MEMORANDUM

TO Rick Schryer - Fortune Minerals Limited **DATE** 23 February 2012

CC Jen Gibson

FROM Bridgette Hendricks, Kevin Conroy **PROJECT No.** 09-1373-1004.9600

UNDERTAKING #1
EFFLUENT TREATMENT SYSTEM INFORMATION

During the Technical Sessions for the NICO Project, the Mackenzie Valley Environmental Impact Review Board asked Fortune Minerals Limited (Fortune) to provide the following:

1) Conceptual design information including waste stream information for the reverse osmosis treatment system.
2) A discussion about the processing of the brine and what would be done with the post-processed brine, where that water would go, as it's still a significant volume of water, and then finally how they would be handling the precipitates from that brine process.
3) Discussion of the entire suite of parameters for treated water quality due to the Effluent Treatment Facility being reconfigured from the ion exchange to reverse osmosis.

An overview of the proposed reverse osmosis (RO) system was provided in the 30 September 2011 update letter "Nico Project Update for the Developer's Assessment Report" and further detail and clarification is provided here.

Overview of Proposed System

The Effluent Treatment Facility (ETF) for the proposed NICO Project includes the following process steps and is shown schematically in Block Diagram format on Figure 1:

- Equalization (in the Surge Pond);
- Influent preheating (note that the heat will be recovered before discharge);
- Microfiltration for reduction of total suspended solids (TSS);
- Reverse osmosis for reduction of constituents of concern (dissolved metals);
- Chemical precipitation of the brine for removal of the majority of the metals; and
- Biological treatment for removal of ammonia and selenium.

Reduction of TSS by microfiltration is the necessary first step for optimum operation of the RO system. Heating of the influent stream will also be beneficial for RO operations and the subsequent biological treatment of the RO brine. The influent stream is preheated by waste heat from power generation to decrease the pumping pressures required in the RO system and increase the treatment efficiency of the biological treatment system. Heat is recovered from the treated effluent prior to discharge. Note that the discharge temperature of the effluent will be within 2 to 4 degrees of the influent. The waste heat available is estimated to be sufficient to heat a stream as low as 1 to 15 degrees Celsius although heat will also be recovered from the treated effluent.

The brine from the RO system will be treated by chemical precipitation to remove metals in a stable solid form as a metal hydroxide sludge. The pH of the brine is increased with lime, allowed to react, and then a microfiltration system is used to remove the precipitated metals. The treated brine is then further treated in a 2 stage biological treatment system for selenium removal and ammonia removal. The active biological treatment system achieves the selenium removal anaerobically and the ammonia removal aerobically. The aerobic step is also included to provide polishing of the anaerobic effluent for parameters that may be added as nutrients (carbon source and phosphorous, if required) and also to aerate the water prior to discharge. The biotreated brine is then recombined with the RO permeate for discharge. The residuals from the brine treatment circuit include metal hydroxide sludge from the precipitation step and biosludge from the biological treatment step.

Treatment Efficiency

All of the treatment processes included in the ETF are proven processes in a variety of water treatment applications including drinking water, industrial wastewater, and mining water treatment. The installation of the ETF system in a building with preheated water allows the ETF to function in similar manner to other water treatment facilities with similar processes and water quality. The impact of operations in a sub-arctic location is mitigated by these design and operational strategies.

Table 1 shows the projected influent and effluent water quality for the ETF. The projected influent water quality to the ETF is not a typical “mining influenced” water with high total dissolved solids (TDS), sulfate, and metals content that is often produced in mining applications. The ETF influent is a relatively low TDS and low metals water that is similar to a groundwater or raw drinking water. Reverse osmosis is considered to be a Best Available Technology (BAT) for treatment of a variety of constituents in drinking water applications. Ion exchange is also a BAT technology for many constituents, however, is operated effectively over a lower range of background TDS conditions. The RO system provides a more robust technology to respond to potential changes in the background water quality.

The Reverse Osmosis Systems Analysis (ROSA) modelling program developed by Dow for their Filmtec membranes was used to model the RO system operations and showed that recovery (permeate production) of 83% could be reasonably achieved. Further system design and optimization may show that higher recovery can be achieved, however, final optimization of the RO system will be completed in detailed design and a conservative value was used for the conceptual evaluation. The ROSA program includes projections of rejection (contaminant removal) for some constituents but not for most of those parameters shown on Table 1. For the purposes of the conceptual evaluation the RO rejection was based on data and information from the treatment of other waters. Table 2 shows the removal efficiency used in the projections for the RO system. It should be noted that permeate quality is often below detection for many metals and so the calculation of removal efficiency for specific parameters is limited because the metal is removed to the detection limit. Higher removal efficiency may be achieved. Table 3 shows the results of the bench-scale RO operations. The bench-scale RO is a single membrane (Dow BW-2540) system operated to produce more concentrated water for bench-scale passive operations. As shown, the majority of the constituents were removed to non-detect levels with the removal efficiency calculated at one-half the detection limit.

Table 1: Projected Effluent Quality for Effluent Treatment Facility Options, Worst Case

Constituent	Units	Site-Specific Water Quality Objectives	ETF Influent Design Basis	RO with Brine Treatment by Chemical Precipitation and Biotreatment - Early Years	RO with Brine Treatment by Chemical Precipitation and Biotreatment - Worst Case
				EOP Level	EOP Level
pH	s.u.	5.5	5.5	6.5 to 9	6.5 to 9
Temperature	˚C	15	15	-	-
Alkalinity	mg/L as $CaCO_3$	-	22.1	0.19	0.807
Aluminum	mg/L	0.41	5.8	0.16	0.377
Ammonia	mg/L	4.16	15.0	2	2
Antimony	mg/L	0.03	0.05	0.0041	0.008
Arsenic	mg/L	0.05	0.72	0.011	0.018
Barium	mg/L	-	0.21	0.009	0.012
Beryllium	mg/L	-	0.00309	0.00003	0.00006
Boron	mg/L	-	0.59	0.134	0.36
Cadmium	mg/L	0.00015	0.00074	0.000011	0.000011
Calcium	mg/L	-	72.5	78	117
Chloride	mg/L	353	107	58	107
Chromium	mg/L	-	0.0066	0.00026	0.00026
Cobalt	mg/L	0.010	0.470	0.0050	0.0052
Copper	mg/L	0.022	0.032	0.0006	0.0007
Iron	mg/L	1.5	9.3	0.19	0.24
Lead	mg/L	0.008	0.015	0.0001	0.0002
Magnesium	mg/L	-	24.7	0.476	0.926
Manganese	mg/L	-	0.28	0.00312	0.00291
Mercury	mg/L	-	0.00016	0.00001	0.00001
Molybdenum	mg/L	-	0.110	0.009	0.017
Nickel	mg/L	-	0.034	0.001	0.001
Nitrate	mg/L as NO_3	133	62	62	62
Nitrite	mg/L	-	35.7	17.9	35.7
Phosphorous	mg/L	-	0.264	0.022	0.044
Potassium	mg/L	-	527	265	527
Selenium	mg/L	0.005	0.127	0.003	0.003
Silver	mg/L	-	0.00260	0.0006	0.001
Sodium	mg/L	-	120	35	120
Strontium	mg/L	-	0.332	0.0051	0.014
Sulfate	mg/L	500	421	117	317
Thallium	mg/L	-	0.0259	0.00038	0.00038
Tin	mg/L	-	0.052	0.008	0.008
Uranium	mg/L	0.027	0.122	0.001	0.002
Vanadium	mg/L	-	0.0047	0.00013	0.00017
Zinc	mg/L	0.11	0.116	0.003	0.003

ETF = Effluent Treatment Facility; EOP = end-of-pipe; RO = reverse osmosis; mg/L = milligram per litre; °C = degrees Celsius

Table 2: Removal Efficiencies for Treatment Processes

Constituent	Reverse Osmosis Removal Efficiency	Chemical Precipitation and Biotreatment Removal Efficiency (Brine)
pH		
Temperature		
Alkalinity	0.97	0.99
Aluminum	0.98	0.95
Ammonia	0.85	0.85
Antimony	0.97	0.88
Arsenic	0.98	0.97
Barium	0.98	0.96
Beryllium	0.99	0.99
Boron	0.60	0.65
Cadmium	0.99	0.99
Calcium	0.98	Increase
Chloride	0.96	0.00
Chromium	0.97	0.99
Cobalt	0.99	0.999
Copper	0.98	0.99
Iron	0.99	0.99
Lead	0.99	0.99
Magnesium	0.99	0.97
Manganese	0.99	1.000
Mercury	0.96	0.99
Molybdenum	0.98	0.86
Nickel	0.98	0.98
Nitrate	0.74	0.00
Nitrite	0.98	0.00
Phosphorous	0.97	0.86
Potassium	0.96	0.00
Selenium	0.98	0.95
Silver	0.97	0.80
Sodium	0.94	0.00
Strontium	0.98	0.97
Sulfate	0.99	0.25
Thallium	0.99	1.00
Tin	0.97	0.88
Uranium	0.99	1.00
Vanadium	0.97	0.99
Zinc	0.98	0.99

Table 3: Bench Scale Reverse Osmosis Removal Efficiency

Constituent	Units	Blended Water from Pilot Plant	Permeate - Bench-Scale Test	Removal Efficiency
pH	s.u.	7.5		-
Aluminum	mg/L	0.180	<0.018	0.950
Antimony	mg/L	0.0087	0.00095	0.891
Arsenic	mg/L	0.046	0.00042	0.991
Barium	mg/L	0.014	<0.00029	0.990
Beryllium	mg/L	<0.00008	<0.00008	-
Boron	mg/L	0.066	0.031	0.530
Cadmium	mg/L	0.000045	<0.00004	0.556
Calcium	mg/L	15	0.042	0.997
Chloride	mg/L	35	-	-
Chromium	mg/L	0.00061	<0.0005	0.590
Cobalt	mg/L	0.012	<0.000054	0.998
Copper	mg/L	0.018	<0.00056	0.984
Iron	mg/L	0.75	<0.022	0.985
Lead	mg/L	0.0014	<0.00018	0.936
Magnesium	mg/L	7.4	0.012	0.998
Manganese	mg/L	0.050	<0.00031	0.997
Mercury	mg/L	<0.000027	<0.000027	-
Molybdenum	mg/L	0.078	<0.00014	0.999
Nickel	mg/L	0.0043	<0.0003	0.965
Phosphorous	mg/L	<0.014	<0.014	-
Potassium	mg/L	81	1.0	0.988
Selenium	mg/L	0.0089	<0.0007	0.961
Silver	mg/L	<0.000015	<0.000015	-
Sodium	mg/L	29	0.7	0.977
Strontium	mg/L	0.039	<0.0003	0.996
Sulfate	mg/L	110		-
Thallium	mg/L	0.0003	<0.00002	0.967
Tin	mg/L	<0.0058	<0.0058	-
Uranium	mg/L	0.017	0.000047	0.997
Vanadium	mg/L	<0.00014	<0.00014	-
Zinc	mg/L	0.042	0.0023	0.945

mg/L = milligram per litre

Table 2 also shows the assumed removal efficiency for the brine treatment system. The removal of selenium and ammonia is due to the biological treatment system and all other metals are removed in the chemical precipitation step. Biotreatment for selenium anaerobically is a proven process and at influent concentrations of selenium in the range of 0.05 to 0.1 mg/L, treated effluent in the range of 0.005 to 0.01 mg/L can be consistently achieved from the biosystem. Further reduction of the selenium concentration is achieved when the treated brine is recombined with the permeate so that final end-of-pipe selenium values, such as the projected ETF discharge of 0.003 mg/L can be achieved. Since the water will be heated there is no reduced effectiveness in the colder months of the biological treatment system. In addition, the aerobic biological polishing process for ammonia is also proven and reduction of ammonia to non-detect levels can be achieved. The lime treatment removal is assumed to be operated at approximately pH 10.

Treatment Residuals

Table 4 shows the quantity of residuals projected for the ETF and include sludge generated by the chemical precipitation process and the biological treatment process. The quantities shown are for clarifier underflow, however, if required for disposal a dewatering step could reduce these quantities by a factor of 3 to 5. In Golder's experience, metal hydroxide sludge (from the chemical precipitation step) typically passes the Toxicity Characteristics Leaching Procedure (TCLP) for hazardous waste determination. Golder's experience with biosludge from selenium treatment also indicates that it would pass TCLP testing. These solid residuals are lower volume and more stable than brine residuals that would be generated with an ion exchange treatment system.

Table 4: Projected Residuals from Effluent Treatment Facility

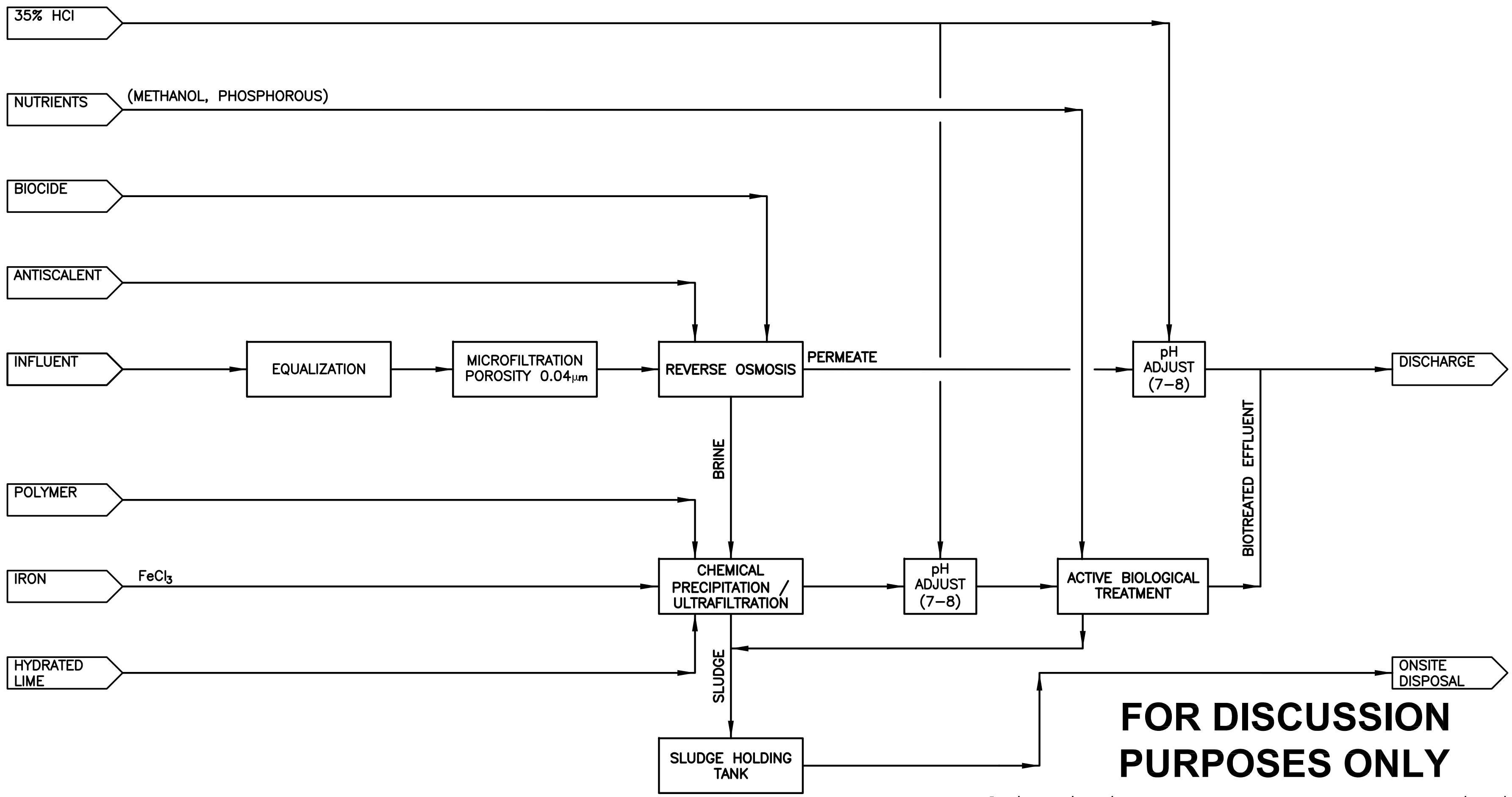
Predicted Flow Volumes to the Effluent Treatment Facility During Operational Years	
Unit	**Average of Startup & End of Operations**
m^3/year	202,713
m^3/day (average ETF inflow)	555
m^3/hr	23
gal/min	102
Secondary Waste Residuals	
Chemical Precipitation Sludge Production	
mg/L (Based on RTW Model)	325
lb/day Dry Sludge	71.56
Concentration	5%
gal/day at 5% solids	172
gal/year at 5% solids	62,632
m^3/year at 5% solids	237
Biological Sludge Production	
lb N removed/gal WAS (ratio with previous projects)	1.23
mg/L MLSS	8000
gal/day	41.77
gal/year	15,245
m^3/year	58

ETF = Effluent Treatment Facility; m^3/year = cubic metre per year; m^3/day = cubic metre per day; m^3/hr = cubic metre per hour; mg/L = milligram per litre; lb/day = pound per day; gal/day = gallon per day; gal/year = gallon per year

Summary

The overall treatment strategy utilizes well proven technologies for the constituents of concern to produce a high quality treated effluent while minimizing the power and resource requirements and producing a low volume stable solids residual. The treated brine and permeate recombination strategy minimizes secondary waste that will be disposed onsite and also provides some buffer capacity to the effluent water. The high quality permeate stream, while very low in metals, is so low in TDS that it is often corrosive and may fail a toxicity test. Therefore, the water quality is actually less toxic when TDS is added back in the form of treated brine. The treatment of the brine stream with the chemical precipitation and biological system is also more efficient (removal of more mass/day) than direct treatment of the raw water with the same technologies with an overall better effluent quality. The treatment of the brine by the chemical precipitation and biological treatment processes has several additional advantages including the following:

- Treatment of ammonia and selenium at a lower flow rate so that longer retention times can be achieved without the requirement for high volumes and footprint.
- The brine produced by the RO system allows for treatment of more concentrated metals in the chemical precipitation step. The ETF influent is a fairly clean stream relative to many mining influenced waters and is more similar to a groundwater or a drinking water source. The precipitation of metals with lime is often more efficient at higher metals concentrations as the solids concentration in the reaction tank can provide more sites for precipitate formation and encourage better precipitation and lower residual metals in the treated water.
- The brine treatment circuit produces residuals in a stable solid form from both the chemical precipitation step and the biological treatment step.



FOR DISCUSSION PURPOSES ONLY

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
3	1/28/11	AMM	YEAR ROUND TREATMENT FLOW REVISION	NTG	BCH	KWC
2	12/15/10	AMM	SITE SPECIFIC WATER QUALITY OBJECTIVES	AMM	BCH	KWC
1	10/11/10	AMM	ACTIVE TREATMENT FLOW REVISION PER WATER BALANCE	AMM	BCH	KWC

PROJECT

FORTUNE MINERALS LIMITED
NICO PROJECT

TITLE

BLOCK FLOW DIAGRAM OF ETF REVERSE OSMOSIS & CHEMICAL/ BIOLOGICAL TREATMENT OF BRINE

Golder Associates
DENVER, COLORADO

PROJECT No. 101–118–0046		
DESIGN	AMM	06/24/10
CADD	AMM	06/24/10
CHECK	BCH	07/13/10
REVIEW	KWC	07/15/10

FILE No. 1011180046A
SCALE N.T.S. REV. A

1

Plot Time: 02/23/12 09:00

Drawing File: N:\10\101-1180046_B (Treatment Requirements and Alternatives)\ 1011180046A_feb2012REV.dwg | Layout: OPTION 4B | Modified: Feb 16, 2012 17:05 RSchipper | Plotted: 02/23/12 9:00am RSchipper