Tailings Relocation Studies
Anvil Range Mining Complex
DRAFT

Report Prepared for

Deloitte & Touche Inc.

Report Prepared by

SRK Consulting
Engineers and Scientists

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Tailings Relocation Studies
Anvil Range Mining Complex
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1 Introduction

The Anvil Range Mining Complex, located in Faro, Yukon, ceased operations in January 1998 when Anvil Range Mining Corporation filed for creditor protection under the Companies' Creditor Arrangement Act. Deloitte & Touche Inc. was appointed Interim Receiver of Anvil Range Mining Corporation ("Interim Receiver") on April 21, 1998. The Interim Receiver has overseen the management of the property under the terms of two water licences since that time.

In 2002, the Interim Receiver initiated the process of developing a Final Closure and Reclamation Plan for the property. This process continued in 2003 and included a Technical Workshop in Whitehorse on June 24 and 25. During the workshop, a series of studies were identified as being necessary for the development of the Final Closure and Reclamation Plan. One of these studies, identified as Task T7 in the workshop, involved the assessment of methods to relocate the tailings from the Rose Creek tailings impoundment to the Faro open pit. The objective of the study would be develop a better understanding of the costs and methods for tailings relocation. The relocation methods identified in the workshop included dredging, hydraulic monitoring and mechanical. Water management would be a primary focus because any water introduced would become contaminated and require treatment prior to discharge. In addition, the establishment of ponded water, such as would be required to undertake dredging, could increase hydraulic head and porewater displacement rates from the tailings to the underlying aquifer. The study would include an assessment of the impact of ponded water and water treatment requirements.

Following the workshop, a series of special projects were established including the assessment of tailings relocation methods, as defined above. Contractors with expertise in each of the methods identified above were asked to provide input to the assessment. Their individual reports are appended to this document. The water balance and water treatment methods were addressed by SRK Consulting.

Key inputs to this report, such as the specialty reports on hydraulic monitoring and mechanical relocation, only became available in late January and mid February, respectively. As a result, the corresponding assessment of water balance and water treatment for these methods has been completed at a very preliminary level. It is anticipated that the next version of this report will include a proper assessment of these aspects of tailings relocation hydraulic monitoring and mechanical methods.

2 Relocation Options and Methods

2.1 Reviews of Tailings Relocation Practices and Costs

SRK Consulting (SRK) previously completed a review of tailings relocation practices and costs as part of a scoping study for the closure of the Anvil Range Mining Complex (SRK, 2003). The results of the review were summarized in a memorandum which has been included in this report as Appendix A. Based on the SRK review, there are three primary methods used when tailings relocation and/or rehandling are considered: dredging, hydraulic mining (monitoring) and mechanical excavation. The review compared the advantages and disadvantages of each of these methods, as well as the typical cost(s) associated with each method.

In 2003, Department of Indian Affairs and Northern Development (DIAND) Type II Mines commissioned Brodie Consulting Ltd. (Brodie) to complete a review of tailings relocation projects and methodologies. This report is included as Appendix B.

Various other studies or technical papers related to tailings relocation are referenced in SRK (2003) and Brodie (2003). Of particular note is a study completed by Kilborn Engineering in 1991 which addressed the use of hydraulic monitoring methods to transport the tailings to the plant site for re-processing. Further comments on this report are provided in Section 4.

2.2 Brief Description of the Rose Creek Tailings Impoundment

The vast majority of the tailings associated with the processing of ore at the Anvil Range Mining Complex are stored in a tailings impoundment situated in Rose Creek (Figure 2.1). From east to west, the Rose Creek tailings impoundment comprises the original 1969 tailings area (approximately 42 ha), the 1974 or secondary tailings area (approximately 55 ha), the Intermediate Dam tailings area (approximately 99 ha) and the Cross Valley Dam which provides a polishing pond area of approximately 22 ha. These facilities are also referred to as the Down Valley structures.

According to the Interim Closure and Abandonment Plan (ICAP) completed in 1996 (Robertson Geoconsultants Inc., 1996), the volume of tailings in each of these areas is as follows: the original 1969 tailings area has 6.3 million m^3, the 1974 tailings area has 10.4 m^3 and the Intermediate Dam tailings area has 11.9 million m^3. The total volume of tailings is, therefore, about 28.6 million m^3.

The density of the tailings has been estimated to be in the range of 1.75 to 2.22 tonnes per cubic metre (Golder, 1991). It is likely that the density of the tailings has increased somewhat since 1991 due to consolidation. However, the extent of this consolidation is unknown.

For purposes of this study, quantity of tailings in the Rose Creek tailings impoundment has been assumed to be 57.0 million tonnes (Robertson Geoconsultants Inc., 1996).

2.3 Total and Partial Relocation Options

The following two relocation options were considered in this study:

- Relocation of the entire quantity of tailings from the Rose Creek tailings impoundment, approximately 57.0 million tonnes, to the Faro open pit.
- Relocation of a portion of these tailings, approximately 43.0 million tonnes, to the Faro pit with the remainder to be left in the tailings impoundment under a water cover.

The rationale for the total relocation option would be to put the tailings in a location (the Faro open pit) which eliminates the possibility of a failure of the Intermediate Dam and the subsequent movement of tailings to the downstream environment, and provides opportunities for other tailings closure methods. A logical consequence of this option is the removal of the Intermediate and Cross Valley Dams and the reclamation of the area currently occupied by the Rose Creek tailings impoundment.

The rationale for the partial relocation option was based on the prevention of acid generation by the use of a water cover. Rather than raising the Intermediate Dam, tailings above elevation 1042 m would be relocated to the Faro open pit and covered by water. The tailings that are left in the impoundment, i.e. those below elevation 1042 m, would be covered by 3 m of water. The existing Intermediate Dam is adequate to provide the 3 m water cover and the freeboard required by current dam safety criteria.

The methods of tailings relocation considered in this study included the following:

- Dredging;
- Hydraulic monitoring; and
- Mechanical, using truck and shovel.

A discussion on each of these methods is provided in Section 3, 4 and 5, respectively.

3 Dredging Method

Fraser River Pile & Dredge Ltd. (FRPD) and E. Zuccolin Consulting (EZC) were commissioned to complete a conceptual plan and preliminary cost estimates to relocate the Rose Creek tailings using hydraulic dredging. The draft report by FRPD/EZC is included as Appendix C. A summary of the draft report is provided below.

3.1 Scope and Key Assumptions

The FRPD/EZC study considered both the total and partial relocation options and consisted of the following scope:

- Undertake a site visit.
- Select the dredge plant and dredge support equipment appropriate to the scale of this project.
- Provide recommendations on the overall power requirements, crewing, training, maintenance and pipelines.
- Provide cost estimates for both diesel and electric power options.
- Provide a comment on the power generation opportunities associated with the dredge return water from the Faro pit.
- Prepare a draft summary report.

The key assumptions used by FRPD/EZC were as follows:

- 100% of the relocated Rose Creek mine tailings (partial or total relocation options) will be deposited into the Faro pit.
- The on site project pumping duration will be five years for the total relocation (57.0 million tonnes) option.
- The on site project pumping duration will be five years for the partial relocation (43.0 million tonnes) option.
- The partial relocation option assumes that the difference between total and partial relocation volume (14.0 million tonnes) is primarily in the lower elevations of the entire Rose Creek tailings impoundment area.
- Dredging operations will be performed by the local mine staff and crews, but the project will employ a full time experienced dredging engineer and/or dredging operations specialist to assist in the daily operations and planning.
- Local mine staff and crew will be specially trained to operate and maintain the dredging equipment.
- Dredge (tailings) pumping operations will shutdown for the winter months (November 1st to March 31st).
- Equipment maintenance work will performed by the dredge operation crews during the winter shutdown period.

- Dredge (tailings) pumping operations will operate for seven months per year (April 1st to October 31st).
- Dredge water management is based on a closed dredge/return water system with no water related downtime or restrictions.
- The water balance and water management issues will be addressed by others
- The cost for the final clean-up of the bottom 1 to 2 m of the Rose Creek tailings impoundment by conventional truck and shovel operations will be completed by others.

3.2 Equipment

The portable suction dredge appropriate for this project will have the following basic operating elements:

- Basket cutterhead or bucketwheel cutterhead to cut, break up and agitate the tailings to form a slurry before entering the submerged suction mouth;
- Ladder supporting the cutterhead and suction pipe that is raised and lowered by cables and winches;
- Centrifugal main pump with 3 or 4 vane impellor powered by diesel or electric drive motors;
- Portable pontoons that will be connected to form the dredge hull that supports the dredging and operating equipment;
- A two spud system at the stern of the dredge hull to act as an operating swing pivot for the dredge and/or a 3 to 5 wire anchoring system to swing and move the dredge hull;
- A floating discharge pipeline (supported by pontoons or pipe float collars) from the stern of the dredge to a land based connection to the land portion of the discharge pipeline; and
- Support equipment such as a specially modified tug boat with a bow A-frame/winch configuration, equipment repair barge and a support boat.

3.3 Mining/Dredge Plan

A detailed mining/dredge plan that addresses the optimum number of cuts, passes, bank cut heights, etc., has not been developed for this early stage in the project. However, a general plan for undertaking the tailings relocation by dredging over a 5-year period is described below.

It is recommended that the suction dredge start pumping operations in the original impoundment area at or near the shoreline generally in alignment with the land based pipeline. An initial start up pond will need to be excavated to assemble the dredge in the dry. The initial start-up pond will comprise an excavation approximately 150 m by 300 m and have a water depth of approximately 3.5 m. When the dredge is completely assembled, the pond will be flooded for the dredge operational start up.

The dredge will start cutting and pumping the tailings to a defined elevation. The dredge would generally be cutting the tailings in approximately 1 to 2 m lifts. As the dredging proceeds, make up water and return water will need to be controlled and balanced to maintain a constant or controlled pond elevation. It is assumed that the pond water elevations will be controlled and maintained to maximize dredging productivities and the optimal average dredging depths for the dredge design.

The dredging sequence would first see the completion of the original impoundment area down to the original ground contours or as close to the original ground contours as economic, before moving the dredging operations to the second impoundment area (alternatively, the original and second impoundments could be completed as a single impoundment). The suction dredge will remove has much tailings in the final ground line contour cut as economically practical. The depth and volume of remaining tailings will be determined by the amount of original ground vegetation and rubble that will impact and reduce the dredge productivity to a predetermined uneconomical level. It is difficult, at this time, to quantify the remaining volume, but based on the site visit discussions with the senior mine personnel, it would be reasonable to conclude that the dredge will be able to maintain its targeted productivities to within the final 1 to 2 m from the original ground contours. The dredge operations could continue to remove tailings in the last 0 to 2 m at lower productivities and resulting higher unit costs, this operation could proceed as long as the overall unit costs remain lower than other tailings removal alternatives (i.e. mechanical excavation using, for example, trucks and loaders). This cost benefit and sensitivity analysis would require a more detailed review and is recommended in any future study.

The dredging operations may encounter some undredgable trash materials and/or large obstructions during the course of the dredging project. Depending on the type of obstruction and material encountered, the dredge will first attempt to work its way around the obstruction and if unsuccessful the obstruction will be removed utilizing either the tug boat/A-frame and divers or by mounting a crawler crane (complete with clamshell bucket) or a long stick backhoe on a barge to clam or grab the obstruction and place it onto a barge for removal/disposal on shore.

The dredging operation may not be able to remove the initial waste rock starter dykes constructed due to the large size of the waste rock. As definitive construction details of the starter dykes are not available, it is assumed that the waste rock starter dykes will not be suitable for removal by the suction dredge and will therefore have to removed by mechanical methods such as trucks and excavators following the completion of the tailings dredging operation and dewatering of the tailings ponds.

The dredging operation will move from the original impoundment area to the secondary impoundment area by first removing and breaching the starter dyke dividing the two ponding areas, sufficiently such that the dredge can work its cuts to open a new starter pond in the secondary impoundment area. The pond water elevations will be controlled to manage this transitional operation. The starter dyke will be replaced behind the dredge once the dredge has excavated a suitable working area in the second impoundment area. At this time, the water remaining in the original impoundment area could be pumped out and/or used for make up water for the secondary impoundment area.

The dredging operations will continue in the secondary impoundment area and the Intermediate impoundment area repeating the dredging operation cuts and sequence similar to the original impoundment area.

3.4 Water Management

The water management plan will comprise the following three main elements:

A dredge pond. A pond of water will have to be formed on the surface of the tailings deposit to facilitate operation of the dredge. The tailings excavation will be an entirely subaqueous process (i.e., the cutterhead can not be lifted out of the water to access dry tailings around the perimeter of the pond). The configuration of the dredge dictates a minimum pond depth of 3.5 m. The deepest water that the dredge can efficiently operate in is about 10 m. The surface area of the pond will vary significantly throughout the life of the operation, ranging from about 45,000 m^2 at startup to over a square kilometre in the final stage of the operation.

Faro Pit. This pit will serve a dual role. It will be the permanent repository for the relocated tailings and will provide a counter storage to the dredge pond, providing water during periods when the dredge pond must grow and receiving water when the pond shrinks. Prior to becoming the repository for tailings produced from the Vangorda Plateau ores, the Faro Pit had an estimated capacity of 55.9 million m^3 up to the low point on the perimeter of the pit (after allowing for partial backfilling of pit with waste rock from the underground mine workings but excluding the volume of storage created by the underground mine workings themselves). The current level of the tailings surface is estimated to be at the 1061 m level, which means some 49.6 million m^3 are available for storing the relocated tailings and for providing the counter water storage for the dredge pond.

Water Diversions. The Rose Creek Diversion Channel and the North Wall Interceptor Ditch would be maintained throughout the dredging operation. Leakages from these two channels are a potential source of inflows to the dredge pond. Additional smaller diversion ditches and/or pipelines may have to be constructed to limit the inflows to the dredge pond. If required, these ditches would intercept runoff from the waste dumps and the mill area and convey this water around the Rose Creek Tailings Impoundment.

In addition to the three main elements above, it may also be necessary to implement a pumping system just downstream of the Rose Creek Tailings Impoundment to intercept a portion of the leakage that would occur from the dredge pond. The water in the dredge pond would be primarily sourced from the Faro Pit and therefore would have high metal concentrations.

To draw up an overall water balance for the dredging operation, it was necessary to first prepare a preliminary mining plan for the relocation of the tailings deposit. The mining plan had to take account of the following characteristics of the tailings deposit and the dredging process:

- The tailings deposit is compartmentalized into three sub-deposits, separated by the dams for the Original and Second Impoundments.
- The dam for the Original Impoundment was not designed to modern engineering standards and, accordingly, could become unstable if the tailings surface on one side of the dam is excavated to a level significantly below the level of the tailings on the other side.
- The surface of the tailings deposit is sloped with its highest point (1078 m) in the northern corner of the Original Tailings Impoundment and its lowest point (approx. 1047 m) near the Intermediate Dam.
- The dredge must operate in a pond with a minimum depth of 3.5 m.

To develop a general understanding of the geometry of the tailings deposit, reference was made to an analysis undertaken in the ICAP Report to estimate the total volume of the deposit. Key information from the ICAP is summarized in Figure 3.1. This figure shows how the planimetric area of the deposit varies as one moves vertically down through the deposit. The planimetric area peaks at just less than 1.4 km^2 at an elevation of about 1046 m.

Using the information in Figure 3.1, together with the general characteristics of the tailings deposit and the dredge pond listed above, a three-stage mining plan was developed as follows (note that while this plan is different that what is described in the mine plan, above, it is still instructive in relation to an assessment of the water balance):

Stage 1. The initial stage of the operation would be confined to the Original Tailings Impoundment. The tailings surface within this impoundment would be cut everywhere to the 1060 m level, or about 4 m below the highest tailings surface in the adjoining impoundment. This stage would take about 2.5 months to complete and would involve the excavation of 2.0 million m^3 of deposited tailings (or about 3.8 million tonnes of tailings solids). Throughout this stage and the two subsequent stages, it was assumed that the pond would be maintained at a depth of about 4 m. The surface area of the pond would start at 45,000 m^2 and would grow to about 350,000 m^2.

Stage 2. This stage would begin by using an excavator to construct a notch in the dam separating the Original and Second Impoundments. The barge would be floated through the notch and begin excavating the portion of the tailings deposit in the Second Impoundment. The dredge would proceed to cut the tailings deposit down to the 1048 m level everywhere in the two upstream impoundments, or about 4 m below the highest tailings surface in the Intermediate Impoundment. In doing this, the dredge would float back and forth between the impoundments via the original notch in the dam (and perhaps through additional notches cut in the dam). The second stage would take a total of 13 operational months of work and, accordingly, would not be completed until the third dredging season. A total of 10.8 million m^3 of deposited tailings (or 20.5 million tonnes of tailings solids) would be relocated. During the second stage, the dredge pond would cover portions of both impoundments. While in operational mode, the surface area of the pond would vary from 350,000 m^2 to 950,000 m^2. At the end of each dredging season, the dredge pond would be completely emptied to minimize seepage losses during the winter. The water from the dredge pond would be pumped to the Faro Pit. Conventional earthworks could be used simultaneously during the dredging operation to excavate those portions of the Original Dam that become exposed by the tailings relocation.

Stage 3. In the third stage, a notch is opened up in the dam of the Second Impoundment to allow the dredge access to the tailings in the Intermediate Impoundment. The dredge would take the remainder of the third season and the following two seasons to complete the relocation of the tailings in the Rose Creek Tailings Impoundment to the Faro Pit. This would involve the removal of about 15.7 million m^3 of deposited tailings (or 29.8 million tonnes of tailings solids). For most of Stage 3, the dredge would have to move back and forth between all three of the impoundments through the breaches in the dams. The surface area of the dredge pond would peak at just less than 1.4 km^2. At a depth of 4 m, this means the pond will contain more than 5 million m^3 of water. Only once the tailings deposit had been cut to the 1029 m elevation would the dredge pond have shrunken adequately to be confined exclusively to the Intermediate Impoundment.

3.5 Water Balance

The dredge report presented in Appendix C assumes the dredging operation would operate from April to October each year and would take a total of five years to complete. A spreadsheet was developed to simulate the water balance of the dredging operation using a monthly time step over its proposed five-year life span. The spreadsheet was organized around the two storage elements: the dredge pond and the Faro Pit.

The following three assumptions were made about water management during the dredging operation:

Seepage from the dredge pond would not be intercepted and pumped to either the dredge pond or Faro Pit. Collecting such seepage could have a potentially significant impact on the water balance of the dredging operation. One option for collecting the seepage would be to develop a fence of dewatering wells in the valley aquifer at the toe of the Cross Valley Dam. The seepage at this point would be diluted with the ambient flow conveyed by the aquifer. As a result, the dewatering wells could be called upon to pump a greater amount of water than would actually seep from the dredge pond.

No ditches or pipelines would be provided to limit runoff into the dredge pond that originates from the mill site or from the waste dumps that drain by gravity to the Rose Creek Tailings Impoundment. The provision of such ditches or pipelines would not have a significant impact on the overall water balance of the dredging operation.

The water level in the Faro Pit would be drawn down substantially prior to commencement of the dredging operation to free up space for the deposition of the tailings.

Table 3.1 summarizes the water balance of the dredge pond. Flows are given as average annual values. Average climatic and hydrologic conditions were assumed to prevail during the five years of tailings relocation. A total of five inflow and four outflow streams were identified for the dredge pond. The most significant inflow is the water supply obtained from the Faro Pit. This is followed by the release of water from the voids of the deposited tailings as these tailings are mined by the dredge. The third largest inflow stream is the combined seepage from the Rose Creek Diversion Channel and the North Wall Interceptor Ditch.

The largest outflow is the water content of the tailings slurry pumped to the Faro Pit. This is followed by i) emptying of the dredge pond at the end of each dredging season; ii) seepage from the dredge pond; and iii) evaporation. As explained in the footnotes to Table 3.1, significant uncertainty is associated with the magnitude of the seepage from the dredge pond. Figure 3.2 shows the simulated monthly flows for each outflow stream over the five year operational period. The surface area of the dredge pond will steadily increase from the first to the fourth season of operation and then decline in the last season. As a result of this, the seepage from the dredge pond was assumed to follow a similar pattern.

Table 3.2 summarizes the mass balance for the Faro Pit. (Table 3.2 is more accurately defined as a mass balance, rather than a water balance, because it keeps track of tailings solids as well as water.) The mass balance comprises a total of seven inflow streams and four outflow streams. The three largest inflows are all related to flows pumped from the dredge pond (viz., the water content of the tailings slurry, the solids content of the tailings slurry and the water pumped to the Faro Pit at the end of each dredging season as a result of emptying the dredge pond). The largest inflow not obtained from the dredge pond is the seepage from the two diversions above the Faro Pit.

The largest outflow is the supply of water to the dredge pond, both to slurry the tailings and to manage the size of the dredge pond. Seepage from the open pit was estimated to be small. The analysis indicated there would be no need to treat water from the Faro Pit during the dredging operation, provided the water level was initially drawn down to a low level (say 1100 m elevation) before commencing the operation.

The Faro Pit would fill at an average rate of 7 million m^3 per year. The largest component of this filling rate is the water trapped in the voids of the deposited tailings. Figure 3.3 provides a prediction of how the water surface and tailings surface in the Faro Pit will change over the five years of the tailings relocation. The water level does not reach the low point on the pit perimeter.

The main conclusions drawn from the water balance analysis are:

The Faro Pit has adequate storage to both contain all the tailings from the Rose Creek Tailings Impoundment and to act as a counter storage for the dredge pond. In making this conclusion, the tailings were assumed to be deposited at a conservatively low dry density of 1.5 tonnes/m^3.

When considering the overall water balance for the dredging pond and the Faro Pit (i.e., excluding internal flows between these two storages), the three largest sources of water are, in descending order: i) water released from voids of tailings in the Rose Creek Tailings Impoundment; ii) seepage from the Faro Creek Diversion Channel; and iii) seepage from the Rose Creek Diversion Channel. The three largest sinks for water are: i) the water stored in voids of tailings deposited in the Faro Pit; ii) seepage from the dredge pond; and iii) evaporation from the surfaces of the dredge pond and the pit lake.

The "base case" model presented in this section suggests that the water treatment plant could be mothballed throughout the five year dredging operation, provided that the water level in the pit is initially drawn down to a low level (say 1100 m). This situation could change if the climate is substantially wetter than average during the dredging operation or, as explained below, it is deemed necessary to collect seepage from the dredge pond.

The component of the water balance with the greatest uncertainty is the seepage from the dredge pond.

The "base case" model assumes that seepage from the dredge pond would not be intercepted and pumped back to the dredge pond. If it was deemed necessary to intercept this seepage, then the impact on the overall water balance could be potentially large. Without this seepage collection, the water balance model indicates that the Faro Pit will fill at a manageable rate and will not have a surplus water balance (i.e., the lake overlying the tailings will have a more or less constant volume throughout the dredging operation). However, if seepage from the dredge pond was collected, then the water treatment plant would probably have to be operated each year to prevent the pit from filling too quickly, and potentially experiencing an uncontrolled spill at the low point on the pit's perimeter.

The seepage from the dredge pond could potentially be intercepted using a fence of dewatering wells below the Cross Valley Dam. Owing to the existence of the valley aquifer underlying the Rose Creek Tailings Impoundment, the volume of water pumped from the wells could be substantially larger than the volume of water that seeps from the dredge pond (i.e., the seepage water would be substantially diluted at the point of interception). This will further increase the amount of water that would have to be treated by the water treatment plant during dredging operations.

3.6 Water Treatment

In progress.

3.7 Cost Estimate

The dredging costs, in 2003 Canadian dollars and with an accuracy of ±30%, are summarized in Table 3.3.

Table 3.1: Table 3.3: Summary of Relocation Costs Based on Dredging

	Diesel Power Alternative	Electric Power Alternative
Total Relocation Option		
Total Cost	$129.5 million	$114.5 million
Cost per Tonne	$2.27	$2.01
Partial Relocation Option		
Total Cost	$108.0 million	$102.5 million
Cost per Tonne	$2.51	$2.38

Excluded from the dredging costs shown in Table 3.3 are the costs of the following:

- Removal of the waste rock and gravel starter dykes at the original and secondary dams using conventional mechanical equipment, i.e. trucks and shovels;
- Removal of up to 2 m of tailings and contaminated original soils using conventional mechanical equipment, i.e. trucks and shovels; and
- Treatment and release of approximately x m^3 of contaminated water from the open pit immediately prior to the commencement of the dredging.

Table 3.2 summarizes some of these incremental costs. Earthworks costs in Table 3.4 are based on \$5 per m^3 to pick up, haul, dump and spread the material to either the waste rock dump or the open pit.

Table 3.2: Table 3.4: Additional Relocation Costs Related to Dredging

	Total Cost	Cost per tonne
Total Relocation Option[1]		
Treatment and release of pit water	$2,800,000	$0.05
Removal of starter dyke, original impoundment	$2,597,000	$0.05
Removal of starter dyke, secondary impoundment	$2,663,000	$0.05
Removal of 1 m of tailings/soil from base	$9,8000,000	$0.17
Subtotal & Incremental Cost per Tonne	$17,860,000	$0.31
Partial Relocation Option		
Treatment and release of pit water	$2,800,000	$0.07
Removal of starter dyke, original impoundment	$2,597,000	$0.06
Removal of starter dyke, secondary impoundment	$2,663,000	$0.06
Removal of 1 m of tailings/soil from base	$4,8500,000	$0.11
Subtotal & Incremental Cost per Tonne	$12,910,000	$0.30

Note 1: the incremental costs of breaching the Intermediate and Cross Valley Dams and reclaiming the valley have been excluded from this table.

Combining the costs in Tables 3.3 and 3.4 leads to a total cost of tailings relocation by dredging in the order of $134 million to $147 million ($2.32 to $2.58/tonne) for total relocation and $115 million to $136 million ($2.68 to $2.81/tonne) for partial relocation.

3.8 Assessment of Method

A review of the dredging option based on the report submitted by FRPD/EZC leads to the following assessment.

3.8.1 Advantages

The dredging option allows the tailings to be pumped as a slurry through a pipeline to the Faro pit.

3.8.2 Disadvantages

The pond of water necessary to float the dredge will lead to seepage losses into the underlying soils and, where solutes are present in these soils, will apply a driving head to the movement of these solutes towards and ultimately past the downstream toe of the Intermediate Dam.

4 Hydraulic Monitoring Method

Environmental, Civil and Mining Projects (Pty) Ltd. (ECMP) of South Africa was commissioned to complete a conceptual plan and preliminary cost estimates to relocate the Rose Creek tailings using hydraulic monitoring (hydro-sluicing). As the ECMP authors did not make a site visit, they relied on the following:

- The content of the tailings relocation report by Kilborn Inc. and A.S. Webster (Kilborn, 1991);
- The FRPD/EZC draft dredging report (2004); and
- Various photos and topography recently obtained from site.

The draft report by ECMP and the Kilborn report (1991) are included as Appendix D. A summary of the ECMP report is provided below.

4.1 Scope and Key Assumptions

The scope of their work consisted of the following:

- A review of all the available data (including the Kilborn report as a baseline) and to confirm an operating methodology.
- Highlight the relevant water balance impacts.
- Prepare a capital and operating cost estimate, utilising current 2003/2004 rates and taking cognisance of the assumptions made in the latest dredging report.
- Prepare a draft summary report to which the Kilborn report (1991) can be appended.

The following assumptions were adopted for this study:

- 100 % of the hydro-sluiced tailings will report to the Faro open pit.
- The projected hydraulic mining duration for the relocation of 50 million tonnes will be 10.5 years (11.9 years for the total relocation option and 9.0 years for the partial relocation option).
- Local crews and mine staff will perform hydraulic mining operations.
- The project will employ a full-time experienced hydraulic mining specialist to assist in the daily operations and planning.
- Local mine staff and crew will be trained to operate and maintain the hydraulic mining equipment.
- Hydraulic mining operations will operate between 15 March and 15 September. On or towards the end of the operational cycle (15 September) the equipment will be disassembled and stored for the winter period and the crew will be laid off. On 1 March the crew will return and, weather permitting, will re-assemble equipment and commence operation.
- Equipment maintenance will be ongoing throughout the operating cycle.
- The water management circuit will be on a closed system with no water related downtime or restrictions.
- Costs estimates for power usage were taken from the FRPD/ECZ dredging report (2004) and the Kilborn report (1991).
- The hydro-sluicing operation will be a top - down and downstream operation, thereby facilitating final clean up and contouring as an ongoing part of the operation.
- The hydraulic monitoring guns will be sourced in South Africa and manufactured for "site specific" conditions.
- All other equipment (i.e. pumps, pipes, earthmoving equipment, etc.) will be purchased or hired in Canada.

4.2 Equipment

The hydraulic monitoring equipment for this project will comprise the following:

- Six operating hydraulic monitoring guns are required with four additional monitoring guns on standby or being relocated.
- The hydraulic monitoring guns will be mounted on skids for stability purposes with the option to fill the skids with water for additional weight.
- The hydraulic monitoring guns will be electrically operated from a weatherproof cabin.
- The cabin will be on wheels and elevated to ± 2 metres above ground level, thereby allowing the operator full visibility of the operation.

4.3 Mining/Monitoring Plan

The ECMP report does not provide a mining/monitoring plan because the authors did not visit the site. However, the basic concepts for developing a plan are described below.

A collector sump will be constructed at a topographical low point (the Kilborn report (1991) provides information on the probable siting of the collection trenches and collection sump for the partial relocation option). The hydraulically mined tailings will gravitate via a mechanically excavated trench or a hydraulically mined gully to the sump. The sump will be constructed of reinforced concrete with self-cleaning screens over the sump to screen off the plus 50 mm material. The slurry will then be pumped to two elevated vibrating screens which will screen out the plus 3 mm fraction. Below these screens will be a 7 m high, 4 m diameter header tank with an agitator. The header tank will feed a train of seven Warman 14 x 12 pumps, or similar, which will then pump the material to the Faro pit.

4.4 Water Management

In progress.

4.5 Water Balance

In progress.

4.6 Water Treatment

In progress.

4.7 Cost Estimate

The hydraulic monitoring costs, in 2003 Canadian dollars and with an accuracy of ±30%, are summarized in Table 4.1.

Table 4.1: Summary of Relocation Costs Based on Hydraulic Monitoring

	Total Relocation Option	Partial Relocation Option
Total Cost	$26.6 million	$20.2 million
Cost per Tonne	$0.47	$0.47

Excluded from the hydraulic monitoring costs shown in Table 4.1 are the costs of the following:

- Removal of the waste rock starter dyke at the secondary dam using conventional mechanical equipment, i.e. trucks and shovels; and
- Treatment and release of approximately x m^3 of contaminated water from the open pit immediately prior to the commencement of the dredging.

Table 4.2 summarizes some of these incremental costs. Earthworks costs in Table 4.2 are based on $5 per m^3 to pick up, haul, dump and spread the material at the waste rock dump.

Table 4.2: Additional Relocation Costs Related to Hydraulic Monitoring

	Total Cost	Cost per tonne
Total Relocation Option[1]		
Treatment and release of pit water	$2,800,000	$0.05
Removal of starter dyke, original impoundment	$2,597,000	$0.05
Subtotal & Incremental Cost per Tonne	$5,397,000	$0.10
Partial Relocation Option		
Treatment and release of pit water	$2,800,000	$0.07
Removal of starter dyke, original impoundment	$2,597,000	$0.05
Subtotal & Incremental Cost per Tonne	$5,397,000	$0.12

Note 1: the incremental costs of breaching the Intermediate and Cross Valley Dams and reclaiming the valley have been excluded from this table.

Combining the costs in Tables 4.1 and 4.2 leads to a total cost of tailings relocation by hydraulic monitoring of $32.0 million ($0.57/tonne) for total relocation and $25.6 million ($0.59/tonne) for partial relocation.

4.8 Assessment of Method

In progress.

5 Conventional Earthworks Method

Pelly Construction Ltd. (Pelly) was commissioned to complete a conceptual plan and preliminary cost estimates to relocate the Rose Creek tailings using mechanical methods. The draft report by Pelly is included as Appendix E. A summary of the contents of that report is provided below.

5.1 Scope and Key Assumptions

The scope of their work consisted of the following:

- A review of all the available data.
- Prepare conceptual design of a system to remove the tailings mechanically so they may be transported to the Faro pit and dumped there.
- Prepare a capital and operating cost estimate, utilising current 2004 rates.
- Prepare a draft summary report.

The following assumptions were adopted for this study:

- The concept of removal by mechanical load and haul methods is based on the tailings being dry enough to support the haul units.
- There will be areas that will not support traffic, but no allowance has been made to deal with these areas.
- 100 % of the tailings will be deposited at the Faro open pit.
- The working season will be 200 working days per year (April to October).
- The projected duration of mechanical mining will be 7.1 years for the total relocation option and 5.4 years for the partial relocation option.
- The water balance and water management issues will be addressed by others.

5.2 Equipment

Within reason, the larger the equipment that can be employed to move material the more economical the unit price will be. The terrain of the valley in which the tailings are located is not uniform. In some areas there are large pits where gravel deposits were found and utilized to construct the intermediate and cross-valley dams. In other areas there are deposits of frozen muck in some cases several meters in thickness. In the areas where gravel was not excavated, the organic mat along with trees that were flattened with bulldozers is covered with the tailings. This layer of organics is of varying depth and in some areas the organics are underlain by black muck. In one area of the dam footprint, black muck had to be removed and it was two to three meters in thickness.

Because of the possible instability of the foundation material it may not be possible to load trucks with front-end loaders. A large capacity belt loader is proposed to load the trucks. Tailings would be pushed to the loader with a D11 size dozer. The haul would be done with Cat 776, 135 tonne wagons.

5.3 Mining Plan

The road from station 0+000 to 2+040 would be properly aligned and the grades improved by using local material and waste rock fill. A non deflecting sub-grade would reduce the rolling resistance to actual grade plus a maximum of 2%. A finished surface of crushed gravel or possibly a bituminous treated surface will substantially reduce tire wear and improve cycle time. The section from 1+840 to 2+040 would be improved to bring the grade down to 12% from 15%. If the tailings are removed in their entirety, adequate gravel roads should be constructed using material from the floor of the containment. If tailings are only removed to a certain elevation (partial relocation), it will be necessary to construct some main haul roads over the remaining tailings utilizing material from outside the containment area or perhaps by reclaiming material that was used to build the dams.

5.4 Water Management

In progress.

5.5 Water Balance

In progress.

5.6 Water Treatment

In progress.

5.7 Cost Estimate

The mechanical excavation costs, in 2004 Canadian dollars are summarized in Table 5.1.

Table 5.1: Summary of Relocation Costs Based on Mechanical Methods

	Total Relocation Option	Partial Relocation Option
Total Cost	$92.0 million	$70.0 million
Cost per Tonne	$1.61	$1.63

Excluded from the hydraulic monitoring costs shown in Table 4.1 are the costs of the following:

- Treatment and release of approximately x m^3 of contaminated water from the open pit immediately prior to the commencement of the dredging.

Table 5.2 summarizes some of these incremental costs.

Table 5.2: Additional Relocation Costs Related to Mechanical Methods

	Total Cost	Cost per tonne
Total Relocation Option[1]		
Treatment and release of pit water		
Incremental dewatering or access development		
Subtotal & Incremental Cost per Tonne		
Partial Relocation Option		
Treatment and release of pit water		
Incremental dewatering or access development		
Subtotal & Incremental Cost per Tonne		

Note 1: the incremental costs of breaching the Intermediate and Cross Valley Dams and reclaiming the valley have been excluded from this table.

Combining the costs in Tables 5.1 and 5.2 leads to a total cost of tailings relocation by dredging of in the order of $x.y million ($x.zz/tonne) for total relocation and $x.y million ($x.zz/tonne) for partial relocation.

5.8 Assessment of Method

In progress.

6 Comparative Assessment of Methods

6.1 General

In progress.

6.2 Risks

In progress.

6.3 Costs

In progress.
Table 6.1 summarizes the basic cost of each of the options and methods evaluated in this study (Appendices C, D and E).

Table 6.1: Summary of Relocation Costs

	Total Relocation Option	Partial Relocation Option
Dredging		
Total Cost	$114.5 to $129.5 million	$102.5 to $108.0 million
Cost per Tonne	$2.01 to $2.27	$2.38 to $2.51
Hydraulic Monitoring		
Total Cost	$26.6 million	$20.2 million
Cost per Tonne	$0.47	$0.47
Mechanical Methods		
Total Cost	$92.0 million	$70.0 million
Cost per Tonne	$1.61	$1.63

Excluded from this table are the incremental costs for water treatment and additional earthworks of a type different from what was considered in the respective method.

Table 6.1 provides a relative comparison of the cost of each of the 3 methods and relocation options. The actual costs do would be higher than what is shown as these costs do not include the following:

- Water treatment and discharge of water from the Faro open pit;
- Any incremental earthworks to remove granular dykes or residual tailings from the floor of the impoundment;
- Breach of the Intermediate and Cross Valley Dams in the total relocation alternative; and
- Reclamation of the valley floor after the tailings have been removed.

7 Conclusions

In progress.

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Appendix A

Review of Tailings Relocation Practices and Costs

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MEMORANDUM

DATE: September 6, 2002

TO: File 1CD003.13 Task 040 (Faro Scoping Study)

FROM: Maritz Rykaart

RE: REVIEW OF TAILINGS RELOCATION PRACTICES AND COSTS

1. Introduction

This memo presents the preliminary findings from a brief review of global tailings relocation practices and costs. Tailings relocation is a common practice, both for reprocessing for economic beneficiation and for stabilization due to environmental concerns. A paper by Goode (1993) listed 20 sites where tailings relocation has been undertaken on a large scale. In addition, SRK knows of at least 30 sites where tailings relocation has been costed and/or undertaken. The purpose of this memo is not to list the details of all these sites, but rather to present a brief summary of the most common relocation practices and costs, in order to facilitate the development of scoping-level cost estimates for the relocation of the tailings situated in the Rose Creek Tailing Facility.

2. Tailings Relocation Practices

There are three primary methods used when tailings relocation and/or rehandling are considered (Goode, 1993):

- Dredging: This technique employs the same equipment and principles as those used for conventional clearing of shipping ways in rivers, canals and harbors. Van Muijen and Ouwerkerk (1997) present a comprehensive overview of the types of dredges typically used in tailings relocation applications.
- Hydraulic mining (monitoring): This technique involves re-liquefying the tailings using water cannons. The slurry is directed to a sump via trenches and pumped to its intended destination.

- Mechanical excavation: Mechanical excavation of tailings is normally undertaken using conventional truck & shovel operations. Often specially adapted equipment or methodologies have to be used since the trafficability, handlability and transport of saturated tailings can be challenging compared to conventional soils.

Goode (1993) provides an overview of these three methods, the primary advantages and disadvantages of which are summarized in Tables 1, 2 and 3, respectively.

Table 1
Advantages and Disadvantages of Dredging

Advantages	Disadvantages
▪ Tailings can be transported as slurry, i.e. using a tailings pipeline ▪ No delays due to wet, untrafficable tailings ▪ Facilitates re-disposal of tailings irrespective of whether they are being reprocessed or not	▪ New overall fluids management plan required for mine ▪ Typically requires continuous dredge pond ± 3m deep ▪ High potential for seepage into vadose zone/groundwater in the immediate vicinity of the dredge pond ▪ High potential to re-trigger solute transport (weak acid dissociable cyanide) and environmental monitoring ▪ Usually has flat excavation angle (7H:1V (horizontal:vertical)) ▪ Requires specialist outside contractor ▪ Surface vegetation may cause blockages in the dredge/pump system ▪ Miscellaneous "junk" buried in the tailings may block or damage the dredge and/or the pump system ▪ Complete relocation may not be achieved with dredging alone, in which case monitoring or mechanical excavation might also be required ▪ Capital investment may be required to purchase and construct pipelines and pump stations

Table 2
Advantages and Disadvantages of Hydraulic Mining (Monitoring)

Advantages	Disadvantages
▪ Typically requires less water than dredging ▪ Relative to dredging, lower potential for: - Seepage losses - Solute transport and monitoring	▪ New overall fluids management plan required for mine ▪ Relative to dredging, higher degree of difficulty meeting consistent slurry S.G., especially during high precipitation and run-off ▪ Surface vegetation may cause blockage ▪ Miscellaneous “junk” buried in the tailings may block or damage the pump system ▪ New overall fluids management plan required for mine (including additional raises) ▪ Process Water Balance (i.e., requires continuous dredge pond ± 8ft deep) ▪ Requires specialist outside contractor ▪ Capital investment may be required to purchase and construct the monitors, pump stations and pipelines

Table 3
Advantages and Disadvantages of Mechanical Excavation

Advantages	Disadvantages
▪ “Dry” operation, therefore no increase above existing condition for process fluids management, seepage, solute transport, monitoring and instability of pit sidewalls. ▪ Flexible disposal options (i.e., re-location on remainder of tailings is feasible, if no re-processing is performed or potential use as a closure cover component) ▪ Can use local conventional earthworks contractor ▪ No capital investment if outside contractors are used	▪ Limitation on excavation, transport and placement methods and rates, due to tailings moisture content, trafficability and potential for liquefaction ▪ Specially adapted equipment may be required for access or, alternatively, special procedures may be required to facilitate access over the tailings

2. Typical Tailings Relocation Costs

Table 4 provides a range of tailings relocation costs from various literature sources. It is clear that the unit costs may vary widely depending on the method employed and the quantity of tailings relocated. Normally, the average unit cost decreases as the volume of tailings increases.

Table 4
Range of Tailings Relocation Costs[1]

Relocation Technique	Monitoring		Dredging	Truck & Shovel		
Source	Anvil (1996)	Goode (1993)	Goode (1993)	Nuna Logistics (2002)		Durango Mine (1991)[4]
Total tonnage (million)	43,5	40,0	8,0	12,0[2]	50,0[3]	3,7
Capital cost (thousand)	$ 6,164	$ 10,208	$ 5,833	n/a	n/a	n/a
Operational cost (thousand)	$ 17,085	$ 25,665	$ 8,003	$ 48,000	$150,000	$ 14,876
Total cost (thousand)	$ 23,249	$ 35,873	$ 13,836	$ 48,000	$150,000	$ 14,876
Unit capital cost ($/tonne)	$ 0.14	$ 0.26	$ 0.73	n/a	n/a	n/a
Unit operational cost ($/tonne)	$ 0.39	$ 0.64	$ 1.00	$ 4.00	$ 3.00	$ 4.05
Unit total cost ($/tonne)	$ 0.53	$ 0.90	$ 1.73	$ 4.00	$ 3.00	$ 4.05

1. All rates have been converted to Canadian Dollar, and to 2002 rates.
2. This rate is for excavating “soupy” overburden at Diamond mines in the Northwest Territories, Canada.
3. This rate is an estimate for excavating wet tailings at large scale, in remote locations.
4. This rate is inclusive of the complete tailings rehabilitation, i.e. construction and capping of the new tailings facility.

3. Rose Creek Tailings Relocation Options and Costs

The typical tailings relocation costs in Table 4 were used to develop a range of approximate tailings relocation costs specific to the Rose Creek tailings. These cost estimates are summarized in Table 5. Given the conditions at the Rose Creek tailings impoundment, the most economical tailings relocation method would be likely be hydraulic mining (monitoring), with the total cost likely to range between $23 million and $53 million depending on the tailings removal objectives. The choice of monitoring over truck and shovel tailings relocation at Rose Creek is based on the fact that the Rose Creek tailings are substantially saturated and, in all likelihood, would not be trafficable for conventional equipment once the first few metres of tailings are removed.

Table 5
Projected Range of Tailings Relocation Costs for the Rose Creek Tailings

Description	Unit Cost	Partial relocation (to 1042 level only)[1]	Total relocation (all tailings)[2]
Total tonnage		43,052,632	57,200,000
Monitoring - low end	$0.53/tonne	**$22,817,895**	$30,316,000
Monitoring - high end	$0.93/tonne	$40,038,947	**$53,196,000**
Dredging	$1.73/tonne	$74,481,053	$98,956,000
Truck & shovel - low end	$3.00/tonne	$129,157,895	$171,600,000
Truck & shovel - high end	$4.05/tonne	$174,363,158	$231,660,000

1. Partial relocation to a level of 1042 would allow for the remainder of tailings to receive a permanent water cover (Robertson Geo-Consultants, 1996)
2. Total relocation implies removal of all tailings in the facility (Robertson Geo-Consultants, 1996)

References

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Appendix B

A Review of Tailings Relocation Projects and Methodology

A REVIEW OF TAILINGS RELOCATION PROJECTS AND METHODOLOGY

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December 2003

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TAILINGS RELOCATION PROJECTS
RESULTS OF LITERATURE SEARCH

1. INTRODUCTION

1.1. BACKGROUND

Tailings deposits at Faro Mine and Mt. Nansen mines in Yukon currently pose an environmental hazard due to the physical and chemical instability of the materials. Physical concerns include long-term performance of the containment dams and water diversion works. Chemical stability issues include arsenic leaching at Mt. Nansen and acid rock drainage (ARD) at Faro Mine.

Reclamation options for these tailings can be grouped into: in-situ solutions where the stability issues are addressed with the material remaining in place, or ex-situ solutions where the material is relocated to a new containment facility. The focus of the work described in this report is on ex-situ or relocation options.

Tailings removal could be conducted in one of two primary methods. Mechanized excavation involving excavator and truck or scrapers is the most common method. In this case, selection of the equipment and excavation method would depend upon a number of factors including; quantity to be removed, existing and final location for the material, slope stability and trafficability of the excavated surface.

An alternative to mechanized removal would involve hydraulic mining. In this method, the tailings are liberated from the deposit by a high pressure water jet and the resulting slurry is pumped away. Success with this method will require careful consideration of the slurry pumps and associated piping and power requirements. Mines have been moving tailings in slurry form for decades. It is clear that if you can get the tailings into the pump then they can be relocated hydraulically. The outstanding questions relate to how to efficiently get the tailings into the pump on a continuous basis.

1.2. OBJECTIVES

The objective of this project is to look at industry experience with tailings relocation, with the aim to understanding:

1. methodologies which have been used,
2. tailings properties (physical and chemical) which will influence selection of removal methodology and potential efficiency, and,
3. site conditions which should be considered in the project design.

1.3. APPROACH

Section 2 describes aspects of tailings properties and deposition which should be considered in the design phase of a relocation project.

The results of a literature search are summarized in Section 3. The original plan was to obtain relevant information from libraries, industry publications and associations, conference proceedings, government sources and an internet search. Preliminary attempts found that suitable references where scarce and that obtaining copies of the material would be difficult. Consequently, it was decided to use the services of a professional research firm. InfoAction of the Vancouver Public Library was used. Two separate searches were conducted. The relevant references are included in Appendix A.

Due to the relatively small number of references which were found to be directly applicable to the potential relocation of northern tailings deposits, other sources were consulted. These included a review with the Toyo Pump Company and examination of the available project files from 1989/90 tailings relocation which was conducted at the Giant Mine.

2. TAILINGS DEPOSITION

This section provides a brief description of tailings deposition as it pertains to potential relocation projects. The methodologies which may be considered for tailings relocation will depend upon a number of factors including: the tailings properties, pore water quality, original deposition, climatic factors and the volume of tailings to be managed. Each of these factors is discussed as follow.

2.1. TAILINGS PROPERTIES

Tailings properties which must be considered in the design phase of a potential relocation project can be considered in two categories, physical and chemical. The physical properties of interest are particle grain size distribution and settled density. The specific gravity of the particles may also be important if hydraulic mining is being considered. Tailings may develop cohesion due to the fines content and consolidation.

Despite the apparent uniform nature of mine tailings, it is incorrect to assume that a tailings deposit is a homogenous mass. Many factors will cause heterogeneity in a tailings deposit. These include: variations in the mineralogy of the ore, hydraulic sorting during beach deposition, distance from the discharge point, and consolidation above and below the water table. Heterogeneity should be expected both horizontally and vertically in a deposit. There are numerous good references on tailings deposition (such as Vick, S. 1990, Planning, Design, and Analysis of Tailings Dams) which provide additional information regarding the in-situ properties of a tailings deposit. Ultimately, these variables would have to be determined on a site specific basis.

Historically, tailings deposits were used as waste repositories for material other than tailings. In addition to randomly located bits of wood, there may be localized deposits of tires and general refuse.

In addition to the physical properties, chemical effects such as precipitates from the metallurgical reagents or oxidation of any reactive minerals may create an additional binding effect in the tailings. Any binding of the tailings particles due to chemical effects is likely to increase the energy required to remove the material.

2.2. PORE WATER QUALITY

The in-situ pore water quality may consist of metallurgical reagents or products of oxidation and/or metal leaching from the tailings minerals. It should be expected that the pore water quality will have an effect on the design of the water management and treatment system associated with any tailings relocation project, particularly if hydraulic mining is being considered.

2.3. ORIGINAL DEPOSITION

Aspects of the original deposition which are important will include the site setting as it influences surface runoff and groundwater flow in and around the tailings deposit, and the potential for debris in the tailings.

The situation of the tailings deposit, including both deposition area and meteorological factors, must be considered in evaluating how the tailings are to be excavated. Very wet tailings due to high precipitation and excessive runoff from the surrounding area, or a high groundwater table will exhibit low trafficability and thus not be amenable to removal using conventional earth moving equipment.

Historic tailings which were discharged to low areas such as creeks and dry gulches may be difficult to remove due to the topographic constraints and the relatively thin deposits which result from discharge into an unconfined area.

Many older tailings impoundments were filled without removal of the original vegetation. The presence of trees and shrubs will impede the removal of the lower layers of tailings, in the case of both hydraulic and mechanized excavation. Trash processing will be required. This may consist of either removal prior to hydraulic transport or shredding and transport of the trash with the tailings. Other debris which could affect tailings removal would be buried pipelines, trestles, and rock causeways.

2.4. CLIMATIC FACTORS

Climatic factors, primarily the influence of cold weather, may require flexibility in operating procedures. Winter deposited tailings may have ice lenses. It may be necessary to provide additional excavation energy to remove these layers or shift to mining an unfrozen area while the frozen area thaws.

Tailings dust could be a problem at arid sites or during the dry season. Dust control measures such as irrigation or use of a soil adhesive, such as Soil Sement may be required.

2.5. VOLUME OF TAILINGS

Aside from the obvious design parameter of having an appropriately sized repository for the tailings, equipment mobilization and commissioning are the main factors which will be influenced by the volume of tailings. Truck and shovel operations will probably have a lower initial cost and higher operating costs than a hydraulic operation, which is likely to have a higher set-up cost but off-setting lower operating costs. It is likely that small projects will favor truck and shovel operations, while both methods will be worth considering for larger projects.

If the tailings are being processed for additional mineral recovery, then the metallurgical process rate will probably govern the mining rate. However, when the tailings are to be relocated for environmental reasons it will generally be preferable to complete the work in a reasonable period of time. Process rates which are 5 to 10 times greater than were used during the original mining may be appropriate, especially if a shut-down during winter is expected. Therefore, it should be expected that even if some of the original mine equipment (trucks, pumps, pipelines, water treatment plant) still remain on site, that they will likely be severely undersized for the task at hand.

3. LITERATURE RESEARCH

3.1. GENERAL

The literature search conducted by InfoAction looked for reference material containing the key words:

- tailings remove/removal,
- tailings relocate/relocation, and,
- tailings excavate/excavation.

This search included a variety of sources including:

- Periodical indexes: Applied Science & Technology Index/ EVSO (Academic Business & Master Files); OCLC Databases; Dow Jones; CBCA (Canadian Business & current Affairs); Elibrary Canada; etc.
- Government Publications: US Environmental Protection Agency, Natural Resources Canada, Federal and Provincial Agencies; etc.
- Industry Associations,
- Reference books within the Vancouver Public Library, and
- Internet Search.

The initial result of the work was:

- A total of 51 references were found.
- There are few references which deal specifically with the subject matter.
- Many of the references found dealt with either projects where tailings relocation was being considered as an option, was proposed but not yet initiated or was the option requested by some stakeholders.

Copies of the relevant reference material are included in Appendix A.

As a result of the limited research findings, a second search was conducted. This second phase included a number of key words in combination with "tailings" such as:

- Hydraulic mining or re-mining,
- Slurry,
- Permafrost, arctic, cold climate.

The result of the second phase work was:

- A total of 27 references were found.
- There are few references which deal specifically with the subject matter.
- Many of the references which were found dealt with projects where tailings disposal in a cold climate was being planned or conducted. These did not involve re-mining of tailings.

Copies of the relevant reference material are included in Appendix A.

3.2. PHASE 1 SEARCH – RELEVANT INFORMATION

This section presents a brief description of the useful findings of the first phase of the literature search.

1. US EPA Re-mining of Pinto Valley tailings. This project involved hydraulic recovery of tailings for vat leaching and copper recovery. Approximately 38 million tons of tailings are to be ultimately processed. “the hydraulic mining operation uses up to four 4-inch hydraulic mining jet monitors, feeding two separate educator pump sets capable of pumping 523 gpm of water at 28 bars of pressure. The hydraulic monitors are automatically controlled. The hydraulic mining peptizes the tailings into a 32.4 percent solids slurry.” The remainder of this reference describes metallurgical factors.

2. Indian and Northern Affairs Canada, Open File 1993-9(T), Faro Down Valley Tailings Research Program Report: Tailings Reprocessing. Written by G. McDonald of Curragh Resources Limited. This report should be in the current government files for the Faro project. Most of the effort is focused on the lead and zinc recovery from the tailings.

3. The Aznalcollar tailings dam failure in 1998 in Spain resulted in the release of 1.3 to 1.9 million tons of tailings. The resulting clean-up, which included removal of some native soil, was conducted using truck and shovel operation.
4. Table 1 summarizes mechanized tailings removal projects. It is worth noting that most of these projects involved semi-arid sites. Many of the smaller projects dealt with historic tailings disposal into rivers and creeks. Although most of these projects consisted of conventional shovel and truck operations, a few of the larger projects utilized rail cars for transport of the material.

Table 1
Summary of Tailings Removal Projects by Mechanized Excavation
(In no particular order)

Location	Site Name	Volume Removed
Montana	Curlew	89,250 yd^3
Montana	Maxville	16,000 yd^3
Montana	Douglas Creek	Very small
Montana	Comet	200,000 yd^3
Utah	Monticello	2.3×10^6 yd^3
Idaho	Bunker Hill	$1.16 \times 10^6 yd^3$
Colorado	Eagle	> 150,000yd^3
Colorado	Bonanza	116,000 yd^3
Colorado	Lackawanna	< 100,000 yd^3
Missouri	Newton	<50,000 ? yd^3
Washington	Ruby Gulch	40,000 yd^3
California	Eureka	6000 yd^3
Montana	High Ore Creek	31,000 yd^3
Utah	Moab	$11.9 \times 10^6 yd^3$
Idaho	Taache	16,000 yd^3
Washington	Kaaba-Texas	? yd^3
New Mexico	Cleveland	165,000 yd^3
Idaho	Silver Crescent	100,000 yd^3
Colorado	Atlas	12×10^6 yd^3
Idaho	Talache	1.9×10^6 yd^3

3.3. PHASE 2 SEARCH – RELEVANT INFORMATION

This second phase of searching provided few relevant documents. Most of the references found involved subaqueous tailings disposal or stabilization by permafrost, either directly or with a cover. A few useful documents were found and are discussed as follow.

1. Reclamation of massive sulphide tailings at the Caribou mine in New Brunswick was proposed by Breakwater Resources. The tailings were to be removed by excavator and then slurried. After treatment the product will be pumped to a new disposal pond.

2. In a 1985 paper, the president of the Toyo pump company (now called "Toyo Pumps North America Corp. of Burnaby, B.C.) describes some case histories involving hydraulic removal of tailings. The tailings removed included zinc/silver, potash, arsenic trioxide, placer gold, overburden, tar-sand, and coal tailings. It is recognized that pumping of granular material in a slurry can be conducted (as has

been done for many years in tailings disposal). Reference is made to agitator pumps and units with cutters, which may compliment a pump-based approach. The author suggests that hydraulic based mining for unconsolidated material may be less than half the cost of mechanized mining. Pump based methods, using either submersible pumps or in a dredging arrangement may be an effective method for re-mining tailings.

3. A PhD thesis titled "Hydraulic Mining in Cold Regions" was submitted to the University of London in 1996 by Sadek E. El-Alfy. He was the lead engineer on the two relocation projects noted below. His thesis describes permafrost and cold regions effects as they pertain to tailings and describes three case histories. His summary of major tailings retreatment operations from around the world is reproduced here as Table 2. The case histories are:
    a. Tailings reclaim project at Giant Yellowknife Mines (named the "TRP" for Tailings Retreatment Plant),
    b. ERG Timmins Gold recovery project,
    c. Proposal for hydraulic mining of the arsenic trioxide dust in the underground chambers at the Giant Mine.

The author describes the tailings relocation projects and suggests that the results of those projects are a good basis for future tailings recovery projects. Although neither of these project were highly successful, both the Giant Mine and the ERG Timmins projects demonstrated that hydraulic reprocessing of tailings can be undertaken. Both projects were terminated prematurely. It is not clear if this was due to technical or economic factors, although both factors may have contributed to the decisions. The arsenic trioxide project was not initiated.

Some details from the two projects are discussed in the following sections.

Table 2
Major World Tailings Retreatment Operations
(Reproduced from S. El-Alfy, 1996)

Company	Location	Commissioned Date	Through-put (ton/month)*
Freegold JMS	O.F.S, South Africa	1976	1.6 million
East Rand Gold & Uranium (ERGO)	Transval, S. Africa	1978	1.8 million
Chemwes	Transval, S. Africa	1979	290,000
Simmergo	Transval, S. Africa	1982	180,000
Mt. Morgan Gold Mines	Australia	1982	250,000
Rand Mines & Milling Co. Ltd.	Transval, S. Africa	1982	370,000
ERGO CIL Plant	Transval, S. Africa	1985	2.0 million
ERGO Daggafontein	Transval, S. Africa	1987	1.0 million
Eastmaque Gold Mines	Kirkland Lake Ontario	1987	80,000
Giant Yellowknife	Yellowknife, N.W.T.	1988	230,000
ERG Res. Timmins Gold Tailings Project	Timmins, Ontario	1990?	1.0 million

* The author has not indicated if the through-put rates are design or actual achieved.

GIANT MINE

Mine records are not precise, however, it is estimated that 2.3 million tonnes of tailings were removed and processed at the Giant mine over two summer seasons. The monthly process rate was in the order of 200,000 tonnes.

Pilot work was conducted prior to full scale mining. Photographs 1, 2 and 3, courtesy of Toyo Pump Company, show the liberation of tailings using a high pressure water monitor and removal with a submersible pump. Note that the water monitor is remotely operated by hydraulic controls. A pad of mine rock was placed to support the water monitor and the excavator which supported the submersible pump.

Tailings recovery seems to have started at the western edge of the North Pond and progressed eastward. A working surface of waste rock was advanced over the original ground surface as the tailings were removed, as shown in Figure 4 (courtesy of Toyo

Pump Company). This allowed movement of the sump pumps and hydraulic monitors by a crane. The tailings face was in the order of 20 m high.

It appears that basic operation involved cutting the tailings with the high pressure monitors and washing the material to a sump. A high lift dredge pump operated in the sump to remove the material and send it to the processing plant, which was located several hundred meters away and about 30 m higher in elevation.

It is understood that the hydraulic monitors were supplied by the English Clays Lovering Poching & Co. Ltd. of England. A dated product brochure obtained from the Giant Mine files is included in Appendix B. Remotely-operated monitors allow the nozzle to be as close as practical to the operating face while maintaining the operator at a safe distance. In this way, slumping or a wash-out of tailings stops moving before reaching the operator.

The author has suggested that the frozen tailings at Giant were being thawed by the water. Company records indicate that hydraulic mining was not practical without the use of dozers to loosen the tailings. Mining of this material left near vertical faces up to 5 m high in the tailings. These faces have not slumped or collapsed in the 10 years since the mining was conducted, as can be seen in Photo 5 (Brodie Consulting Ltd). It is suggested here that the tailings have a cohesion which is in addition to any ice effects and that this may have influenced the mining of this material. This uncertainty in the tailings properties may have affected the performance of the tailings removal process.

A section of the thesis discusses the merits of vertical versus horizontal mining of the tailings. It is suggested that horizontal mining, similar to laterally advancing benches in open pit mining, is more effective because it keeps equipment well away from the working area and allows gravity to aid in the loosening of the material. This appears to be practical advice.

Based upon review of the project files, located at the Giant Mine, the following supplemental information and discussion is presented.

- Three hydraulic monitors, with two dozers for assistance, were unable to produce the target of 10,000 tons per day.
- Problems were experienced with the submersible Toyo pumps. These included performance of the seals and motor overheating. An employee of the Toyo Pump Company was aware of these problems and reports that TRP staff would not replace the seals as recommended and insisted on operating the pumps without the cooling jacket.
- The approximate operating costs at the Giant Mine were $1.03/tonne in 1987 dollars. This consisted of $0.39/tonne for power (37%), $.055/tonne for labour (53%), and $0.09/tonne for maintenance supplies (10%). No estimate of the amortizing capital cost was found.
- In a brief discussion with a former Giant Mine employee (Malcolm Robb, Robbm@inac.gc.ca), the following key points were identified as factors which contributed to the termination of the TRP project:
    1. The difficulty of mining the frozen tailings was under-estimated.
    2. The volume of wood debris, primarily mine junk – not trees, was under-estimated. This mostly affected the TRP plant and not the mining of the tailings.
    3. There was not enough drilling to characterize the variability in the tailings deposit. There were no maps of the spigot points used in filling the tailings pond.
    4. There was no thickener in the first year of operation, resulting in a low slurry density to the plant.

ERG PROJECT

The thesis by El-Alfy includes an operations manual for the ERG Tailings project. This material could be useful in the design of hydraulic mining plan. Much of this manual is directed at the day-to-day operations for the conditions and equipment as existed at the ERG project. It may be of use in planning future operations.

It should be noted that at the ERG operation, tailings recovery from the working sump to the processing plant was conducted with a high lift dredge pump. Some aspects of pumping and pipe arrangement are discussed further in the following section on Toyo Pumps.

The author has included a number of drawings and description of the method and sequence for removal of tailings using hydraulic monitors. In general, it is suggested that the monitors provide peak performance if the upper portion of a face is cut away first, followed by washing of the slumped material and then cutting of the lower portion of the face.

3.4. PHASE 3 – TOYO PUMPS

A key issue in the design of the tailings removal method is the selection of the pumps for transporting the material away. An investigation into pump technology was conducted with the Toyo Pump company. They suggest that two basic options exist: high-lift end-suction pumps and submersible agitator pumps.

High-lift end-suction pumps are the type commonly used in dredge applications. These use a conventional horizontal-mounted motor and pump assembly which is operated on a platform just above the water level. An intake pipe extends from the pump down to the surface of the material to be removed. Movement of the water over the material lifts it in much the same way as a domestic vacuum cleaner works. Cutters may be added to the intake end of the pipe to aid in loosening the material. The advantage of this method is that very large motors can be used as they do not have to be operated underwater. Disadvantages include typically low slurry density and inability to process high density slurry.

The Toyo Pump company is a recognized world leader in pumps. They manufacture a range of pumps from 3 to 1200 hp units. The largest standard submersible pumps are 150 hp. A brochure is attached as Appendix B.

In the context of the potentially large tailings relocation project at Faro, the review with Toyo Pump staff focused on their largest submersible pumps. The DP 150B pump is reported to achieve a peak performance of about 1000 cubic yards per hour at 70 – 80 % solids. This rate would depend upon particle density and elevation that the material is lifted. The manufacturer suggests that pre-feasibility production be based upon not more than 300 – 350 yd^3/hr for mining of slightly cohesive fine grained sand.

The key feature of the Toyo submersible pump is the shaft mounted agitator. It breaks up the tailings material and mixes it with water to produce a high-density slurry at the pump intake. The agitator also breaks up any debris such as wood which may otherwise clog the intake.

A submersible pump could be used in one of two methods. The shaft mounted agitator allows the pump to be used as the "mining machine". Suspended by a crane it could be lowered into the tailings and it would excavate its own hole, assuming that there was sufficient water available. Although this may not be the normal operation, it could be used to dig a new sump each time it becomes necessary to relocate the sump closer to the working face.

In the more likely scenario, the pump would remain stationary in a sump, suspended about a foot off the bottom of the sump. Material washed from the working face would be flushed into the sump and removed by the pump. A limiting factor in an operation of this type would be the slurry density of the flow into the sump. The slope and length of the ditches which drain to the sump would have to be carefully regulated in order to achieve optimal efficiency.

3.5. DISCUSSION

GENERAL

Re-mining of tailings could be conducted by a truck and shovel method or hydraulically. Hydraulic re-mining of tailings can be undertaken by one of two basic approaches;

dredging (sub-aqueous) or cutting and slurrying (sub-aerial). Each of these are discussed in the following sections.

TRUCK & SHOVEL

Re-mining of tailings using truck and shovel methods has been conducted at many sites. This approach is likely to be problematic at sites such as Faro and Mt. Nansen where there is a high water table in the tailings. The presence of excess water in the tailings will make it very difficult to effectively excavate and load the material into trucks. Extensive use of geotextile and a constructed road way on the tailings could alleviate this problem. Slopping of the material out of the truck boxes during transport would also be a problem. Operation during winter conditions could help to off-set these concerns, although additional energy from either dozers or blasting would be required to excavate the material.

Although a truck and shovel approach may be effective for some parts of the Yukon projects, such as perimeter areas or final clean up of the original ground surface, this approach is unlikely to be the primary method used. Consequently, emphasis is placed on hydraulic methods in this report.

DREDGING

Dredging is a well established technology for removal of sediment from the base of water bodies. It is practiced around the world in harbors, lakes and rivers. No references were found where it is used for tailings. However, it is understood that this approach is used for recovery of alluvial diamonds in Africa.

It is important to note that a dredge must operate in a body of water. As more solids are removed, the body of water will grow. Careful attention to the mining sequence and water management would be required to avoid a very large pond. The dams associated with the Yukon projects may not have an acceptable factor of safety against failure (seepage and piping) if the tailings are removed from the upstream face. A practical solution could involve a dredge operating in a small stationary pond which is continuously fed with slurry from sub-aerial hydraulic mining, as described in the following section.

Dredging operations typically move a low density slurry, less than 20% solids. In conventional applications this is probably not much an issue because the product is not lifted very high or far. In the case of the Yukon projects the tailings must be moved a significant distance both horizontally and vertically. Consequently, it would be appropriate to carefully consider the power implications associated with moving water in this approach.

CUTTING & SLURRY METHOD

Sub-aerial hydraulic re-mining using cutting and slurrying appears to be a viable approach. Curiously, documented case histories of successful operations are difficult to locate. There are several outstanding issues which must be addressed in the detailed design phase of a project. Based on the review completed to date, the most efficient method of hydraulic mining would involve cutting and washing the material with monitors and removing and transporting the material using submersible pumps. Major components, general operating procedure and outstanding design and operation issues are discussed as follow.

MAJOR COMPONENTS

The major components of a hydraulic re-mining operation would be:

- Remote high-pressure water monitors and associated high pressure pumps,
- A supply of clean water for the high pressure monitors (either off-site water or on-site water which has been clarified by settling/filtering and/or flocculation),
- Submersible agitator pumps, each with a dedicated crane,
- Excavator, dump truck and dozer to construct gravel working pad for the cranes, (depending on the substrate, geotextile may also be required), this equipment may also be required to remove any internal dams, buried causeways, and trestles,
- Pipe lines and booster pumps, as necessary, to transport the material to the discharge location,

- Water treatment system for circulating process water and/or tailings treatment before final disposal,
- Power supply and distribution system,

MINING

The most practical mining method appears to involve excavation of horizontal slices, rather like open pit mining. A full height face of 10 m or more could be opened up in front of a series of sumps for removal of the tailings. The number of sumps would depend upon the desired overall process rate and the pump capacity. Ditches would be excavated from the face to the sumps using the hydraulic monitors. These ditches could be either narrow channels to maintain high velocity or steep cone-shaped funnels to direct the water and tailings into the sumps. In the latter case, the slope of the cone leading to the sump would have to be steeper than the beaches on which the tailings originally deposited. The sumps must be moved periodically. Otherwise, the slope of the ditch will gradually decrease as it becomes longer, resulting in settling of the tailings particles.

Performance of the system will depend, in part, upon the ability of the monitors to liberate the tailings. This will be influenced by the selection and operation of the monitors. A paper which may aid in optimization of monitors may be found at www.wjta.org/Book%201/3_4a_Davies_and_Jackson.pdf .

If practical and safe, mining of the full depth of tailings down to the original ground surface should be conducted. This avoids having to maintain trafficable surfaces on the tailings and minimizes the requirement to move pipelines. It does require maintaining sumps below the original ground surface which could be a problem if bedrock is encountered. There is a safety issue associated with slope failure of the working face, which increases as the face gets higher.

In the case of both the Mt. Nansen and Faro sites, the length of pipe from the tailings pond to the pit will be significant; two or more kilometers. It should be recognized that it will be virtually impossible to operate the entire tailings relocation project without an upset condition resulting in lack of solids and or water flowing to the collection sump. When an upset condition arises movement of tailings in the line will slow or stop. If the tailings settle in the line it may be very difficult to resume operations. A solution to this problem would be to have a surge tank of water, possibly with a dedicated pump to flush the line. The surge tank should have a volume which is equal to the volume of the pipe.

At the Giant Mine, the replacement of submersible pumps with cantilever pumps partially solved the problems with performance. Cantilever pumps will operate with lower maintenance requirements than submersible pumps. However, this is provided at a loss of operational flexibility because they require a rigid platform and some sort of "pump box" in which to operate. This pump box must be placed in an excavated sump. It cannot "dig" its own sump.

Several options could be considered for routing the discharge from the sumps to the final disposal site. A single pipeline leading from each pump, with booster pumps as necessary could be installed. This approach would allow each pump to operate at or near to its peak efficiency. However, there may be a significant cost in pipes, especially if insulated pipes are required. The alternative would involve a single pipeline leading from a central point at which all of the sumps discharge.

A single pipeline leading from a pump box, as is commonly used in many mills could be used. This is a relatively low cost approach. However, the pump discharging from the pump box would often operate a low efficiency due to surges arising from the sumps in the mining area. In cases such as Faro Mine where the tailings must be pumped up several hundred metres in elevation, pump efficiency will have an effect on energy requirements. If the pump box were large enough to provide surge capacity, then the tailings would settle. The solution to this problem would be the installation of a thickener to keep the tailings in suspension. Although a thickener may be costly to install, it may be justified by the saving in pipelines, and improved pump efficiency. Furthermore, excess water could be decanted, thus avoiding the need to pump it up hill.

A single pipeline with a manifold to receive the discharge from multiple sumps is not recommended because of the inefficiency due to back pressure from one pump on another.

This condition would be expected to arise regularly because of variations in slurry density being discharged from each sump.

Mining of the tailings in the perimeter area of the impoundment, and any other areas where the deposit is relatively thin, may require a modified approach. In these areas, buried trees, vegetation and local topography may prevent efficient removal with the monitors. Removal may be conducted using dozers to push the tailings into mounds. These may be reduced in volume by washing some of the tailings away. The balance may have to be removed using conventional truck and shovel methods. It may be difficult for the dozer operator to identify the bottom of the tailings deposit, particularly where the vegetation is sparse. Estimates of the volume of tailings to be removed should include an allowance for a layer of the subgrade material.

4. CONCLUSIONS

The following conclusions are presented:

1. The lack of references to tailings removal in any manner suggests that this is not a common practice in North America (or else rarely documented), even including cases where there is residual mineral value in the tailings.

2. Based upon the number of references found, mechanized mining of tailings is far more common than hydraulic mining. Even some larger relocation projects involving more than a million cubic yards of material were done with truck and shovel.

3. Hydraulic re-mining of tailings is technically viable. It is probably less costly than mechanized mining, if the operational problems can be resolved. Careful characterization of the tailings deposit is essential for success. A pilot operation may also be helpful in resolving some problems before full-scale mining is initiated. It appears that the very early stages of a hydraulic mining operation can be made to work. Success of the overall operation will depend upon how the method is adapted to move across the tailings deposit.

4. Two tailings relocation projects involving hydraulic mining were conducted in Canada. Although these were not entirely successful, some knowledge can be gained by reviewing the discussion on these projects. It appears that a viable methodology has evolved from the lessons of those projects. Virtually no useful information on the cost of hydraulic mining of tailings was found in the literature.

Please contact the undersigned if you have any questions concerning this report.

Brodie Consulting Ltd.

M. John Brodie, P. Eng.

APPENDIX A

RELEVANT REFERENCES

APPENDIX B

PHOTOGRAPHS

TOYO PUMP COMPANY SPECIFICATION SHEET FOR SUBMERSIBLE AGITATOR PUMPS

ECLP – HYDRAULIC MONITOR DATA

Photographs provided by Toyo Pump Company

Photo 1 Close up of hydraulic mining trail showing remotely operated monitor and submersible pump suspended from excavator

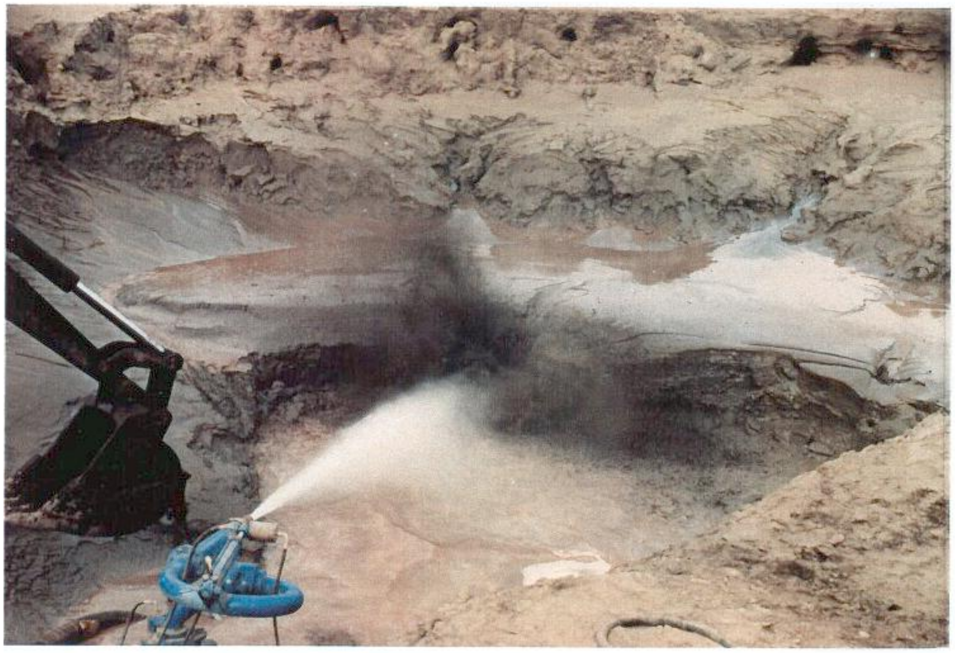
Photo 2 and 3 Same as photo 1 from different view points

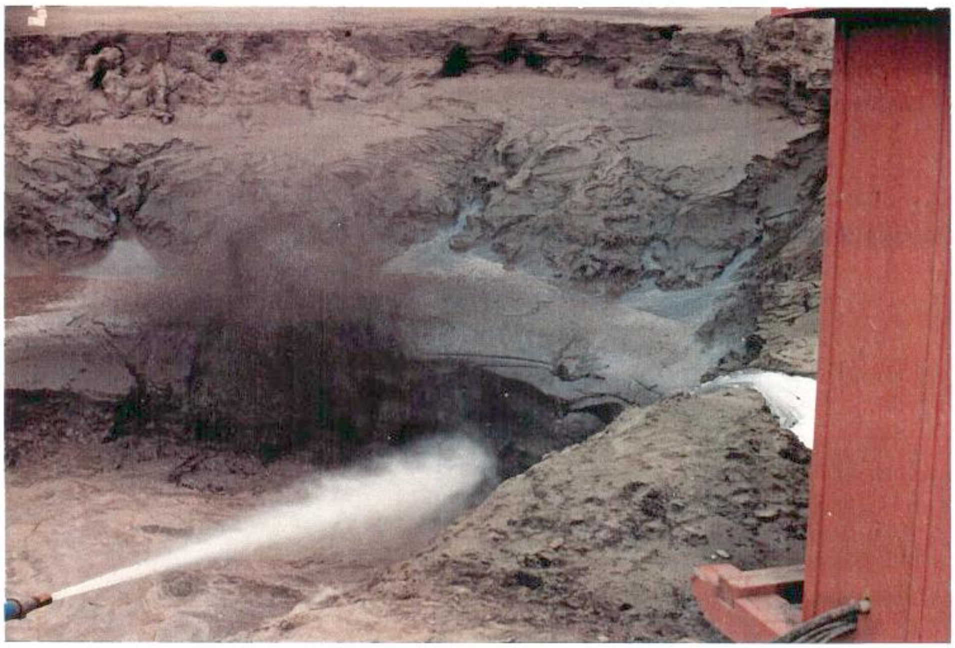
Photo 4 View of North Pond at Giant Mine, looking north from TRP plant

Photo 5 – Giant Mine Central Pond – Note escarpment left by tailings removal. (Brodie Consulting Ltd. 1999)

Toyo Pumps North America Corp.

TAILINGS RECLAMATION





Preproduction tests of hydraulic mining of tailings. Production rates of 60 to 70% solids achieved.

Production pit after more than 1 million tons have been removed by two, 8" Toyo systems. (Toyo is under surface of slurry, suspended by crane.)

TOYO DP – A Serious Pump!

Toyo can pick up and pump rocks up to twice this size

The Toyo DP Pump was specifically designed to pump solids that have settled out of fluid suspension, the very situation in which conventional pumps fail.
The rotating cutter blades of Toyo's built-in agitator will move - from rest - material up to 70% solids by weight into the Toyo impeller. Toyo slurry pumps are built to stand up to the most abrasive applications. Toyo pumps may be combined with booster slurry pumps to move material over long distances.

The Toyo DP Pump was designed to pick up and transport abrasive material, with the least amount of water possible. The DP Pump combines a pump and an excavator in one solid unit. The design incorporates a built in agitator (granted a USA patent) attached directly to the pump shaft. The agitator blades are curved towards the direction of rotation on its upper part, straightening at an oblique angle to the axis of rotation of the lower part. As the agitator rotates, the surrounding settled out material is mixed with fluid into a highly concentrated slurry and fed to the impeller.
The combination of the agitator, the closed impeller with large open passages, the replaceable top and bottom wear plates (all in 28% hardened high chrome iron), the heavy duty shaft/bearing configuration and the custom built submersible motor with a 1.35 service factor result in the most rugged submersible slurry pump available in the world market.

With over 50 years of experience in the most difficult slurry applications, the Toyo DP pump has proved to be the better way to pick up and transport abrasive material.
Toyo submersible pumps are available in either the Model DP electric drive or the Model TO hydraulic drive.

Applications include:

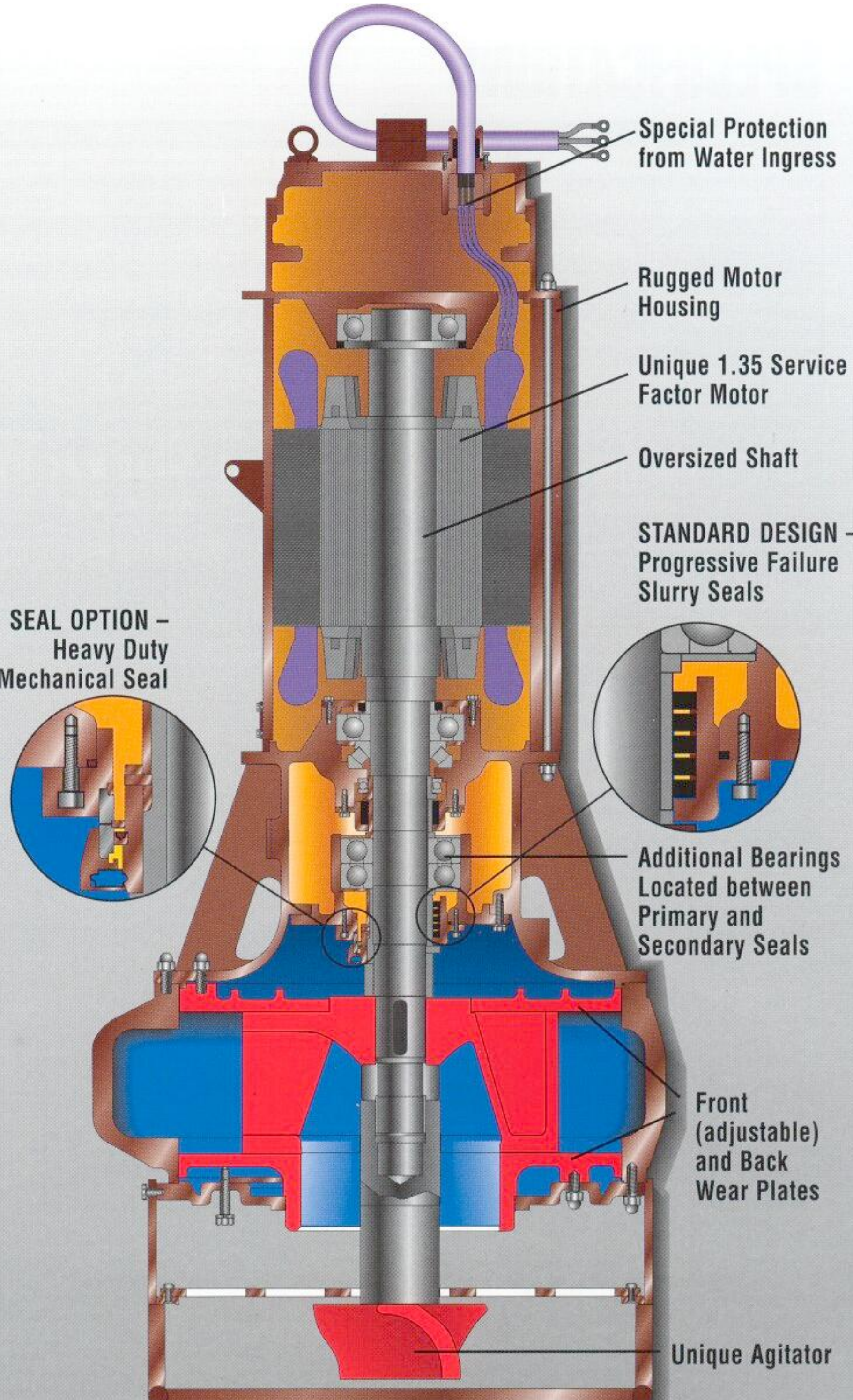
- Tailings Ponds
- Fly Ash / Bottom Ash
- Coal Pile Runoff
- Sand and Gravel Excavation
- Hazardous Waste Clean-Up
- Tank Clean-Out (replace vacuum trucks)
- Clean Out Sumps at
- Cement Plants
- Agriculture Wash-Down Pits (carrots, beets etc.)
- Pipeline Burial
- Dredging out Caissons / Coffer Dams
- Coke Pits
- Mill Scale / Slag Pits
- Barge Unloading
- Dredging Ponds, Marinas etc.
- Silt Removal from Sand and Gravel Collection Ponds
- Removal of filter Media at Waste Treatment Plants

"High Pressure Water Jet Ring mounted on a Toyo DP-50"

In applications where solids are compacted and are difficult to pump, or just where more agitation is desired, Toyo offers a special high pressure water jet ring. This combination has proven to be an extremely effective "agitation team".

Toyo DP-150B sitting on dry dredge spoils.

The Toyo DP-150B Submersible Pump shown here unloading pocket barges. The practical solution to the ban on bottom dumping!



(DP-150B shown - pump weight 7,700 pounds)

OPTIONS AND FEATURES

Heavy-Duty submersible agitator pumps ranging from 3 HP to 600 HP. High Chrome iron standard wear parts.

Options Include:

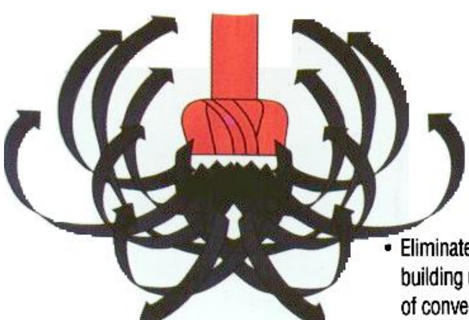
- High Temperature Package
- Hydraulic Drive
- Water Jetting Ring
- Mechanical Seals
- Cooling Water Jackets

Toyo Pumps can move material in applications that were not previously considered pumpable and at less cost than conventional methods. ***Features Include:***

- Abrasion Resistant Metallurgies
- Heavy-Duty Design
- Our 10 inch pump weighs 8,000 lbs.
- Low Operating Speeds
- Replaceable Wear Parts and Easy Maintenance Access
- Pump Includes Front (adjustable) and Back Wear Plates

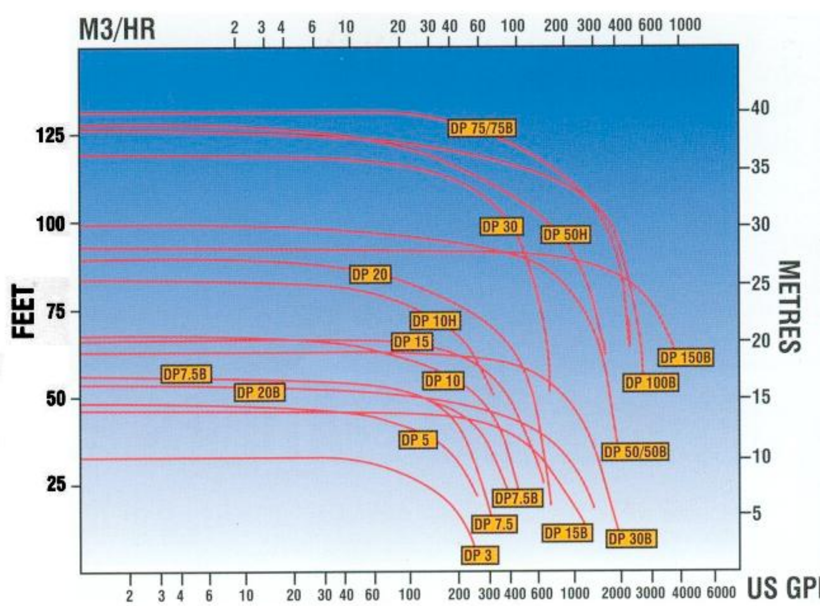
SPECIFICATIONS

MODEL NUMBER	DP-3	DP-5	DP-7.5	DP-7.5B	DP-10	DP-10H	DP-15	DP-15B	DP-20
Discharge diameter - inch (mm)	3(80)	3(80)	3(80)	4(100)	4(100)	4(100)	4(100)	6(150)	4(100)
Flow at rated point-USgpm(m3/min)	132(0.5)	132(0.5)	132(0.5)	264(1.0)	264(1.0)	198(0.75)	400(1.5)	880(3.33)	400(1.5)
Head at rated point - ft.(m)	26(7.9)	39(11.9)	49(14.9)	39(11.9)	49(11.9)	66(20.1)	49(11.9)	24(7.3)	65(19.8)
Imp. - Diameter - in. (mm)	7.08(180)	7.88(200)	8.9(225)	8.9(225)	9.84(250)	10.5(267)	12.6(320)	11.5(290)	13.9(353)
Max. Solid Size - in. (mm)	0.8(20)	0.8(20)	1.0(25)	1.0(25)	1.0(25)	0.55(14)	1.4(35)	2.4(60)	1.4(35)
Weight - lb. (kg)	320(145)	342(155)	430(195)	430(195)	474(215)	474(215)	1036(470)	1124(510)	1212(550)
Standard Motor HP	3	5	7.5	7.5	10	10	15	15	20
Std. Seal	Dbl.Mec,Si	Dbl.Mec,Si	Dbl.Mec,Si	Dbl.Mec,Si	Dbl.Mec,Si	Dbl.Mec,Si	Toyo lip	Toyo lip	Toyo lip
Number of Bearings	3	3	3	3	3	3	4	4	4
Speed (RPM)	1740	1740	1750	1750	1750	1750	1170	1170	1160
Voltage	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575
Motor Protector - Clixon	Included	Included	Included	Included	Included	Included	N/A	N/A	N/A
Thermisters + Relay	Optional	Optional	Optional	Optional	Optional	Optional	Included	Included	Included
Moisture Sensor + Relay	Optional	Optional	Optional	Optional	Optional	Optional	Included	Included	Included
Starting Method	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.
Motor Service Factor	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Electric Cable Length - ft (m)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)
Max. Pumpage Temp. (Standard)	115° F	115° F	115° F	115° F	115° F	115° F	115° F	115° F	115° F
Max. Pumpage Temp. (Optional)	175° F	175° F	175° F	175° F	175° F	175° F	175° F	175° F	175° F
Max. Run Time Motor in Air	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min
Water Jacket	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
MODEL NUMBER	**DP-20B**	**DP-30**	**DP-30B**	**DP-50**	**DP-50B**	**DP-75**	**DP-75B**	**DP-100B**	**DP-150B**
Discharge diameter - inch (mm)	6(150)	4(100)	6(150)	6(150)	8(200)	6(150)	8(200)	8(200)	10(250)
Flow at rated point-USgpm(m3/min)	880(3.33)	400(1.5)	880(3.33)	880(3.33)	1600(6.0)	880(3.33)	1600(6.0)	1600(6.0)	3200(12)
Head at rated point - ft.(m)	33(10.0)	98(29.9)	49(11.9)	82(25.0)	48(14.6)	115(35.2)	95(29.0)	98(30.0)	72(22.0)
Imp. - Diameter - in. (mm)	11.8(300)	16.56(420)	14.0(358)	14.94(380)	14.94(380)	16.92(430)	16.92(430)	21.65(550)	25(635)
Max. Solid Size - in. (mm)	2.4(60)	1.4(35)	2.4(60)	2.4(60)	2.4(60)	2.4(60)	2.4(60)	2.4(60)	4.72(120)
Weight - lb. (kg)	1190(540)	1653(750)	1610(730)	2100(950)	2410(970)	2410(1095)	2450(1113)	4850(2200)	7700(3500)
Standard Motor HP	20	30	30	50	50	75	75	100	150
Std. Seal	Toyo lip	Toyo lip	Toyo lip	Toyo lip	Toyo lip	Toyo lip	Toyo lip	Toyo lip	Toyo lip
Number of Bearings	4	4	4	4	4	4	4	5	6
Speed (RPM)	1160	1185	1185	1185	1185	1185	1185	885	705
Voltage	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	220/460/575	460/575	460/575
Motor Protector - Clixon	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thermisters + Relay	Included	Included	Included	Included	Included	Included	Included	Included	Optional
Moisture Sensor + Relay	Included	Included	Included	Included	Included	Included	Included	Included	Included
Starting Method	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.	D.O.L.
Motor Service Factor	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Electric Cable Length - ft (m)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)	65(20)
Max. Pumpage Temp. (Standard)	115° F	115° F	115° F	115° F	115° F	115° F	115° F	115° F	115° F
Max. Pumpage Temp. (Optional)	175° F	175° F	175° F	175° F	175° F	175° F	175° F	175° F	175° F
Max. Run Time Motor in Air	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min
Water Jacket	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional



- Eliminates downtime due to solids building up and choking off the suction of conventional pumps.
- Reduces maintenance costs in digging out sumps.
- Eliminates solids accumulating on the sump floor.
- Allows pumping of high concentrations of solids.

Toyo is the world leader in Agitator Pumps. The pumps were originally designed based on the agitator, not as an "add-on", to the existing product.



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Appendix C

Draft Report by Zuccolin Consulting on Dredging

1.0 INTRODUCTION

Steffen, Robertson and Kirsten Consulting ("SRK") have retained Fraser River Pile & Dredge Ltd. ("FRPD") and E. Zuccolin Consulting ("EZC") to complete a feasibility study, conceptual plan and preliminary cost estimates to relocate the Rose Creek mine tailings at the Anvil Range Mining Complex.

The Anvil Range Mine, a former lead-zinc mine, is located in the central Yukon, approximately 200 km north of Whitehorse and 22 km north of the Town of Faro. The single impoundment facility, Rose Creek tailings impoundment, is located 2 to 4 km south of the Faro open pit mine site. The mine has been inactive for a number of years and is being managed by a year round staff and mine maintenance crew, dealing primarily with environmental and water treatment and water management issues.

Based on the assignment terms of reference prepared by SRK, this study will focus on two options:

- **<u>Option 1:</u>**
    - the total relocation of the Rose Creek tailings, approximately 57.0 million tonnes of mine tailings

    and

- **<u>Option 2:</u>**
    - the partial relocation of the Rose Creek tailings, approximately 43.0 million tonnes of mine tailings

The other significant assignment terms of reference are as follows:

- 100% of the relocated Rose Creek mine tailings (partial or total relocation options) will be deposited into the Faro pit

- the on site project pumping duration will be a maximum five years for the total relocation (57.0 million tonnes) option

- the on site project pumping duration will be a maximum five years for the partial relocation (43.0 million tonnes) option

- the partial relocation option assumes that the difference between total and partial relocation volume (14.0 million tonnes) is primarily in the lower elevations of the entire Rose Creek tailings impoundment area

- dredging operations will be performed by the local mine staff and crews, and the project will employ a full-time experienced dredging engineer and/or dredging operations specialist to assist in the daily operations and planning

- local mine staff and crew will be specially trained to operate and maintain the dredging equipment

- dredge (tailings) pumping operations will shutdown for the winter months (November 1st to March 31st)

- equipment maintenance work will performed by the dredge operation crews during the winter shutdown period

- dredge (tailings) pumping operations will operate for seven months per year (April 1st to October 31st)

- dredge water management is based on a closed dredge/return water system with no water related downtime or restrictions

- a water balance and water management study will be completed by others

- cost estimates will include both diesel and electric power options

- comments on the power generation opportunities associated with the dredge return water from the Faro pit will be provided

- the final clean-up (the bottom 1 to 2 m) of the Rose Creek tailings impoundment facility will be completed by conventional truck and shovel operations and the costs will not be included in this report

The report and the cost estimates will also include recommendations on the dredge plant selection, dredge support equipment, overall power requirements, crewing, training, maintenance and pipelines.

2.0 EQUIPMENT SELECTION CRITERIA

The following tailings properties, production criteria and site characteristics were used in the selection of the dredge equipment:

MINE TAILINGS CHARACTERISTICS AND PROPERTIES:

- In-situ Void Ratios 0.73 to 0.92
- In-situ Dry Density 1770 kg/m^3
- Mean Specific Gravity 3.86
- Specific Gravity Ranges 3.1 – 4.5
- Tailings Grain Size Silt and fine to med. sand

PROJECT DURATION AND PLANT PRODUCTION:

- **OPTION (1) TOTAL RELOCATION - 57.0 Million Tonnes**
    - Conversion to bank cubic metres (BM^3) @ 2.0 T/BM^3
    - Assume approx**. 28.5 Million BM^3**
    - Project duration (maximum) 5 years
    - Average annual production @ **5.7 Million BM^3/yr.**

- Operating (pumping) months @ 7 months/yr.
- Operating (pumping) days per year @ 205 days/yr.
- Average operating (pumping) hrs/day @ 20.0 hrs/day
- Required average production per hr @ **1,600 BM^3/hr**

- **<u>OPTION (2) PARTIAL RELOCATION - 43.0 Million Tonnes</u>**

  - Conversion to Bank M^3 @ 2.0 T/BM^3
  - Assume approx. **21.5 Million BM^3**
  - Project duration (maximum) 5 years
  - Average annual production @ **4.3 Million BM^3**
  - Operating (pumping) months @ 7 months/yr.
  - Operating (pumping) days per year @ 205 days/yr.
  - Average operating (pumping) hrs/day @ 20.0 hrs/day
  - Required average production per hr. @ **1,200 BM^3/hr**

DREDGE PUMPING DISTANCES AND ELEVATIONS:

- **OPTION (1) TOTAL RELOCATION:**

Average pumping distance to pit:	3,000 m
Minimum pumping distance to pit:	2,200 m
Maximum pumping distance to pit:	4,000 m
Average tailings elevation (approx.):	1,045 m
Highest tailings elevation:	1,070 m
Lowest tailings elevation (approx.):	1,020 m
Highest crest elevation:	1,180 m
Faro pit entrance elevation:	1,145 m

- **OPTION (2) PARTIAL RELOCATION:**

Average pumping distance to pit:	2,800 m
Minimum pumping distance to pit:	2,200 m
Maximum pumping distance to pit:	4,000 m
Average tailings elevation: (approx.)	1,059 m
Highest tailings elevation:	1,070 m
Lowest tailings elevation: (approx.)	1,042 m
Highest crest elevation:	1,180 m
Faro pit entrance elevation:	1,145 m

3.0 DREDGE OPERATIONS, SCHEDULE & MINING PLAN

3.1 DREDGE GENERAL ARRANGEMENTS:

- The appropriate cutter suction dredge for this project will have the following basic operating elements:
  - Basket cutterhead or Bucketwheel cutterhead to cut, break up and agitate the tailings to form a slurry before entering the submerged suction mouth
  - Ladder supporting the cutterhead and suction pipe that is raised and lowered by cables and winches
  - Centrifugal main pump with 3 or 4 Vane Impellor powered by diesel or electric drive motors
  - Portable pontoons that will be connected to form the dredge hull that supports the dredging and operating equipment
  - A two spud system at the stern of the dredge hull to act as an operating swing pivot for the dredge and/or a 3 to 5 wire anchoring system to swing and move the dredge hull
  - A floating discharge pipeline (supported by pontoons or pipe float collars) from the stern of the dredge to a land based connection to the land portion of the discharge pipeline. This pipeline will likely be a high density polyethylene (HDPE) line, however a steel pipeline or combination of steel and plastic would also be considered

- Dredge operations support equipment would include the following:

    - specially modified tug boat with a bow a-frame/winch configuration to handle anchors, pipelines, spare parts, dredge obstructions, etc.,
    - fuel, spare parts and equipment repair barge
    - crew change/survey/first aid support boat
    - power cable-reel barge (for the electrical power alternative)

3.2 DREDGE SELECTION & OPERATIONS:

- The size of the suction dredge(s) recommended for the tailings relocation project:

- **Option 1 – Total Relocation: 700 mm CS Dredge**

- **Option 2 – Partial Relocation: 600 mm CS Dredge**

These dredges are the minimum size required to complete the tailings relocation project(s) within the specified (maximum) five-year completion period.

Both options will require a land based booster station to maintain the target productivities, slurry densities and slurry velocity.

The two dredge sizes recommended fall comfortably within standard industry sizing for portable suction dredges. Portable suction dredges of this sizing are available from several different manufacture(s) in the U.S.A., Europe and Asia. We would recommend that during the next phase of this project, Ellicott, a major U.S. dredge manufacture out of Baltimore and IHC, probably the world leader in dredge design and construction, from Holland, should be contacted for pricing and design proposals.

The final selection on dredge size(s) can be fine tuned at a later date subject future studies and project related decisions on overall schedule, water balance/water management issues, dredge slurry pumping analysis, detailed costing analysis, diesel versus electrical power options, etc. For example, it would be possible to shorten the project duration down to 2 to 3 years by increasing the dredge sizing and horsepower (not recommended at this time for economic and portability issues) or, by having two dredges operating at the same time (this option may have some merit and could be considered in some future study). The above noted recommended dredge sizes are the most cost effective portable dredges that best meet the current overall project criteria and objectives.

Dredge design details such as cutterhead vs. bucketwheel, spud carriage, spuds vs wires, ladder length, underwater pump, pump impellors, etc., are unnecessary for this stage of study. Industry standard configuration of the dredge components have been assumed for the production analysis and preliminary cost estimates.

The dredge and booster station will require special design and construction to best meet the overall project criteria. The dredge design specifics need not be addressed for this stage of study and are best left to a later and more detailed project study.

The results of a comparison of electric versus diesel powered dredge and booster can be summarized as follows:

- Electric Power advantages/disadvantages:

    - lower overall power consumption costs
    - environmentally cleaner
    - lower equipment maintenance costs
    - easier to automate operational functions
    - power cables to dredge have negative operational issues
    - equipment maintenance personnel not has familiar as with diesel
    - not standard in the industry and would be an economic issue on re-sale at the end of the project
    - spare parts may not be as readily available as diesel
    - initial higher equipment capital costs
    - larger hull require to support electrical equipment

- Diesel Power advantages/disadvantages:

    - higher overall power consumption costs
    - environmental risks with handling diesel on site
    - higher equipment maintenance costs
    - experienced maintenance personnel are readily available
    - standard in the industry and will have a significantly higher market worth on re-sale at the end of the project
    - spare parts are readily available
    - lower initial equipment capital costs

Based on the electric versus diesel power comparison noted above, the following recommendations are made:

Both diesel and electrical powered equipment options will be considered for the cost estimates in this study.

Electrical power generation from the Faro pit return water system may provide the project with an opportunity to produce some efficient and low cost electricity to supplement the overall project power requirements. The electrical power generated from the return water system could well be used to provide some of the power requirements for the land based booster pump station. This potential electrical power generation option should be considered in any future study to further develop and refine the cost estimates for this project.

3.3 DREDGE MINING PLAN:

It is not necessary to complete a detailed mining/dredge plan at this early stage in the project development. However, it is appropriate to broadly define a dredging sequence.

It is recommended that the suction dredge start pumping operations in the Original Impoundment Tailings Pond at or near the shoreline generally in alignment with the land based pipeline. An initial start up pond will need to be excavated to assemble the dredge in the dry and then when the dredge is completely assembled, the pond will be flooded for the dredge operational start up.

The initial start-up pond (excavation) will be approximately 150 m by 300 m and have a water depth capacity of approximately 3.5 m.

The dredge will start cutting and pumping the tailings to a defined elevation. The dredge would generally be cutting the tailings in approximately 1 to 2 m cuts. As the dredging proceeds, make-up water and return water will need to be controlled and balanced to maintain a constant or controlled pond elevation. It is assumed that the pond water elevations will be controlled and maintained to maximize dredging productivities and the optimal average dredging depths for the dredge design. A detailed mine/dredging plan will address and optimize the number of cuts, passes, bank cut heights, water balance issues, etc. in a future study.

The dredging sequence would first see the completion of the Original Impoundment Tailings Pond down to the original ground contours or as close to the original ground contours as economic, before moving the dredging operations to the Second Impoundment Tailings Pond. The suction dredge will remove has much tailings in the final ground line contour cut as economically practical. The depth and volume of remaining tailings will be determined by the amount of original ground vegetation and rubble that will impact and reduce the dredge productivity to a predetermined uneconomical levels. It is difficult, at this time, to quantify the remaining volume, but based on the site visit discussions with the senior mine personnel, it would be reasonable to conclude that the dredge will be able to maintain its targeted productivities to within the final 1 to 2 m from the original ground contours. The dredge operations could continue to remove tailings in the last 0 to 2 m. at lower productivities and resulting higher unit costs, this operation could proceed as long as the overall unit costs remain lower than other tailings removal alternatives (i.e. truck and backhoes). A cost benefit and sensitivity analysis will require a more detailed effort as part of any further study.

The dredging operations may encounter some undredgeable trash materials and/or large obstructions during the course of the dredging project. Depending on the type of obstruction and material encountered the dredge will first attempt to work its way around the obstruction and if unsuccessful the obstruction will be removed utilizing either the tug boat/A-frame and divers or by mounting a crawler crane (complete with clamshell bucket) or a long stick backhoe on a barge to clam or grab the obstruction and place it onto a barge for removal/disposal on shore.

The dredging operation may not be able to remove the initial waste rock starter dykes constructed due to the large size of the waste rock. As definitive construction details of the starter dykes are not available, it is assumed that the waste rock starter dykes originally constructed with trucks and dozers, will not be suitable for removal by the suction dredge.

It is assumed that the waste rock starter dykes will be removed by truck and hoes following the completion of the tailings dredging operation and dewatering of the tailings ponds.

The dredging operation will move from the Original Impoundment Tailings Pond to the Second Impoundment Tailing Pond by first removing and breaching the starter dyke dividing the two ponding areas, sufficiently such that the dredge can work its cuts to open a new starter pond in the Second Impoundment Tailings Pond. The pond water elevations will be controlled to manage this transitional operation. The starter dyke will be replaced behind the dredge once the dredge has excavated a suitable working area in the Second Impoundment Tailings Pond. At this time, the water remaining in the Original Impoundment Tailings Pond could be pumped out and/or used for make up water for the Second Impoundment Tailings Pond.

The dredging operations will continue in the Second Impoundment Tailings Pond and the Intermediate Impoundment Area repeating the dredging operation cuts and sequence similar to the Original Tailings Impoundment Pond.

A detailed dredge mining execution and dredge cut plan would be developed during a subsequent stage of the project.

3.4 DREDGING WATER BALANCE PARAMETERS:

A dredge water balance study has not been prepared as part of this study. However, a detailed water balance would be required to better define the dredge design, the dredge mining plan and cost estimates for any further studies.

The following may provide some insight into the basic water balance requirements:

- Based on an average dredge tailings pipeline slurry concentration of 20% tailings by volume:
    - 1 m^3 of dredge slurry equals 0.20 m^3 of tailings

  and
    - 1 m^3 of dredge slurry equals 0.80 m^3 of water
- Assuming that the in-situ tailings have an average water content of 20% water by volume:
    - 1 m^3 of in-situ tailings equals 0.80 m^3 of tailings

and

- 1 m^3 of in-situ tailings equals 0.20 m^3 of water

- Therefore, to transport 1 m^3 of in-situ tailings via pipeline would require 3.2 m^3 of water

Therefore, the minimum make up/return water requirements to maintain a constant dredge pond water elevation would be as follows:

- **Option 1:**
  - Based on an estimated hourly in-situ BM^3 production of 1,600 BM^3/hr, the minimum make-up/return water requirements will be approx.:
    - (3.2 m3 – 0.2 m3) + (1.0 m^3) x (1,600BM^3/hr.) = 6,400 m^3 of water per slurry pumping hour
    - estimated per day make-up/return water requirements = (22 avg. pumping hrs/day x 6,400 m^3/hr.) = **140,800 m^3 per day.**

- **Option 2:**
  - Based on an estimated hourly in-situ BM3 production of 1200 BM^3/hr. the minimum make up/return water requirements will be approx.:
    - (3.2 m3 – 0.2 m3) + (1.0 m3) x (1,200 BM^3/hr.) = 4,800 m^3 of water per slurry pumping hour
    - estimated per day make up/return water requirements = (22 avg. pumping hrs/day x 4,800 m^3/hr) = **105,600 m^3 per day.**

The initial pond excavation to be used to assemble the dredge in the dry and then to be flooded for the start of the dredging operations will be approx. 150 m by 300 m. The minimum depth of water required for floatation and start up dredging operations should be 3.5 m. Therefore, the minimum volume of water required to flood the pond to commence dredging will approx. 160,000 m^3 of water.

The above is a simplified approach to the dredging water balance analysis. A much more detailed water management and water balance study will be required at some later date that will be part of a more refined dredge design, dredging/tailings mining plan and cost estimates.

The dredge and pumping operations will proceed on a 7 day per week / 24 hrs/day, 8-hour crew shifts and the crews would rotate shifts every two weeks during the seven-month long dredge pumping season. During the five-month winter shutdown period, a preventative maintenance program that deploys the key operating personnel would insure operational continuity and targeted productivities.

4.0 PRELIMINARY COST ESTIMATES:

The preliminary cost estimates are based on the mine purchasing all the project dredging equipment, pipelines and support equipment, the training of existing mine personnel to supervise, operate and maintain the dredging equipment, operating the dredging equipment, maintaining the dredging equipment year round and the recapture of a percentage of the original purchase costs by selling the equipment at the completion of the tailings relocation project.

The tailings dredging operations will be completed within a four and half year construction period. The general site operations and supervision have been carried for a five year period.

An alternative approach to the above would be to take a dredging contractor/competitive bid perspective to costing out the project. At this time, we do not see a significant cost differential advantage and/or any significant operational advantages do warrant this review.

However, it is our recommendation that the dredging contractor/competitive bid alternative should be considered and reviewed in any future study.

The preliminary cost estimates are +/- 30%

OPTION 1 - Total Relocation of Tailings (57.0 Million Tonnes)

- **Diesel Powered Alternative:**
  - **700 mm Portable Cutter Suction Dredge, 700 mm Land Based Booster Pump Station, 700 mm Pipelines, Dredge Support Equipment**
  - **: Initial Capital Costs:**

▪ CS Dredge	$20,000,000
▪ Booster Station	$ 4,000,000
▪ Pipelines	$ 7,000,000
▪ Support Equipment	$ 2,000,000
• Sub-Total	$33,000,000
▪ Less: Re-capture (end of project sale)	$12,500,000
• Total Net Capital Costs:	$20,500,000

- **Dredging Operations:**

  - Mobilization and Initial Set Up $ 3,000,000
  - Demobilization – Site Work $ 2,000,000
  - Dredge Operations - Daily Costs:
  - Total Direct Operating Costs:
    - 4.5 Years @ $22,000,000/yr.= $99,000,000
  - General Site Expenses:
    - 5 Years @ $1,000,00/yr. $ 5,000,000

▪ Total Costs - Dredge Operations:	$109,000,000

• **Total Costs: Option 1 (Diesel)**	**$129,500,000**
• **Total Unit Cost per Tonne**	**$2.27 per Tonne**
• **Total Unit Cost per BM^3**	**$4.54 per BM^3**

OPTION 2 – Partial Relocation of Tailings (43.0 Million Tonnes)

- **Diesel Powered Alternative:**
  - **600 mm Portable Cutter Suction Dredge, 600 mm Land Based Booster Pump Station, 600 mm Pipelines, Dredge Support Equipment**
    - **Initial Capital Costs:**

▪ CS Dredge	$17,000,000
▪ Booster Station	$ 3,000,000
▪ Pipelines	$ 6,000,000
▪ Support Equipment	$ 2,000,000
• Sub-Total	$28,000,000
▪ Less: Re-capture (end of project sale)	$11,000,000
▪ Total Net Capital Costs:	$17,000,000

- **<u>Dredging Operations:</u>**

  - Mobilization & Initial Set Up $ 3,000,000
  - Demobilization – Site Work $ 2,000,000
  - Dredge Operations – Daily Costs:
  - Total Direct Operating Costs:
    - 4.5 Years @ $18,000,000/yr.= $81,000,000
  - General Site Expenses:
    - 5 Years @ $1,000,000/yr. $ 5,000,000

Total Costs - Dredge Operations:	$91,000,000

Total Costs: Option 2 (Diesel)	**$108,000,000**
Total Unit Cost per Tonne	**$2.51 per Tonne**
Total Unit Cost per BM^3	**$5.02 per BM^3**

OPTION 1 – Total Relocation of Tailings (57.0 Million Tonnes)

- **Electrical Powered Alternative:**
  - **700 mm Portable Cutter Suction Dredge, 700 mm Land Based Booster Pump Station, 700 mm Pipelines, Dredge Support Equipment**
    - **Initial Capital Costs:**

▪ CS Dredge	$25,000,000
▪ Booster Station	$ 5,000,000
▪ Pipelines	$ 7,000,000
▪ Support Equipment	$ 4,000,000
• Sub-Total	$41,000,000
▪ Less: Re-capture (end of project sale)	$13,000,000
• Total Net Capital Costs:	$28,000,000

- **<u>Dredging Operations:</u>**

  - Mobilization and Initial Set Up $ 3,000,000
  - Demobilization – Site Work $ 2,000,000
  - Dredge Operations – Daily Costs:
  - Total Direct Operating Costs:
    - 4.5 Years @ $17,000,000/yr.= $76,500,000
  - General Site Expenses:
    - 5 Years @ $1,000,00/yr. $ 5,000,000

  - Total Costs - Dredge Operations: $86,500,000

• **Total Costs: Option 1 (Electric)**	**$114,500,000**
• **Total Unit Cost per Tonne**	**$2.01 per Tonne**
• **Total Unit Cost per BM^3**	**$4.02 per BM^3**

OPTION 2 – Partial Relocation of Tailings (43.0 Million Tonnes)

- **Electrical Powered Alternative:**
  - **600 mm Portable Cutter Suction Dredge, 600 mm Land Based Booster Pump Station, 600 mm Pipelines, Dredge Support Equipment**
    - **Initial Capital Costs:**

▪ CS Dredge	$22,000,000
▪ Booster Station	$ 4,000,000
▪ Pipelines	$ 6,000,000
▪ Support Equipment	$ 4,000,000
• Sub-Total	$36,000,000
▪ Less: Re-capture (end of project sale)	$11,000,000
▪ Total Net Capital Costs:	$25,000,000

- **<u>Dredging Operations:</u>**

  - Mobilization & Initial Set Up $ 3,000,000
  - Demobilization – Site Work $ 2,000,000
  - Dredge Operations – Daily Costs:
  - Total Direct Operating Costs:
    - 4.5 Years @ $15,000,000/yr.= $67,500,000
  - General Site Expenses:
    - 5 Years @ $1,000,000/yr. $ 5,000,000

  - Total Costs - Dredge Operations: $77,500,000

• **Total Costs: Option 2 (Electric)**	**$102,500,000**
• **Total Unit Cost per Tonne**	**$2.38 per Tonne**
• **Total Unit Cost per BM^3**	**$4.77 per BM^3**

- **<u>Cost Estimate Notes:</u>**

  - **Costs are in 2003 Canadian Dollars**
  - **No inflationary factors added**
  - **All dredging equipment is project specific designed and built**
  - **All dredging equipment is assumed to be diesel powered**
  - **Diesel Fuel was assumed to be available @ $0.80 per litre**
  - **Electric Power assumed to be available @ $0.08 per kwhr.**
  - **All the equipment is purchased at the start of the project and sold on completion**
  - **Annual winter shutdown November 1st to March 1st**
  - **Local mining personnel will be trained to supervise, operate and maintain all the equipment.**
  - **Dredge operating crews will be retained year round and will work on maintenance in the winter shut down periods.**
  - **Costs to not include the clean up of the final 1 to 2 m (from original ground line) of tailings at the bottom of the tailings ponds**

- **Costs to not include the removal of any gravel and rock tailings pond retention dykes**
- **Costs do not include any treatment of the return water from Faro Pit**
- **Dredge pond make up water will be available from the Faro pit and from Rose Creek**
- **Costs do not include any impacts or potential savings/recovery from generating power from the return water system**
- **Costs do not include any Faro Pit ongoing maintenance costs, other than pumping/gravity return water system**
- **Cost Estimate accuracy to +/- 30%**

5.0 SUMMARY & RECOMMENDATIONS:

The relocation of the mine tailings from the Rose Creek Impoundment Ponds back to the Faro Pit can be successfully completed by suction dredging and pipeline methods within the project guidelines given by SRK Consulting.

This study indicates that the electrical powered dredging equipment alternative is the most cost effective alternative, however, the differences as summarized in the table below are not such that we would recommend only pricing out the electrical alternative in future studies.

COST SUMMARY TABLE

	Diesel Power Alternative	Electric Power Alternative
Total Relocation Option 1		
Total Cost	**$129.5 Million**	**$114.5 Million**
Cost per Tonne	**$2.27**	**$2.01**
Partial Relocation Option 2		
Total Cost	**$108 Million**	**$102.5 Million**
Cost per Tonne	**$2.51**	**$2.38**

It is our recommendation that both diesel and electrical power alternatives continue to be considered in any future study.

A number of engineering and technical issues will need to be addressed in future studies to refine the dredging system selection and design, dredge mining plan and cost estimates. The following is a summary of the key issues:

- portable dredge plant detailed design issues
- maximize automation of dredging functions incorporating the latest dredging technology
- dredge and booster pump slurry analysis
- cutterhead analysis and alternatives
- maximize dredging productivities
- tailings dredging/mining plan
- tailings pond dredge cut plan
- water balance study
- water management study
- in-situ tailings sampling program
- in-situ tailings samples to hydraulic dredging laboratories for definitive slurry concentrations, pumping characteristics, pump/parts wear/pipeline friction/cutterhead, etc, analysis and recommendations
- optimize dredge design and productivities

- detailed study of diesel fuel and electrical power consumption, pricing, environmental and availability issues

- cost benefit analysis to generate electrical power from Faro pit return water system

- detailed plan and costing study to clean up the final 0 to 2 m of tailings from the impoundment area floor

- detailed plan and costing to remove and dispose of obstructions and debris in the tailings impoundment ponds

- detailed plan and costing study to remove the undredgeable mine rock and gravel dykes from the tailings impoundment areas

- review and study of local manpower and dredge operations training issues

- comprehensive review and study to determine if an open competitive tender process with selective world wide dredging contractors would be more cost effective and beneficial rather than the in-house purchase and local manpower training and operation approach

Appendix D

Draft Report by ECMP on Hydraulic Monitoring

23 January 2004

Environmental, Civil and Mining Projects (Pty) Ltd
P O Box 783697 Sandton 2146 SOUTH AFRICA
Stratford Office Park – Block 6, c/o Cedar & Valley Road, Broadacres
Tel (011) 705 1111 Fax (011) 705 1908
e-mail: general@ecmp.co.za

Steffen Robertson & Kirsten (Canada) Inc.
Suite 800, 1066 West Hastings Street
Vancouver, B.C.
Canada, V6E 3X2

ATTENTION: MR CAM SCOTT

RE: DRAFT SUMMARY REPORT FOR TAILINGS DAM HYDRO-SLUICING: ANVIL RANGE MINING COMPLEX - TAILINGS RELOCATION

1. INTRODUCTION

Environmental, Civil and Mining Projects (Pty) Limited (ECMP) were appointed by Steffen Robertson & Kirsten Consulting (SRK) to prepare a preliminary cost estimate to hydro-sluice the Rose Creek Mine tailings at the Anvil Range Mining Complex.

2. PROJECT REQUIREMENT

The project requires the relocation of the total Rose Creek tailings volume utilising hydro-sluicing operating techniques (see Webster Report, 1991). It is understood that 50 million tons will be hydro-sluiced at a rate of 4.8 million tons per six-month operating cycle.

3. SCOPE OF WORK

The scope of work includes the following:

i. A review of all the available data (including the Webster report as a baseline) and to confirm an operating methodology.

ii. Highlight the relevant water balance impacts.

iii. Prepare a capital and operating cost estimate, utilising current 2003/2004 rates and taking cognisance of the assumptions made in the latest dredging report.

iv. Prepare a draft summary report to which the Webster report can eventually be appended.

4. ASSUMPTIONS

The following assumptions were adopted for this study:

- 100 % of the hydro-sluiced tailings will report to the Faro open pit.
- The projected hydraulic mining duration for the relocation of 50 Million tons will be 10.45 years.

- Local crews and mine staff will perform hydraulic mining operations (we gather from the dredging report that a full time maintenance crew is on site).

- The project will employ a full time experienced hydraulic mining specialist to assist in the daily operations and planning.

- Local mine staff and crew will be trained to operate and maintain the hydraulic mining equipment.

- Hydraulic mining operations will operate between 15 March and 15 September. On or towards the end of the operational cycle (15 September) the equipment will be disassembled and stored for the winter period and the crew will be laid off. On 1 March the crew will return, and weather permitting will re site establish, and commence operation.

- Equipment maintenance will be ongoing throughout the operating cycle.

- The water management circuit will be on a closed system with no water related downtime or restrictions.

- Costs estimates for power usage were taken from the Dredge Report and Curragh Resources Report.

- The hydro-sluicing operation will be a top - down and downstream operation thereby facilitating final clean up and contouring as an ongoing part of the operation.

- The hydraulic monitoring guns will be sourced in South Africa and manufactured for "site specific" conditions.

- All other equipment (i.e. pumps, pipes, earthmoving equipment, etc.) will be purchased or hired in Canada.

5. WATER BALANCE IMPACTS

The water balance impacts can be summarised as follows:

- Spray losses will be minimal due to the proposed top-down and downstream mining method that will be followed.

- The target slurry density for the slurry product is 1.45. Seepage losses are therefore expected to be minimal.

- The system will be operated as a closed system and excess water will be pumped to the Faro pit.

- By adopting a downstream mining method, the area already monitored (upstream) will be progressively rehabilitated by removing slime material mechanically and then constructing contour walls and berms. Precipitation run-off will be allowed to flow into the nearest watercourse.

6. CALCULATIONS

The design calculations can be summarised as follows:

Table 1: Design Criteria
Design Parameter

Life in Years	10.42		
Life in Months	125		
Reserves	50,000,000		**Water Contingency**
Tonnage	800,000		
Daily	26,316		10.00%
Hourly	1,096		1799.94
Number of Guns		**5.52**	499.98

A. Slurry Calculations

Insitu Density	SRD	**3.000**	
Slurry Density	SRD	**1.450**	
Solids specific gravity	SSG	**3.68**	
Availability		**90**	%
Hours per day	**24**	21.6	Hrs
Days per month		**30.5**	Days
Specific gravity, water	SG	**1.000**	

Calculations for 1 (one) gun only

Solids by weight	42.61%	%
Solids by volume	16.79%	%
Total volume	356	m^3/hr
Water volume	296	m^3/hr
Water volume	**82.28**	**l/s**
Solids volume	60	m^3/hr
Total tonnage	516	tph
Water tonnage	296	tph
Solids tonnage	220	tph
Solids tonnage	144,811	tph

B. Orifice Calculations

Gun diameter	D	150	mm
Pressure	H	32	BAR
Orifice diameter	D	47	mm
Temperature of liquid	T	15	Deg C
Viscosity of liquid	v	1.141	mm^2/s

Calculations

Reynolds number	Rd	612079	
Sizing factor	Sm	0.0592	
Beta ratio	Beta	0.31	
Liquid flow rate	Q	296.19	m^3/hr

Calculations for total guns required

Total volume	1967	m^3/hr
Water volume	1636	m^s/hr
Water volume	**454.53**	**l/s**
Solids volume	330	m^3
Total tonnage	2851	tph
Water tonnage	1636	tph
Solids tonnage	1215	tph
Solids tonnage	800,000	tpm

7. HYDRO-SLUICING OPERATIONS

7.1 Hydraulic Monitoring Guns - General Arrangement

- Six operating hydraulic monitoring guns are required with four additional monitoring guns on standby or being relocated.
- The hydraulic monitoring guns will be mounted on skids for stability purposes with the option to fill the skids with water for additional weight.
- The hydraulic monitoring guns will be electrically operated from a weatherproof cabin.
- The cabin will be on wheels and elevated to ± 2 metres above ground level, thereby allowing the operator full visibility of the operation.

7.2 Mining Plan

We believe that it is meaningless to present a mining plan at this stage of the study, since we have not had an opportunity to visit the site.

7.3 Operations

A collector sump will be constructed at a topographical low point. The hydraulically mined tailings will gravitate via a mechanically excavated trench or a hydraulically mined gully to the sump. The sump will be constructed of reinforced concrete with self-cleaning screens over the sump to screen off the plus 50mm material. The slurry will then be pumped to two elevated vibrating screens, which will screen out the plus 3mm fraction.

Below these screens will be a 7m high, 4m diameter header tank with an agitator. The header tank will feed a train of seven Warman 14 x 12 Pumps, or similar, which will then pump the material to the Faro Pit.

7.4 Preliminary Cost Estimate

A breakdown of the costs can be summarised as follows (Boundary limit: from the main water line at the top of the tailings dam to the screens at the gravity fed slurry sump):

Table 2: Cost Breakdown

% Split on Contract Elements	
Total contract period in months	125.00
Monthly Tonnage	**800,000**
Total Reserves	**50,000,000**

Operations	Canadian $: Cost	Split %
Salaries	14,950.00	0.04
Vehicles	0.00	0.00
Wages	184,062.23	0.45
WD O/Time	4,922.50	1.21
SD O/Time	0.00	0.00
Stat Holidays	2,047.76	0.50
Shift Allow	1,230.59	0.30
Medical	5,805.45	1.42
L.O.A.	0.00	0.00
Training	1,225.68	0.30
Bonus or other Payments	0.00	0.00
Severance Pay	1,422.06	0.35
Office	500.00	0.12
P.P.E.	567.19	0.14
Stores	418.58	0.10
Sundry	66.67	0.02
Travel	1,833.16	0.45
Services	350.52	0.09
Maintenance	13,209.98	3.24
Contingency	23,261.24	5.70
Power Consumption	71,106.23	17.42
Plant	30,000.00	7.35
Fuel	2,733.33	0.67
Contingency	3,273.33	0.80
Total Overheads	26,534.57	6.50
EQUIPMENT AMORTISED	**Canadian $**	
Monitoring Capital Equipment	18,730.98	4.59
TOTAL	**408,252.06**	**100.00**

Assumptions:

- The hydro-sluicing team will operate 7 days per week, 24 hours per day at 90% utilisation. Three 8-hour shifts will be implemented with shift rotation as required by law.
- The preliminary cost estimate is based on the mine purchasing and installing all the hydro-sluicing equipment, pipelines and support equipment, mobilizing and demobilizing the staff and accommodating the staff.
- All rates are based on a project, Lamaque Mining in Val'd Or Quebec. The latest dredging rates were used as a check and we believe that the accuracy should be ± 30%. No allowance has been made for profit or interest on capital.

	Canadian $
Base Rate	**337,145.82**
Variable Rate $ /Ton	**0.09**
Total $ per Ton Operating	**0.51**
TOTAL MONTHLY COST OF CONTRACT	**337,856.89**

First operating cycle:

Site establishment and set up: 1st cycle		= C$ 717,611.07
Cycle cost	C$ 337,856.89 x 6 months	= C$ 2,027,141.34
Total first cycle costs		**= C$ 2,744,752.41**

In the second cycle the site establishment costs are less because there is no equipment to transport to site.

Second operating cycle and following cycles:

Site establishment and set up	= C$ 158,813.02
Cycle cost	= C$ 2,027,141.34
Total second cycle cost	**= C$ 2,185,954.36**

TOTAL OPERATION COST (for 50,000,000)

First Cycle	= C$ 2,744,752.41
Second Cycle	= C$ 2,185,954.36
Third Cycle	= C$ 2,185,954.36
Fourth Cycle	= C$ 2,185,954.36
Fifth Cycle	= C$ 2,185.954.36
Sixth Cycle	= C$ 2,185.954.36
Seventh Cycle	= C$ 2,185.954.36
Eight Cycle	= C$ 2,185.954.36
Ninth Cycle	= C$ 2,185.954,36
Tenth Cycle	= C$ 2,185.954.36
Last cycle	= C$ 2,185.954.36
Total cost for hydro-sluicing 50 million tons	**= C$ 22,418,341.65**

We have not included or done any pricing for the support equipment as this is well documented in both the Dredging report and Curragh Resources report.

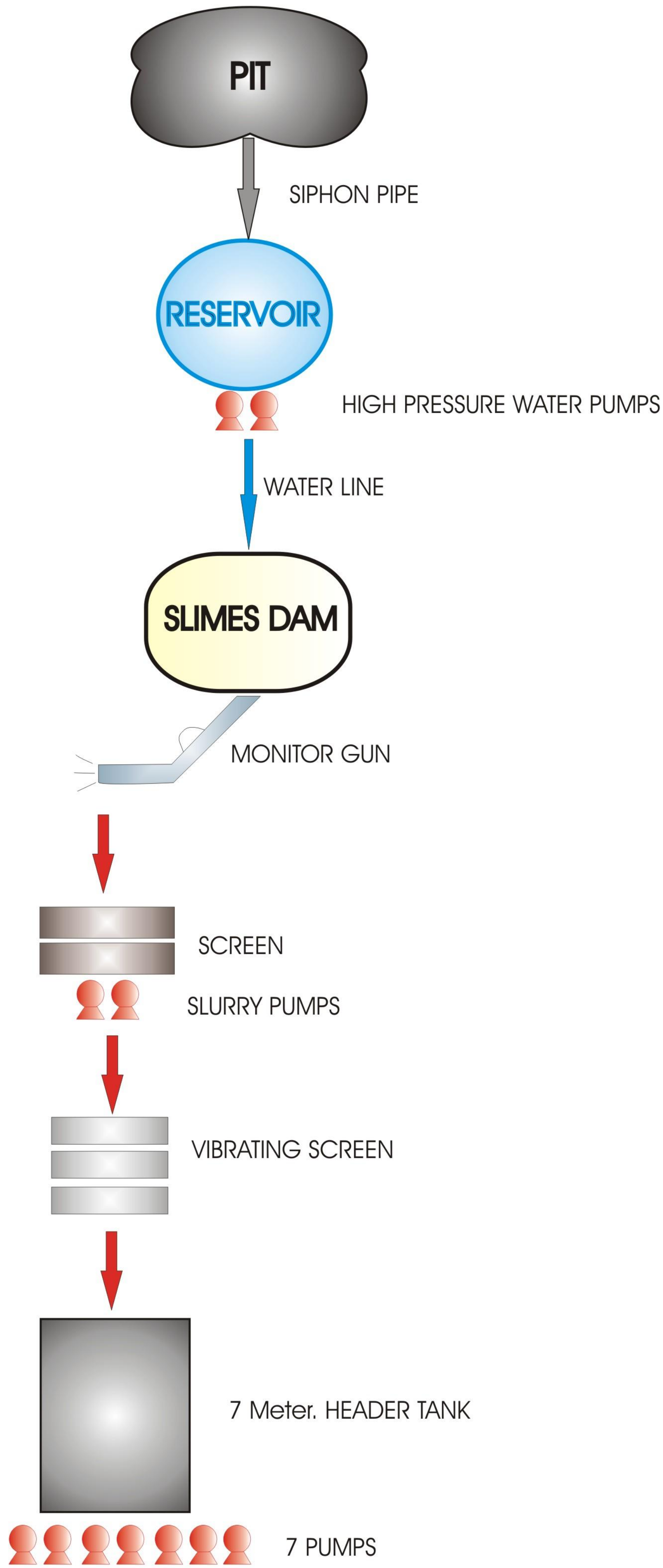
Additional Notes:

- Costs are in 2003 Canadian Dollars.
- No inflationary factors added.
- All hydraulic mining equipment is project specific and is designed and manufactured accordingly.
- Diesel fuel is assumed to be available at C$0.80 per litre.
- Electric power is assumed to be available on top of the dam.
- All the hydraulic mining equipment is to be purchased by the mine.
- Local mining personnel will be trained to supervise, operate and maintain all the equipment.
- Costs do not include removal of non-slurry material e.g. gravel, rock, or retention dykes.
- Water for the re-mining operation to be available at the top of the dam at 32 bar pressure.
- Costs do not include maintenance of the support equipment.

We trust that the above meets with your approval. Please do not hesitate to contact us should you have any queries.

Yours faithfully

DAVE JANSSON **GUILLAUME DE SWARDT**


PIT
SIPHON PIPE
RESERVOIR
HIGH PRESSURE WATER PUMPS
WATER LINE
SLIMES DAM
MONITOR GUN
SCREEN
SLURRY PUMPS
VIBRATING SCREEN
7 Meter. HEADER TANK
7 PUMPS

December 4, 1991

Mr.Gerry Acott P.Biol.
Manager, Environmental Affairs
117 Industrial Road
Whitehorse
Yukon
Y1A 2T8

Dear Gerry:

Reference: Faro Tailings Relocation

As requested, we have completed a preliminary design and cost estimates for an 800 000 t/month tailings relocation system for the Rose Creek tailings. The proposed operation uses water delivered from the Faro pit using an existing siphon supplemented by an additional siphon into a new pipeline. It delivers trash-free tailings (100 % passing 2 mm) into the mill building for reprocessing. The treated tailings are then pumped to the Faro pit using the pumps and pumpbox which are currently being installed. Allowances are included in the estimate to use one of the existing Zinc conditioners as a pumpbox.

I hope we have successfully incorporated all comments into this final version of the report.

We have based the labour operating costs on a 6 month operating season only as we understand that you have included allowances for annual mobilization, start up and demobilization in your report covering the reprocessing. The cost data are for the relocation operation only and do not include for reprocessing or chemical treatment of the tailings. The power costs for pumping to the Faro pit from the mill are shown separately.

The capital cost of the proposed relocation scheme is $6.6 million and operating costs are estimated to be $0.39/t. An average operating season of 6 months should be achievable.

I trust the attached report satisfies your immediate needs. Please call the undersigned, John Goode or Ted Jurgens if any questions arise.

Yours very truly,

KILBORN INC.

R.H. Walton, P.Eng
Senior Metallurgist

RHW/rw

cc: C. Benner, G. Jilson, G. McDonald,
J. Mitchell, J.R. Goode, E. Jurgens,
A. Webster.

wp/3509-32

CURRAGH RESOURCES INC.
FARO MINE
TAILINGS RELOCATION PROJECT

TABLE OF CONTENTS

CURRAGH RESOURCES INC.

FARO MINE

TAILINGS RELOCATION PROJECT

1.0 INTRODUCTION AND SCOPE

In November of 1990, Kilborn Inc. (Kilborn) were contracted by Curragh Resources Inc. (Curragh) to evaluate various options for future tailings deposition and water recycle. The selected method, described in final report No. 3509-28 entitled "Water Recycle and Tailings Deposition Plan", submitted to the Yukon Territory Water Board in July of 1991, was based on environmental and economic considerations. The above study dealt both with the operational phase of tailings management and with the closure related aspects of tailings reprocessing and relocation.

Curragh has since requested that Kilborn conduct a more comprehensive evaluation of the hydraulic monitoring component of tailings relocation using input from a worldwide expert who offers working experience in this field. The report identifies a working methodology for the relocation of the Faro tailings, defines a conceptual mining plan, sizes and locates equipment and includes capital and operating costs for the plan.

In the proposed relocation scheme as outlined in SRK report 60635, it is only necessary to remove the tailings above the 1 044 metre elevation (UTM datum). The remaining tailings will then be allowed to flood behind the Intermediate Dam, which was raised to its final elevation of 1 049.4 metre (1 081.7 metre Down Valley Datum) in October 1991, and a permanent water cover will be established.

This study does not include examination of the metallurgical aspects of reprocessing tailings as Curragh are independently evaluating potential methods to maximise the profitability of reprocessing. No costs are included for the reprocessing of tailings or chemical treatment of the tailings should they not be reprocessed.

The results of this study cannot be considered definitive. The estimates are however sufficiently accurate to be used for preliminary evaluation of the project.

Metric units of measurement are used throughout this report except where specifically noted to the contrary. All costs are stated in fourth quarter 1991 Canadian dollars.

CURRAGH RESOURCES INC.
FARO MINE
TAILINGS RELOCATION PROJECT

2.0 SUMMARY

Kilborn has selected and examined a method for relocation of the tailings which consists of a downstream hydraulic monitoring operation. The proposed operation is described in the report as Alternative 1 in section 3 and uses a single in-dam permanent pump station which pumps slurry to a trash screening plant and booster pumping station located outside of the dam area. Some bulldozing may be necessary where hydroxide crusts have formed or where the tailings depth is insufficient to allow cost efficient monitoring.

In the proposed relocation scheme, only the tailings above the 1 044 metre elevation (UTM datum) are removed. The remaining tailings are then submerged in the man-made lake behind the Intermediate Dam, which was raised to its final elevation of 1 049.4 metre (1 081.7 Down Valley Datum) in October 1991. The relocation rate of 800 000 tonnes per month was selected by Curragh as being the maximum level consistent with a reprocessing operation in the existing mill.

The capital and operating costs for the operation have been estimated as $6,582,000 and $0.39/t respectively for an operation moving 4 800 000 tonnes per year during a 6 month annual operating season. Depending on the bulk density of the tailings, and the exact area which has to be cleared, the operating life of the project will be between 5 and 8 operating seasons.

@ 50¢/tonne
$ 18,850
6,582
$ 25,432
3,233
$ 28,664,900

37,700,000 tonne x .39¢
$ 14,703,000
op
cap + 6,582,000
$ 21,285,000
+ 3,233,000
$ 24,518,000

CURRAGH RESOURCES INC.

FARO MINE

TAILINGS RELOCATION PROJECT

3.0 PROJECT DESCRIPTION

3.1 PRESENT TAILINGS STORAGE AREA

The present tailings storage facilities for the Faro Mine are located in the Rose Creek Valley, below the mine site. The tailings (from east to west) comprise the original 1969 tailings area (approximately 42 hectares), the 1974 tailings area (approximately 62 hectares), the Down Valley Intermediate Dam impoundment (approximately 89 hectares), and finally the Cross Valley Dam, which provides an approximate 22 hectare polishing pond area. These last two dams were both constructed in 1980.

The original dyke system was constructed by the former operators, Cyprus Anvil, in 1969 using borrow materials from excavated glacial tills and sands from the Rose Creek Valley. Tailings were discharged from a single point at the north west corner of the pond with spigotting during the summer months along the inner wall of the dyke, to raise the dyke with tailings sands. The water level in the original tailings area was first maintained by a decant tower. This was modified in 1971 when a surface spillway decant was installed at the eastern end of the pond. An attempt was made to raise the original tailings dyke at the western end using cycloned sand fill. This method was labour intensive and it was decided to employ a dragline to stack the tailings sand from the beach area to raise the dyke. The eastern end of the dyke near the slimes end of the basin was raised using mine waste rock. In the final two summers of operating this area, the dyke was raised further with excavated gravels.

A geotechnical study of the tailings structure carried out by Golder Associates Ltd. (Golder) in the summer of 1973 concluded that the original dykes as constructed by a variety of techniques were not capable of resisting anticipated seismic forces. Consequently, an expanded storage area, the second tailings impoundment, was designed to encompass the original tailings area with an engineered dyke system. The new starter dyke system was constructed in 1974 and completed in 1975. Discharge to this was from a single point discharge adjacent to the starter dyke. Dyke raising was accomplished by mechanical placement of tailings sand borrowed from within the pond area or gravel from the surrounding area. Construction of this expanded tailings area required that Rose Creek be diverted along the base of the south slope of the valley.

It was recognized during the mill expansion in 1980 - 1981 that appreciably more tailings would need to be stored in the valley and consequently a major expansion was undertaken to develop the Down Valley Impoundment Area. New facilities included the construction of the Intermediate Dam for the containment of the tailings solids, and the Cross Valley Dam located 500 metre downstream for decanted supernatant water. The polishing pond between the two dams provided sufficient retention time to permit chemical degradation and settlement of fine particles prior to release into Rose Creek.

Since both dams extended across Rose Creek, it was necessary to undertake a major Rose Creek realignment by a further extension of the 1974 - 1975 diversion. Excavated material from the diversion and additional imported fill was used to create a levee dyke parallel to the diversion channel.

Both dams and diversion channel were designed by Golder as engineered structures with criteria mandated by the Yukon Water Board with respect to flood flow handling and earthworks stability. An operating license was issued subject to the submission of an acceptable abandonment plan. Several consultants reports were prepared and issued on alternative abandonment plans during the period from 1982 to 1985, when the Faro operation was temporarily closed down.

Following resumption of milling operations in 1986, Curragh started depositing tailings into the Down Valley area, from a single point at the east end of the impoundment adjacent to the 1974 dam. The Intermediate Dam originally constructed in 1982 has been raised in stages three times. Each raise has been nominally 5 metre. All raisings have been carried out on the downstream side and involved placement of a number of zones of local natural borrow materials. Special filter zones have been prepared by crushing and screening operations.

A detailed account of the design and construction of the dams and the Rose Creek diversion channel is given in the various reports prepared by Golder in the period from 1980 to 1990.

3.2 TAILINGS RELOCATION METHODS

Although this study is not intended to evaluate alternate methods of tailings relocation, Kilborn has considered dredging and mechanical mining. Dredging is not considered practical for this project as it is usually applied to lake bottom or submerged deposits to allow the dredge to be floated. Mechanical mining could be more expensive than hydraulic monitoring, mainly due to the long haul distance. As the tailings have to enter a reprocessing plant, a repulping section would also be required to accept tailings delivered by truck.

Hydraulic monitoring is a low cost method, from both a capital and operating viewpoint, for removing large volumes of tailings. It is proposed to use this method for the majority of the tailings. Mechanical removal will be used to relocate tailings which are difficult to monitor for reasons such as low depth or hydroxide crusting.

It was decided that any pumps located within the dam boundary would have hydraulic drives to avoid flooding of electric motors. Also, in order to reduce the operating pressures and hence the maintenance of these pumps which operate under an arduous duty, it was decided that a booster pump station would be constructed at the north side of the dam. This is also a convenient location for a combined trash screening plant and monitor water booster station. A specialist consultant, Mr. A.S. Webster, the ex General Manager of East Rand Gold and Uranium Co. Ltd. (ERGO) was contacted regarding methods of hydraulic monitoring. His report is appended, it was with his input that the preferred alternative was developed. Based on his recommendations, normal operating slurry trench gradients to transport the material to the pump station will be 1 in a 100, and in the final stages of dam clean-up this will be reduced to 1 in 150.

3.3 ALTERNATE HYDRAULIC MONITORING METHODS

Selected Alternative (Alternative 1). The selected hydraulic monitoring method consists of downstream monitoring with a permanent pump station located at the end of a trench in a deep excavation.

This option has a number of similarities with the McIntyre reclamation site at the ERG project. Although this project was not a financial success, the hydraulic monitoring of tailings was effective and tailings tonnages in excess of 1.2 million tonnes per month were successfully and economically moved by this method. The technique is also widely used in South Africa for large above ground tailings dams. The advantages of this method are:

1) it avoids the extra work involved with repeatedly moving a satellite pump station.
2) clean up of the area can continue behind the monitoring operation without interference

The permanent pump station will be located in the north east corner of the Intermediate tailings storage area, adjacent to the former plug dam. It will have a floor elevation of 1 036 metres. Monitoring will start on the 1974 tailings dam, near the pump station, to establish a face running from south west to north east along the northerly edge of the tailings dam. The exact direction of the face will be determined by the necessity to achieve a suitable slope for the slurry to gravitate to the collection trenches on the site of the former plug dam. The face would be at its greatest depth at the western end and then taper out on the east. When the initial pass from south west to north east has traversed the tailings dam, the monitors will be moved back near the permanent pump station and a second traverse will be made. The monitoring of the tailings will continue in this manner. The furthest point of the monitoring operation will move progressively around in a clockwise manner with the pump station at the centre across the entire area of the tailings dam which is to be reclaimed. This is illustrated on Drawing no. 100-03-003, included in section 6.

The permanent pump station consists of two horizontal dredge pumps (one standby), capable of handling large pieces of trash (Goulds/Morris CKB or equivalent).

Several alternative hydraulic monitoring methods were considered and rejected. These are briefly described below.

Alternative 2. Downstream monitoring with temporary satellite pump stations located in shallow excavations.

With this approach, monitoring would begin at the extreme eastern end of the dam with a 5 metre cut through the tailings from a monitor gun located on the surface of the tailings. The satellite pump station would consist of a vertical pump suspended from a frame into an excavation made into the tailings located at the western end of a 100 metre trench. Once a 5 metre cut had been successfully made, the excavation would be deepened and a new trench dug. Subsequent 5 metre cuts would continue until an approximately 20 metre face had been formed and monitoring would proceed in a westerly direction. The satellite pump station would then be moved to a location convenient for the ground slope.

This method together with the selected alternative has the advantage of working down the slope so that the slurried tailings do not interfere with the monitor operations. However, the use of movable satellite pumps and pump stations involves extra work but allows flexibility to changing ground conditions and slopes.

Alternative 3. Upstream monitoring with a permanent pump station located outside of the second tailings dam on the dam wall in the south western corner of the dam.

Upstream monitoring has the disadvantage that monitored slurries have to be diverted around the ongoing monitoring operations. However once the initial excavation had been made, a high vertical face is available for monitoring. As the tailings relocation project progresses, an increasingly long ditch will be required to transport the tailings to the pump station. This will require some maintenance and the provision of adequate slope angles will be critical.

Alternative 4. Upstream monitoring with a pump station located outside of the second tailings dam connected to the second dam impoundment through a culvert.

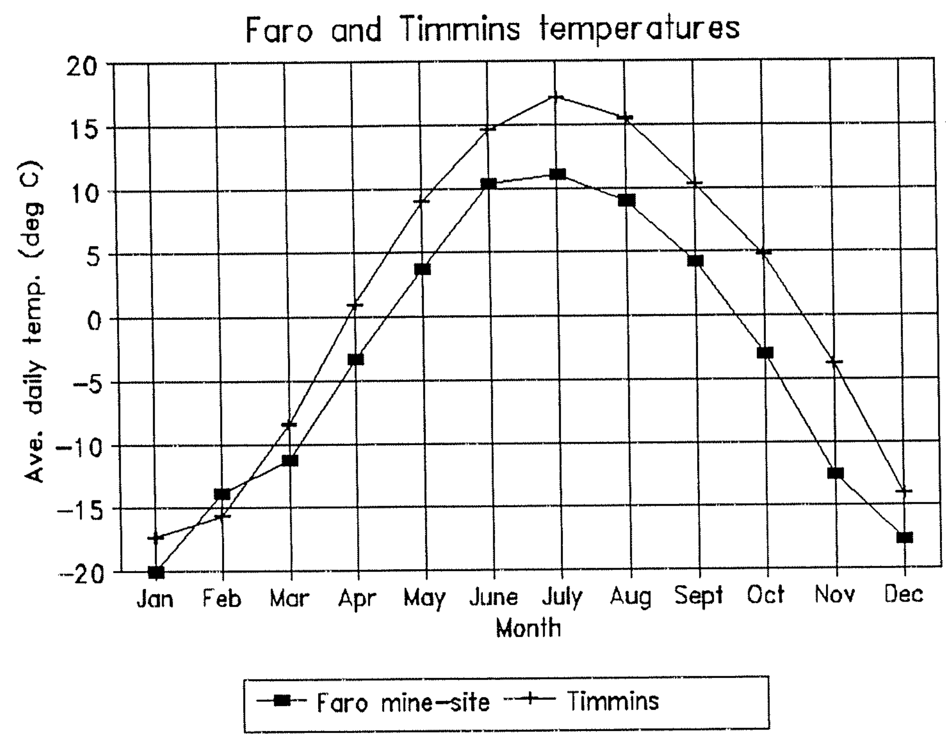
This method is similar to Alternative 3 but employs a culvert to direct the slurried tails to the pumps. Even large diameter culverts give problems with choking and plugging with trash and they are generally to be avoided.

3.4 OPERATING SCHEDULE AND LABOUR REQUIREMENTS

The proposed relocation method uses water as the medium for moving the tailings and it is not workable at water temperatures close to the freezing point. The annual operating period is dictated by the temperature of the water recycled from the open-pit which in turn will depend primarily on ambient air temperatures, but also on other factors such as the frequency of cloud cover.

The ERG tailings reprocessing plant near Timmins, Ontario operated over a one and a half year period. Experience at ERG suggests that an annual operating period of between 7 and 8 months was achievable.

Temperature ranges at the Faro mine site and Timmins are compared in Table 3.1. included overleaf and are illustrated on the graph below.



By measuring the distance between the lines as they cross the zero degree Celsius line, a comparison can be made between water temperatures in Faro and Timmins. It can be seen that ambient temperatures in Timmins rise above zero approximately 2 weeks earlier and fall below zero 4 weeks later in Timmins than at the Faro mine site. It would seem reasonable to assume that a monitoring season at the Faro mine would be 6 weeks shorter than in Timmins for a total of 6 months.

Operations would begin in mid April with preparations for the forthcoming year. The actual monitoring operations would begin in May and run for 6 months until the end of October at which time the operation would be shutdown and the equipment winterized. Contouring of the reclaimed area and general clean up would be an ongoing operational activity. The staff and labour will take leave from mid November to mid April. The operating labour costs are based on a 6 month per year, 24 hour per day, 7 day per week operation. The mobilization, start up and demobilization costs are included in the Curragh reprocessing costs. The shift system is described in section 4.2.

The proposed operation will employ a labour force of 25. All operating positions could be filled by unskilled personnel following a brief training period.

Table 3.1 Air temperatures in Timmins and Faro.

Month	Average Daily Temperatures °C	
	Faro Mine Site	Timmins
January	-20.0	-17.3
February	-13.9	-15.6
March	-11.2	-8.4
April	-3.3	1.0
May	3.7	9.0
June	10.4	14.6
July	11.1	17.2
August	9.0	15.5
September	4.2	10.3
October	-3.0	4.8
November	-12.6	-3.8
December	-17.6	-14.0

Construction of the project would probably be done in a 4 month period between April and July following completion of detailed engineering and procurement during the previous January to March period. This would allow a short monitoring season of 3 months in the first year of operation.

The calculations included in section 6 show that a project life of between 5 and 6 years could be expected at a reclamation rate of 4 800 000 tonnes per year depending on the bulk density used. This will increase to 8 years if the tailings in the Intermediate Dam are included.

CURRAGH RESOURCES INC.

FARO MINE

TAILINGS RELOCATION PROJECT

4.0 OPERATING COSTS

The operating costs for a 4 800 000 t/a tailings relocation project are presented in the following sections and tables. No costs are included for the reprocessing of tailings or chemical treatment of the tailings should they not be reprocessed or the supernatant water in the pit.

4.1 SUMMARY

Operating costs for the proposed operation are $0.39/t. The costs are summarized below in Table 1.

Table 1 - Summary

ITEM	ANNUAL COST ($)	TOTAL COST ($/t)
Labour costs	600,615	0.13
Subcontractor costs	290,000	0.06
Supplies costs	430,000	0.09
Power costs	570,905	0.12
Total process costs	1,891,520	0.39

4.2 LABOUR COSTS

The labour costs shown below in Table 2 reflect the 6 month operating season only. The mobilization, start up and demobilization costs are included in the Curragh reprocessing costs.

It is assumed that two, twelve hour shifts will be worked per day, seven days per week during the 6 month operating season. Four workers are required for each shift operating position. Maintenance support will be provided by the mill crew who will be involved in reprocessing the tailings.

Table 2 Labour costs

POSITION	NO.	DIRECT RATE $/h	SALARY $/a/PERS	PAYROLL $/a/PERS	TOTAL $/a
Site foreman	1	-	22,500	30,375	30,375
Monitor operator	8	17	18,700	25,245	201,960
Booster operator	8	17	18,700	25,245	201,960
Labourers	8	14	15,400	20,790	166,320
Mech./electricians	incl'd in Curragh processing costs				
Total	25	-	-	-	600,615

4.3 SUPPLIES COSTS

The costs included below in Table 3 are to cover consumable items such as pump, pipe and screen spares, lubricants and off-site equipment repair.

Table 3 Supplies costs

ITEM	ANNUAL COST $
Pump/pipe/screen spares	300,000
Electrical spares	35,000
Lubricants	15,000
Major repairs and overhaul	50,000
Vehicle repairs	30,000
Total supplies cost	430,000

4.4 POWER COSTS

The power costs included in Table 4 are for relocation of the tailings from their present position to the mill. The additional annual costs for pumping from the mill to the open-pit using both of the available pumps which have 500 hp motors are estimated at $220 000 for the 6 month operating season, [(4 motors) x (500 hp each) x (0.746 hp to kW) x ($0.05/kWh) x (85% availability) x (80 % power draw) x (24 h/d) x (180 d)] or $0.05/t.

Table 4 Motor list and power costs

ITEM	MOTOR hp	NO. INSTALLED	INSTALLED POWER hp	LOAD FACTOR	AVERAGE hp	AVERAGE kW
Reclaim pumps	600	2	1,200	0.4	480.0	358.1
Slurry booster pumps	700	4	2,800	0.6	1,680.0	1,253.3
Trash screen	50	2	100	0.8	80.0	59.7
Sump pump	15	2	30	0.1	3.0	2.2
Monitor water booster pumps	800	2	1,600	0.8	1,280.0	954.9
Misc.lighting	50	1	50	0.4	20.0	14.9
Total		13	5,780	-	3,543	2,643
Annual operating cost for 180 d/a at $0.05/kWh						570,905

4.5 SUBCONTRACTOR COSTS

It is assumed that routine activities such as trench-digging, trash removal, vehicle maintenance and other activities will be done by contractor. Allowances have also been included for removal of edge material within the dam, rough contouring and road and building maintenance. These are shown below in Table 5.

Table 5 Subcontractor costs

ITEM	ANNUAL COST $
Trench construction, and edge material removal	200,000
Trash removal	40,000
Roads/building maint.	25,000
Surface vehicle operation	25,000
Total subcontract cost	290,000

CURRAGH RESOURCES INC.
FARO MINE
TAILINGS RELOCATION PROJECT

5.0 CAPITAL COSTS

5.1 COST BASIS

The capital costs for the tailings relocation project are presented on the summary page (page 1) of the attached estimate. No attempt has been made to utilize existing equipment except the existing siphon from the pit to the mill, a zinc conditioner, and the existing tailings pumps and pipeline from the mill to the pit. The scope of the estimate is described on the 5 pages attached to the summary page, the flowsheet in section 6 and the equipment list presented below.

The estimate is expressed in fourth quarter 1991 Canadian dollars. The construction crew manhour rate used is $50/hour.

Specific exclusions from the estimate are financing costs, escalation, taxes including G.S.T., further studies, permitting and working capital.

5.2 EQUIPMENT LIST

The proposed tailings relocation system uses water delivered from the Faro pit and delivers trash free tailings (100 % passing 2 mm) into the existing mill building using the equipment listed below. After being reprocessed, the tailings are then pumped to the Faro pit. Allowances are included to relocate one set of tailings pumps to the zinc conditioner which will be used as a tailings pumpbox. No costs are included for the tailings reprocessing operation itself.

- Second siphon - open pit to mill
- Second pump delivery line - mill to open pit
- Bypass pipeline for mill water tank
- Pipeline - mill to monitor water booster pumps
- Two monitor water booster pumps c/w motors (both operating)
- Pressure reducers and filters to provide gland service from the monitor water
- Six, 6" hydraulic monitor guns c/w controllers (includes one spare)
- Permanent pump station c/w one sump pump c/w motor, two reclaim pumps c/w motors (one standby) and hydraulic drives
- Pipeline - Permanent pump station to booster pump station

- Booster pump station, two trash screens c/w decks, splitter box and chutes, pumpbox and small building for electrical supply and operator shelter only
- Four Slurry booster pumps c/w motors (one variable speed) including one standby
- Pipeline - booster pump station to mill
- Relocation of tails pumps to zinc conditioner
- All misc. piping and valves, civils, structural steel, electrical and instrumentation

CURRAGH RESOURCES INC.

FARO TAILINGS RELOCATION PROJECT

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ACCOUNT CODE Ar. Gp. No.	DESCRIPTION	TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mh Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
			* 001 FARO TAILINGS RELOCATION PROJECT *										
001	FARO TAILINGS RELOCATION PROJECT					13,765	-	688,250	-	3,533,546	-	652,720	4,875,000
	CONSTRUCTION INDIRECTS	(5 % of Direct Costs)				-	-	-	-	-	-	-	244,000
	ENGINEER., PROCUREMENT. CONST. MAN.	(10 % of Direct Costs)				-	-	-	-	-	-	-	488,000
	CONTINGENCY	(20 % of Above Costs)				-	-	-	-	-	-	-	975,000
	TOTAL CAPITAL COSTS		-			13,765	-	688.250	-	3,533,546	-	652,720	6,582,000

NOTES:

1 ESTIMATE IS EXPRESSED IN FOURTH QUARTER 1991 CANADIAN DOLLARS

2 ESTIMATE MANHOURS REFLECT YUKON CONTRACTORS REQUIREMENTS, MANHOUR RATE $50.00 REFLECTS LOCAL RATES AND PRODUCTIVITY.

3 EXCLUSIONS FROM COST ESTIMATE TABULATED HEREIN ARE:

1. FINANCING COSTS
2. ESCALATION
3. TAXES (INCL.G.S.T.)
4. FURTHER STUDIES
5. PERMITTING
6. WORKING CAPITAL

ACCOUNT CODE Ar. Gp. No.	DESCRIPTION	TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mh Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
001													
001				* AREA 001	*	FARO TAILINGS RELOCATION PROJECT				*			
001													
001													
001	Water tank		1	each	Existing at mill								
001													
001	Gravity piping (2nd siphon) - Faro pit to mill			see below									
001													
001	Piping 500mm DR 21		1,550	m	0.60	930	50.00	46,500	94	145,700	0.00	0	192,200
001													
001	Gravity piping - mill to monitor booster pumps			see below									
001													
001	Piping 700mm DR 17		650	m	0.70	455	50.00	22,750	335	217,750	0.00	0	240,500
001													
001	Piping 700mm DR 13.5		900	m	0.70	630	50.00	31,500	410	369,000	0.00	0	400,500
001													
001	Monitor water booster pump (Goulds 10 x 12)		2	each	100	200	50.00	10,000	40,000	80,000	0	0	90,000
001													
001	Motor for Above (rpm and HP) 1,800	800	2	each	400	800	50.00	40,000	45,000	90,000	0	0	130,000
001													
001	Piping - monitor booster pumps to monitor		see below										
001													
001	Piping 450mm (CS welded)		600	m	2.40	1,440	50.00	72,000	240	144,000	0.00	0	216,000
001													
001	Piping 150mm (vic.groove)		100	m	0.70	70	50.00	3,500	60	6,000	0.00	0	9,500
001													
001	Excavation for concrete pumpstation		320	m^3	0	0	50.00	0	0	0	10.00	3,200	3,200
001													
001	Backfill for concrete pumpstation		320	m^3	0	0	50.00	0	0	0	10.00	3,200	3,200
001													
001	Concrete for pumpstation		35	m^3	0	0	50.00	0	0	0	700.00	24,640	24,640

CURRAGH RESOURCES INC. | FARO TAILINGS RELOCATION PROJECT | 10:01 AM 02-Dec-91

ACCOUNT CODE Ar. Gp. No.	DESCRIPTION		TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mh Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
001														
001	Reclaim pumps (14" x 16" x 42")			2	each	80	160	50.00	8,000	50,000	100,000	0	0	108,000
001	Goulds model CKX or equiv.													
001														
001	Variable speed drive for above			1	each	200	200	50.00	10,000	90,000	90,000	0	0	100,000
001														
001	Motor for Above (rpm and HP)	1,800	600	2	each	300	600	50.00	30,000	38,000	76,000	0	0	106,000
001														
001	Allowance for hydraulics			1	lot	200	200	50.00	10,000	75,000	75,000	0	0	85,000
001														
001	Sump pump			1	each	30	30	50.00	1,500	9,000	9,000	0	0	10,500
001														
001	Motor for Above (rpm and HP)	1,800	15	1	each	10	10	50.00	500	968	968	0	0	1,468
001														
001	Hoist for pump maintenance			1	each	100	100	50.00	5,000	10,000	10,000	0	0	15,000
001														
001	Piping - Reclaim pump to booster pumps			see below										
001														
001	Piping 700mm DR 26			200	m	0.70	140	50.00	7,000	150	30,000	0.00	0	37,000
001														
001	150mm hydraulic monitor gun			6	each	100	600	50.00	30,000	30,000	180,000	0	0	210,000
001														
001	Drive control unit for above (1 spare)			7	each	100	700	50.00	35,000	14,000	98,000	0	0	133,000
001														
001	Motor for Above (rpm and HP)	1,800	3	7	each	10	70	50.00	3,500	incl. above	0	0	0	3,500
001														
001	Slurry collection trench and sump			2,000	m3	0	0	50.00	0	0	0	10	20,000	20,000
001														
001	Slurry booster pumps - 3 stage			4	each	100	400	50.00	20,000	55,000	220,000	0	0	240,000
001	(20" x 18" x 40") SRL XT													
001														

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ACCOUNT CODE Ar. Gp. No.	DESCRIPTION	TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mn Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
001	Variable speed drive for above		1	each	200	200	50.00	10,000	90,000	90,000	0	0	100,000
001													
001	Motor for Above (rpm and HP) 1,800	700	4	each	350	1,400	50.00	70,000	35,000	140,000	0	0	210,000
001													
001	Gland water supply pressure reducers		1	lot	0	0	50.00	0	0	0	15,000	15,000	15,000
001													
001	Piping - Booster pumps to mill		see below										
001													
001	Piping 800mm DR 11		900	m	0.80	720	50.00	36,000	438	394,200	0.00	0	430,200
001													
001	Piping 800mm DR 17		650	m	0.80	520	50.00	26,000	286	185,900	0.00	0	211,900
001													
001	Misc.piping allowance		1	lot	0	0	50.00	0	0	0	50,000	50,000	50,000
001													
001	Misc. valve allowance		1	lot	0	0	50.00	0	0	0	70,000	70,000	70,000
001													
001	Pipe bed grading		1	lot	0	0	50.00	0	0	0	15,000	15,000	15,000
001													
001	Access road crossing		1	lot	0	0	50.00	0	0	0	12,000	12,000	12,000
001													
001	Excavation for booster station		720	m^3	0	0	50.00	0	0	0	10.00	7,200	7,200
001													
001	Backfill for booster station		720	m^3	0	0	50.00	0	0	0	10.00	7,200	7,200
001													
001	Concrete foundations and floor for booster		49	m3	0	0	50.00	0	0	0	700.00	34,160	34,160
001	station												
001													
001	Building for booster station electrics		64	m3	0	0	50.00	0	0	0	80.00	5,120	5,120
001													
001	Trash screen 2400 x 6000		2	each	450	900	50.00	45,000	160,000	320,000	0	0	365,000
001													

CURRAGH RESOURCES INC. FARO TAILINGS RELOCATION PROJECT 10:01 AM 02-Dec-91

ACCOUNT CODE Ar. Gp. No.	DESCRIPTION		TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mh Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
001	Motor for Above (rpm and HP)	1,800	50	2	each	25	50	50.00	2,500	4,530	9,060	0	0	11,560
001														
001	Pumpbox 6000 x 8000			1	each	150	150	50.00	7,500	40,000	40,000	0	0	47,500
001														
001	Sump pump			1	each	30	30	50.00	1,500	9,000	9,000	0	0	10,500
001														
001	Motor for Above (rpm and HP)	1,800	10	1	each	10	10	50.00	500	968	968	0	0	1,468
001														
001	Struct. steel for screen etc. incl.chutes			25	t	0	0	50.00	0	0	0	3,000	75,000	75,000
001														
001	Building services			1	lot	0	0	50.00	0	0	0	10,000	10,000	10,000
001														
001	4 WD pick-up			1	each	existing								
001														
001	2nd Pipeline 600mm HDPE (mill to pit)			1,800	m	0.80	1,440	50.00	72,000	130	234,000	0.00	0	306,000
001														
001	Allowance to relocate existing tails pumps			1	each	0	0	50.00	0	0	0	100,000	100,000	100,000
001	to mill at Zn cond.													
001														
001	Allowance for new pipeline			1	each	0	0	50.00	0	0	0	40,000	40,000	40,000
001	(float cells to Zn cond.)													
001														
001	Allowance for elect. connections at mill			1	lot	0	0	50.00	0	0	0	30,000	30,000	30,000
001														
001	4 kV overhead line			900	m	0	0	50.00	0	0	0	40.00	36,000	36,000
001														
001	4 kV starters			6	each	40	240	50.00	12,000	15,000	90,000	0	0	102,000
001														
001	Interruptor switch			1	each	30	30	50.00	1,500	10,000	10,000	0	0	11,500
001														
001	750 kVA transformer			1	each	30	30	50.00	1,500	20,000	20,000	0	0	21,500

CURRAGH RESOURCES INC. FARO TAILINGS RELOCATION PROJECT 10:01 AM 02-Dec-91

ACCOUNT CODE Ar. Gp. No.	DESCRIPTION	TYPE	QTY	UNIT	LABOUR mh/Unit	LABOUR Total mh	LABOUR mh Rate	LABOUR Cost	MATERIAL Unit Cost	MATERIAL Cost	SUB-CONTRACT Unit Cost	SUB-CONTRACT Cost	TOTAL COST
001													
001	600 V switchgear		1	each	40	40	50.00	2.000	15,000	15,000	0	0	17,000
001													
001	Bus duct		1	each	20	20	50.00	1,000	5,000	5.000	0	0	6,000
001													
001	MCC		1	each	10	10	50.00	500	10,000	10,000	0	0	10,500
001													
001	MCC/Motor wiring		1	each	240	240	50.00	12,000	19,000	19,000	0	0	31,000
001													
001	Allowance for lighting (fixed and portable)		1	lot	0	0	50.00	0	0	0	30,000	30,000	30,000
001													
001	Allowance for weatherproofing elect.equipment		1	lot	0	0	50.00	0	0	0	20,000	20,000	20,000
001													
001	Allowance for Freight and insurance		1	lot	0	0	50.00	0	0	0	25,000	25,000	25,000
001													
001	Allowance for Instrumentation		1	lot	0	0	50.00	0	0	0	20,000	20,000	20,000
001													
001	FARO TAILINGS RELOCATION PROJECT		-		-	13,765	-	688,250		3,533,546	-	652,720	4,874,516

CURRAGH RESOURCES INC.

FARO MINE

TAILINGS RELOCATION PROJECT

6.0 DRAWINGS

The following drawings are included to describe the tailings relocation project.

Flowsheet	Dwg. No. 100-03-001
General Arrangement, Booster Station	Dwg. No. 100-03-002
Site Plan	Dwg. No. 100-03-003
Tailings Area Plan and Profile	Dwg. No. 100-03-004

Oct 24/91

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CURRAGH RESOURCES INC
FARO MINE
TAILINGS RELOCATION PROJECT

Comments on the project report prepared by KILBORN INC October 1991

Proposed relocation method

The option selected, of hydraulic downstream monitoring is the most economic and flexible method for the reclamation of tailings. The only limitation being a short season of operation due to low temperatures but this equally applies to dredging and to a lesser extent to earthmoving. Downstream monitoring where the ground slope falls away from the monitor guns is clean, safe and an efficient method. Upstream monitoring is dirty, often unsafe and inefficient as all services become inundated with slurry and access extremely difficult.

Siting of primary pumping installations

Alternative I proposed a satellite station consisting of a vertical pump suspended from a frame into an excavation made into the tailings located at the end of a collecting trench. Sited 'in dam' this arrangement has similar disadvantages to upstream monitoring, namely messy and difficult access for maintenance and the removal of floating trash or trash too large to be pumped. Furthermore the total installation, pump and services require to be resited frequently. The ideal installation (option I) is a permanent pump station located outside the dam receiving the stream of monitored slurry over a vibrating screen. This requires a collecting trench to be constructed outside the dam and the invert at the screen to allow for a 1:100 but not less than 1:150 slope to the furthest point of reclamation.

A deeper (and more expensive) excavation is required to accommodate the screen and conventional slurry pumps with a flooded suction. A conveyor is required to carry the trash to a stockpile for further removal.

There is some preference to construct a cheaper primary pumps station (option II) to house a hydraulic drive vertical pump to deliver to a vibrating screen mounted over a large sump box feeding conventional sets of slurry pumps. This installation can be located above ground level and provides far better all round access and trash removal.

Option I may require a deep excavation to accommodate the vibrating screen and pump basement. An alternative sump site shown on the sketch could possibly eliminate some of this if a site could be found low enough to accommodate the equipment with minimum excavation.

are not suitable for this duty. The required pressure should be achieved by using single stage pumps in series.

As regards slurry pumping the following data derived at ERGO may be of some use when checking your own calculations.

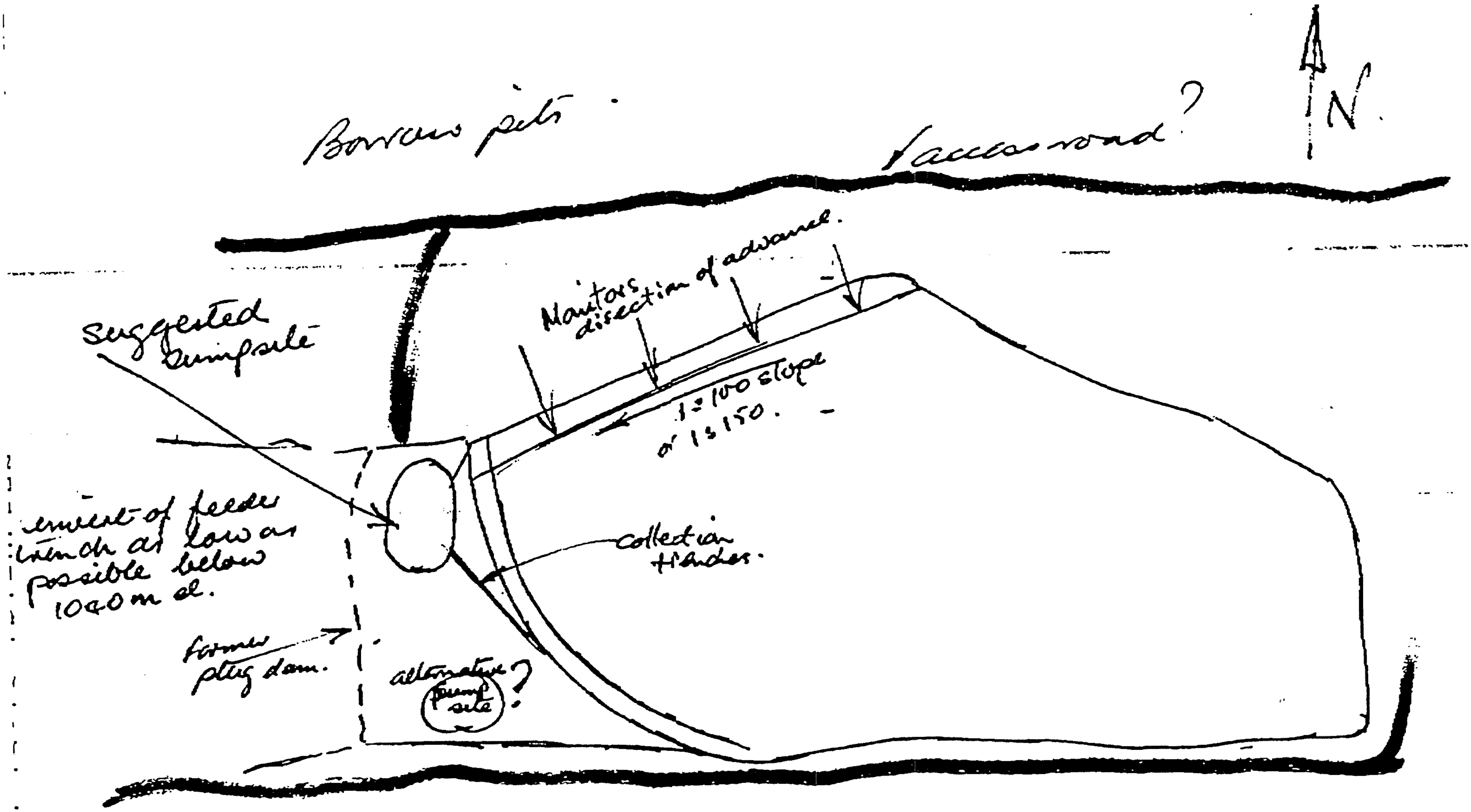
Flow at 1,9m/sec 450mm dia pipe.

Pressure gradients

Water	5,75m H_2O per kilometre				
Slurry	45% solids	8,4m H_2O	per	kilometre	
"	35% "	7,2m	"	"	"
"	55% "	9,3m	"	"	"

Conclusion

The siting of the receiving sump for either option is of paramount importance and necessitates a site visit with a surveyor to thoroughly search the area for the optimum position. Once this is established there should be no difficulty in reclaiming the tonnage required.



SUGGESTED MINING METHOD.

Appendix E

Draft Report by Pelly Consultants on Mechanical Excavation

INTRODUCTION

SRK has requested an estimate of the cost to move the tailings from the tailings containment area to the main pit utilizing conventional excavation and trucking methods.

The writer has had considerable experience with this site from 1969 to the present. I was the principal technical person on the contractor's side for the following projects:

- **Two raises of the tailings dam prior to the construction of the cross valley and intermediate dams. This work included the excavation of tailings to construct a beach on the inside of the gravel and till structure.**

- **Construction of the cross-valley and intermediate dams and the relocation of Rose Creek out of the tailings area.**

- **Raise intermediate dam.**

- **Strip Grum pit utilizing 195 ton trucks and 33 c.y. electric shovel.**

- **Construct the portion of Vangorda Plateau to mill site road that was not built out of mine waste.**

- **Construct Vangorda fresh water dam.**

- **Construct till cover on a portion of the Vangorda tailings dump.**

- **Screen 1,300,000 tons of oxide ore.**

- **Main pit till stripping contract**

- **Breach the fresh water storage dam and restore Rose Creek to its approximate original location.**

Keith Byram, P.Eng.
President
Pelly Construction Ltd.

PROPOSED METHOD

Within reason, the larger the equipment that can be employed to move material the more economical the unit price will be. The terrain of the valley in which the tailings are located is not uniform. In some areas there are large pits where gravel deposits were found and utilized to construct the intermediate and cross-valley dams. In other areas there are deposits of frozen muck in some cases several meters in thickness. In the areas where gravel was not excavated, the organic mat along with trees that were flattened with bulldozers is covered with the tailings. This layer of organics is of varying depth and in some areas the organics are underlain by black muck. In one area of the dam footprint, black muck had to be removed and it was two to three meters in thickness.

Because of the possible instability of the foundation material it may not be possible to load trucks with front-end loaders. A large capacity belt loader is proposed to load the trucks. Tailings would be pushed to the loader with a D11 size dozer. The haul would be done with Cat 776, 135 tonne wagons.

The road from station 0+000 to 2+040 would be properly aligned and the grades improved by using local material and waste rock fill. A non deflecting sub-grade would reduce the rolling resistance to actual grade plus a maximum of 2%. A finished surface of crushed gravel or possibly a bituminous treated surface will substantially reduce tire wear and improve cycle time. The section from 1+840 to 2+040 would be improved to bring the grade down to 12% from 15%. If the tailings are removed in their entirety adequate gravel roads should be constructed using material from the floor of the containment. If tailings are only removed to a certain elevation it will be necessary to construct some main haul roads over the remaining tailings utilizing material from outside the containment area or perhaps by reclaiming material that was used to build the dams.

The dry density of the in situ material is reported to be 1779kg/m3. An average of 10% moisture is estimated to give an in situ density of about 2000 kg./m^3.

The fine grained nature of the material combined with moisture will create a severe buildup problem in the feeder and in the truck boxes. It is likely that this will restrict the season to a period of May through October or a 200 day season.

The concept of removal by load and haul is based on the tailings being dry enough to support the haul units. Information to confirm this is not yet available. The following pricing is based on a positive confirmation. It is almost certain that there are areas that currently would not support traffic and a method of dewatering these areas would have to be worked out.

HAUL FROM UPPER IMPOUNDMENT

SECTION	GRADE %	RR%	TOTAL%	Dist. M.	TIME m
2+530 – 2+040	2.3	6	8.3	490	2.0
1+040 – 1+840	12.0	2	14	200	1.2
1+840 – 1+640	2.0	2	4	200	0.4
1+640 – 1+160	11.0	2	13	480	3.0
1+160 – 0+400	2.4	2	4.4	760	1.8
0+400 – 0+800	-6.0	2	-4.0	320	0.6
0+080 – 0+000	modify to suitable dump			80	0.2
Total				2530	9.2

10% increase in time due to extra wagon axle ---------------1.0
Return trip – retard to equivalent 0% -------------------------- 3.0
Load --- 3.0
Maneuver and Dump -- 1.5
Total Cycle Time -- 17.7
Round off to 18 minutes

Assume a 50 minute hour

50/18 = 2.8 trips per hour

2.8 trips per hour x 135 t = 378 t per hour per truck.

Use 6 trucks for 16 trips per hour

16 trips x 135 t x 20 hours per day = 43,000 ton per day

Assume 200 working days per year x 43,000 = 8,600,000 tonne per year

HAUL FROM LOWER IMPOUNDMENT

SECTION	GRADE %	RR%	TOTAL%	DIST. M.	TIME m
2+180 – 1+600	0	6	6	580	1.6
1+600 – 1+200	1	6	7	400	1.4
1+200 – 1+000	7	2	9	200	0.7
1+000 – 0+400	2.5	2	4.5	600	1.5
0+400 – 0+000	7	2	9	400	1.6
(0+000 on this line is 1+840 on upper imp. road)					
1+840 U.I.R. to Dump				1840	6.0
Total				4020	12.8

10% increase in time due to extra wagon axle----------------- 1.3
Return trip – retard to 0% --- 4.1
Load--- 3.0
Maneuver and dump -- 1.5
Total Cycle Time ---22.7
Round off to 23 minutes

Assume a 50 minute hour

50/23.0 = 2.2 trips per hour

2.2 trips per hour x 135 t per hour per truck

Use 7 trucks for 15 trips per hour

15 trips per hour x 135 t x 20 hours per day = 40,000 t per day

Assume 200 working days per year x 40,000 = 8,000,000 tonnes per year

COSTS

Lump Sum Road Construction

Improve grade and provide a minimal deflection road sub-grade and surface with 0.3 m of crushed gravel from the edge of the tailings containment to the main pit -- $2,000,000.

REMOVAL FROM UPPER IMPOUNDMENT

UNITS	HOURLY RATE ($)	TOTAL ($)
2 D11 Dozer	400	800
1 Belt Loader	150	150
6 776 Wagons	300	1,800
1 D9 Dump Cat	200	200
1 #16 Grader	150	150
1 Foreman c/w Pickup	75	75
Total		3,175

$3175 / 2160 t = 1.46 $/t

REMOVAL FROM LOWER IMPOUNDMENT

UNITS	HOURLY RATE ($)	TOTAL ($)
2 D11 Dozer	400	800
1 Belt Loader	150	150
7 776 Wagons	300	2100
1 D9 Dump Cat	200	200
1 #16 Grader	150	150
1 Foreman c/w Pickup	75	75
Total		3,475

$3,475 / 2025 t = 1.72 $/t

Upper Impoundment is 58% of total. 0.58 x $1.46 = $0.85
Lower Impoundment is 42% of total. 0.42 x $1.72 = $0.72

Overall cost to move all of the tailings ---------------- = $1.57/ t

SUMMARY

Fixed costs

Mobilization ---$500,000
Prepare Haul Road ---$2,000,000

Unit Costs

Load, haul and dump --$1.57/tonne

Notes: Additional information on the current stability and load carrying characteristics of the tailings is required before it can be assured that this method of removal can be guaranteed.

The numbers are based on one fleet of equipment working approximately two hundred days per year, April through October.