95	.03

SAMPLE NUMBER	MG PPM	MN PPM	MO PPM	NA PPM	NI PPM	P PPM	PB PPM	SB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TI PPM	V PPM	ZN PPM
0121-1	72.04	2.825	.012	328.18	.120	5.79	.102	.002	.150	3.65	.020	.136	.002	.023	.109
0121-2	63.34	2.825	.012	503.65	.050	.24	.090	.002	.140	3.14	.008	.018	.002	.033	2.491
0121-3	58.34	2.490	.010	576.01	.020	2.66	.056	.002	.135	3.12	.002	.002	.002	.034	.122
0121-4	81.20	3.340	.026	24.43	.250	.22	.104	.002	.110	2.70	.004	.376	.002	.011	14.402
0130-1	72.75	3.095	.018	23.64	.275	.68	.110	.002	.090	3.31	.002	.326	.002	.009	10.397
0130-2	72.26	3.040	.020	36.25	.260	.21	.126	.002	.100	3.20	.002	.314	.002	.010	3.568
0130-3	63.97	2.825	.012	301.23	.130	5.37	.050	.002	.110	3.23	.002	.140	.002	.019	6.510
0206-1	71.97	3.065	.022	22.53	.240	1.18	.114	.002	.095	3.13	.004	.340	.002	.007	16.725
0206-2	73.37	3.070	.018	24.90	.255	.20	.074	.002	.085	3.23	.008	.336	.002	.001	16.767
0206-3	70.54	3.010	.014	29.45	.185	.52	.088	.002	.090	3.22	.008	.312	.002	.003	17.877
0206-4	73.80	3.120	.024	20.62	.245	.29	.120	.002	.095	2.96	.004	.348	.002	.009	20.558

COMP: SRK
PROJ: COL
ATTN: JOHN CHAPMAN

MIN-EN LABS — ICP REPORT

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WJ4
DATE: 92/02/12
* * (ACT:WATER)

SAMPLE NUMBER	AG PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	BI PPM	CA PPM	CD PPM	CO PPM	CR PPM	CU PPM	FE PPM	K PPM	LI PPM	MG PPM	MN PPM	MO PPM	NA PPM	NI PPM	P PPM	PB PPM	SB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TI PPM	V PPM	ZN PPM
C01-0214-1	.003	.19	.01	.01	.015	.0017	.006	98.94	.015	.045	.025	.024	1.79	6.45	.08	55.96	2.990	.022	19.76	.200	2.47	.120	.008	.095	3.67	.002	.370	.002	.017	14.557
C01-0214-2	.001	.19	.04	.01	.015	.0018	.002	96.70	.018	.050	.030	.002	2.81	6.22	.06	57.32	2.990	.026	20.89	.240	.24	.116	.008	.110	3.75	.004	.374	.002	.017	18.538
C01-0214-3	.002	.11	.03	.01	.015	.0015	.012	99.16	.012	.065	.025	.008	3.94	6.79	.06	57.05	3.015	.026	24.19	.160	.52	.118	.008	.115	3.93	.002	.356	.002	.022	20.184
C01-0220-1	.001	.24	.01	.01	.015	.0014	.002	96.49	.010	.050	.025	.004	1.89	5.70	.06	55.66	2.970	.018	18.40	.220	.78	.094	.002	.090	3.49	.002	.358	.002	.014	5.303
C01-0220-2	.001	.16	.01	.01	.010	.0012	.002	94.94	.017	.045	.025	.004	2.24	5.75	.06	54.63	2.840	.022	18.70	.215	.23	.110	.002	.105	3.45	.002	.348	.002	.013	15.240
C01-0220-3	.001	.09	.01	.01	.015	.0017	.002	95.74	.010	.065	.035	.004	3.96	5.99	.06	54.25	2.890	.020	20.39	.165	.41	.100	.004	.100	3.60	.002	.340	.002	.015	21.746
C01-0220-4	.001	.08	.01	.02	.020	.0009	.002	94.60	.027	.090	.030	.034	1.22	6.06	.06	54.57	2.930	.022	17.13	.250	.25	.124	.002	.080	3.42	.002	.354	.002	.011	27.649
C01-0227-1	.001	.05	.05	.01	.010	.0014	.006	96.44	.016	.020	.030	.006	1.42	6.19	.05	56.61	2.930	.022	18.29	.065	.46	.106	.006	.095	3.59	.002	.362	.002	.015	5.118
C01-0227-2	.001	.13	.05	.01	.010	.0015	.004	96.14	.020	.045	.030	.002	2.67	5.96	.05	56.12	2.860	.022	18.66	.200	.23	.114	.006	.095	3.54	.002	.360	.002	.017	13.022
C01-0227-3	.001	.05	.01	.02	.010	.0014	.002	95.68	.013	.070	.025	.002	3.73	6.04	.05	54.36	2.900	.022	18.94	.145	.42	.098	.002	.095	3.55	.002	.348	.002	.014	21.896
C01-0227-4	.001	.03	.05	.01	.010	.0007	.006	96.28	.025	.085	.030	.030	.90	6.45	.06	56.55	2.985	.022	17.92	.225	.22	.100	.006	.100	3.39	.002	.372	.002	.014	11.706

COMP: SRK
PROJ: COL
ATTN: JOHN CHAPMAN

MIN-EN LABS — ICP REPORT

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WJ5
DATE: 92/03/30
* SOLUTION * (ACT:WATER)

SAMPLE NUMBER	AG PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	BI PPM	CA PPM	CD PPM	CO PPM	CR PPM	CU PPM	FE PPM	K PPM	LI PPM
C01-302-1	.001	.02	.01	.01	.010	.0011	.002	78.97	.022	.015	.025	.016	1.01	6.38	.11
C01-302-2	.001	.12	.02	.02	.010	.0012	.002	78.50	.022	.040	.025	.004	4.46	6.32	.09
C01-302-3	.001	.03	.02	.02	.010	.0015	.006	80.05	.013	.065	.030	.008	3.61	6.39	.07
C01-302-4	.002	.05	.04	.01	.010	.0012	.006	80.95	.026	.085	.035	.032	.94	7.00	.07
C01-309-1	.002	.01	.05	.01	.010	.0013	.016	77.79	.018	.010	.030	.016	1.62	6.32	.07
C01-309-2	.002	.09	.02	.01	.015	.0015	.006	80.86	.012	.005	.030	.002	3.62	6.73	.07
C01-309-3	.001	.02	.01	.02	.010	.0012	.006	84.51	.014	.015	.030	.002	1.66	7.60	.07
C01-312-1	.001	.11	.04	.02	.190	.0012	.006	80.45	.020	.035	.030	.016	1.11	6.56	.06
C01-312-2	.001	.08	.01	.01	.010	.0011	.002	77.46	.020	.045	.025	.002	3.99	5.83	.06
C01-312-3	.001	.05	.01	.01	.010	.0012	.002	77.52	.018	.060	.025	.002	2.66	5.75	.06
C01-312-4	.001	.02	.02	.01	.010	.0012	.006	80.26	.029	.080	.030	.060	.81	6.59	.07
C01-316-1	.001	.01	.01	.01	.010	.0014	.006	80.15	.017	.015	.025	.006	1.04	6.22	.06
C01-316-2	.002	.03	.02	.01	.015	.0012	.006	81.52	.012	.020	.035	.002	3.07	6.55	.07
C01-316-3	.003	.06	.04	.01	.015	.0012	.006	80.28	.013	.020	.030	.004	1.62	6.34	.06
C01-316-4	.002	.02	.05	.01	.010	.0009	.006	80.05	.024	.080	.030	.024	.86	6.53	.07
C01-323-1	.004	.02	.07	.01	.015	.0012	.006	81.50	.012	.020	.030	.012	1.05	6.93	.07
C01-323-2	.002	.05	.05	.01	.015	.0012	.014	80.31	.012	.030	.030	.004	3.47	6.54	.07
C01-323-3	.002	.05	.06	.01	.015	.0011	.018	81.45	.008	.030	.035	.022	1.62	6.26	.07
C01-323-4	.002	.04	.04	.01	.015	.0011	.006	82.64	.027	.080	.030	.036	.91	7.24	.07

SAMPLE NUMBER	MG PPM	MN PPM	MO PPM	NA PPM	NI PPM	P PPM	PB PPM	SB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TI PPM	V PPM	ZN PPM
C01-302-1	56.07	2.715	.016	18.29	.045	.57	.088	.002	.095	3.68	.002	.360	.002	.012	4.363
C01-302-2	55.93	2.750	.024	18.62	.165	.27	.104	.004	.095	3.69	.002	.362	.002	.015	12.173
C01-302-3	56.64	2.885	.022	19.47	.155	.40	.086	.012	.100	3.80	.002	.364	.002	.018	17.458
C01-302-4	57.93	2.980	.022	18.31	.225	.21	.098	.020	.105	3.57	.002	.382	.002	.015	11.988
C01-309-1	55.15	2.650	.018	18.26	.035	.53	.070	.012	.100	3.60	.002	.354	.002	.015	2.085
C01-309-2	57.10	2.955	.018	19.24	.145	.26	.092	.008	.090	3.76	.002	.366	.002	.016	1.838
C01-309-3	57.48	4.530	.018	20.89	.070	.36	.106	.006	.090	3.79	.002	.344	.002	.016	3.187
C01-312-1	56.25	2.790	.020	18.09	.065	.49	.060	.006	.095	3.63	.002	.364	.002	.014	4.178
C01-312-2	54.56	2.800	.018	17.76	.150	.20	.080	.002	.105	3.51	.002	.354	.002	.012	12.214
C01-312-3	54.23	2.805	.016	18.03	.135	.31	.054	.002	.090	3.55	.002	.350	.002	.013	12.011
C01-312-4	56.84	2.945	.020	17.93	.220	.24	.084	.010	.100	3.46	.002	.374	.002	.014	10.440
C01-316-1	55.77	2.685	.018	18.03	.045	.24	.086	.002	.100	3.51	.002	.364	.002	.013	1.273
C01-316-2	56.24	2.950	.022	18.92	.125	.22	.104	.010	.105	3.61	.002	.366	.002	.016	3.635
C01-316-3	55.92	2.880	.018	19.04	.080	.33	.106	.006	.095	3.69	.002	.360	.002	.020	3.048
C01-316-4	56.54	2.920	.022	17.93	.220	.22	.092	.010	.110	3.38	.002	.374	.002	.015	8.819
C01-323-1	57.34	2.845	.016	18.70	.065	.22	.100	.008	.100	3.57	.002	.374	.002	.016	.712
C01-323-2	56.67	2.895	.018	18.54	.130	.17	.086	.008	.105	3.60	.002	.368	.002	.015	1.513
C01-323-3	57.39	2.930	.018	19.11	.100	.20	.098	.008	.095	3.72	.002	.374	.002	.017	1.222
C01-323-4	57.66	2.965	.018	18.58	.205	.15	.106	.016	.100	3.39	.002	.380	.002	.014	7.640

COMP: SRK
PROJ: C01
ATTN: JOHN CHAPMAN

MIN-EN LABS — ICP REPORT

705 WEST 15TH ST., NORTH VANCOUVER, B.C. V7M 1T2
(604)980-5814 OR (604)988-4524

FILE NO: 2V-0024-WF5
DATE: 92/04/15
* CONCENTRATE * (ACT:WATER)

SAMPLE NUMBER	AG PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	BI PPM	CA PPM	CD PPM	CO PPM	CR PPM	CU PPM	FE PPM	K PPM	LI PPM	MG PPM	MN PPM	MO PPM	NA PPM	NI PPM	P PPM	PB PPM	SB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TI PPM	V PPM	ZN PPM
C01-330-1	.005	.01	.07	.02	.015	.0007	.020	96.42	.013	.010	.030	.008	1.71	6.90	.10	58.50	2.755	.018	19.06	.040	.20	.100	.014	.125	3.64	.006	.362	.002	.017	.358
C01-330-2	.005	.01	.10	.02	.020	.0009	.030	96.85	.016	.025	.040	.002	3.28	6.93	.09	58.84	2.905	.020	19.27	.085	.23	.102	.018	.125	3.76	.006	.372	.004	.021	4.321
C01-330-3	.004	.01	.07	.01	.020	.0007	.022	96.97	.012	.010	.035	.002	1.40	6.72	.08	58.57	2.940	.018	19.52	.050	.24	.108	.014	.125	3.80	.010	.364	.002	.019	.724
C01-330-4	.004	.01	.09	.01	.015	.0013	.028	96.41	.032	.080	.035	.004	1.04	7.16	.08	58.53	2.970	.024	18.68	.205	.25	.102	.018	.120	3.46	.004	.372	.004	.019	6.997