Keno Hill Water Treatment Systems Sludge Management Plan – Keno Hill Silver District Mining Operations

Prepared by:

Alexco Keno Hill Mining Corp.

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Revision No. 2

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LIST OF ABBREVIATIONS

gpm .... Gallons per minute
l .... Litres
lps .... Litres per second
m .... Meters
MMF .... Multi-Media Filtration System
TSS .... Total Suspended Solids
VFD .... Variable Frequency Drive
WTSOM .... Water Treatment System Operations Manual

1.0 BACKGROUND

Alexco Resource Corp. (Alexco), through its wholly owned subsidiary Alexco Keno Hill Mining Corp. (AKHM) maintains and operates the water treatment facility for the Bellekeno Undertaking at Keno Hill under Type "A" Water Use License (WUL) QZ12-053. Pursuant to Part H, Condition 84-85 of WUL QZ12-053, within six months of the effective date of the licence, the Licensee shall submit to the board an updated **Sludge Management Plan** dealing specifically with the Keno Hill Silver District Undertaking and shall implement the plan. This submittal fulfills those requirements of Conditions 84-85. The Keno Hill Silver District undertaking only currently consists of one water treatment system at the Bellekeno Mine. If additional water treatment system(s) are commissioned the Sludge Management Plan will be updated and re-submitted to the Board. This revised plan incorporates the sludge management for the proposed Flame and Moth mine and its associated water treatment plant in support of the Water Licence application.

The Bellekeno water treatment plant (WTP) uses basic metal hydroxide precipitation technology and particulate removal technology including coagulation, settling, and filtration. In general, lime solution is added to the underground mine collected waters and a zinc hydroxide precipitate (sludge) is formed and settles to the bottom of two lined ponds. The suspended solids in the mine discharge and the zinc hydroxide particulates are removed by coagulation with lime, settling in ponds, and filtration in a multimedia filtration process. The purpose of the Sludge Management Plan is to outline the process by which the sludge that is produced as a byproduct of the water treatment system is managed.

The proposed Flame & Moth treatment plant design builds on Alexco's experience of successfully treating water over the past eight years in the Keno Hill Silver District as part of care and maintenance of the Silver King, Galkeno 300, and Galkeno 900 sites and mining operations at the Bellekeno mine. The new Flame & Moth treatment facility would be located adjacent to and within the Keno District Mill, and the processes used in the treatment plant will be comprised of the following general processes:

1. Particle removal via a hydrocyclone, multimedia filter, clarifier/thickener, and/or settling pond;
2. Metals removal as needed with the addition of air, pH adjustment, a polymer, and settling in a clarifier/thickener;
3. Ammonia removal via biological oxidation/degradation processes (with the addition of air and organic carbon) and an optional ion exchange (IX) system for final polishing.

This manual is intended to be an operational document that will require periodic updates as modifications and improvements are made to the current water treatment system process and sludge management. This document is released as Revision Two (2).

1.1. PRECIPITATION CHEMISTRY

To help understand the system's functionality, it is important to outline the chemistry of metal hydroxide precipitation. With hydroxide precipitation, soluble heavy metal ions are converted to relatively insoluble metal hydroxide precipitates by adding an alkaline precipitating agent (e.g. lime slurry). Precipitation reactions, which originate in the rapid mix tank, form metal-hydroxide precipitates as shown below where M^+ is the soluble metal cation being removed.

$$\mathbf{M^+ + Ca(OH)_2 = M(OH)_2\ (s) + Ca^{2+}}$$

The metal ion combines with hydroxide ion to form the insoluble metal hydroxide solid. This reaction is pH dependent; as more base (e.g. lime solution) is added, the reaction is driven further to the right on the pH scale and more metals precipitate out of solution. Conversely, as the pH is decreased, the thermodynamic equilibrium moves to the left, which could allow metals to resolubilize. Generally, excess lime is added, which stabilizes the metal hydroxide precipitate, making this reaction practically irreversible.

The solubilities of the metal hydroxide precipitates (sludge) vary, depending on the metal ion being precipitated, the pH of the water, and to a limited extent the precipitating agent(s) being used. Typically the solubilities of most metal hydroxide precipitates decrease with increasing pH to a minimum value beyond which the precipitates become more soluble (i.e. amphoteric properties). By controlling the pH levels to within a specific range, the efficiency of metals removal can be maximized. The Bellekeno and Flame & Moth water treatment facilities target a pH range between 8.5 and 9.5, which is the range that is expected to create the lowest concentration of heavy metals in the treated water

1.2. LIME MIXING AND CONSUMPTION

Lime slurry is used at the Bellekeno WTP to adjust the pH and precipitate metals from the water, and also aid the settling of suspended particles by changing the surface charge on particles. Lime slurry will also likely be used in the Flame & Moth WTP. Currently, the Alexco mill includes a lime slurry mixing facility, which involves the addition of hydrated lime ($Ca(OH)_2$) into a large mixing tank, where water is added to produce lime slurry. This lime slurry would be piped to the reactor and applied within the reactor as previously stated with the use of a small metering pump, PLC, and pH probes.

As an alternative pH adjustment reagent, Alexco is considering the use of sodium hydroxide (NaOH) or caustic soda. Preliminary studies of this reagent show that less sludge is generated within the water treatment process, thereby reducing the amount solids generation and labor required to operate the system.

1.3. FERRIC IRON

Although zinc concentrations are elevated in the adit discharge (Bellekeno 625 median zinc concentration was 2 mg/L between 2009 and 2013), other metals such as iron and manganese texist at relatively low concentrations. Such metals can aid in the co-precipitation reactions, where, for example, iron hydroxides co-precipitate with or sorbs zinc, effectively removing it from solution. For adit discharge waters that have relatively low iron and/or manganese concentrations, iron may be added to enhance the removal of the heavy metals.

In the treatment solution, ferric iron undergoes hydrolysis and reacts with the hydroxide ion to form a floc particle comprised of iron(III) hydroxide onto which zinc hydroxides attach. The properties of iron enhance the formation of stronger and larger floc particles, which promotes the removal of arsenic and suspended solids, and thereby improving the efficiency of sludge generation. The process of ferric ions transferring into iron hydroxide is shown in the equation below:

$$\mathbf{Fe^{3+} + 3\ OH^{-} \rightarrow Fe(OH)_3\ (s) \rightarrow FeO(OH)\ (s) + H_2O}$$

The ferric iron would be added to the reactor via a metering pump that would be proportionally controlled based on the incoming flow rate. The iron addition rate would be periodically adjusted based on the sludge characteristics, as well as the heavy metal removal efficiency. The added iron would coat the surfaces of the colloidal particles, encouraging agglomeration and settling within the clarifier, thereby making a more durable sludge that would then be more effectively captured in the dewatering bags. Ferric iron solids are very efficient sorbents and co-precipitants for heavy metals, such as arsenic, cadmium, and zinc, making the use of iron a significant factor in efficient plant operation.

1.4. ORGANIC POLYMER

To aid the creation of larger and more competent sludge particles or floc, Alexco may consider the addition of an organic polymer at the reactor. The polymer would be injected after the pH has been adjusted with the expectation that it would attach to the metal hydroxide particles and improve settling. With the addition of a polymer, the hydroxide particles become entangled in the long chains of the polymer, causing the sludge particles to increase in size. As the flocs increase in size, they become heavier and settle more quickly to the bottom of the clarifier cone. This floc formation is illustrated in Figure 1 (University of Maryland, Engineering Research Center Report):

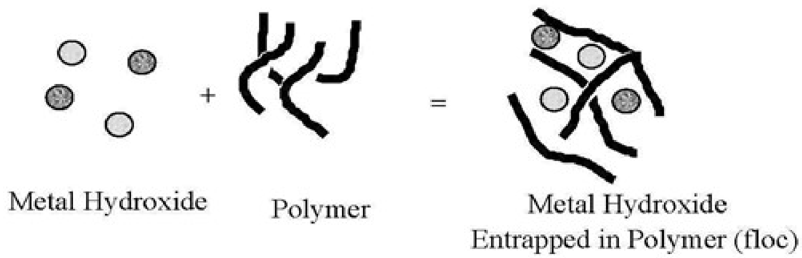


FIGURE 1 – FLOC FORMATION

If an organic polymer is used, it would be stored within the WTF and added via a small metering pump with the addition rate proportional to the inlet flow rate.

1.5. TREATMENT FOR NON-METALS AND AMMONIA

Alexco may need to treat for ammonia depending on the type of explosives used underground. From previous experience working in the Keno Hill District, some ammonia is typically removed by sorption to the sludge in the settling ponds, as well as removal via off-gassing due to the high pH of the treated water after it passes through the reactor (ammonia is a dissolved gas at high pH). Additional ammonia removal may be required to provide further operational tolerances between the ammonia discharge performance and the water licence parameter.

Two options are considered for ammonia removal: an Ion Exchange System and a Biological Treatment System. The former is in operation at the Bellekeno WTP, whereas the latter is also under consideration for the Flame & Moth WTP.

For the Flame & Moth WTP, the Ion Exchange (IX) System would include:

1) The IX system would contain tanks loaded with zeolite that sorbs and removes ammonia from the water prior to discharge. This zeolite would function in the same capacity as that explained previously for the Biological Treatment System.
2) A brine tank would be used to regenerate the ammonia sorption resin. During the regeneration cycle, the system's operation would be halted and the zeolite within one tank would be bathed in a 10% sodium chloride (NaCl) brine. This brine causes the ammonia to desorb from the zeolite and become part of the brine. After the zeolite is allowed to soak for 30 minutes, the brine and collected

ammonia would be pumped from the IX tank to a secondary holding tank. This tank would then be used to biologically break-down the collected ammonia or the ammonia / brine solution, which would be transported for disposal.

3) Muriatic acid may be used periodically on the system to clean portions of the system if scaling occurs. The brine may be re-used with the occasional addition of salt (NaCl) and pH adjustment reagents, either hydrochloric acid (HCl) or sodium hydroxide (NaOH), to keep its chemical characteristics optimal for resin regeneration.
4) Once it passes through the IX System, treated water will be comingled with any water that bypassed the IX System and then discharged for final release.

A Biological Treatment System would include:

1) Tanks and / or a lined pond with zeolite that sorbs and removes ammonia from the water prior to discharge. The zeolite is an ammonia-specific resin, i.e. Resin Tech's SIR-600 or other suitable resins, which is a material that preferentially sorbs ammonia over other common cations such as sodium or calcium. With the removal of the ammonia by the zeolite, the treated water would then be acceptable for discharge.
2) Rather than using a brine solution for regeneration, the zeolite would be regenerated with the addition of phosphate, blown air, and a carbon source, such as dilute molasses, alcohol, or sugar. This method of regeneration allows for the ammonia to be biologically degraded and consumed, thereby allowing the zeolite to sorb additional ammonia.

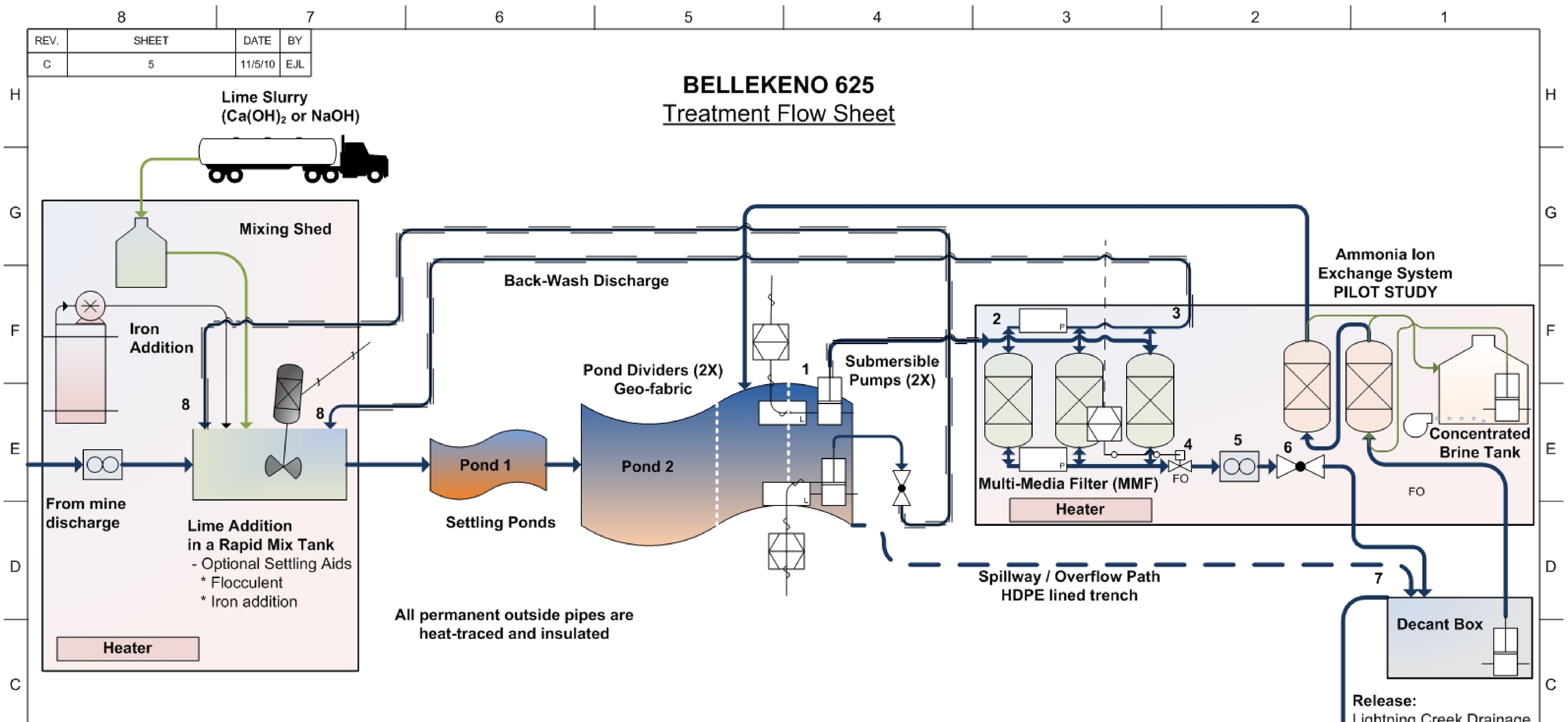
After passing through the proposed WTF and optional ammonia treatment system, it is expected that the water quality would meet the discharge standards. The water would pass through a flowmeter / totalizer where discharge flow rates and total volume discharged are recorded prior to the effluent release to the environment.

2.0 BELLEKENO TREATMENT SYSTEM

2.1. WATER TREATMENT PROCESS

As with most underground mines, water inflows into the Bellekeno mine must be managed. The inflowing water pools and collects within the Bellekeno mine's drifts, stopes, and underground workings. To keep this water from slowly filling the mine, it is collected in sumps located underground at different levels. Dewatering pumps suspended from the ceiling remove the top layer of water and send it through overhead steel pipes to the surface for treatment.

Figure 2 provides a diagram of the overall Bellekeno treatment system which should be used for reference.



Connection List

Connection #	Equipment	Part Number	Interface	Material	Description
1	BJM Submersible Pump	J37H	2" NPT-Male	Cast Iron	Verticle discharge, need conversion to 3" pipe as well as steel to HDPE
2	MMF - Influent	MM 2460-3A	3" 150# Flange	Cast Iron	Influent interface w/ MMF - requires 3" gasket and 4 bolts/nuts
3	MMF - Backwash	MM 2460-3A	2" NPT - Male	Cast Iron	Backwash interface w/ MMF - NPT to 2" HDPE line for return to mix tank
4	MMF - Effluent	MM 2460-3A	3" 150# Flange	Cast Iron	Effluent interface w/ MMF - requires 3" gasket and 4 bolts/nuts
5	Sea Metrics Flow Meter	WTP-101-300-18	3" 150# Flange	PVC	Interface w/ Flow Meter - requires 3" gasket and 4 bolts/nuts
6	3" Flanged Ball Valve	3700	3" 150# Flange	Steel	3" teflon coated ball valve - American Valve
7	Open Pipe	NA	Decant Box - Open Tank	HDPE	Release into Decant Box
8	Open Pipe	NA	Open Tank	HDPE	Release into Mix Tank - Fluid will pass back through the system

Figure 2 – Bellekeno Water Treatment Flow Sheet

After water is pumped to the surface, it enters a small water treatment shed seen in Figure 3 that is located near the Bellekeno 625 portal. The treatment shed houses a lime slurry tank and barrels of ferric chloride (ferric chloride being repositioned into the ion exchange building). On average, the flow is between 3.0 and 7.0 litres per second (lps). Downstream of the flow meter, the water reports to a circular rapid mix tank and mixer located underneath the treatment shed that ensures proper mixing of the water as the lime slurry and ferric chloride are added to the tank.

From the rapid mix tank, water passes into the first lined holding pond (Pond 1). It is in this pond that the majority of total suspended solids (TSS) and metal hydroxide flocculants settle out in the form of a grey sludge that collects at the bottom. To keep the pond from filling with sludge, a vacuum truck removes the sludge on a weekly basis.

FIGURE 3 – BELLEKENO WATER TREATMENT SHED

Pond 1 is connected to a much larger pond termed Pond 2 via a weir. Surface water is decanted from Pond 1 and spills into Pond 2 to allow for additional settling.

Once water slowly flows through Pond 2, it enters a submersible pump, filtered through a Multi-Media Filtration (MMF) system, if ammonia levels are elevated it is pumped through an ion exchange unit and then discharged through a diffuser, where it flows down to join the Lightning Creek drainage system.

2.2. POND DESLUDGING

Once or twice a year depending on pond sludge volumes, the Bellekeno 625 water treatment settling ponds get a significant volume of built up sludge containing bentonite clay from the underground drilling operations which makes normal pond desludging operations difficult to undertake. When the settling ponds reach capacity, they require desludging to ensure that the adequate retention time is available to properly treat the wastewater.

The desludging of the Bellekeno 625 settling ponds will include:

- Building a temporarily unlined bermed dewatering area east of the settling ponds (site previously used for this purpose);
- Dewatering pond #1 and bypassing treated flows to pond #2. Once pond #1 is desludged, return treated flow to pond and bypass pond #2 to allow desludging in pond #2;
- Pumping the sludge into the newly constructed dewatering area;
- Allowing the sludge to dewater;
- Using a dump truck to haul the dried sludge to the Valley Tailings sludge pit;
- Removing approximately 10 cm of soil from below the dewatering area and hauling it to the Valley Tailings sludge pit; and,
- Recontouring of the berm and dewatering area.

All water released from the pond and from the dewatering area will be in compliance with the effluent discharge criteria. There will be no additional environmental impacts associated with the desludging of the settling ponds as the sludge will be contained and the water quality will meet licence discharge standards.

FIGURE 4 – VACUUM TRUCK USED TO DESLUDGING PONDS

3.0 FLAME & MOTH TREATMENT SYSTEM

The Flame & Moth mine will require continual dewatering, with discharge flows dependent on mine depth. It is estimated that incoming water quality is generally compliant except for some metals (current groundwater wells show some iron and zinc), and with elevated levels of ammonia and total suspended solids from underground mining activities. The new treatment facility would be located adjacent to and within the Keno District Mill (Figure 5).

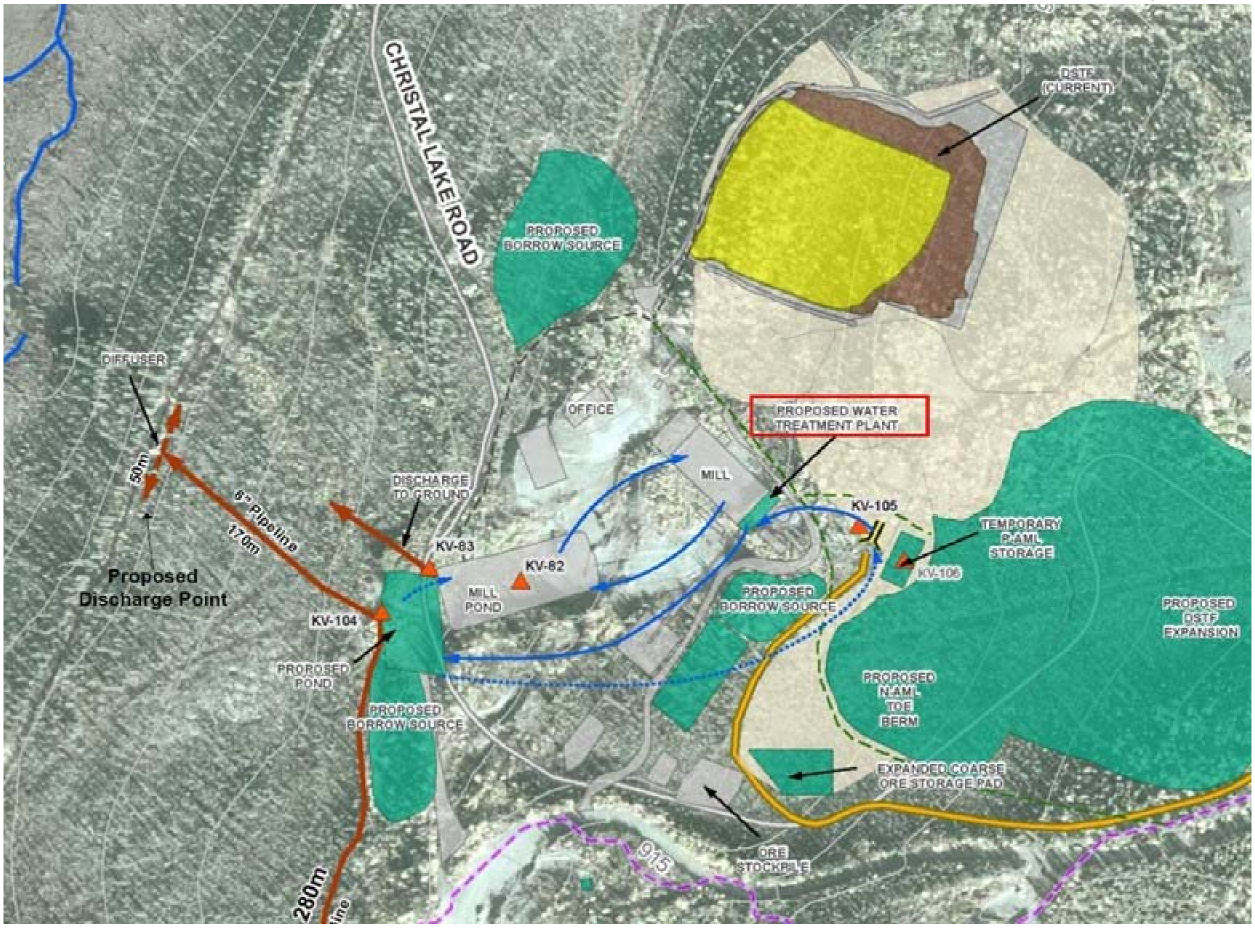


FIGURE 5 – LOCATION OF PROPOSED FLAME & MOTH WTP

The processes used in the treatment plant will comprise the following general procedures:

1) Particle removal via a hydrocyclone, multimedia filter, clarifier/thickener, and/or settling pond;
2) Metals removal as needed with the addition of air, pH adjustment, a polymer, and settling in a clarifier/thickener;
3) Ammonia removal via biological oxidation/degradation processes (with the addition of air and organic carbon) and an optional ion exchange (IX) system for final polishing.

On average, the expected flow rates from the Flame & Moth adit should range between 10 to 25 litres per second (lps). Because of these variations, Alexco proposes that this Water Treatment Facility be built to accommodate a maximum flow of 35 lps or 555 gallons per minute. This is the expected maximum flow rate of water that will be discharged from the Flame & Moth adit during active dewatering.

The layout of the proposed Flame & Moth WTP is shown in Figure 6.

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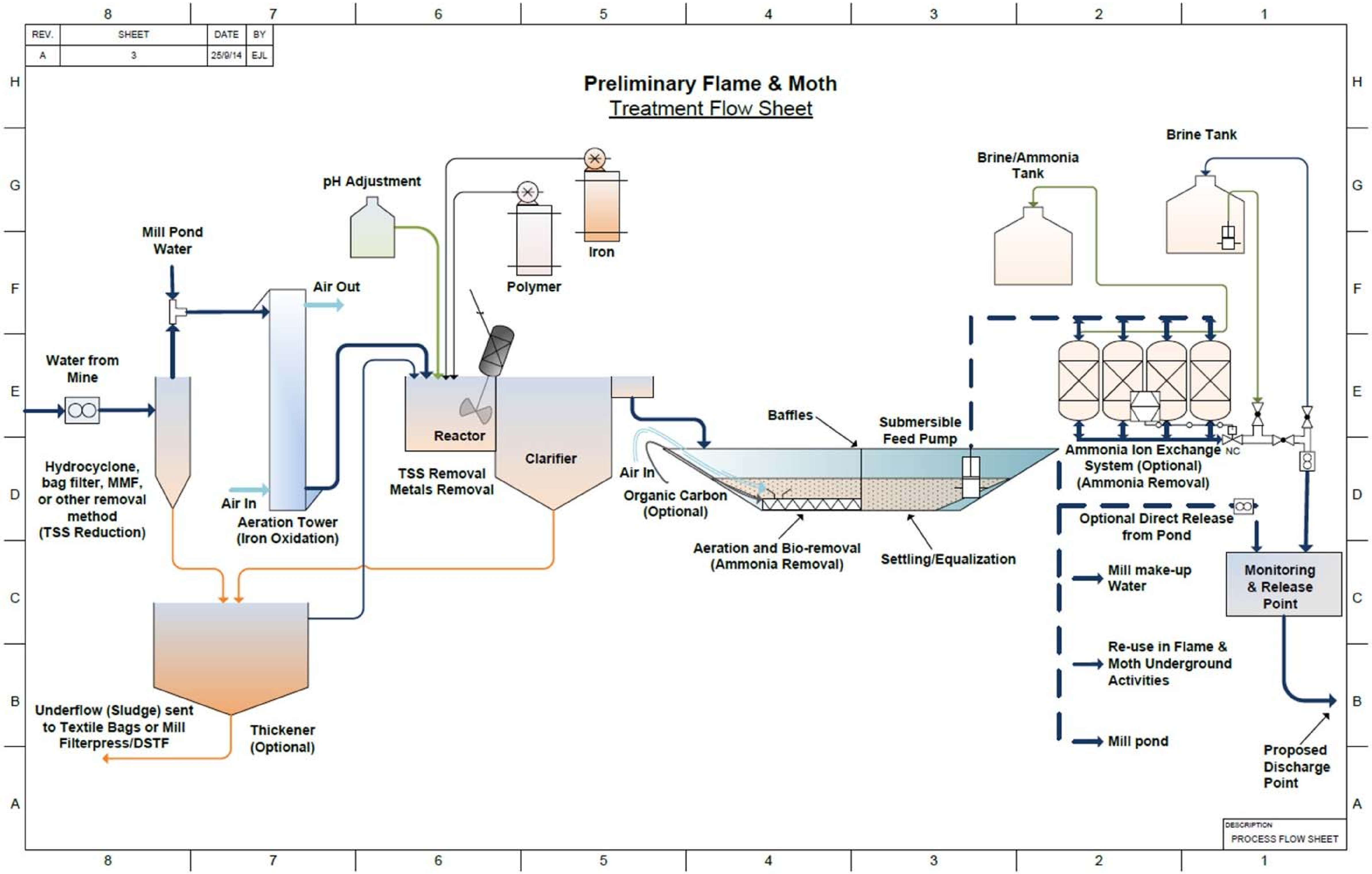

FIGURE 6 – FLAME & MOTH WATER TREATMENT FLOWESHEET

3.1. Overview of Flame & Moth WTP

All of the systems and technology proposed for the Flame & Moth WTF are proven technologies operating at Keno Hill or elsewhere in the water treatment industry. The system operates as follows:

- Water is collected underground and pumped to surface where it passes through one, or several, hydrocyclone(s), multimedia filters, or other type of initial solids removal system. If a hydrocyclone is selected, water enters tangentially and spins at the cylindrical entrance. The spinning action causes heavier particles to be thrown toward the wall of the chamber and drift downward, thereby removing total suspended solids (TSS). Water, which is less dense, continues spinning and moves vertically up and out of the unit.
- Water then passes through an aeration tower where high volumes of air and water are intimately mixed allowing for the oxidation of iron and air stripping of ammonia nitrogen (NH_3).
- Water then flows into a rapid mix tank where it is mechanically agitated and reagents are added to adjust the pH. By raising the pH, a small portion of the ammonia is transformed into a dissolved gas, and some treatment of ammonia occurs in the rapid mix tank and subsequent settling. A polymer is added to densify the sludge and in the future, additional reagents such as coagulant aids and/or iron may be added into the reactor to remove other metals if determined necessary during plant commissioning.
- Water flows from the rapid mix tank into the clarifier settling body where heavier particles accumulate at the bottom of the cone as sludge. This sludge is pumped from the clarifier by a sludge blow-down system and sent to a thickener.
- Sludge and heavier particles from both the clarifier and hydrocyclone enter an optional thickener which increases the percent solids of this combined slurry before sending the sludge to either textile dewatering bags or the mill filter presses and drystack tailings facility (DTF). The overflow from the thickener is sent back to the rapid mix tank for additional treatment.
- Water from the clarifier travels vertically up and out of the settling body where it enters the aeration and treatment portion of a lined pond.
- Within the pond, both air and an optional organic carbon source are added. As an example, the optional organic carbon may be either an alcohol (methanol/ethanol) or a sugar source (corn syrup or molasses), in very low concentrations. In addition, a phosphate nutrient in the form of phosphoric acid or an organic phosphate source may be added with the organic carbon source. These organic carbon/phosphate nutrients support biological treatment processes for the removal/breakdown of remaining ammonia within the pond. Air will also be injected to create an aerobic condition throughout the pond.
- The pond is separated with baffling to divide the aeration and ammonia removal portion of the pond from the settling and equalization portion. Once water enters the settling and equalization area, residence time will allow for final particle removal and polishing of the treated water.
- Water can then be decanted from the pond for discharge, sent to the mill as make-up water, reused within the Flame & Moth underground activities, pumped to the mill pond, or pumped to an optional ion exchange ammonia removal system for final treatment.
- If additional ammonia removal is necessary, water will be transferred via a submersible pump to an ion exchange system. Resins within the ion exchange tanks sorb ammonia until they reach a maximum threshold at which time each tank must be regenerated with a salt water (brine) solution. This solution is pumped into one tank at a time, while the remaining tanks continue to remove ammonia prior to discharge. The brine/ammonia solution is collected and pumped to the brine/ammonia tank where it is disposed.
- Finally, the effluent from the ion exchange passes through a flow meter with a totalizer that tracks the total amount of discharged water that has passed through the system, then the Monitoring and Release Point, and finally the product water is released to the environment.

3.2. Total Suspended Solids

Total Suspended Solids (TSS) are finely ground or broken rock from drilling or mining operations that might be released or mobilized within the workings of the Flame & Moth mine, or fine particulate created from the water treatment process, specifically the precipitation of dissolved metals to form metal hydroxides. TSS levels will be greatly reduced at the clarifier, with the suspended solids settling within the settling tubes and pulled from the system via the air diaphragm pump. These solids would then be pumped to the dewatering bags, along with the floc, for dewatering and finally disposal as stated earlier.

3.3. Clarifier Performance

After passing through a flow meter / datalogger and an initial filtration system, water would report to a reactor or rapid mix tank with an electric mixer that would provide mechanical agitation. Within this reactor, reagents would be added to the incoming water via small metering pumps. These reagents may include:

1) Lime ($Ca(OH)_2$) slurry or caustic soda (NaOH)
2) Ferric Iron
3) Polymer

The addition of these reagents would be controlled by a Programmable Logic Controller (PLC). This system would allow the treatment plant operations to establish a pH set-point for the addition of lime slurry, where the metering pumps would add more lime to the reactor at times of low pH and less lime during times of high pH. Alternative alkaline reagents such as sodium hydroxide may be utilized as an alternative to lime. This system would respond to the variable incoming flow rates seen from the Flame & Moth adit. In addition, the PLC would control metering pumps for both the iron addition and polymer, with dose rates set proportional to incoming flow rates monitored at the inlet to the reactor. Daily operational water quality review is planned, to adjust dosing rates to the variable chemistry of the Flame & Moth mine drainage. Alexco has built similar systems and found this approach to perform well. From the reactor, water would pass into a clarifier. Figure 7 shows the cross-section of a lamella clarifier with water entering from the right, experiencing agitation and reagent addition in the reactor, then flowing up settling tubes, and exiting on the left.

Clarifiers are currently in use at other district adits (e.g. Galkeno 300) within the Keno Hill Silver District (KHSD) and have been very successful at removing metals and TSS prior to discharge. The settling clarifier currently under consideration is an up-flow solids contact unit complete with settling tubes at a 60° angle. After passing through the reactor, water enters the clarifier at the bottom of the settler through a full length distribution manifold, and then passes upward in laminar flow patterns. Heavier floc particles settle to the floor of the settling tubes and slide downward towards the cone at the bottom of the clarifier. Clarified water slowly up-wells and is collected at the surface of the tank through full length collection launders. The settling tube cell size and angle helps to ensure self-cleaning under normal operating conditions to maximize sludge separation from the treated water.

A sludge blanket is maintained in the lower cone-shaped portion of the clarifier and its thickness can be monitored through sampling valves installed in the cone wall. This cone section of the clarifier is shaped like a “V” to encourage sludge thickening and collection within the central hopper of the cone. Periodically, this sludge must be removed hydraulically by opening a valve at the bottom of the “V”, and actively pumping the sludge to a dewatering bag.

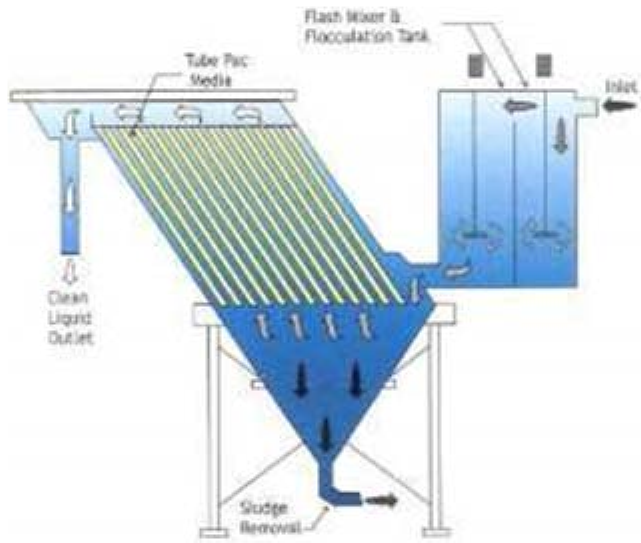

FIGURE 7 – FLAME & MOTH WTP CLARIFIER

The de-sludging operation is typically performed by a Sludge Blow-down System (SBS). When started, this system opens a valve at the bottom of the cone and then starts an air diaphragm pump to move the accumulated sludge from the clarifier cone. The frequency and duration of this system may be controlled by a timer placed near the clarifier, with set-points adjusted based on the accumulation rate of collected solids. This densified sludge typically contains solids ranging from 2% to 5% by weight. When activated, the SBS would pump the collected slurry to dewatering bags which allow for passive filtration and densification of the collected sludge.

These dewatering bags would be positioned within an insulated building or structure that would be placed near to the WTF. Sludge would be injected into one bag at a time, allowing additional bag(s) time to dewater. The floor that the bags rest on would be lined and slightly slanted, allowing water to run from the bag and be recollected in a sump, and pumped to the reactor for re-treatment. This process would allow the dewatering bags time to fill, drain, and densify the sludge solids. Once full, the dewatering bags/sludge could be removed, and the dewatered sludge placed in the drystack tailings facility (DTF).

Within the clarifier, treated water that rises through the settling tubes spills over into a final discharge cell. At this location, a second pH probe is attached to monitor discharge pH. This water then drops down into a pipe and flows to an equalization pond. This pond would allow for careful monitoring and testing of the treated water prior to discharge and allows for upsets which may occur during operations of the treatment system.

4.0 SLUDGE MANAGEMENT

4.1. SLUDGE VOLUMES

From past experience, AKHM has found that removing between three to five truckloads of sludge per week is needed from Pond 1 to maintain settling capacity in this pond. The maximum estimated sludge weight produced in a given week is approximately 2,400 kilograms. This calculation is based on the tank volume of the vacuum truck and an estimation of 4% solids in the collected sludge.

4.2. Sludge Characteristics

The characteristics of the sludge produced at Bellekeno were determined as part of the sludge management process. A sample of sludge was removed from the first settling pond on November 12, 2010, and submitted to Maxxam Analytics of Burnaby, BC. The results are summarized in the following tables:

Table 1. Summary of Physical and ABA Parameters of Bellekeno Sludge.

	BK625 Sludge	Detection Limits
Wet Sample Wt. (g)	948.22	-
Dry Sample Wt. (g)	121.01	-
Sample Type & Condition	Wet Tailings/Sediment	-
% Moisture (Wt.%)	83.9	-
Pulp Density (g/ml)	1.06	-
Paste pH	8.4	0.5
Total Sulphur (Wt.%)	0.85	0.02
Sulphate Sulphur (Wt.%)	0.29	0.01
Sulphide Sulphur* (Wt.%)	0.56	0.02
Maximum Potential Acidity** (Kg CaCO3/Tonne)	17.5	0.6
Neutralization Potential (Kg CaCO3/Tonne)	327.9	-
Net Nuetralization Potential*** (Kg CaCO3/Tonne)	310.4	-
Fizz Rating	Strong	-

These data show that the Bellekeno sludge is highly neutralizing (see “Net Neutralizing Potential” and “Neutralization Potential” data points) and that despite whatever sulfide sulfur the suspended solids in the mine discharge may have, the amount of lime added is sufficient to create a strongly alkaline sludge. Sludge produced by the Flame & Moth WTP is expect to have similar characteristics.

TABLE 2. MAJOR METALS, CATIONS, AND TRACE METALS, BELLEKENO SLUDGE. (INCLUDES QA/QC INFORMATION.)

Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe %	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca %	P %	La	Cr	Mg %	Ba	Ti %	B	Al %	Na %	K %	W	Hg	Sc	Tl	S %	Ga	Se	Te
BK625 Sludge	5.3	95.2	4663	4066	47.6	35.7	8.1	2125	2.58	118.4	8.4	1.3	5.3	227	57.6	19	1.5	13	12.74	0.043	6	53	0.39	102	0.003	<20	0.78	0.024	0.09	31.3	0.1	1.4	0.1	0.89	2	0.9	<0.2
QAQC																																					
Reference Material (1)																																					
STD OREAS45PA	1	632.6	18.5	120	0.3	310.7	113.1	1111	16.83	4.1	1.1	49	6.4	15	<0.1	0.1	0.2	233	0.25	0.035	17	867	0.12	193	0.145	<20	3.69	0.009	0.08	<0.1	0.03	46.6	<0.1	<0.05	18	0.5	<0.2
True Value STD OREAS45PA	0.9	600	19	119	0.3	281	104	1130	16.559	4.2	1.2	43	6	14	0.09	0.13	0.18	221	0.2411	0.034	16.2	873	0.095	187	0.124	-	3.34	0.011	0.0665	0.011	0.03	43	0.07	0.03	16.8	0.54	-
Percent Difference	11.1	5.4	-2.6	0.8	0	10.6	8.7	-1.7	1.6	-2.4	-8.3	14	6.7	7.1		-23.1	11.1	5.4	3.7	2.9	4.9	-0.7	26.3	3.2	16.9	-	10.5	-18.2	20.3	-	0	8.4	-	-	7.1	-7.4	-
Reference Material (2)																																					
STD DS7	19	105.6	61.9	382	0.8	55.5	9.8	603	2.31	51.9	4.3	49.6	3.7	68	5.9	4.4	4.4	80	0.91	0.074	11	189	1.04	390	0.122	36	0.99	0.09	0.46	2.9	0.21	2.3	3.6	0.19	4	3.6	0.9
True Value STD DS7	20.5	109	70.6	411	0.9	56	9.7	627	2.39	48.2	4.9	70	4.4	69	6.4	4.6	4.5	84	0.93	0.08	12	179	1.05	410	0.124	39	0.959	0.089	0.44	3.4	0.2	2.5	4.2	0.19	5	3.5	1.08
Percent Difference	-7.3	-3.1	-12.3	-7.1	-11.1	-0.9	1	-3.8	-3.3	7.7	-12.2	-29.1	-15.9	-1.4	-7.8	-4.3	-2.2	-4.8	-2.2	-7.5	-8.3	5.6	-1	-4.9	-1.6	-7.7	3.2	1.1	4.5	-14.7	5	-8	-14.3	0	-20	2.9	-16.7
Detection Limits	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.1	0.5	0.1	1	0.1	0.1	0.1	2	0.01	0.001	1	1	0.01	1	0.001	20	0.01	0.001	0.01	0.1	0.01	0.1	0.1	0.05	1	0.5	0.2
Acme Group No.	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX

TABLE 3. WHOLE ROCK ANALYSIS, BELLEKENO SLUDGE. (INCLUDES QA/QC INFORMATION.)

Sample ID	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	MnO %	TiO_2 %	P_2O_5 %	Cr_2O_3 %	Ba %	LOI %	Total %
BK625 Sludge	40.6	9.1	4.51	19.1	0.88	0.25	1.35	0.3	0.62	0.1	0.02	0.09	19.7	96.65
QA/QC														
Reference Materials-1														
STD: SY-4(D)	50	20.66	6.31	8.06	0.52	7.15	1.62	0.11	0.27	0.12	<0.001	0.04	4.56	99.39
True Value STD SY-4	49.9	20.69	6.21	8.05	0.54	7.1	1.66	0.11	0.29	0.13	0.03	4.56	-	-
Percent Difference	0.2	-0.1	1.6	0.1	-3.7	0.7	-2.4	0	-6.9	-7.7	17.6	0	-	-
Reference Materials-2														
STD SO-18	58.1	14	7.6	6.3	3.4	3.8	2.2	0.4	0.7	0.8	0.6	0.1	1.93	99.16
True Value STD SO-18	58.47	7.67	6.42	3.35	3.71	2.17	0.4	0.7	0.83	-	-	-	-	-
Percent Difference	-0.6	-1	-1.6	0.6	1.6	0	2.6	4.3	-2.4	-	-	-	-	-
Detection Limits	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	-	-
Method	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X

Some of the general characteristics of the Bellekeno sludge are:

- After densification along the bottom of Pond 1, the sludge is approximately 84% water with the 16% solids being fine particulates from the mine operations, and lime-based metal hydroxide sludge principally comprised of excess lime and hydroxides of manganese, iron and zinc.
- The whole rock analysis shows that the major constituents are principally silicates and residual lime, low percentages of gangue minerals, and minor minerals associated with the vein materials (Table 3).
- The lead, zinc, and silver content are consistent with some minor amounts of broken fine grain vein material being suspended in the mine discharge, and being removed by settling and filtration processes in the treatment system.
- As of this writing, the only additive used (other than lime) is ferric chloride which promotes flocculent formation. The sludge is highly alkaline because of its significant makeup consisting of a hydroxide from the lime that is added. In the future, an additional polymer may be used to aid in settling.
- Because of the lime content, the sludge is highly net neutralizing with a Neutralization Potential of 310.4 kg $CaCO_3$/Tonne, a maximum potential acidity of 17.5 $CaCO_3$/Tonne, and a neutralization potential of 327.9 $CaCO_3$/Tonne. The ratio of approximately NP/AP = 18.7:1 shows a highly alkaline sludge with a strong excess of lime.

Acidification or low redox conditions generally could lead to particle breakdown. The circum-neutral drainage from Bellekeno indicates that there is no acid generating potential that would potentially destabilize and re-leach metals from the sludge, especially in light of the significant NP:AP ratio of the sludge and the amount of AP necessary to cause dissolution of the sludge. The general characteristics of the tailings are mildly net neutralizing conditions; the addition of lime-rich sludge will benefit the tailings if mixed into the DSTF with respect of net neutralization, pH, and physical characteristics (the lime enhances cementation reactions). If the sludge is closed in the valley tailings area, the sludge composition is such that the sludge should be expected to remain stable under the conditions found in the valley tailings storage pond area.

4.3. SLUDGE DISPOSAL

Bellekeno sludge collected in the vacuum truck will be transported either to the separate Bellekeno storage pond in the Valley Tailings Facility or to the Keno Hill District Mill and deposited in the low pyrite thickener where it will be mixed with filtered and dry stacked tailings. Both of these locations are suitable long term storage locations and the sludge characteristics presented demonstrate the sludge will be stable in either area. The separate sludge storage location for Bellekeno sludge at the VTF is shown in Figure 5.

Sludge from the Flame & Moth WTP will be sent to the District Mill filter presses for further moisture removal, then mixed with the tailings in the DSTF. If the Mill is not in operation, the sludge will be sent to textile dewatering bags and the dewatered sludge then placed in the DSTF.

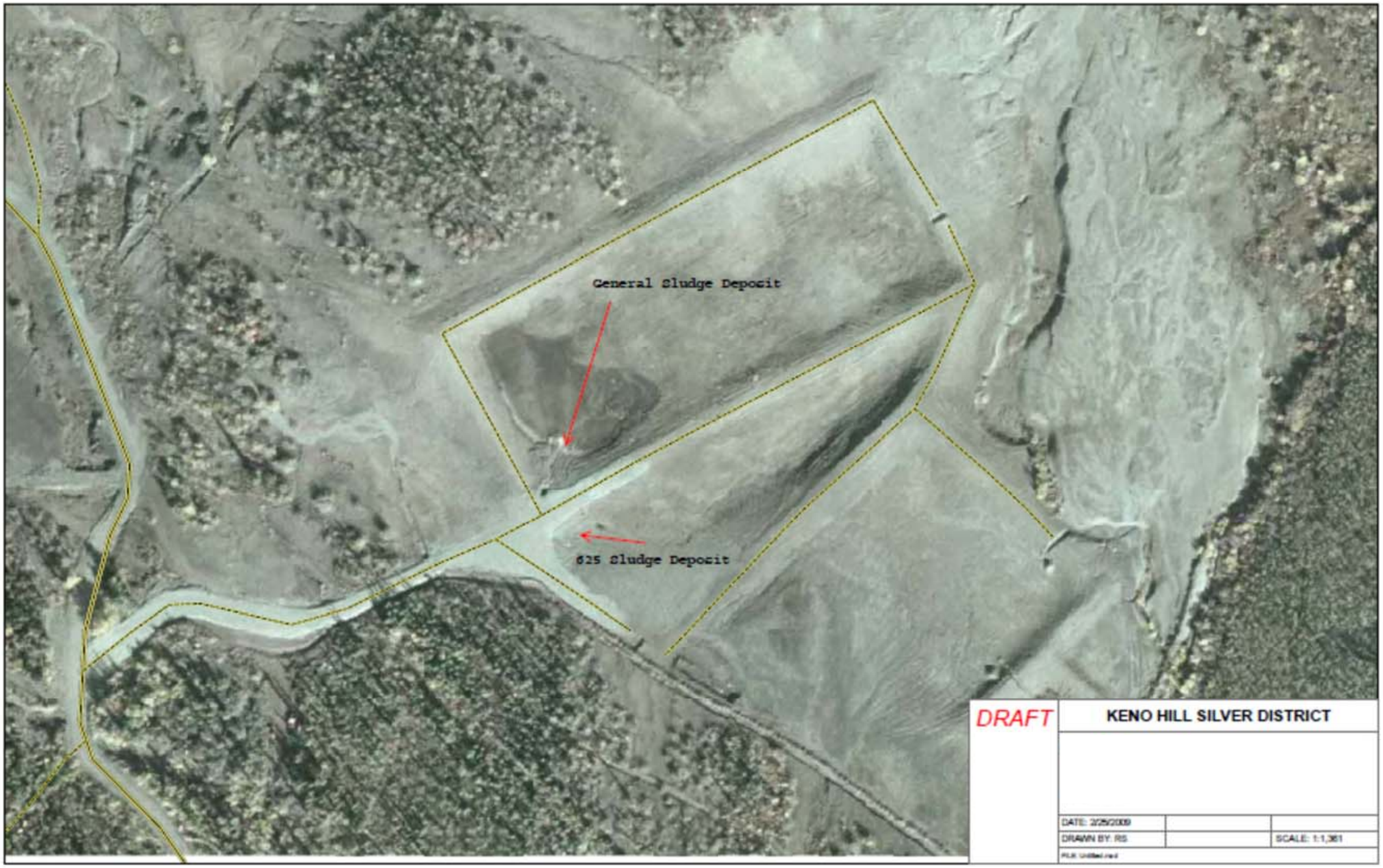

FIGURE 8 – BELLEKENO 625 SLUDGE DEPOSIT LOCATION IN VALLEY TAILINGS AREA.

4.4. PROPOSED CLOSURE

In the approved water license, the Water Board agreed that the use of a bioreactor to treat closure water discharged from the Bellekeno 625 underground mine workings is a feasible technology for long term treatment of waters generated from the mine. In addition, AKHM plans to implement various passive measures if required, such as potentially in situ treatment of the mine pool, in conjunction with the bioreactor to maximize performance of the system.

AKHM plans to build the bioreactor in the existing settling ponds and that effort would be undertaken during closure when the Bellekeno mine is flooding. The ponds will be drained and completely desludged at that time, and then the empty ponds would be converted into bioreactors. That would allow the discharge from the mine to be controlled as necessary through active pumping thereby giving the bioreactor time to become established. The Board also requested additional information such as details required to design and operate such a bioreactor and further evaluation of the performance from the Galkeno 900 bioreactor system. That information will be provided as part of the revised Reclamation and Closure Plan.

4.5. MONITORING AND MITIGATION

The following measures will be implemented during the duration of water treatment and sludge generation at Bellekeno and Flame & Moth:

- Sludge volumes will be recorded in the Operator's Log Book for each load of sludge pulled from the Water Treatment retention ponds
- Sludge samples will be collected quarterly and tested for metals and ABA.
- The above information will be included in the Company's Monthly Report to the Yukon Water Board as well as summarized in the Annual Report

The template used for the Operator's Log Book is included for reference in this document's Appendix.

5.0 APPENDIX

Sludge/Water Tracking Log

Week:

Sludge Removal

Removed From	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Comment
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
SK 100															
GK 300 Desludge Pond															
GK 900															
BK 625															
Other:															
Other:															

Sludge Deposit

Deposited At	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Comment
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
Sime Pit															
Valley															
Mill/DSTF															
Other:															
Operator:															

Water Removal

Removed From	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Comment
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
Flat Creek															
SK 100															
GK 300 Old Pond															
GK 900															
Other:															

Lime Deposit

Deposited At	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Comment
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
SK 100															
GK 300															
GK 900															
BK 625															
Mill															
Other:															
Operator:															