APPENDIX 4-T
HDS WATER TREATMENT PLANT DESIGN AND COST UPDATE FOR INCREASED CAPACITY

Seabridge Gold Inc.

KSM PROJECT
HDS Water Treatment Plant Design and Cost Update for Increased Capacity

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KSM PROJECT

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Acknowledgment

This report was prepared to reflect the increased water treatment capacity from an average of 2.2 m^3/s to 2.5 m^3/s and maximum throughput capacity from 3.35 m^3/s to 7.5 m^3/s. The original High Density Sludge (HDS) Water Treatment design work was completed by SGS-CEMI in May 2011. The civil works were designed by Klohn Crippen Berger and the cost estimate was performed by Tetra Tech. In October 2012, Seabridge Gold commissioned a pilot plant to provide guidance for the design of the HDS water treatment plant with increased capacity. The pilot plant work was reported in January 2013 by SGS. This updated engineering design report is based on the latest pilot plant results and provides design and cost estimate for the 7.5 m^3/s throughput design capacity. The work builds on the original work from SGS-CEMI, Klohn Crippen Berger, and Tetra Tech. The report was prepared by Rescan and led by Hoe Teh, P.Eng., water treatment design engineer, and Patrick Lefebvre, P.Eng., mechanical engineer and was reviewed by Clem Pelletier, senior director for the KSM Project.

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Executive Summary

Rescan Environmental Services has reviewed and updated the SGS-CEMI KSM High Density Sludge Water Treatment Plant design and report to treat a wide range of acidic contact water flow rate during the year. The flow rate is projected to be as low as 0.1 m^3/s during December to March then increasing to match natural stream flows through spring to a maximum of 7.5 m^3/s in the summer months. The previous SGS-CEMI design, based on preliminary batch tests, was for an average flow rate of 2.2 m^3/s and a peak of 3.35 m^3/s.

The current conceptual plant design has been based on the subsequent SGS pilot plant testing of the HDS process conducted in October 2012 and reported in "An Investigation into KSM Project HDS Pilot Plant," January 11, 2013 by SGS. It adopts the flow sheet developed by SGS but with updated mass balance, process design criteria, sizing of major equipment, plant design and general arrangement drawings of the plant and site to accommodate the new range of flow rates.

The pilot plant test work showed that the acid and metals of concern can be removed by the High Density Sludge (HDS) process operating at a pH of 10.5, residence time of 90 min, and a sludge recycle ratio of 35:1. Based on the pilot plant results, over 90% of the influent contaminants of concern will be removed to meet the authorised MMER monthly mean concentrations.

The plant is projected to produce 680 tpd (dry) sludge at the peak flow of 7.5 m^3/s.

The HDS plant has been designed to treat the 7.5 m^3/s maximum flow in 7 parallel trains at approximately 1 m^3/s per train. A HDS plant for this capacity based on individual trains has been proven commercially as it is operated within Barrick Gold Corp's Pueblo Viejo Gold Project facilities in the Dominican Republic. The plant will operate continuously with the number of online trains governed by the influent flow rate.

Each train will consist of a lime/sludge mix tank, two reactors in series, and a 64 m conventional clarifier. There will be four 1000 t lime silos, three slakers, and three lime slurry feed tanks to make up and provide lime to the reactor trains. The treated clarifier overflows will be channeled to the polishing pond while the sludge from each clarifier will be purged to a common filter feed tank that will feed three membrane filter presses. The filter cake will be trucked to a secure landfill during construction and to the crusher during operations. During decommissioning and closure, the sludge will be permanently stored in secure storage areas on the rock storage facility. The filtrates from the filter presses will be collected in a common filtrate tank then recycled to a clarifier. Sulphuric acid will be added to the total combined clarifier overflow to reduce the pH to between 7 and 8 prior to the polishing pond to reduce aluminum concentrations and comply with effluent discharge regulations.

With seven reactor trains and the designed sizes of tanks, the plant is able to handle short term surges such as when one train goes offline for service during maximum influent flow. In such cases, the load to each of the remaining six trains increases by about 17%. The plant will maintain target effluent quality by increasing the lime consumption based on the pilot plant test work at 60 min residence time. With properly controlled sludge recycle and flocculation, the clarifier will handle the small increase in hydraulic loading.

Redundancies of key pieces of equipment have been incorporated in the design to ensure continuous operation. These include installed standby pumps, dedicated air compressors for each train, and duplicate lime loops and sludge recycle lines in case of failures and plugups.

Two smaller reactors in series have been included in the plant for treating the very low flows during the winter months.

The equipment will be robust for a long-term operating life. The process is highly alkaline and steel will largely be used in wetted equipment such as tanks, agitators and pumps. The clarifiers will be constructed out of concrete for durability and because of their large size.

The plant will be instrumented for automatic control and minimal operator intervention using PLCs coupled with HMI operator interface. Built-in process alarms will alert the operator to operation issues for prompt corrective actions. The automatic control and alarms will ensure a reliable operation.

The estimated direct capital cost including civil works is $170 million.

KSM PROJECT

HDS WATER TREATMENT PLANT - DESIGN AND COST UPDATE FOR INCREASED CAPACITY

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1. Introduction

The KSM Project is located approximately 65 km northwest of Stewart in British Columbia, Canada at North 56°30' and West 130°. It is a copper-gold-silver-molybdenum mine where acidic contact water will be produced during and after the life of the mine operation. The contact water will be captured and treated before discharging to the environment. The treatment process tested and selected is a lime-based High Density Sludge (HDS) process that will remove the acid and metals prior to discharging to the environment. This process is selected as it is effective in neutralizing acid and removing metals as a chemically stable high density sludge, containing gypsum and metal hydroxides, while minimizing sludge volume for handling and storage.

A previous design report was issued by SGS-CEMI in May 26, 2011, based on bench-scale tests and data from previous HDS plants designed by SGS-CEMI. The current design in this update is based on the pilot plant test work at SGS in October 2012 and the increased capacity associated with the latest mine design.

1.1 THE HDS PROCESS

The primary feature of the HDS process is the ratio of recycled sludge to new precipitate production. The precipitation of gypsum and co-precipitation of metal hydroxides with iron occur on the surfaces of the recycled sludge particles in an oxidizing environment. The co-precipitation of metals with iron results in effective metal removal and a chemically stable sludge. The chemical stability of sludge is affected by the ratio of total iron to total metals, whereby a sufficiently high ratio is favourable. Iron is added in cases where the concentration and ratio of iron to metals are inadequate. It is not anticipated that iron will be required in this situation. Sludge recycle results in more discrete sludge particles which enhances solid-liquid separation and sludge compaction.

The key chemical reaction is the oxidation of ferrous iron to ferric with oxygen. This reaction is the main oxygen consumer. Normally, oxygen is provided through air sparging and the oxidation rate is controlled by mass transfer of oxygen. Consequently, reactor sizing, aeration rate and agitator design are critical to proper air/oxygen dispersion and mass transfer.

The precipitation of metals (M) as hydroxides and sulphate as gypsum and neutralization of acid using lime addition in a highly alkaline solution are governed by the following reactions:

$$M^{2+} + SO_4^{2-} + Ca^{2+} + 2(OH)^- + 2H_2O \rightarrow M(OH)_2 + CaSO_4.2H_2O$$

$$2M^{2+} + 3SO_4)^{2-} + 3Ca^{2+} + 6(OH)^- + 6H_2O \rightarrow 2M(OH)_3 + 3CaSO_4.2H_2O$$

Gypsum will precipitate when gypsum saturation occurs. The presence of gypsum and excess lime in the sludge act as a buffer and help to stabilise the sludge chemically and enhance solid-liquid separation. Hence, the HDS technology is beneficial to operations that produce a high amount of sulphate.

A typical HDS process comprises the following: Lime is added to recycled sludge in a lime-sludge mix tank at the start of the process and the slurry mixture becomes the main neutralizing agent for the process. The slurry then discharges into the first lime reactor, a rapid mix tank, where it is mixed with the raw acidic influent to neutralize the acid and precipitate the dissolved metals. Aggressive agitation and aeration in the reactor promote the oxidation of iron, acid neutralization and effective precipitation of gypsum and metal hydroxides. The slurry cascades to the second lime reactor to ensure that the precipitation reactions are compete. The slurry then discharges into an agitated flocculation tank (optional) to be mixed with flocculent for solids settling in the clarifier. The solids and treated water are separated in the clarifier. The sludge, as clarifier underflow, is continuously recycled to the lime-sludge mix tank while a portion, equivalent to new sludge production, is purged off intermittently to sludge filtration then long term storage or co-mingling with the tailing through ore processing. The clarifier overflow is the treated water which is neutralized and discharged to the environment.

Operating pH in the lime reactors is typically controlled between 8.5 and 9.5 as it is the range where ferrous iron oxidation rate is fast and most metals will precipitate as hydroxides. However, the optimum pH in this situation is 10.5 due to specific dissolved metal requirements as determined during the pilot plant operations. Air is commonly used to provide oxygen for the oxidation reaction.

1.2 ADVANTAGES OF HDS PROCESS

There are advantages of an HDS process over the simple lime neutralization process, aside from the improved chemical stability of the sludge mentioned earlier.

The main advantage is the reduction of sludge volume and improved compaction. Typically, sludge production is around 1 kg/m^3 of influent and this low amount of solids from a simple lime process is challenging to settle effectively. In addition, the metal hydroxides formed are typically voluminous and do not compact which adds to the challenges for settling. The resultant clarifier underflow has low density (around 5% solids) and the underflow sludge is too dilute for efficient filtration or storage. Comparatively, HDS underflow sludge particles are more discrete and will compact to a high density, typically over 25% solids. These factors enhance filtration and decrease the sludge volume, handling, storage, and disposal costs, making the HDS process more cost effective than a simple lime process.

The HDS process is an established and proven process with successful operations worldwide and the sludge has been proven to be chemically stable.

Other advantages of the HDS process include:

- Improved physical stability. The water in the sludge can drain within a few days of deposition and compact to over 65% solids to provide the physical strength for supporting heavy equipment;
- Use of conventional equipment that are readily available from many vendors with the benefits of competitive pricing and a small spare parts inventory;
- Simple process that can be easily automated;
- Production of high quality effluent in terms of TSS and dissolved metals; and
- Lower neutralization costs compared with simple lime processes.

2. HDS Pilot Plant

A pilot plant test program on the HDS process was completed at the SGS Mineral Services Research laboratory in Burnaby, BC from October 20, 2012 to October 29, 2012. The pilot plant program was an extension of the batch tests conducted by SGS in October 2011. The program consisted of several 24-hour continuous campaigns to evaluate and optimize the key process variables. The continuous test program demonstrated that the HDS process is effective in removing dissolved metals, particularly Fe, Cu, Zn, As and Hg, and generated process design criteria for a commercial operation. The pilot plant also demonstrated that selenite could be effectively removed.

The pilot plant was set up in a typical HDS configuration comprising a lime/sludge mix tank, 2 lime reactors, a flocculation mix tank, a clarifier and lime and flocculent feed systems.

2.1 FEED SOLUTION

Raw water for the program was collected from upper Mitchell Creek, below the toe of Mitchell Glacier. Laboratory grade reagents were then added to the water to simulate the predicted contact water chemistry so that the optimized process parameters and performance achieved would be applicable to the commercial operation. Table 2.1-1 lists the predicted contact water quality, quality of the Mitchell Creek water at the time of sampling, and the adjusted pilot plant feed solutions.

Table 2.1-1. Quality of Predicted Water and Pilot Plant Feed (mg/L)

	Predicted Water Quality	Mitchell Creek Water	Pilot Plant Batch 1	Pilot Plant Batch 2
pH	2.5 to 3.5	3.09	2.79	2.73
Aluminum	35	6.89	34.4	34.1
Antimony	0.005	<0.00010	0.0009	0.0018
Arsenic	0.162	0.00044	0.129	0.153
Barium	0.015	0.0368	0.091	0.0975
Beryllium	0.02	0.00206	0.00277	0.0187
Boron	0.05	<0.010	<0.020	<0.05
Cadmium	0.0314	0.0207	0.0446	0.0418
Calcium	150	30.4	54.3	165
Chromium	0.02	0.00039	0.0242	0.0224
Cobalt	0.45	0.0217	0.487	0.518
Copper	25	2.45	20.6	24.9
Iron	300	13.9	234	257
Lead	0.04	0.0247	0.038	0.034
Lithium	0.038	0.0084	0.012	0.012
Magnesium	17.2	4.99	24	24.8
Manganese	15	2.29	13.8	16.6
Mercury	0.00005	<0.000010	0.000025	0.000033
Molybdenum	0.23	<0.000050	0.151	0.0135
Nickel	0.147	0.00774	0.188	0.196

(continued)

Table 2.1-1. Quality of Predicted Water and Pilot Plant Feed (mg/L) (completed)

	Predicted Water Quality	Mitchell Creek Water	Pilot Plant Batch 1	Pilot Plan Batch 2
Phosphorus	20	<0.30	<0.3	<0.3
Potassium	1.8	0.526	1.76	1.94
Selenium	0.12	0.00054	0.128	0.130
Silver	0.005	0.000031	0.0044	0.00485
Sodium	4.1	<2.0	5.8	4.17
Strontium	0.8	0.246	0.737	0.804
Zinc	3.2	1.37	3.64	3.52
Sulphate	1850	222	1170	1540

2.2 PILOT PLANT OPERATION

Several continuous campaigns were run to evaluate the effect on effluent quality and reagent consumptions of the key parameters: pH, residence time and sludge recycle ratio. Other preliminary bench tests were made to determine solids production, settling and filtration characteristics, and metals precipitation using sulphide for comparison with HDS process. Fish toxicity testing of the treated water was also completed.

2.2.1 Effect of pH

The process variables tested are shown in Table 2.2-1 while the corresponding treated water quality is listed in Table 2.2-2.

Table 2.2-1. pH Optimization Process Variables

	Residence Time min	pH	Recycle Ratio	Lime Consumption kg/m^3
Test 2A	60	9.6	35.1	0.55
Test 3A	60	10.5	19.1	1.19

Table 2.2-2. Treated Water Quality from pH Optimization Tests (mg/L)

	Feed	Test 2A pH 9.6	Test 3A pH 10.5
Aluminum	31.3	2.13	2.13
Antimony	0.00077	<0.00050	<0.00050
Arsenic	0.130	<0.00050	<0.00050
Barium	0.0910	0.0236	0.0173
Beryllium	0.0193	<0.00050	<0.00050
Boron	<0.0025	<0.0025	<0.0025
Cadmium	<0.050	<0.050	<0.050
Calcium	162	628	482
Chromium	0.0209	0.00418	0.00517
Cobalt	0.496	0.00064	<0.00050
Copper	23.6	0.0032	0.0042
Iron	235	<0.050	0.051

(continued)

Table 2.2-2: Treated Water Quality from pH Optimization Tests (mg/L) (completed)

	Feed	Test 2A pH 9.6	Test 3A pH 10.5
Lead	0.0391	<0.00025	<0.00025
Lithium	0.0133	0.0112	0.0047
Magnesium	24.9	18.2	1.11
Manganese*	15.6	0.116	0.00261
Mercury	0.000042	<0.000010	<0.000010
Molybdenum	0.0146	0.0241	0.0234
Nickel	0.189	<0.0025	<0.0025
Phosphorus	<0.30	<0.30	<0.30
Potassium	1.88	1.92	1.87
Selenium	0.119	0.0628	0.0635
Silicon	6.73	0.063	0.149
Silver	0.00523	<0.000050	<0.000050
Sodium	3.96	4.26	4.18
Strontium	0.894	0.905	0.801
Thallium	0.000149	0.000067	<0.000050
Tin	<0.00050	<0.00050	<0.00050
Titanium	0.96	0.012	<0.010
Uranium	0.00236	<0.000050	<0.000050
Vanadium	0.0072	<0.0050	<0.0050
Zinc	3.42	<0.0050	<0.0050
Sulphate*	1540	1630	1130

** Manganese at pH 9.6 was 116 µg/L and at pH 10.5 was 2.6 µg/L*
Sulphate was reduced from 1630 mg/L to 1130 mg/L.

The results in Table 2.2-2 show that pH 10.5 is the optimum pH for metals removal from this contact water.

The majority of the metals, including arsenic, cadmium, copper, selenium and zinc, were removed at both pH values of 9.6 and 10.5 to below the British Columbia discharge limits. This is attributed to the relatively high iron to metals ratio and resultant co-precipitation with iron. The higher pH of 10.5, though, was more effective in removing cobalt, lithium, magnesium, and manganese.

2.2.2 Effect of Residence Time

The process variables utilized in the residence time optimization tests are listed in Table 2.2-3. The optimum pH of 10.5 was used in all the tests while the effects of 40 min to 90 min residence times in 2 lime reactors were evaluated. Solution quality in the first lime reactor was also analyzed to determine the effect of shorter retention times down to 20 min.

The treated water quality achieved for residence times of 20 min to 90 min are tabulated in Table 2.2-4.

Table 2.2-3. Process Variables in Residence Time Tests

	Residence Time min	pH	Recycle Ratio	Lime Consumption kg/m^3
Test 1A	96	10.6	35:1	0.83
Test 3A	62	10.6	19:1	1.19
Test 4A	43	10.6	15:1	1.15

Table 2.2-4. Treated Water Quality from Residence Time Optimization Tests (mg/L)

	Feed	Test 1A 90 min	Test 3A 60 min	Test 4A 40 min	Test 4A 20 min
pH		8.89	9.84	10.64	
Aluminum	35.2	2.27	2.13	3.22	3.96
Antimony	0.00051	<0.00020	<0.00050	<0.00050	<0.00050
Arsenic	0.135	<0.00020	<0.00050	<0.00050	<0.00050
Barium	0.0935	0.0118	0.0173	0.0225	0.0277
Beryllium	0.0186	<0.00020	<0.00050	<0.00050	<0.00050
Bismuth	<0.0025	<0.0010	<0.0025	<0.0025	<0.0025
Boron	<0.050	<0.020	<0.050	<0.050	<0.050
Cadmium	0.0430	0.000121	0.000085	0.000054	0.000058
Calcium	167	341	482	526	541
Chromium	0.0242	0.00482	0.00517	0.00417	0.0038
Cobalt	0.525	0.0002	<0.00050	<0.00050	<0.00050
Copper	24.2	0.00412	0.0042	0.0082	0.0109
Iron	247	0.029	0.051	0.074	0.107
Lead	0.0336	<0.00010	<0.00025	<0.00025	<0.00025
Lithium	0.0128	0.0058	0.0047	0.0054	0.0067
Magnesium	25.1	1.11	1.11	1.3	4.85
Manganese	15.5	0.00167	0.00261	0.00461	0.00689
Mercury	0.0000330	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum	0.0116	0.0579	0.0234	0.0178	0.0139
Nickel	0.203	<0.0010	<0.0025	<0.0025	<0.0025
Phosphorus	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	1.97	1.36	1.67	1.9	1.98
Selenium	0.131	0.0463	0.0635	0.066	0.066
Silicon	6.68	0.112	0.149	0.152	0.092
Silver	0.00457	<0.000020	<0.000050	<.000050	<0.000050
Sodium	4.42	4.73	4.18	4.26	4.56
Strontium	0.792	0.615	0.801	0.839	0.884
Thallium	0.000120	0.000027	<0.000050	<0.000050	<0.000050
Tin	0.00182	0.00092	<0.00050	<0.00050	<0.00050
Titanium	0.95	0.014	<0.010	<0.010	<0.010
Uranium	0.00199	<0.000020	<0.000050	<0.000050	<0.000050
Vanadium	0.0070	<0.0020	<0.0050	<0.0050	<0.0050
Zinc	3.62	<0.0020	<0.0050	<0.0050	<0.0050

The general observations from Table 2.2-4 are:

- Efficient removal of the metals, except for aluminum. This was expected as aluminum solubility decreases with a decrease in pH and it would be expected to precipitate when the treated water pH is lowered to 7.5 prior to discharge.
- 60 min residence time would be adequate to achieve acceptable treated water quality with higher lime consumption.
- 90 min is the optimum residence time as the residence time beyond 60 min improved the removal of calcium, iron, magnesium and manganese.

It was also observed that lime consumption reduced by about 30% at the longer residence time, suggesting better utilization given the longer time to react. The consequent decreased amount of excess lime in the sludge, however, appeared to increase flocculent consumption by about 33%. This effect can be expected as lime is known to act as a coagulant enhancing settling.

2.2.3 Effect of Sludge Recycle Ratio

Sludge recycle ratio is the ratio of the amount of recycled solids to the amount of new precipitate generated from the feed solution. There is an optimum recycle ratio for each set of water chemistry for optimum HDS process performance. An appropriately high sludge recycle ratio also leads to decreased scale formation in the plant as gypsum removal is improved by the increased surface area of recycled solids.

The effect of 15:1 to 35:1 sludge recycle ratio was evaluated through the duration of the pilot plant program. The results showed that:

- The range of sludge recycle ratio had no impact on clarifier overflow clarity.
- The optimum sludge recycle ratio is 35:1. This, in combination with long residence time and high pH, decreased lime consumption, as $Ca(OH)_2$, to 0.83 kg/m^3.
- High sludge recycle ratio increased flocculent consumption due to the increased solids flux in the clarifier. The high recycle ratio would also increase the size of reactors since the overall flow rate is increased.

2.2.4 Solids Production

Batch direct lime neutralization, without sludge recycle, determined that 1.05 g/L of precipitates would be generated from the contact water at the optimum pH of 10.5. This parameter is critical for optimum process chemistry as it defines the clarifier underflow (sludge) recycle flow rate and ratio. These in turn affect plant flows, reactor sizing and sludge handling and disposal.

2.2.5 Metals Precipitation with Sulphide

Batch scoping sulphide precipitation tests were conducted to assess if the sulphide process would be more efficient than the HDS process since the solubility of certain metal sulphides is lower than their hydroxides. The tests were run at lower pH values of 4 to 5 for best sulphide precipitation.

The results indicated that the sulphide process gave better removal of molybdenum but was less efficient than the HDS process on the overall chemistry. Besides, lime addition is required to neutralize the solution after sulphide precipitation. This also aided further removal of certain metals. Consequently, the HDS process is preferred over the sulphide process for treating this contact water.

2.2.6 Sludge Settling and Filtration

Preliminary batch sludge settling tests were run by SGS while the pressure filtration tests were run by Delkor.

The settling tests, conducted at 0.5 mg/L and 0.75 mg/L dosages of Magnafloc 10, gave free settling rates of 0.52 m/h and 0.76 m/h, respectively. Clear supernatant was achieved in both cases suggesting clear overflow would be achieved in the clarifier.

The Delkor filtration tests, simulating conventional filter presses, showed that the sludge could be filtered easily. The results for 2 cake thicknesses are shown in Table 2.2-5.

Table 2.2-5. Pressure Filtration Results

Filtration Pressure Bar	Cake Thickness mm	Cake Moisture %	Dry Bulk Density kg/m^3
7.0	20	67.9	492
7.0	40	67.6	460

The results show that the cake moistures achieved from feed pump pressure and air drying were relatively high due to the morphology of the sludge and its limited compressibility. Delkor, however, indicated that 50% moisture can be achieved if cake pressing is included in the filtration cycle. It is recommended that membrane filter presses be used in the commercial plant to achieve the minimum moisture and a firmer and more manageable cake.

2.2.7 Treated Water Toxicity Tests

Toxicity tests were conducted by Nautilus Environmental, Burnaby, BC on the treated water collected at 0200 hr in the October 28, 2012 pilot plant run. The pH was adjusted to 7.3 for the 96-h LC50 rainbow trout toxicity test and to 8.5 for the 48-h LC50 Daphnia magna toxicity test. The tests met all the criteria outlined in the Environment Canada protocols. The results of the tests are listed in Table 2.2-6.

Table 2.2-6. Treated Water Toxicity Test Results

Rainbow trout	96-h LC50 (%v/v)	>100
Daphnia magna	48 h LC50 (%v/v)	16.5
	with confidence limits	14.5 – 18.8

2.3 PILOT PLANT PRODUCTS

2.3.1 Treated Water Quality

The pilot plant demonstrated that the HDS process will produce clarifier overflow (treated water) that meets the discharge criteria in Sulphurets Creek when operating at the optimum conditions of pH 10.5, 90 min residence time and 35:1 sludge recycle ratio. The clarifier overflow quality achieved under these conditions is listed in Table 2.2-4, Test 1A.

It is noted that about 38% of selenium was removed. The HDS process does not normally remove selenium unless it occurs as selenium (IV) which then could be co-precipitated with iron. Subsequent selenium speciation work confirmed that the majority of the residual selenium in the treated water was selenium (VI).

Mercury concentration was reduced to below detection limit in the treated water, indicating that the HDS process could remove mercury. The removal is expected to be aided by the presence of iron.

2.3.2 Sludge Characterization

The chemical analysis shows that the main components in the sludge are 12.7% calcium, occurring as gypsum (calculated at 54.6%), 19.5% iron, occurring as iron hydroxide, and the miscellaneous metal hydroxides. The pH of the sludge was 9.5.

It should be noted that during operation, the sludge will be trucked year round to the ore processing circuit, fed through the milling circuit, and deposited in a blend with the tailing in the Tailing Management Facility (TMF). The metals will remain immobilized with no potential for dissolution through the mill and in the TMF because the milling process and tailing are alkaline (around pH 10).

3. Process Design and Basis of Design

3.1 PROCESS DESCRIPTION

The acidic contact water collected at the Water Storage Facility (WSF) will be directed to the water treatment site located downstream near the confluence of Mitchell Creek and Sulphurets Creek. A proven, conventional HDS Water Treatment Plant has been proposed to treat the contact water at varying flow rates of up to a maximum of 7.5 m^3/s. The process, flow sheet and design in this update have been based on the successful pilot plant testing of site water at SGS Mineral Services Research Laboratory in October 2012 in Vancouver, BC, Canada. The flow sheets are appended in Appendix 1.

A single large plant to treat 7.5 m^3/s has not been proven commercially, but a plant treating approximately 1 m^3/s has been proven and operating successfully. Consequently, a plant with 7 parallel trains to treat between 1.0 and 1.2 m^3/s per train has been designed for the KSM project.

Depending on flow rate, the contact water from the WSF will be evenly distributed to the operating parallel trains. The water will feed the first lime reactor and optionally to the second lime reactor. Quick lime will be conveyed from the silo to the lime slaker utilizing a vertimill. The vertimill discharge flows through a separation chamber where the oversize material is returned to the vertimill while the fine product (slaked lime) is directed to a pump box. Water is added to the pump box to adjust the slaked lime slurry density to 20% solids then pumped to the lime slurry tank.

The lime slurry in each train will be pumped in a pressure regulated, closed loop to the lime/sludge tank and the two lime reactors. Lime will normally be added only to the lime/sludge tank but it may be added to the lime reactors, if required. Lime addition will be through pinch valves controlled by a feedback loop to maintain the set-point pH in the first lime reactor.

Recycled clarifier underflow (sludge) will also be added to the lime/sludge tank. The combined lime and recycled sludge slurry cascades to the first lime reactor where raw acidic contact water will be added. In the first lime reactor, air will be sparged and vigorous agitation will be used for oxygen dispersion, mass transfer, effective acid neutralization and metals precipitation. The slurry will cascade via an upcomer to the second lime reactor to complete and stabilise the chemical reactions. The slurry will then overflow the second reactor via an upcomer to the clarifier.

Flocculent will be added to the discharge from the second lime reactor. The high flow rate and residence time in the clarifier launder are sufficient for effective flocculent dispersion, solids flocculation and solids settling in the clarifier.

The solids (sludge) will settle as the clarifier underflow which will be continuously recycled to the lime/sludge tank. A portion of the underflow sludge will be purged intermittently to sludge filtration as needed to maintain the desired sludge bed and density in the clarifier. The continuous sludge recycle is needed to promote metals precipitation in the reactors and to improve lime utilization and solids morphology for effective settling and a clear overflow. The clarifier overflow (treated water) pH will be modified with sulphuric acid to the permissible discharge range then directed to the polishing pond to remove any residual total suspended solids (TSS) to less than 15 mg/L prior to discharging to the receiving environment.

3.2 DESIGN OBJECTIVES

The primary objectives of this update are to:

1. Design an HDS plant to treat contaminated contact water during late construction, operation and on closure to perpetuity. The plant will fit within the area where the previous smaller plant was designed to be located.
2. Re-design a plant that will treat a wide range of water flow rates from 0.1 m^3/s to 7.5 m^3/s and produce the quality of treated water achieved in the pilot plant that is acceptable for discharge.
3. Develop the mass balance and process design criteria based on the updated flows and data from the pilot plant.
4. Size the major pieces of equipment.
5. Develop preliminary general arrangement drawings of site and water treatment plant layout.
6. Develop a preliminary summary capital cost estimate for the water treatment plant.

3.3 BASIS OF DESIGN

The process design criteria are tabulated in Appendix 2. The key general criteria are as follows, based on the optimized conditions defined in the SGS pilot plant work.

1. Operate 24 hours, 365 days per year, 100% availability.
2. Minimum influent flow of 0.1 m^3/s, maximum influent flow of 7.5 m^3/s – calculated at 100% availability.
3. Process pH of 10.5.
4. Lime consumption - 0.83 kg/m^3 as $Ca(OH)_2$.
5. Sludge production – 1.05 g/L.
6. Sludge recycle ratio – 35:1
7. Total residence time of 90 min in 2 reactors at maximum influent flow.
8. Clarifier rise rate of 1.2 m/h at maximum influent flow.

The plant has been designed to operate with seven parallel trains such that each train of two reactors in series will treat a maximum of about 1.1 m^3/s influent. This maximum flow rate is selected based on a proven commercial operation at this rate. Barrick Gold Corp's Pueblo Viejo Gold Project in the Dominican Republic operates a 1.5 m^3/s HDS plant. One additional train of smaller reactors has been provided to treat the minimum influent flow rate to avoid the very low line velocities and very long residence time in the large train. The small train will use the same lime system, lime/sludge mix tank and clarifier designed for one of the large trains.

The plant will be able to operate all the time as a result of the multi-train design. If more than one train is offline for a short period of time, the remaining trains will operate at their maximum hydraulic capacity and the balance of the contact water flow will be held back at the WSF.

The plant has been designed with flexibility to bypass the first lime reactor and operate with just the second lime reactor on a temporary basis. Hence, the contact water and lime/sludge slurry may be directed to the second lime reactor if the first reactor is offline for short term service.

The underflow sludge from all the clarifiers will be pumped to a common filter feed tank. The sludge will be filtered in three membrane filter presses. The three filter presses have been designed for cake capacity at maximum flow based on the filtration data in the SGS pilot plant report.

Filtrate from all the filters will be pumped to a common filtrate tank then recycled to a clarifier.

The seven clarifiers are laid out such that the overflows can be directed easily to the polishing pond. The largest pond that will fit the original site has been laid out. The residence time in the pond is estimated at about seven hours at maximum influent flow.

A new access road around the plant has been provided to service the lime silos and for sludge transportation to the storage building, secure landfill or up to the ore conveyor belt.

3.4 MASS BALANCE

The volumetric and mass flows of solids and liquid for 0.1 m^3/s and 7.5 m^3/s influent cases, based on the developed design criteria, are appended in Appendix 3. The mass balance assumes that the specific gravity of sludge solids is 2.5.

3.5 DESIGN CHEMISTRY

The plant has been designed for the Mitchell Creek water used in the pilot plant test work that was spiked to simulate the predicted contact water chemistry. This was shown previously in Table 2.1-1. Consequently, the sludge production, lime requirements and the process parameters that achieved target effluent quality in the test work would apply to the design of the commercial plant. The commercial plant effluent quality would be similar to that achieved in pilot plant Test 1A shown in Table 2.2-4.

As shown in Table 2.2-4, the HDS process is effective in treating contaminated water. It has been proven to be a robust and reliable process in numerous installations around the world to meet water quality objectives. Iron in a HDS system has been proven to be an effective co-precipitant and absorber of metals including arsenic and selenite. Contaminated water with high sulphate concentration can be removed to below the saturation limit of about 1600 mg/L to 1800 mg/L.

3.6 REAGENT CONSUMPTION

The three principal reagents for the process are quick lime, flocculent (Magnafloc 10) and sulphuric acid. The acid will be used to adjust the high process pH of 10.5 down to about 7.5 for discharge. Table 3.6-1 lists the estimated annual consumptions of the three reagents for an average 71 Mm^3 of water treated. The predicted annual volume of water for treatment will range between 63 Mm^3 and 79 Mm^3. The predicted post-closure long term annual volume of water for treatment is 63.6 Mm^3.

It is noted that the quick lime consumption assumes that the commercial lime used will contain 90% available CaO.

Table 3.6-1. Annual Reagent Consumption

Reagent	Dosage	Average Annual Water Treated	Total Annual Reagent Consumption
Quick lime	0.70 kg/m^3	71 Mm^3	50,000 tonnes
Magnafloc 10	3 g/m^3	71 Mm^3	213 tonnes
Sulphuric acid	11 ml/m^3 of 36.8N	71 Mm^3	780 m^3

4. Plant Design

4.1 GENERAL LAYOUT CONSIDERATIONS

The general arrangement drawings for site, water treatment plant, main process building and typical lime slaking system are appended in Appendix 4.

The plant has been designed to treat the maximum influent flow through seven parallel trains of lime/sludge tank, two lime reactors, and a clarifier. The seven trains provide robustness and flexibility such that six trains or 86% availability can handle the maximum flow temporarily without adverse effects on operation and effluent quality should one train go offline for maintenance.

The seven clarifiers have been laid out along Coulter-Sulphurets Road to create a more open design within the constraints on the site with clear accesses to the large clarifiers and all the process equipment. The layout also provides for lay down areas and spaces for sludge truck and small vehicle movements. An 8 m wide access road surrounding the plant, connected to Coulter-Sulphurets Road, has been provided for delivery trucks and sludge trucking.

The plant is designed to minimize pumping and to take advantage of the terrain. The lime/sludge mix tank, lime reactors, and clarifier in each train are stepped such that the slurry will cascade down the train. The in-ground clarifiers have been arranged linearly and stepped as well, using the sloping terrain, so that the overflows are easily collected in a single channel and gravitate to the polishing pond.

All the process tanks and clarifiers are located in the open given their large sizes. Insulation and heat tracing will be used where required. Only the lime slaker, MCC and compressors will be located in buildings to service the operations in their vicinity. There will be a Main Process Building to house the facilities that need to be covered - filter presses, flocculent makeup system, dry flocculent storage, offices, control room, lunch room, laboratory, maintenance shop and main electrical equipment.

4.2 LIME SYSTEM

4.2.1 Lime Slaker

Quick lime and a vertimill slaker will be used to provide lime slurry for the process. Assuming 90% CaO purity, the quick lime consumption would be about 452 tpd at maximum influent flow rate based on the 0.83 kg/m^3 $Ca(OH)_2$ requirement measured in the pilot plant. Four 1,000 t silos have been provided assuming one week storage in the silos.

One slaker, comprising the typical vertimill system, will be installed to service each pair of lime reactor trains. Quick lime will be metered through a screw conveyor to the slaker. The vertimill slaker discharge will be diluted to about 20% solids and stored in agitated lime slurry tanks. Each slaker will be located in a building near the bottom of the lime silo.

Fresh water will be used for slaking. Process water is not available and generally not recommended for slaking because it has been found in research and from operations to impair neutralization capacity. This is attributed to the typically high sulphate level in the process water which causes gypsum precipitation when contacted with lime and the consequent passivation of quick lime surfaces.

Each slaker will have a capacity of 10 tph. It has been oversized for catch-up capability to refill the lime slurry tank should a slaker go offline temporarily for emergency maintenance.

With the open layout and long distances between process equipment, small MCC and compressor units will also be located in the slaker building to service the trains of equipment in its vicinity. The compressors will service control instrumentation and also provide the oxidation air to the reactors.

4.2.2 Lime Slurry Tank

Three lime slurry tanks will be installed. One tank will service lime/sludge and reactor trains 1 to 3 and two smaller tanks will service trains 4 to 7. A single lime slurry tank for the entire operation is not as favorable because the lime loop will be too long due to the long distances between the first and last reactor trains. Such a long line is more prone to plugups.

Each tank will be fitted with baffles and an agitator.

The lime slurry will be pumped continuously at 3 to 4 times the consumption rate around the reactor trains in a pressure regulated, closed loop with the lime slurry tank. Duplicate HDPE piping loops will be installed to avoid shutdowns when the supply of this key reagent is interrupted by a plugup in the loop. Low flow gland water pumps, one operating and one standby, will be used to minimize continuous dilution by the gland seal water. Lime slurry will be added to the lime/sludge tank on demand via pinch valves as controlled by the pH in the first lime reactor in each train. There is provision to add lime to the first lime reactor, if necessary for pH trimming during operation.

The lime slurry storage tank for trains 1 to 3 is sized at 10 m dia x 11 m and each of the 2 tanks for trains 4 to 7 is sized at 9 m dia x 10 m. The tanks have been sized to provide about 24 hour storage capacity at a pulp density of 20% solids. The tank will be made of carbon steel. The design capacity allows for short slaker down times while maintaining operation through the rest of the process train.

4.3 LIME/SLUDGE MIX TANK

Each lime/sludge mix tank is sized for mixing the maximum lime consumption per train with recycled sludge corresponding to the 35:1 sludge recycle ratio. The residence time will be about 3 min at maximum flow. The tank will be made of carbon steel, given the highly alkaline slurry.

Each tank will be fitted with baffles, an upcomer and an agitator with high pumping capacity for efficient blending of the viscous mixture of lime slurry and recycled sludge. The mixture will overflow via an upcomer to the first lime reactor.

There is provision for the lime/sludge slurry to bypass the first lime reactor to the second reactor should the first reactor go offline temporarily for service.

The tank is sized at 3 m dia x 3.5 m, one for each train.

4.4 LIME REACTORS

The 2 lime reactors in series within each train will be made of concrete for robustness given their large size and aggressive agitation forces. The agitator gear reducer will be of very heavy duty design for the required vigorous solids suspension and fine gas (air) dispersion and oxygen mass transfer. The reactors will have four baffles for improved mixing. The agitator will have pitched blade impellors to provide efficient solids suspension, liquid-solid mixing and air dispersion.

Each reactor is sized to provide 45 min residence time at maximum influent flow rate and the corresponding lime slurry and recycled sludge flows. Each reactor will have air sparging to provide oxygen for the oxidation of ferrous iron. A train of two smaller reactors will be used during periods of minimum influent flows. Each reactor will have an upcomer to avoid short-circuiting as the slurry overflows to the next stage. The pH in the first reactor will be controlled via a feedback loop on lime addition to the lime/sludge tank. The slurry will overflow the second lime reactor to the clarifier.

Piping is installed to bypass either lime reactor for operating flexibility. Each reactor in the seven trains for the high flow case will be 16 m dia x 17 m. The two reactors for the low flow case will be 7 m dia x 8 m. There will be 1 m of freeboard in every reactor.

4.5 CLARIFIER

4.5.1 Clarifier Sizing

Preliminary static settling tests at low flocculent dosages were run during the pilot plant. The free settling rate with 0.75 mg/L Magnafloc 10 addition was 0.76 m/h. This is significantly slower than the hydraulic rate of 1.2 m/h, or better, achieved in commercial conventional HDS clarifiers with 2 mg/L to 3 mg/L flocculent additions. Consequently, each clarifier was sized for maximum influent flow assuming a hydraulic loading of 1.2 m/h and 3 mg/L Magnafloc 10 addition. Accordingly, a 64 m dia. clarifier will be installed for each reactor train. In-ground, concrete clarifiers will be used given their large size. For sludge applications, thixoposts will be installed on the rake to minimize disturbances to the sludge bed given its relatively light solids. The clarifier should achieve at least 25% solids underflow density based on the numerous commercial HDS plants that have been operating successfully.

4.5.2 Clarifier Underflow (Sludge)

One operating and one standby underflow sludge recycle pumps will be used on each clarifier to continuously recycle the sludge to the lime/sludge mix tank.

Another pair of pumps will be installed for intermittent sludge purging to the Filter Feed Tank located in the Main Process Building. The purge frequency will be controlled by the bed depth and density in the clarifier.

All the pumps will be located underneath each clarifier to minimize the intake piping length and possibility of plugups. Process water will also be piped into the pump intakes for flushing if needed.

4.5.3 Clarifier Overflow

The overflows from the clarifiers will be collected in a channel running along the line of clarifiers. The channel will be sloped according to the terrain for gravity flow to the polishing pond. Sulphuric acid will be added to the total flow ahead of the pond to adjust the pH to 7.5 measured at the pond receiving point. The flow will be distributed across the pond width to minimize the velocity through the pond and optimize the settling of any residual suspended solids prior to discharging to the receiving environment.

A pumping system will be installed at the pond to recycle the treated water as process water for future use at the mine.

4.6 FILTER PRESSES

Filtration tests simulating filter press operation were tested by Delkor (Vancouver, BC) and reported in the SGS-CEMI pilot plant report. The tests did not incorporate cake pressing to minimize cake moisture. The dry cake density achieved in a 40 mm cake with just air drying was 460 kg/m^3 with a moisture content of 67.6%. Delkor indicated that 50% moisture by weight and a dry cake density of 714 kg/m^3 can be achieved if cake pressing is used. It is recommended that membrane filter presses be used in the plant to minimize cake moisture and produce a firm, manageable cake. This will improve handling and reduce cake volume and handling costs.

Filters are more limited by cake capacity than by hydraulic capacity in sludge filtration applications. Consequently, three membrane filter presses will be required based on a dry cake density of 714 kg/m^3 and a maximum dry cake production of 29 tph at peak influent flow rate.

Each of the three membrane filter presses will have 110 chambers of 1.5 m by 40 mm plates. The filter presses will be located in the Main Process Building.

The filter presses will be elevated for dumping cake on the ground then loaded into trucks or onto conveyors and conveyed into trucks. During operations, the trucks will then transport the sludge cake to the ore conveyor belt or to the adjacent storage building. With the large throughput during the summer, some sludge will be stored in the sludge storage to better regulate sludge addition to the ore conveyor belt feeding the process plant.

The filter presses will be fed from a 10 m dia. steel filter feed tank located just outside the Main Process Building. The tank will be baffled and an agitator installed to keep the solids in suspension and to maintain a homogeneous feed to the filter presses. There will be one filter feed pump dedicated to each filter. An uninstalled spare pump will be available.

The filtrate from all the filter presses will be collected in a pump tank then pumped to a common 5 m dia. steel filtrate tank located outside the Main Process Building. Filter cloth wash, using process (treated) water, will also be collected and pumped to the Filtrate Tank. The combined water will then be pumped back to a clarifier.

4.7 FLOCCULENT SYSTEM

The entire flocculent system will be located in the Main Process Building. A dry flocculent makeup system will be supplied as a vendor package. This will include a feed bin, dry flocculent metering system, wetting system, agitated makeup tank, pumps and dedicated PLC. The bags of flocculent will be stored adjacent to the makeup system inside the Main Process Building

4.7.1 Flocculent Preparation

Based on the pilot plant work, Magnafloc 10 flocculent will be used. Dry flocculent will be delivered in 1 t bags, dumped into the feed bin then mixed with fresh water in the vendor supplied package to make up a 0.5% stock solution. Fresh water will be used instead of process water to ensure flocculent efficiency. Following an appropriate ageing time, the stock solution will be automatically transferred to the Flocculent Holding Tank according to the level controller in the Holding Tank.

The Holding Tank will be 5 m dia. by 6 m to provide 8-hour capacity at maximum influent flow rate.

4.7.2 Flocculent Distribution

Seven variable speed metering pumps will deliver the stock solution in carbon steel lines to the clarifier feed slurries. Each metering pump is dedicated to one clarifier and is individually controlled based on the requirement and performance of the corresponding clarifier. Positive displacement pumps will be used to avoid shear and breakdown of the polymer chains. An uninstalled spare metering pump will be available.

The stock solution will be diluted and mixed with water through an inline static mixer to 0.05% concentration prior to its addition to the clarifier feed slurry. Fresh water is preferred for the dilution but recycled clarifier overflow may also be used. The diluted flocculent solution is more easily dispersed and efficient, thus minimizing its consumption.

4.8 MAIN PROCESS BUILDING

The Main Process Building will be located close to the access road to facilitate delivery of flocculent and truck access for sludge handling. The building is situated closer to the north end of the plant site so as to be closer to Clarifier No.1 to facilitate pumping of a small flow of underflow sludge during winter low influent flow operation. It provides for truck drive-through and 2 levels of working spaces at one end of the building. The building will house the following:

- Offices
- Control room – with view of the south end of the operations
- Lunch room
- Laboratory
- Maintenance shop
- MCC-electrical room
- Compressor area
- Flocculent makeup system, storage and holding tank, including curbed containment area, sump and sump pump
- Filtration area comprising filter feed pumps, three filter presses, filtrate pump tank and pump
- Drive through truck access
- Space for forklift and loader operation
- Fire suppression system

4.9 POLISHING POND

An 80 m by 225 m polishing pond has been provided to settle out residual suspended solids (aluminum oxyhydroxide) in the treated water after pH adjustment prior to discharging to the receiving environment. The treated water will be distributed across the pond to minimize the flow velocity and assist solids settling. Residence time is estimated to be approximately 7 hours at maximum flow rate.

5. Utilities

This updated study does not include the design of infrastructure and services. The utilities required for the Water Treatment Plant are summarized as follows.

5.1 FRESH WATER

Fresh water must not be corrosive and must have minimal suspended solids. Water from the Sulphurets Creek will be pumped to a fresh water tank. It will be needed for:

- Lime slaking;
- Flocculent makeup, possibly for dilution at clarifiers;
- Slurry pump gland seals;
- Safety showers and eye washers; and
- Fire water.

5.2 POWER

Electrical power for the plant will be supplied from the proposed power grid, KSM hydro-plants and the Energy Recovery Plant. Emergency power will be supplied by diesel generators to maintain operation of key pieces of equipment, such as clarifier rakes, and site lighting during power outages. The clarifier rakes have to be running all the time, otherwise the sludge bed will compact and the rakes will be very difficult to re-start particularly in such large clarifiers.

5.3 COMPRESSED AIR

Compressors will be installed around the plant site to provide compressed air for control instrumentation, lime reactor aeration, lime slaker, filter presses, shop, laboratory and general purposes. They will mainly be located in the lime slaker buildings and the Main Process Building.

5.4 PROCESS WATER

Treated water will be pumped from the polishing pond and piped around the plant site for general purposes, via hose stations, in the shop, line flushing and filter cloth wash.

5.5 FIRE WATER AND SUPPRESSION

Fire (fresh) water will be stored in the bottom portion of the fresh water tank. Fresh water for process uses will be drawn through a pipe located part way up the fresh water tank such that the water volume below this out-take pipe will always and only be available as fire water. The installed fire water pumps will include one diesel powered pump so that there will be one operable pump in the event that electrical power is disabled by a fire.

Fire hydrants will be located around the plant site and at the Main Process Building. Fire extinguishers will also be available at critical locations including at MCCs, control room, lime reactor platforms, clarifier bridges and clarifier underflow discharge cone.

6. Process Control

Control of the HDS process is easily automated for efficient and reliable operation using standard field instrumentation and communications system. Cameras will be installed at key locations, such as at the lime slakers, lime reactors and clarifiers, for operation monitoring from the control room. Pumps and valves can be remotely operated from the control room but local switches will also be available. Inline pH probes, mass flow meters and density meters will provide inputs to the control system to regulate operating parameters including lime requirements and sludge recycle rate.

The control instrumentation and communications system are summarized as follows.

6.1 CONTROL HARDWARE

A variety of typical field control equipment will be used in combination with PLCs and associated I/O modules to fully automate the plant. Field equipment includes:

- solenoid actuated valves;
- mass flow meters;
- density meters;
- variable frequency drives;
- level indicators/transmitters;
- pH controllers;
- sludge bed detectors; and
- turbidity meters.

The control panels will comprise an analog and a discrete panel.

6.2 HMI OPERATOR GRAPHICAL INTERFACE

A desktop computer will run the operator interface. A backup computer will be available to ensure uninterrupted operation and control of the process plant. A dedicated Ethernet will be installed for communications between the computer and the process so that plant operation will not be affected by other network users. There will be a separate network for the offices.

The HMI software will include a historical database for analog and discrete data for reporting purposes and analysis of the operation. The plant operation will be fully automated, but it can also be operated manually by using local stop-starts. The HMI will also generate alarms to alert the operator when any process variable is at fault to ensure timely acknowledgement and remedial action, either remotely via the system or manually at the equipment location.

7. Capital Cost Estimate

7.1 BASIS OF COST ESTIMATE

The preliminary capital cost of the current updated Water Treatment Plant has been estimated using current quotations for the major equipment and by factoring the 2011-2012 Prefeasibility Study estimates by SGS for the water treatment plant and by Tetra Tech Wardrop primarily for the earthworks. The same project scope and battery limits have been adopted for costing this updated plant.

7.1.1 SGS Cost Estimate

The SGS capital cost estimated was based on quotations for the major equipment of the KSM water treatment plant and their database of factors and assumptions used in their designs of other similar plants. Quotations were obtained for the complete lime slaker system, clarifier and flocculent system.

The scope of the estimate was as follows.

<u>Inclusions</u>

- Process equipment including lime slaker, tanks, agitators, clarifier, flocculent system, pumps, process piping
- Buildings for MCC and offices
- Instrumentation and process control systems
- Plant lighting, electrical with grounding
- General excavation

<u>Exclusions</u>

- Sludge filter presses
- Overall site preparation
- Plant roads
- Electrical power feed to the plant
- Water supply and septic systems
- Site lighting
- Emergency power – gensets
- Service facilities including laboratory, washroom, mechanical shop
- Ponds
- Temporary facilities and equipment for construction

7.1.2 Tetra Tech Wardrop Cost Estimate

The Tetra Tech Wardrop cost estimate was for the entire KSM project. Costing line items that apply to the water treatment plant were extracted for addition to the SGS scope of estimate to develop the cost estimate of this updated water treatment plant.

The items used for the cost estimate cover site preparation, water treatment plant feed water piping systems, water tanks and their site preparation.

7.2 COST ESTIMATE DEVELOPMENT

The capital cost estimate has been developed by applying the 0.6 power rule to the SGS/Tetra Tech Wardrop costs, excluding the major equipment costs, then adding the current equipment costs. This industry rule-of-thumb factored methodology is deemed applicable to the water treatment plant because only the capacity has changed while the process, scope and battery limits have remained the same.

As shown in Table 7.2-1, the factored capital cost of the updated water treatment plant is $170 M.

Table 7.2-1. Capital Cost Estimate of Updated Water Treatment Plant

SGS capital cost		$69.9 M	
Less:	lime slaking system	$2.8 M	
	reactor agitators	$1.0 M	
	clarifier mechanisms	$2.7 M	
	flocculent system	$0.3 M	
SGS cost without equipment			$63.1 M
Tetra Tech Wardrop line costs			
	plant site preparation	$19.3 M	
	water tank and earthworks	$1.5 M	
	sludge trucks	$0.6 M	
Tetra Tech Wardop total cost			$21.4 M
Total 2011-2012 estimate without equipment			$84.6 M
2013 cost at 3%/year escalation for 2 years			$89.7 M
Updated WTP flow rate		7.5 m^3/s	
2011 SGS WTP flow rate		3.35 m^3/s	
Updated flow increase factor		2.24	
2013 expanded plant cost by 0.6 rule (no equip)			$145.5 M
Add 2013 major equipment costs			
	lime slaking systems (3)	$9.0 M	
	clarifier mechanisms (7)	$6.0 M	
	reactor agitators (14)	$5.6 M	
	filter presses (3)	$3.6 M	
	flocculent system	$0.5 M	
Total 2013 Capital Cost Estimate			**$170 M**

8. Operating Cost Estimate

8.1 BASIS OF COST ESTIMATE

The preliminary, average operating cost estimate for the water treatment plant has been developed for treating the average annual water volume of 71 Mm^3. The estimate covers the operating costs for water treatment and sludge handling.

The water treatment operating cost portion covers lime slaking through to sludge filtration. The reagent consumptions for the treatment are described in Section 3.6.

- Average annual water volume of 71 Mm3
- Lime consumption of 50,000 t
- Magnafloc 10 consumption of 213 t
- Sulphuric acid consumption of 780 m3 (1,435 t)

It is also assumed that operating and maintenance labor are maintained throughout the year although the operating capacity will vary according to the seasonal flow rates. For example, only one reactor train will operate during the winter months while the entire plant will operate during the summer months.

The total power consumption has been estimated based on the large electrical demands by the three lime slakers and fourteen lime reactor agitators plus allowances for miscellaneous equipment such as pumps, compressors, and general lighting. The estimated connected power is 373 kW for each slaker system and each lime reactor agitator.

The sludge handling cost has been estimated based on:

- Annual dry sludge production of 74,550 t from the 71 Mm^3 of water treated
- Sludge filter cake moisture of 50%
- Distance of 8 km from the water treatment plant to the ore conveyor area
- Use of front-end loader to load 40 t trucks
- All-in operating cost of $110/hr for the loader and $225/hr for the trucks

8.2 COST ESTIMATE DEVELOPMENT

8.2.1 Processing Operating Cost

The annual average operating cost for the water treatment plant is summarized in Table 8.2-1.

The costs of process reagents are based on July, 2013 budgetary prices obtained from vendors.

The average utilization of connected power for the lime slaker systems and lime reactor agitators has been estimated considering the seasonal flow rates and corresponding number of operating reactor trains. An allowance of 20% of the slaker and agitator power consumptions has been provided to cover the consumption by miscellaneous equipment including compressors, pumps, and lighting.

Table 8.2-1. Operating Cost Estimate of Updated Water Treatment Plant

Annual average volume of water treated = 71 Mm^3

A. Labour

	No. Per Shift	Total Labour	Loaded Annual Salary	Total Annual Salary
Supervisor	Day only	1	$128,250	$128,250
Operators	3	6	$95,572	$573,431
Maintenance	Day only	2	$95,572	$191,144
Maintenance	2	4	$95,572	$382,288
Technician	Day only	1	$95,572	$95,572
Helpers	Day only	2	$74,795	$149,591
Sub-total Labour				**$1,520,276**

B. Operating Supplies

	Annual Consumption	Unit Cost	Annual Cost
Quick lime	50,000 t	$280/tonne	$14,000,000
Magnaloc 10	213 t	$3,356/tonne	$714,828
Sulphuric acid	780 m^3	$360/tonne	$516,672
Sub-total Operating Supplies			**$15,231,500**

C. Maintenance Supplies

	Annual Cost
8% of equipment capital cost	$1,976,000
Sub-total Operating and Maintenance Supplies	**$1976,000**

D. Power

Power unit cost = $0.051 kWh

	Number of Systems	Connected kW per system	Utilization %	Annual Consumption kWh	Annual Cost
Lime slaker	3	373	50	4,901,220	
Lime reactor agitators	14	373	65	29,734,068	
Miscellaneous @ 20%				6,927,058	
Sub-total Power				**41,562,346**	**$2,119,680**

TOTAL ANNUAL AVERAGE PROCESS OPERATING COST $20,847,455

Annual Average Unit Operating Cost Distribution

	$/m^3$
Labour	$0.02
Operating supplies	$0.21
Maintenance supplies	$0.03
Power	$0.03
Total	**$0.29**

There is an allowance of 8% of the cost of major equipment for maintenance supplies. The major equipment includes the lime slaker systems, lime reactor agitators, clarifiers, filters and flocculent system.

It is noted that the cost of reagents constitute about 70% of the total processing cost and its unit cost does not vary with treated water volume throughout the year. With full labor deployment through the year, the unit cost for labor, however, will vary by season and the volume of water treated. Consequently, the labor cost portion would range between about $0.48/m^3$ in the winter and $0.01/m^3$ in the summer.

8.2.2 Sludge Handling Operating Cost

The sludge handling operating cost includes loading of the 40 t trucks and trucking from the water treatment plant to the ore conveyor site, and excludes sludge handling from the trucks to the point of addition in the ore conveying system.

The annual average sludge handling operating cost, shown in Table 8.2-2, has been estimated based on:

- Approximately 10 of 40 t round-trips per day,
- Approximately 1-hour round-trips including loading at the water treatment plant to unloading at the ore conveyor site
- Total loader operation of 3 hours/day and truck operation of 13 hours/day, including 20% productivity factor.

Table 8.2-2. Annual Average Operating Cost Estimate for Sludge Handling

Annual average water volume treated	71 Mm^3
Annual dry sludge production	74,550 t
Daily dry sludge production	204 t
Daily wet sludge production	408 t
Loader operating hours per day	3 h
Truck operating hours per day	13 h

	$/hour	Annual Cost	Unit Cost $/m3
Loader operating cost	$110	$123,008	$0.002
Trucking operating cost	$225	$1,039,974	$0.015
Total sludge handling cost		**$1,162,981**	**$0.02**

It is noted that sludge handling requirements vary seasonally. In the winter, only one half truck-load of wet sludge cake will be produced per day, whereas in the summer, 34 truckloads of sludge will be produced each day. However, the unit cost based on water volume treated does not vary through the year.

References

SGS Canada. January 11, 2013. *An Investigation into KSM Project HDS Pilot Plant*. Project 1298, Final Report.

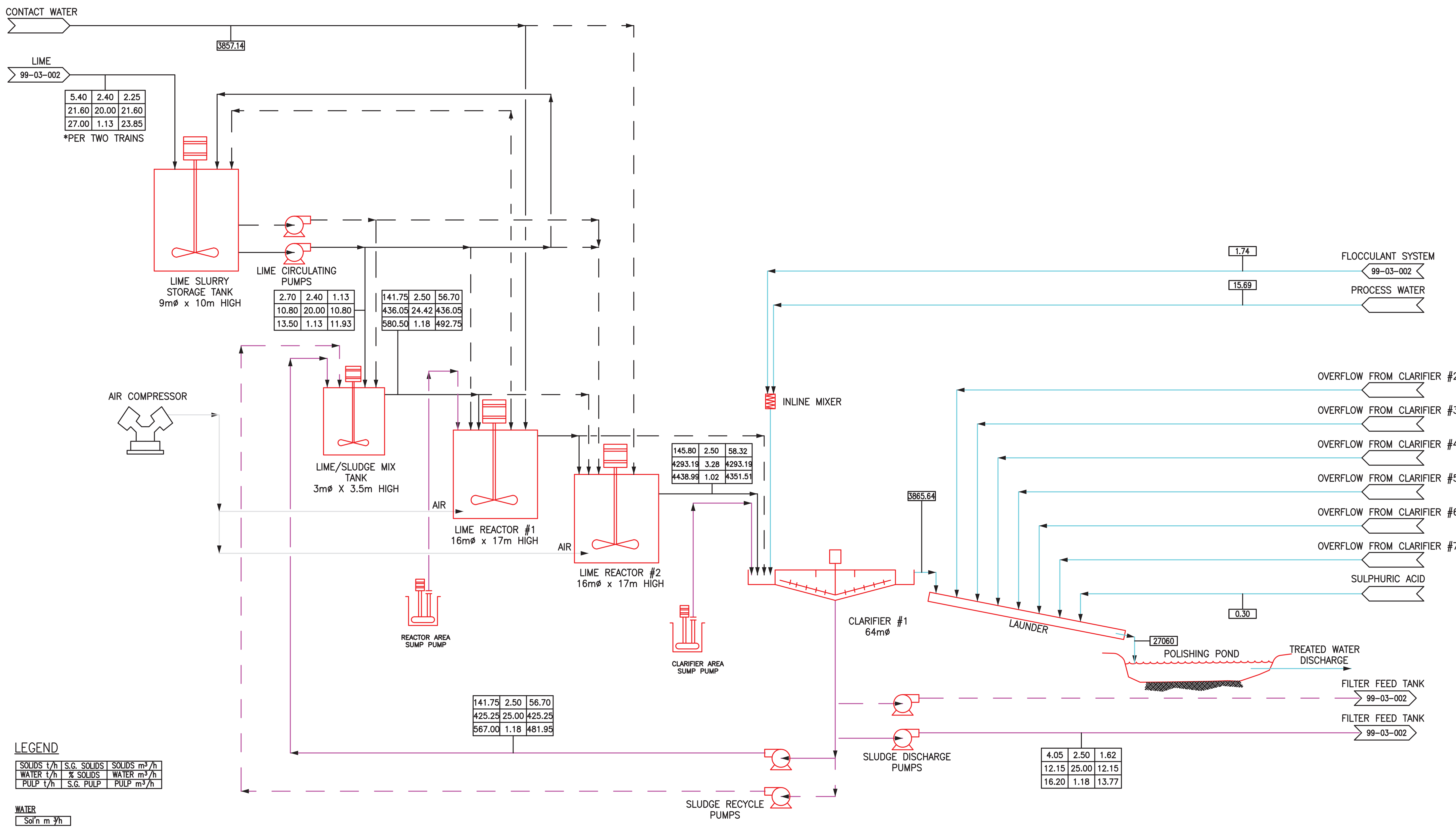
SGS-CEMI. May 26, 2011. *KSM High Density Sludge Feasibility Report, Water Treatment Plant*. Project CEMI-0995, Report No. 0995-0511R03-01

Tetra Tech Wardrop. June 22, 2012. *2012 KSM (Kerr-Sulphurets-Mitchell) Prefeasibility Study*. Document No. 1252880100-REP-R0001-02

Appendix 1

KSM Water Treatment Plant Flow Sheets

PROJECT # 868-027-002 ILLUSTRATION # a42715w_T May 9, 2013



WATER TREATMENT CIRCUIT #1 - TYPICAL FOR CIRCUIT #2 TO #7

SEABRIDGE GOLD
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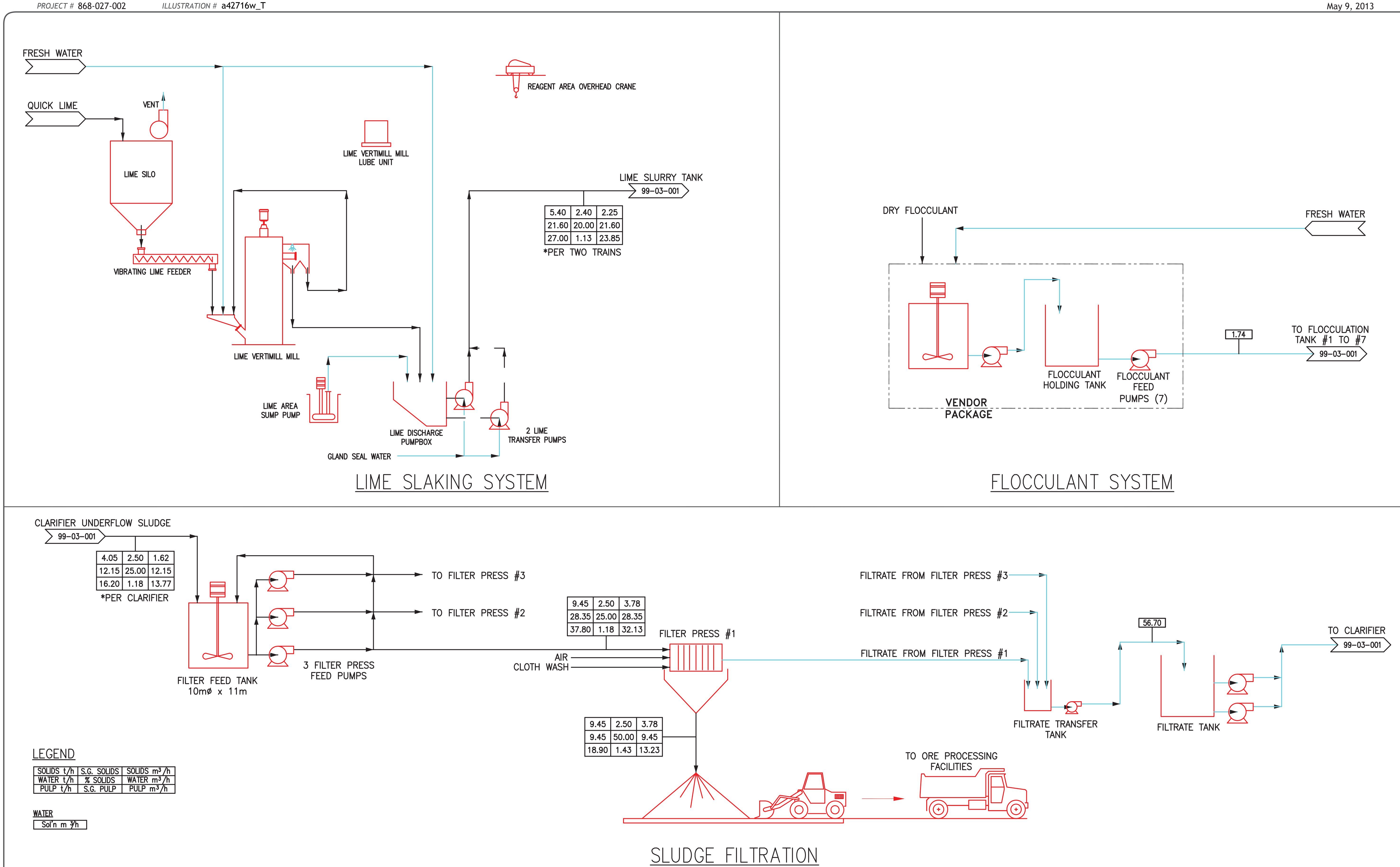
Figure 1-1

PFS Update 2012 Water Treatment Plant Process Flowsheet



SEABRIDGE GOLD
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Figure 1-2

PFS Update 2012 Sludge Filtration and Reagents Process Flowsheet

Appendix 2
Process Design Criteria

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Appendix 2. Process Design Criteria

SEABRIDGE KSM PROJECT - WATER TREATMENT PLANT

PROCESS DESIGN CRITERIA	
PROJECT	KSM WATER TREATMENT PLANT
CLIENT	SEABRIDGE GOLD
DATE	5/1/2013
REVISION	A

SOURCE
1.- CLIENT
2.- CALCULATION
3.- MASS BALANCE
4.- SGS TEST WORK
5.- ENGINEERING DATA
6.- RESCAN
7.- OTHER

		UNITS	VALUE	SOURCE
A	**GENERAL**			
	OPERATING TIME	day/year	365	1
	OPERATING TIME	hr/day	24	1
	MAXIMUM INFLUENT FLOW RATE	m^3/s	7.5	1
	MINIMUM INFLUENT FLOW RATE	m^3/s	0.1	1
	AVAILABILITY	%	100	1
	NO. OF PARALLEL PROCESS TRAINS FOR MAXIMUM INFLUENT		7	6
	NO. OF PROCESS TRAINS FOR MINIMUM INFLUENT		1	6
	OPERATING pH		10.5	4
	SLUDGE SOLIDS PRODUCTION	g/L	1.05	4
	TOTAL SLUDGE SOLIDS PRODUCTION AT MAXIMUM INFLUENT	t/d	680	3
	SLUDGE SOLIDS RECYCLE RATIO		35	4
	SLUDGE SOLIDS SG		2.5	6
B	**PROCESS PLANT**			
	<u>LIME SYSTEM</u>			
	NO. OF LIME SILOS		4	6
	TYPE OF LIME		Quicklime	6
	CAPACITY OF LIME SILOS	t	1000	5
	LIME REQUIREMENT (Ca(OH)2)	kg/m^3	0.83	4
	LIME REQUIREMENT (QUICKLIME CaO)	kg/m^3	0.63	2
	QUICKLIME PURITY (ASSUMED)	%	90	
	COMMERCIAL QUICKLIME REQUIREMENT	kg/m^3	0.70	2
	TOTAL QUICKLIME CONSUMPTION, MAXIMUM INFLUENT	t/hr	18.84	2
	TOTAL QUICKLIME CONSUMPTION, MAXIMUM INFLUENT	t/d	452	2
	LIME SG		2.4	6
	TOTAL NO. OF SLAKERS		3	6
	<u>FOR TRAINS 1 TO 3</u>			
	NO. OF LIME SLAKERS		1	6
	LIME OPERATING RATE, MAXIMUM PER SLAKER	t/h	10	2
	<u>FOR TRAINS 4 TO 7</u>			
	NO. OF LIME SLAKERS		2	6
	LIME OPERATING RATE, MAXIMUM PER SLAKER	t/h	10	2

(continued)

Appendix 2. Process Design Criteria

SEABRIDGE KSM PROJECT - WATER TREATMENT PLANT

PROCESS DESIGN CRITERIA	
PROJECT	KSM WATER TREATMENT PLANT
CLIENT	SEABRIDGE GOLD
DATE	5/1/2013
REVISION	A

SOURCE
1.- CLIENT
2.- CALCULATION
3.- MASS BALANCE
4.- SGS TEST WORK
5.- ENGINEERING DATA
6.- RESCAN
7.- OTHER

		UNITS	VALUE	SOURCE
B	**PROCESS PLANT (continued)**			
	FOR TRAINS 1 TO 3			
	NO. OF LIME SLURRY HOLDING TANKS		1	6
	LIME SLURRY DENSITY	% solids	20	5
	LIME SLURRY CONSUMPTION, MAXIMUM	m^3/h	35.8	2
	LIME SLURRY HOLDING TANK CAPACITY AT MAX FLOW RATE	h	24	2
	LIME SLURRY HOLDING TANK DIAMETER	m	10	2
	LIME SLURRY HOLDING TANK HEIGHT	m	11	2
	FOR TRAINS 4 TO 7			
	NO. OF LIME SLURRY HOLDING TANKS		2	6
	LIME SLURRY DENSITY	% solids	20	5
	LIME SLURRY CONSUMPTION PER TANK, MAXIMUM	m3/h	23.9	2
	LIME SLURRY HOLDING TANK CAPACITY AT MAX FLOW RATE	h	24	2
	LIME SLURRY HOLDING TANK DIAMETER	m	9	2
	LIME SLURRY HOLDING TANK HEIGHT	m	10	2
	LIME/SLUDGE TANK			
	NO. OF TANKS	per train	1	6
	TANK DISCHARGE FLOW RATE, MAXIMUM	m^3/h	493	3
	RETENTION TIME AT MAXIMUM FLOW RATE	min	3	5
	TANK DIAMETER	m	3.0	2
	TANK HEIGHT	m	3.5	2
	REACTORS (MAXIMUM INFLUENT OPTION)			
	NO. OF REACTORS PER TRAIN		2	6
	SLURRY FLOW RATE	m^3/h	4352	2
	RETENTION TIME PER REACTOR AT MAXIMUM FLOW RATE	min	45	3
	REACTOR DIAMETER	m	16	2
	REACTOR HEIGHT	m	17	2
	REACTORS (MINIMUM INFLUENT OPTION)			
	NO. OF REACTORS (ONE TRAIN)		2	6
	SLURRY FLOW RATE	m^3/h	406	2
	RETENTION TIME PER REACTOR AT MINMUM FLOW RATE	min	45	3
	REACTOR DIAMETER	m	7	2
	REACTOR HEIGHT	m	8	2

(continued)

Appendix 2. Process Design Criteria

SEABRIDGE KSM PROJECT - WATER TREATMENT PLANT

PROCESS DESIGN CRITERIA	
PROJECT	KSM WATER TREATMENT PLANT
CLIENT	SEABRIDGE GOLD
DATE	5/1/2013
REVISION	A

SOURCE
1.- CLIENT
2.- CALCULATION
3.- MASS BALANCE
4.- SGS TEST WORK
5.- ENGINEERING DATA
6.- RESCAN
7.- OTHER

		UNITS	VALUE	SOURCE
C	**DEWATERING**			
	CLARIFIER			
	NO. OF CLARIFIER PER TRAIN		1	6
	RISE RATE, DESIGN AT MAXIMUM FLOW RATE	m/h	1.2	5
	FEED SLURRY SOLIDS CONTENT	% solids	3.2	3
	FEED SLURRY FLOW RATE, MAXIMUM	m^3/h	4370	3
	FILTRATE RECYCLE FLOW RATE, MAXIMUM	m^3/h	8.1	3
	FLOCCULANT ADDITION	mg/L	3	4
	FLOCCULANT, 0.5% STOCK SOLUTION FLOW RATE (MAXIMUM)	m^3/h	2.62	2
	FLOCCULANT DILUTION WATER	m^3/h	23.6	3
	CLARIFIER DIAMETER	m	64	2
	CLARIFIER UNDERFLOW DENSITY	% solids	25	4
	CLARIFIER UNDERFLOW RECYCLE, MAXIMUM	m^3/h	482	3
	CLARIFIER UNDERFLOW PURGE, MAXIMUM	m^3/h	13.8	3
	CLARIFIER OVERFLOW (EFFLUENT), MAXIMUM	m^3/h	3913	3
	SLUDGE FILTRATION			
	FILTER FEED, TOTAL	m^3/h	96.6	6
	NO. OF FILTER FEED TANKS, TOTAL		1	6
	FILTER FEED TANK CAPACITY AT MAXIMUM FLOW	h	8	5
	FILTER FEED TANK DIAMETER, EACH	m	10.0	2
	FILTER FEED TANK HEIGHT, EACH	m	11.0	2
	TYPE OF FILTER		Membrane Filter Press	6
	NO. OF FILTERS		3	7
	FILTER FEED FLOW RATE, MAXIMUM PER FILTER	m^3/h	32.1	3
	FILTER CAKE MOISTURE	%	50	5
	CAKE PRODUCTION PER FILTER, MAXIMUM DRY SOLIDS	t/h	9.5	3
	CAKE PRODUCTION PER FILTER, MAXIMUM WET	t/h	18.9	2
	CAKE DENSITY, DRY	kg/m^3	714	7
	FILTER PLATE SIZE	m	1.5	7
	FILTER CHAMBER DEPTH	mm	40	7
	NO. OF FILTER CHAMBERS		110	7
	FILTRATE PRODUCTION PER FILTER, MAXIMUM	m^3/h	18.9	2
	FILTRATE PRODUCTION , TOTAL	m^3/h	56.7	2
	FILTRATE TANK CAPACITY AT MAXIMUM FLOW	h	2	6
	NO. OF FILTRATE TANKS		1	6
	FILTRATE TANK DIAMETER	m	5	2
	FILTRATE TANK HEIGHT	m	6	2

Appendix 3
Mass Balance

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Appendix 3. Mass Balance

PROCESS MASS BALANCE - MAXIMUM INFLUENT CASE
PROJECT: SEABRIDGE KSM WATER TREATMENT PLANT
PROJ. No:
CLIENT: Seabridge Gold Inc.
DATE: 1-May-13

Basis:

No. of trains	7				
Max flow	7.50 m^3/s		27,000 m^3/h		
Max flow/train	1.07 m^3/s		3,857 m^3/h		
Solids SG	2.50				
No. of lime/sludge tanks		7			
Sludge production		1.05 g/L		4.05 t/h per train	
Lime consumption		0.70 kg/m^3		2.70 t/h per train	
Flocculant consumption		3.00 mg/L clarifier feed			0.013 t/h per train
Sludge recycle ratio		35			

STREAM NO	DESCRIPTION	SOLIDS tph	% SOLIDS	SOLN tph	SOLIDS S.G.	SLURRY tph	SOLIDS m^3/h	SOL'N m^3/h	SLURRY m^3/h	SLURRY S.G.	COMMENTS SET PNTS
	EACH TRAIN										
	INFLUENT			3857.14				3857.14		**1.00**	
	LIME SLURRY MAKEUP										
	CYCLONE FEED	6.75	**56.00**	5.30	**2.40**	12.05	2.81	5.30	8.12	1.49	
	CYCLONE UNDERFLOW	4.05	**75.00**	1.35	2.40	5.40	1.69	1.35	3.04	1.78	
	CYCLONE OVERFLOW	2.70	40.58	3.95	2.40	6.65	1.13	3.95	5.08	1.31	
	LIME SLURRY CONSUMPTION	2.70	**20.00**	10.80	2.40	13.50	1.13	10.80	11.93	1.13	
	WATER - LIME MAKEUP/DILUTION			6.85				6.85			
	FLOCCULANT MAKEUP										
	FLOCCULANT STOCK MAKEUP	0.01	**0.50**	2.62				2.62		1.00	
	FLOCCULANT SOLUTION, STOCK			2.62				2.62			
	LIME/SLUDGE TANK										
	LIME SLURRY	2.70	20.00	10.80	2.40	13.50	1.13	10.80	11.93	1.13	
	RECYCLED SLUDGE	141.75	25.00	425.25	2.50	567.00	56.70	425.25	481.95	1.18	
	TANK DISCHARGE	141.75	24.42	436.05	2.50	580.50	56.70	436.05	492.75	1.18	
	REACTORS 1 AND 2										
	INFLUENT			3857.14				3857.14			
	SLUDGE PRODUCTION	4.05	**100.00**		2.50		1.62				
	DISCHARGE SLURRY	145.80	3.28	4293.19	2.50	4438.99	58.32	4293.19	4351.51	1.02	
	CLARIFIER										
	FILTRATE RECYCLE			18.90				18.90			
	FEED SLURRY, NEW	145.80	3.28	4293.19	2.50	4438.99	58.32	4293.19	4351.51	1.02	4377.74
	FEED SLURRY, TOTAL	145.80	3.27	4312.09	2.50	4457.89	58.32	4312.09	4370.41	1.02	
	FLOCCULANT, STOCK SOLUTION			2.62				2.62			
	FLOCCULANT, DILUTION WATER			23.60				23.60			0.05 % diluted floc
	THICKENER UNDERFLOW	145.80	25.00	437.40	7.50	583.20	19.44	437.40	456.84	1.28	26.22 t/h diluted floc
	THICKENER OVERFLOW, TOTAL			3913.07				3913.07			
	THICKENER OVERFLOW (EFFLUENT)			3877.32				3877.32			23.60 t/h water
	THICKENER UNDERFLOW, RECYCLE	141.75	**25.00**	425.25	2.50	567.00	56.70	425.25	481.95	1.18	
	SLUDGE PURGE	4.05	25.00	12.15	2.50	16.20	1.62	12.15	13.77	1.18	
				3889.465							
	SLUDGE FILTRATION										
	PER FILTER OF 3 FILTERS										
	FILTER FEED	9.45	25.00	28.35	2.50	37.80	3.78	28.35	32.13	1.18	
	FILTER CAKE	9.45	**50.00**	9.45	2.50	18.90	3.78	9.45	13.23	1.43	
	FILTRATE RECYCLE			18.90				18.90			
	EFFLUENT										
	TOTAL CLARIFIER OVERFLOWS			27141.21				27141.21			
	ACID ADDITION							0.30			11.00 mL/m3 acid addition
	TOTAL EFFLUENT							27141.50			0.30 m3/h 36.8N acid

Appendix 3. Mass Balance

PROCESS MASS BALANCE - MINIMUM INFLUENT CASE
PROJECT: SEABRIDGE KSM WATER TREATMENT PLANT
PROJ. No:
CLIENT: Seabridge Gold Inc.
DATE: 28-Mar-13

Basis:

No. of trains	1			
Min flow	0.10 m3/s	360 m^3/h		
Max flow/train	0.10 m3/s	360 m^3/h		
Solids SG	2.50			
No. of lime/sludge tanks	1			
Sludge production	1.05 g/L		0.38 t/h per train	
Lime consumption	0.70 kg/m^3		0.25 t/h per train	
Flocculant consumption	3.00 mg/L clarifier feed			0.001 t/h per train
Sludge recycle ratio	35			

STREAM NO	DESCRIPTION	SOLIDS tph	% SOLIDS	SOLN tph	SOLIDS S.G.	SLURRY tph	SOLIDS m^3/h	SOL'N m^3/h	SLURRY m^3/h	SLURRY S.G.	COMMENTS SET PNTS
	EACH TRAIN										
	INFLUENT			360.00				360.00		**1.00**	
	LIME SLURRY MAKEUP										
	LIME SLURRY CONSUMPTION	0.25	**20.00**	1.01	**2.40**	1.26	0.11	1.01	1.11	1.13	
	WATER - LIME MAKEUP			1.01				1.01			
	FLOCCULANT MAKEUP										
	FLOCCULANT STOCK MAKEUP	0.00	**0.50**	0.24				0.24		1.00	
	FLOCCULANT SOLUTION, STOCK			0.24				0.24			
	LIME/SLUDGE TANK										
	LIME SLURRY	0.25	20.00	1.01	2.40	1.26	0.11	1.01	1.11	1.13	
	RECYCLED SLUDGE	13.23	25.00	39.69	2.50	52.92	5.29	39.69	44.98	1.18	
	TANK DISCHARGE	13.23	24.42	40.70	2.50	54.18	5.29	40.70	45.99	1.18	
	REACTORS 1 AND 2										
	INFLUENT			360.00				360.00			
	SLUDGE PRODUCTION	0.38	**100.00**		2.50		0.15				
	DISCHARGE SLURRY	13.61	3.28	400.70	2.50	414.31	5.44	400.70	406.14	1.02	
	CLARIFIER										
	FILTRATE RECYCLE			0.76				0.76			
	FEED SLURRY, NEW	13.61	3.28	400.70	2.50	414.31	5.44	400.70	406.14	1.02	408.58
	FEED SLURRY, TOTAL	13.61	3.28	401.45	2.50	415.06	5.44	401.45	406.90	1.02	
	FLOCCULANT, STOCK SOLUTION			0.24				0.24			
	FLOCCULANT, DILUTION WATER			2.20				2.20			0.05 % diluted floc
	THICKENER UNDERFLOW	13.61	25.00	40.82	0.10	54.43	136.08	40.82	176.90	0.31	2.44 t/h diluted floc
	THICKENER OVERFLOW, TOTAL			364.21				364.21			
	THICKENER OVERFLOW (EFFLUENT)			360.87				360.87			2.20 t/h water
	THICKENER UNDERFLOW, RECYCLE	13.23	**25.00**	39.69	2.50	52.92	5.29	39.69	44.98	1.18	
	SLUDGE PURGE	0.38	25.00	1.13	2.50	1.51	0.15	1.13	1.29	1.18	
	SLUDGE FILTRATION										
	FILTER FEED	0.38	25.00	1.13	2.50	1.51	0.15	1.13	1.29	1.18	
	FILTER CAKE	0.38	**50.00**	0.38	2.50	0.76	0.15	0.38	0.53	1.43	
	FILTRATE RECYCLE			0.76				0.76			

Appendix 3. Mass Balance

Mass Balance Blocks for Flowsheets

KSM WTP

Legend

solids t/h	solids SG	solids m^3/h
water t/h	% solids	water m^3/h
pulp t/h	pulp SG	pulp m^3/h

m^3/h

Stream

1

3857.14

2

2.70	2.40	1.13
3.95	40.58	3.95
6.65	1.31	5.08

10

6.85

3

2.70	2.40	1.13
10.80	20.00	10.80
13.50	1.13	11.93

5.40	2.40	2.25
21.60	20.00	21.60
27.00	1.13	23.85

4

141.75	2.50	56.70
436.05	24.42	436.05
580.50	1.18	492.75

5

145.80	2.50	58.32
4293.19	3.28	4293.19
4438.99	1.02	4351.51

6

3877.3151

7

141.75	2.50	56.70
425.25	25.00	425.25
567.00	1.18	481.95

8

4.05	2.50	1.62
12.15	25.00	12.15
16.20	1.18	13.77

9.45	2.50	3.78
28.35	25.00	28.35
37.80	1.18	32.13

9

9.45	2.50	3.78
9.45	50.00	9.45
18.90	1.43	13.23

11

18.9

56.70

12

2.62

13

27142

14

0.30

Appendix 4
General Arrangement Drawings

Engineers and Scientists

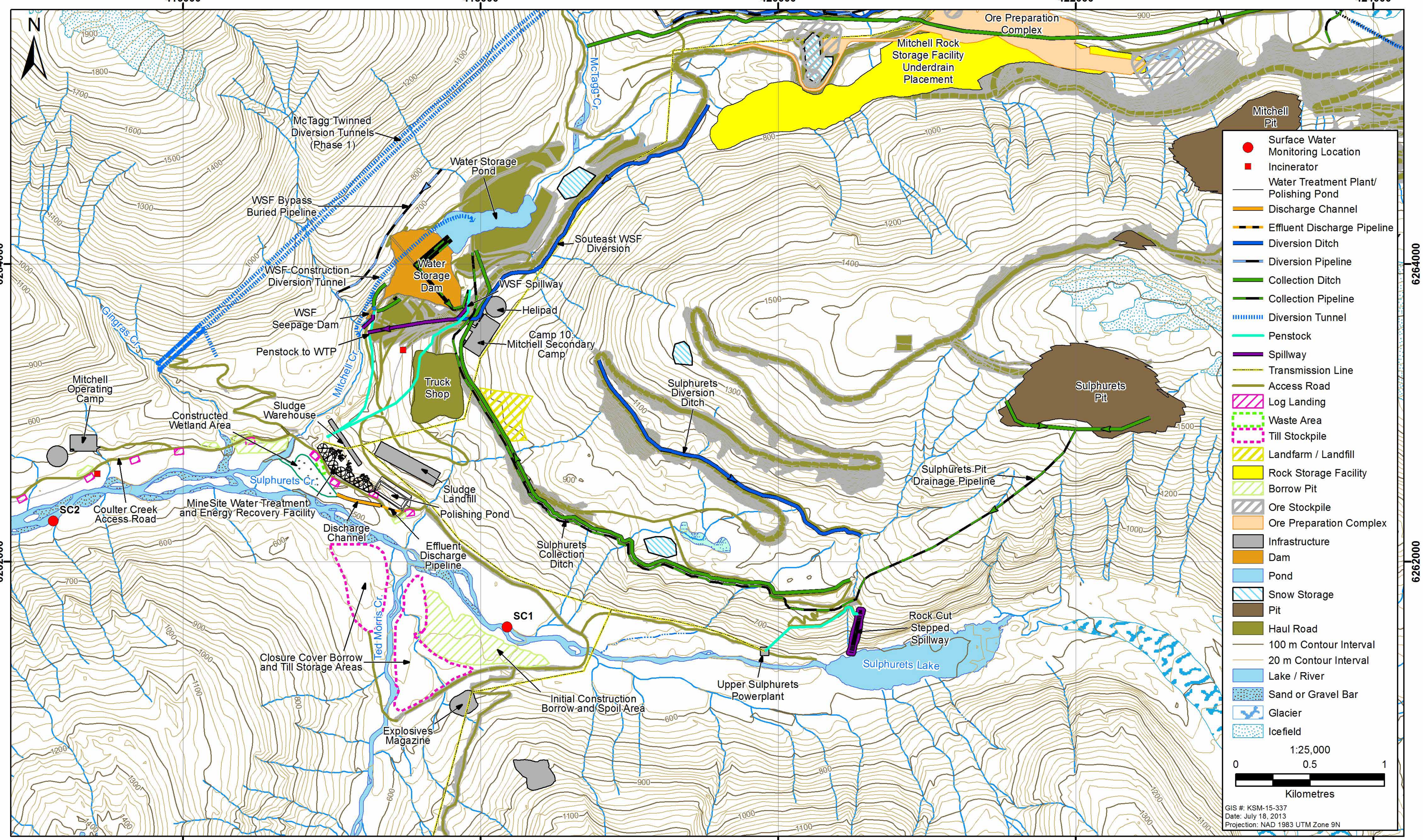

Figure 4-1

SEABRIDGE GOLD
KSM PROJECT

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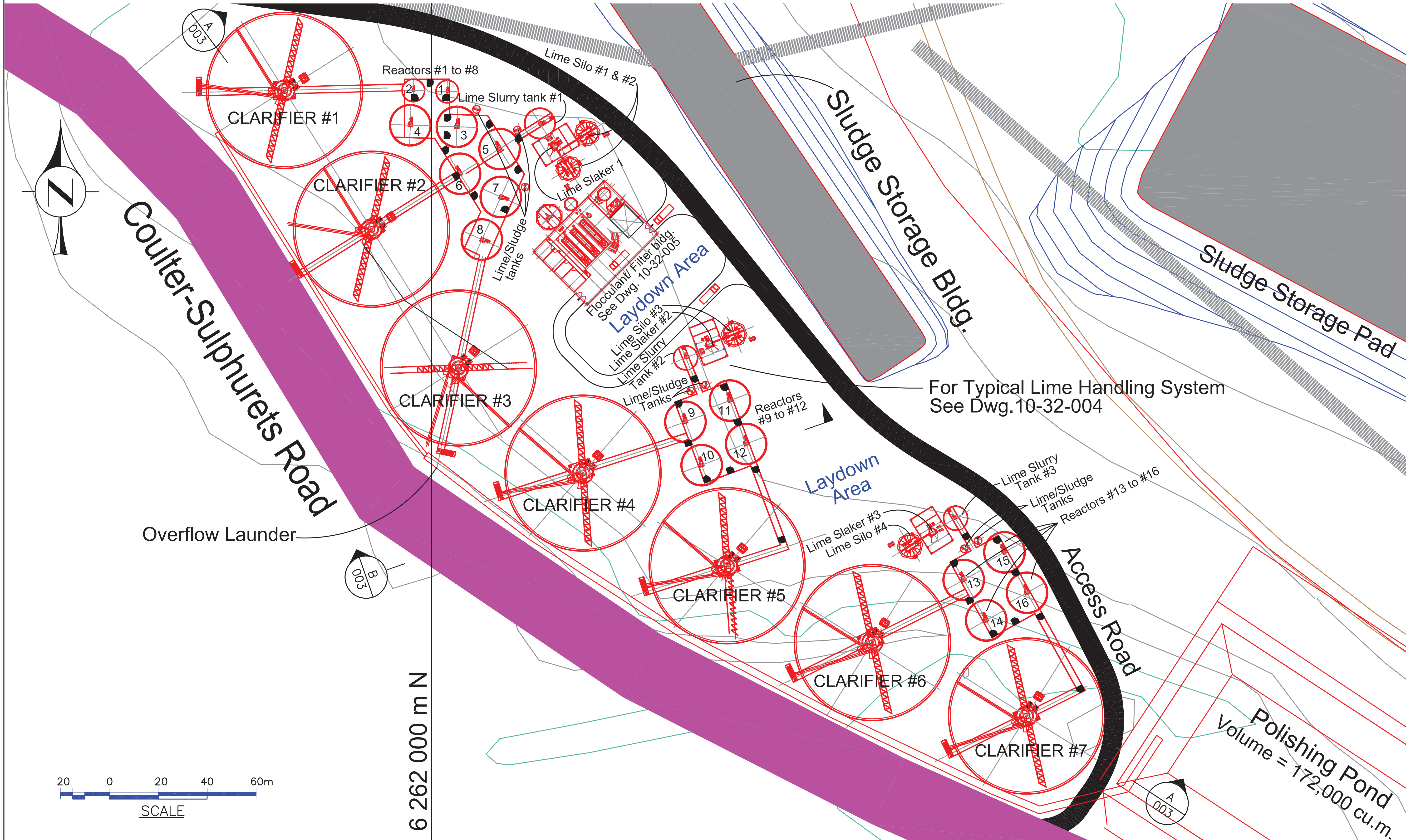
PFS Update - 2012 Water Treatment Overall Site Plan

Figure 4-2

PFS Update 2012
Water Treatment Overall Site Plan



SEABRIDGE GOLD
KSM PROJECT

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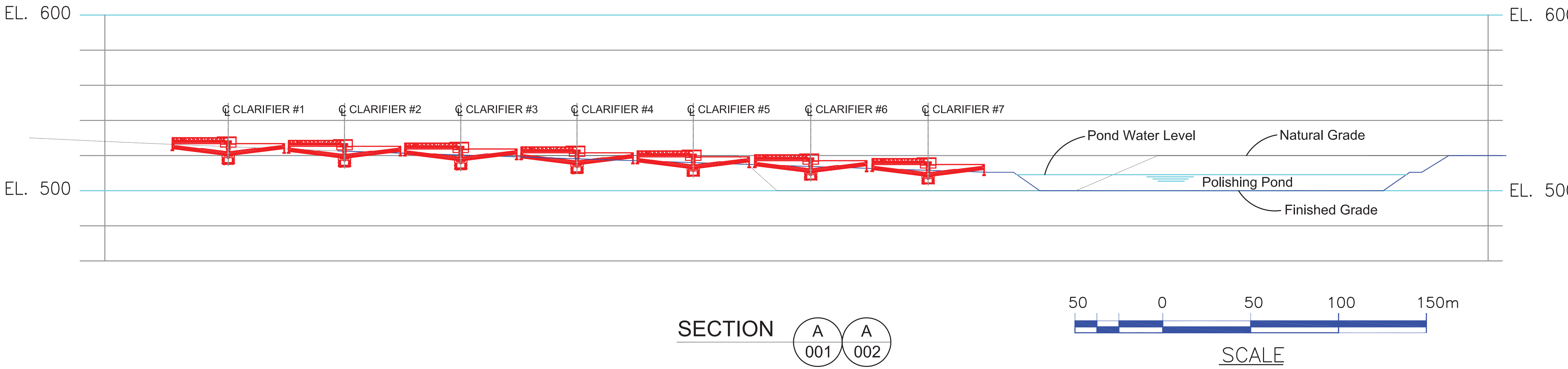
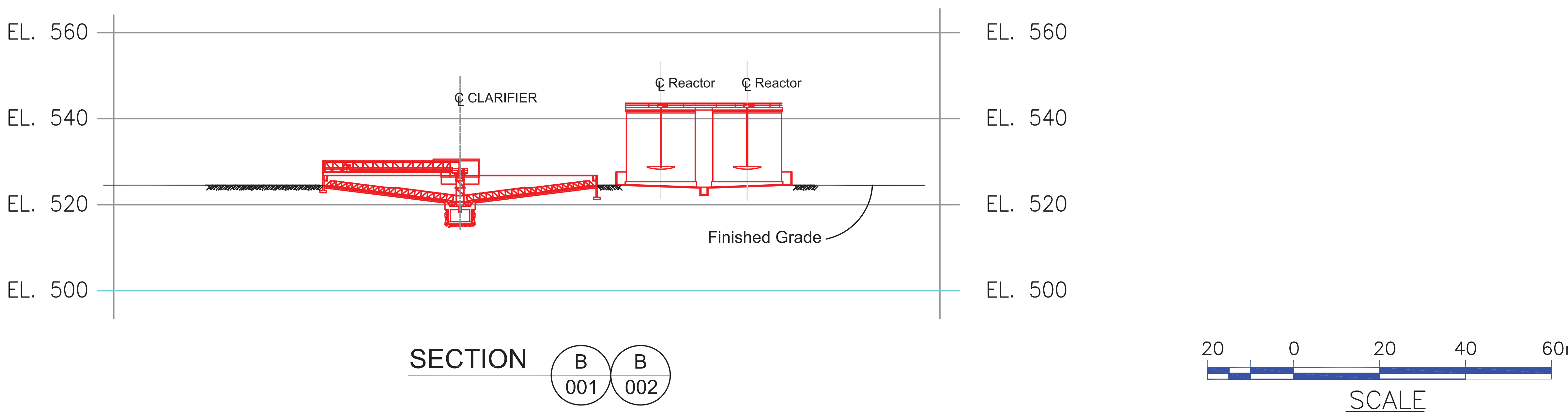
Figure 4-3

PFS Update 2012
Water Treatment Plant Plan



SECTION A 001 A 002



SECTION B 001 B 002

SEABRIDGE GOLD KSM PROJECT

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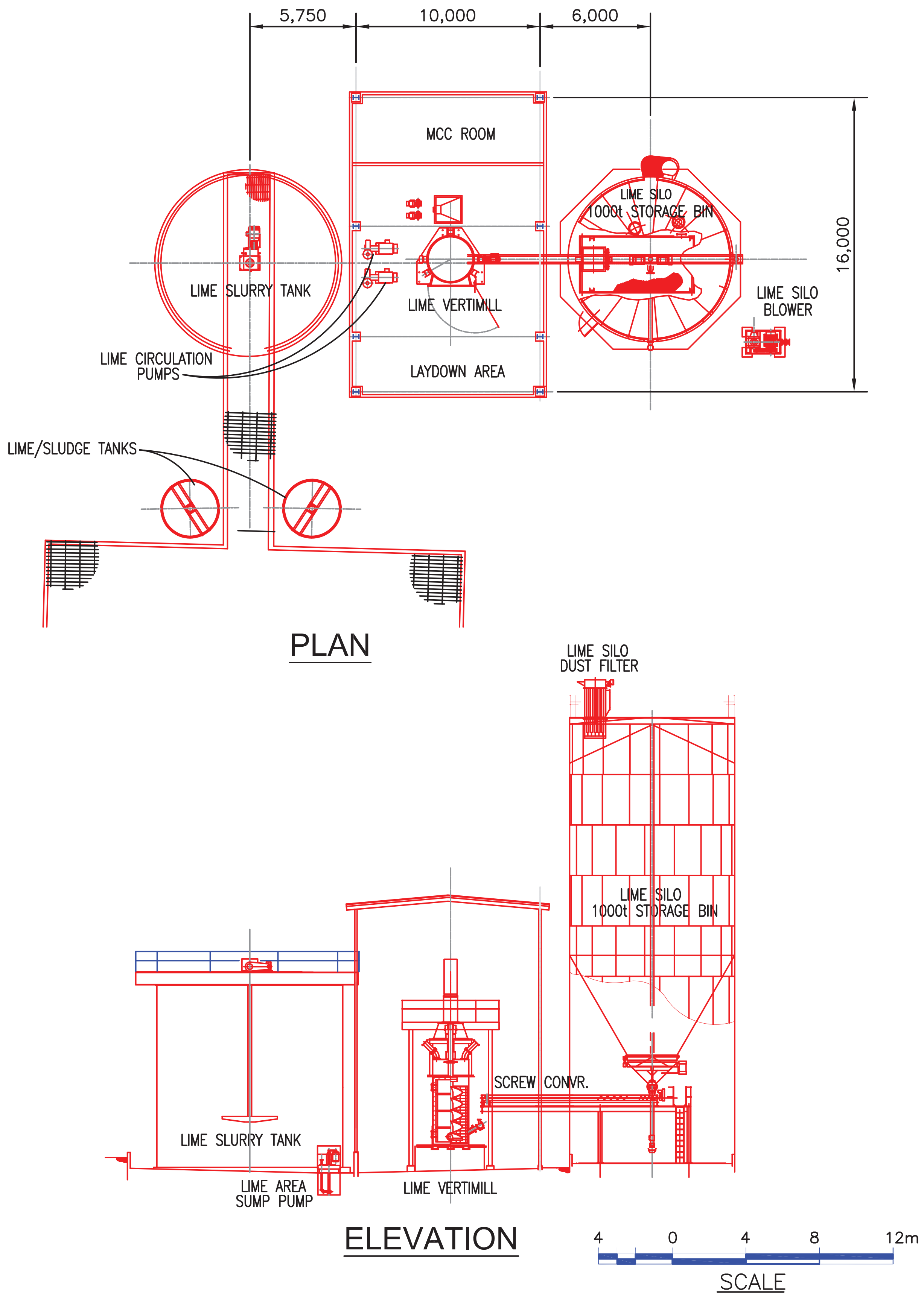
Figure 4-4

PFS Update 2012
Water Treatment Sections



SEABRIDGE GOLD
KSM PROJECT

PFS Update 2012 Typical Lime Slaking System Plan and Elevation

Figure 4-5

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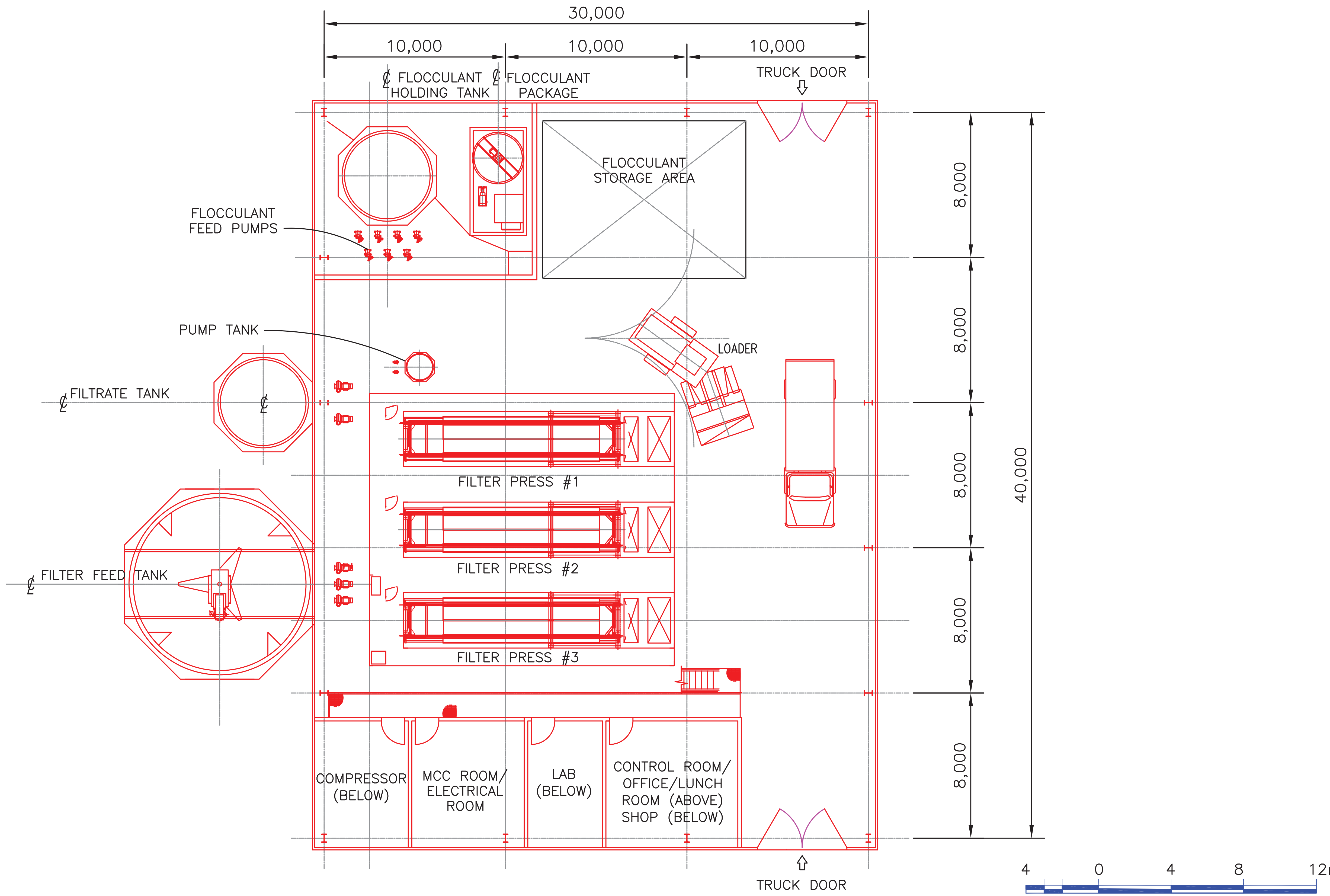

PLAN - FLOCCULANT AND FILTER BUILDING

SEABRIDGE GOLD KSM PROJECT

Rescan Engineers & Scientists

Figure 4-6

PFS Update 2012
Flocculant and Filter Building Plan