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Memorandum

To:	SRK Consulting	**Date:**	16 November 2009
Attention:	Daryl Hockley	**From:**	John Chapman
cc:		**Project No:**	1CY001.028.003
SUBJECT:	**CONTAMINATED WATER TREATMENT OPTIONS EVALUATION**		

1 INTRODUCTION

A scope of work intended to identify and evaluate water treatment options for the Grum Waste Rock seepage currently directed to the Moose Pond was generated by others (see Attachment 1). During the recent meetings held in Vancouver, SRK was asked to comment on potential passive treatment options for the waste rock dump, as well as to identify other locations that may also be included in the assessment. The purpose of the assessment was to identify specific options and locations that may be identified in the scope of work that would be put out to bid.

This memorandum presents the outcome of the assessment undertaken by SRK, and provides preliminary recommendations for options that may be considered suitable for inclusion in the scope of work.

2 APPROACH

The assessment was completed as follows. First, the seep survey results for the Grum/Vangorda and Faro areas from the past six years were reviewed for flow, contaminant concentrations and pH to determine if they could reasonably be considered for in-situ treatment options. Second, the location was assessed to determine if the seepage could reasonably be intercepted or directed for treatment and if there is sufficient area available to implement or accommodate a treatment system. Third, candidate treatment options weer identified based on water quality and flows and simple performance calculations were undertaken to determine if the size or area requirements can be accommodated within the location of the seep. These performance calculations utilised standard design criteria reported in the literature. Finally, based on the feasibility of accommodating the treatment option candidate strategies were either identified or rejected for each location.

The treatment options considered included i) sorption (onto organics), ii) sulphate reduction (biocell) using engineered upflow reactor systems, and, iii) aerobic wetlands. *Note that permeable reactive barrier systems could equally function to substitute for i) and ii) if correctly engineered and implemented, since they function on the basis of sorption or sulphate reduction or combination of these mechanisms.*

Based on the outcome of this analyses recommendations were developed for candidate treatment options.

3 RESULTS

A summary of the assumed/prevailing water quality and flows is provided in Table 1 below. Note that while the Zone II outwash area has been identified in the table, water quality data were not available for this assessment. Furthermore, whilst the seepage rate for the Outer Haul Road West Dump is small, the groundwater flow component is not quantified and could approach that observed at the S-wells.

Table 1 Summary of Potentially Feasible Sites and Associated Water Quality

Location	Description	Monitoring Locations	Flow Range (min/max)		pH	Zn Conc.	Zn Loading
			L/min	L/min		(max) mg/L	(max) kg/day
Faro	Northeast Dump (NE1; NE2)	FD05	0	120	7	4.5	0.78
		FD06	0	240	7.2	14	4.84
		TOTAL		360.00			5.62
	Zone II Outwash Area	?	?	?	?	?	?
	Zone II Pit			390 (avg)	?	115	64.53
	Outer Haul Rd West Dump	FD49	trace surface (GW?)		5.2	73	??
	ETA	X23	2000	10000	6	330	2376
	Northwest Dump (lower)	FD19	0.1	180	6.5	87	23
	Northwest Dump (upper)	FD16	40	600	6.6	0.02	0.017
		FD17	1.5	25.5	7.2	0.088	0.003
		FD18	0	75	6	0.16	0.017
		TOTAL		700.500			0.038
Down Valley tailings	Surface pond (Est. runoff 320000 m3/year)	runoff	609	3235	7	clean + TSS Contaminated interflow	
	Toe of Secondary Dam	source?	Flow?	?	?	?	
Grum Pit	Annual outflow			1260	7	5	9.072
Grum Dump	Moose Pond	GD01 – GD21	0	440	7	7.8	4.942
	South End (V14)	GD05	1	30	7.5	5.2	0.225
		GD06	0	30	7.5	3.9	0.168
		GD16	0	30	7.4	139	6.005
		TOTAL		90.000			6.398

Table 2 Summary of Preliminary Treatment Option Evaluation

		Sorption						Sulphate reduction (biocell)				Aerobic Wetlands		
Location	Description	Available Area (est.) m^2	Peat depth (Est.) m	Peat vol. m^3	Zinc storage kg	Period Years	Feasible?	Flow Area m^2	Labile orgainic m^3	Total vol. fill m^3	Feasible?	Flow limited Area m^2	Load Area m^2	Feasible?
Faro	Northeast Dump	6000	1	6000	12000	5.9	Maybe	7200	288	396	Yes	176.7	430345	No
	Zone II Outwash	1000	1	1000	2000	??	??	??	??	??	??	??	??	??
	Zone II Pit	n/a	n/a	n/a	n/a		n/a	7793	3309	4550		191.2	4944657	No
	Outer Haul Rd West Dump	4000	1	4000	8000		??	??	??	??	??	??	??	??
	ETA	30000	3	90000	180000	0.2	No	200000	121846	167538	No	4907.1	182068966	No
	NorthWest Dump (lower)	10000	1	10000	20000	2.4	No	3600	1156	1590	Yes	88.3	1728000	No
	Northwest Dump (upper)	10000	1	10000	20000	1450	Yes	14010	1.94	2.66	No - flow too high	343.7	2896	Possible
Down Valley tailings	Surface pond	n/a	n/a	n/a	n/a	n/a	n/a	64700	??	??	??	1587.5	??	??
	Toe of Secondary Dam	1000	1	1000	2000	??	??	??	??	??	??	??	??	??
Grum Pit	Annual outflow	12500	1	12500	25000	7.5	Maybe	25200	465	640	possible	618.3	695172	No
Grum Dump	Moose Pond	1000	1	1000	2000	1.1	No	8800	253	348	Flow may be too high	215.9	378703	No
	South End (V14)	2000	1	2000	4000	1.7	No	1800	328	451	Yes	44.2	490262	No

Table 2 shows a summary of the estimated areas and other constraints that may preclude/allow implementation of each option.

The results can be summarised as follows:

- Sorption (using peat or local organic materials) may be applicable at the Northwest Dump (upper) location where concentrations (and loadings) are low and sufficient organic materials may be placed to ensure long term effectiveness. Other locations that could potentially be considered include the Northeast dump (Faro) and the Grum Pit outflow (when overtopping).
- Sulphate reduction (or biocell) appears to be feasible at the Faro Northeast dumps seepage, the Northwest Dump (lower), Grum dump South End. The Grum Dump seeps to Moose Pond may potentially be treated with this method; however, the flows may be too high during the spring freshet. Flow attenuation and equalisation could however overcome this issue.
- Aerobic wetlands could potentially be feasible only at the Northwest Dump (upper) where seepage has low concentrations and sufficient area is available for implementation.
- Other areas that may be considered for treatment include the Zone II Outwash area and the Outer Haul Road West Dump, however, additional data are required to complete the assessment.

Whilst the conditions for the Down Valley locations are not well defined, and may not be defined until closure strategy has been finalised, consideration should be given for these locations if the options considered for the waste rock dumps are shown to be successful.

As noted before, permeable reactive barriers may be considered where either sorption or sulphate reduction has been identified as feasible.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

A preliminary assessment of potential in-situ treatment options has been completed for the Anvil Range site. Options that were considered included sulphate reduction (biocell), wetland systems and permeable reactive barriers. Based on this preliminary assessment we conclude that:

- Options including sulphate reduction (biocell) and permeable reactive barriers could be successful at a number of locations around the Anvil Range minesite, including:
    - Grum Dump seeps to Moose Pond
    - Grum Dump South end
    - Faro Northeast dump
    - Faro Northwest Dump (lower)
    - Grum Pit outflow
- Insufficient information currently exists for the Zone II outwash area to allow an assessment of potentially applicable technologies.
- Insufficient information exists on the sources and potential loadings on the Down valley Tailings deposit (toe of second dam; surface pond) exists to allow an assessment of potential applications during and after closure.

Of the sites identified above, form an accessibility and water quality perspective, the seepage from the Grum (South End and to Moose Pond) appear to be most favourable for an initial assessment. O

4.2 Recommendations

Based on the above conclusions we therefore recommend that a scope of work be provided to a group of vendors to prepare a proposal for the assessment of potential in-situ treatment options at the Grumm Dump only. We suggest that Alexco Resources (in in-situ sulphate reduction), Nature Works (arsenic removal, zinc removal), Waterloo University Hydrogeology Department (for reactive Barriers), AMEC or HIS be approached as potential candidates for submitting proposals.

Consideration should be given to both sorption and in-situ sulphate reduction technologies, including biocell and reactive barriers as applicable. Whilst the seepage flow rate to Moose Pond is high, most benefit (i.e. load reduction) can be obtained by assessing the treatability of this flow. However, successful implementation may be achieved more readily for the South End seepage. We therefore recommend that both locations be considered.

Once successful treatment has been demonstrated at one or both of these locations, then the potential for implementation at the other locations identified herein may be considered.

We also recommend that supplemental flow and water quality monitoring be undertaken for the Zone II outwash area to facilitate a similar assessment at this location. For the Down Valley tailings area, the seepage at the Secondary Embankment needs to be monitored to determine the source of flow and assess the need for management during and after closure.

APPENDIX 1
Grum Dump Water Treatment Scope of Work

Faro Mine Closure Project
Contaminated Water Treatment Options Evaluation
Grum Waste Rock Dump

Introduction

The quality of water emanating from the Grum Waste Rock Dump at the Faro Mine Complex is beginning to deteriorate, demonstrating patterns similar to those that have occurred at other waste rock dumps at the Faro Mine Complex. Initial steps were taken in 2007 to address potential adverse effects on receiving waters (Vangorda Creek) by redirecting surface seepage flows to a natural dry topographic depression (Moose "Pond") where water exfiltrates to ground approximately 100 m from Vangorda Creek. Groundwater monitoring indicates that contaminant plumes have not reached Vangorda Creek. Experience from other locations on the site indicates that the contaminant migration delay that is occurring between Moose Pond and Vangorda Creek will be temporary.

This project is intended to identify and evaluate water treatment options for the Grum Waste Rock water that is currently directed to Moose Pond. The focus of the work is to be on options that could delay the need for implementation of collection, pumping, treatment of this water at the centralized water treatment facility.

Site Background

The Faro Mine Complex is comprised of two main sites: the Faro Mine and the Vangorda Plateau which includes the Vangorda and Grum Mines. The lead/zinc mine opened in 1969. Mining ceased in 1998 and since that time, the complex has been in a state of care-and-maintenance. Extensive investigations, analysis and engineering have been conducted to support development of a closure and remediation plan for the site. A final plan is nearing completion for submission to environmental assessment and regulatory processes.

All of the tailings (approximately 70×10^6 tonnes) and much of the waste rock (total of approximately 320×10^6 tonnes) generated from the mining process are potentially acid generating. Seepage and groundwater quality from waste rock dumps has deteriorated in some areas. Flow rates and water quality vary depending on the waste rock types, catchment conditions, timing of construction, groundwater flow paths/rates, etc. Conditions continue to change as geochemical conditions develop and contaminant plumes expand. There is an extensive surface water, groundwater and seepage monitoring program in place to understand important trends and changes.

Adjacent streams contain important ecological values, and are tributaries of the Pelly River. At the Faro Mine site, fish utilization occurs in Rose Creek that flows adjacent to and through the site. Vangorda Creek and its tributary Grum Creek flow through the Vangorda/Grum site but fish utilization on this system is limited to the mouth of Vangorda Creek, several kilometers downstream of the site.

Current care-and-maintenance activities protect the aquatic ecosystem in Rose and Vangorda Creeks. A primary objective of the proposed closure plan is to continue to provide such protection in the long-term. This will require ongoing collection, remediation and/or treatment of contaminated groundwater at the site. Active, permanent post closure activities are a recognized component of the closure and remediation plan. Initial collection and treatment systems are already in place in areas where contaminated site water would affect the aquatic ecosystem. Additional and improved control mechanisms will be established throughout the care-and-maintenance,

closure/remediation and post-closure phases of the project. Decisions about implementation of additional measures are currently, and will be, guided by a comprehensive adaptive management plan.

Grum Waste Rock Dump Water Quality Current Conditions

The Grum Waste Rock Dump is the most recent waste rock dump at the site, constructed in the 1990s. Seepage and groundwater monitoring for this dump has been carried out for several years and water quality has begun to deteriorate at some locations showing increases in oxidation products including sulphate. Over the past several years, monitoring locations and frequencies downgradient of the Grum Dump have been increased in response to water quality changes identified through an adaptive management program. The adaptive management program also led to construction of a seepage interception system in 2007 because zinc concentrations exceeded effluent discharge standards for the mine. At the time, seepage reported to a surface stream, "Tributary A" of Vangorda Creek (Monitoring Station V2).

Seepage from the interception system now reports to a natural, dry depression called Moose Pond, located within 100m of Vangorda Creek. Moose Pond is located well above Vangorda Creek creating a groundwater gradient towards the creek. A single monitoring well (Moose Well No. 2) and a downgradient surface seep (Moose Seep) provide information about groundwater quality downgradient of Moose Pond. Following construction of the seepage interception system, concentrations of oxidation products in Moose Well No. 2 have increased.

A review of monitoring results completed by Robertson GeoConsultants Inc. in early 2009 described Moose Well No. 2 conditions as follows:

> "Groundwater quality for most of the wells located down-stream of Grum Rock Dump remained unchanged during the monitoring period. An exception was SRK05-09 (a.k.a. Moose Well 2), which is located downstream of Moose Pond. In this well, the concentrations of SO4 and Mg increased significantly throughout 2008. Groundwater quality in Moose Well #2 has been shown to be impacted by seepage from Moose Pond (station V2A), which collects seepage from the Grum Rock Dump (RGC, 2008). Note that the seepage collection system at Grum Dump was changed in 2007, resulting in direction of more contaminated water to Moose Pond (to prevent direct discharge to surface waters). This change in seepage management is likely responsible for the deterioration in groundwater quality at 'Moose Well 2'."

The current recommendation issued by SRK Consulting in its annual adaptive management plan evaluation of conditions at the Grum Dump is:

> "Collection and transfer of water to Vangorda Pit if zinc concentrations exceed acceptable levels at station V2, at Moose Seep, or at Moose Well 2."

Planning is currently under way to ensure that infrastructure is in place for implementation of collection and pumping systems on short notice. Planning is also underway for the early implementation of remediation measures that are intended to reduce the loading from sources within the Grum Waste Rock. These include relocation and covering of high strength sources of oxidation products.

Project Purpose

The Faro Mine closure team wishes to evaluate water treatment alternatives that may delay the onset of full-scale collection and pumping of water from the Grum Waste Rock Dump for treatment at the central water treatment facility at the Vangorda/Grum site.
Should appropriate alternatives be identified, planning for implementation in 2010 would be required.

Scope of Work

1. Assess water quality conditions and site conditions at the Grum Waste Rock Dump. Water quality data from monitoring programs can be provided. Results and reports from various investigations, adaptive management reviews, etc can also be provided. A site visit should be considered.
2. Identify potential on-site treatment methods that may be effective, and select those that warrant more detailed consideration.
3. Evaluate short-listed treatment options, including treatment lab testing as appropriate.
4. Prepare report (draft and final) detailing results of evaluation and test programs, including recommendations for treatment to be implemented in 2010 as appropriate. Cost estimates, construction requirements and operation requirements should be identified.

Provision should be made for ongoing discussions with the project team throughout the program, including providing memos that describe interim status and decision-making on the project.