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January 2024, Kensington Mine Tailings Line Spill

Executive Summary

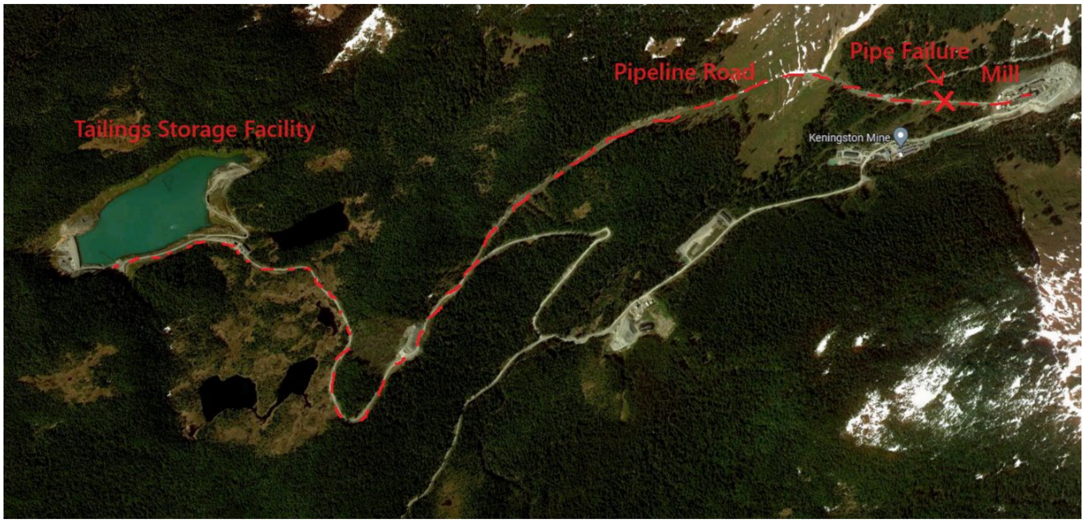
- A tailings spill occurred at the Kensington Mine on January 31st 2024. The duration of the leak is estimated to be 23 hours. A portion of the spill reached Johnson Creek, the duration of the contact with Johnson Creek is estimated to be 2.5 hours.
- The length the tailings traveled before reaching Johnson Creek is approximately 430 meters, approximately half of the tailings spilled were recovered from the surface of Pipeline Road or from small drainages before reaching Johnson Creek.
- The estimated spill volume is 105,581 gallons of tailings slurry (water + tailings). The tailings component of the slurry is estimated to be 16,787 gallons of which an estimated 8,111 gallons have been recovered.
- The majority of the tailings slurry is water (84%), much of the water component would have infiltrated the ground before reaching Johnson Creek, given the tailings pipeline is buried and the distance the tailings traveled before reaching water.
- The tailings are geochemically inert, they are comprised mainly of diorite and quartz. They pose no long-term impacts to Johnson Creek as demonstrated by the sediment sampling data and comparisons with historical data.
- Upon discovery of the leak, mill shutdown was initiated immediately. A response team was quickly assembled to place straw wattles in drainages to further prevent tailings from entering Johnson Creek. Heavy equipment was deployed to the scene to remove tailings from Pipeline Road. Within 40 minutes of the spill discovery water samples were taken to characterize any impact to Johnson Creek.

Background

The Kensington Mine pumps a tailings slurry consisting of tailings and water through a buried double-wall pipeline. The pipeline travels approximately 3.5 miles from the Mill to the Tailings Treatment Facility (TTF) (Figure 1). The buried pipeline runs adjacent to the Pipeline Road. There are nine concrete access vaults distributed along the 3.5 mile stretch of pipeline which allow access points for inspection of the pipeline. The pipeline consists of an inner 6-inch HDPE pipe and a 10-inch HDPE outer pipe (Figure 2).

The tailings are disposed of in the TTF tails pond through a floating Tremie Barge that allows for distribution of tailings throughout the tails pond.

Figure 1. Overview of tailings pipeline route.



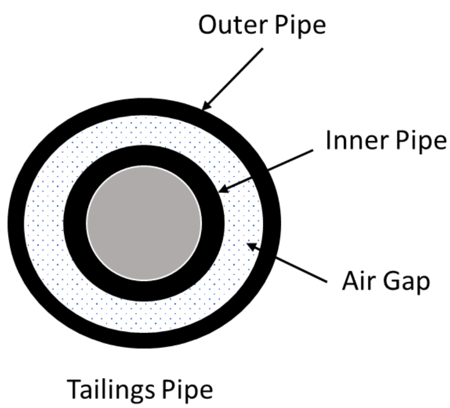


Figure 2. Cross section of tailings pipe.

Events Leading Up to the Incident:

On 1/31/24 at approximately 12:00pm, the Mill Control Room Operator noticed a pressure drop in the tailings line and proceeded to contact the Surface Supervisors and the Mill Supervisor notifying them that he suspected that there may be a leak in the tailings pipeline, and that the pipeline vaults should be checked.

Surface Supervisors contacted the Environmental Department, and an Environmental Coordinator was tasked to start inspecting the Pipeline Vaults. Vault inspections commenced at approximately 1:20pm starting from Vault 9 at the TTF working back towards the Mill. At approximately 2:30pm the Environmental Coordinator drove over Bridge 1(downstream bridge) and noted the water was clear and no indication of tailings in the creek. The Environmental Coordinator then drove north and crossed Bridge 2 (upstream bridge) at approximately 2:35pm and discovered the water was cloudy. See Figure 5 for Bridge 1 & 2 locations. The Environmental Coordinator immediately notified Mill Operations, and then sought assistance from Safety Department personnel on the way to the Mill to continue inspecting the Pipeline.

At approximately 3:00 pm the tailings pipeline leak was discovered on Pipeline Road south of the Assay Lab. Tailings were found flowing underneath a deep layer of snow and ice continuing into the freshwater drainage alongside Pipeline Road which flows into Johnson Creek (see photos 1, 2 &3). See Figure 3 for a map of the area where the spill occurred and the flow path towards Johnson Creek. See Figure 4 for a graphical representation of tailings flow and line pressure over time.

Figure 3. Flow Path of Tailings.

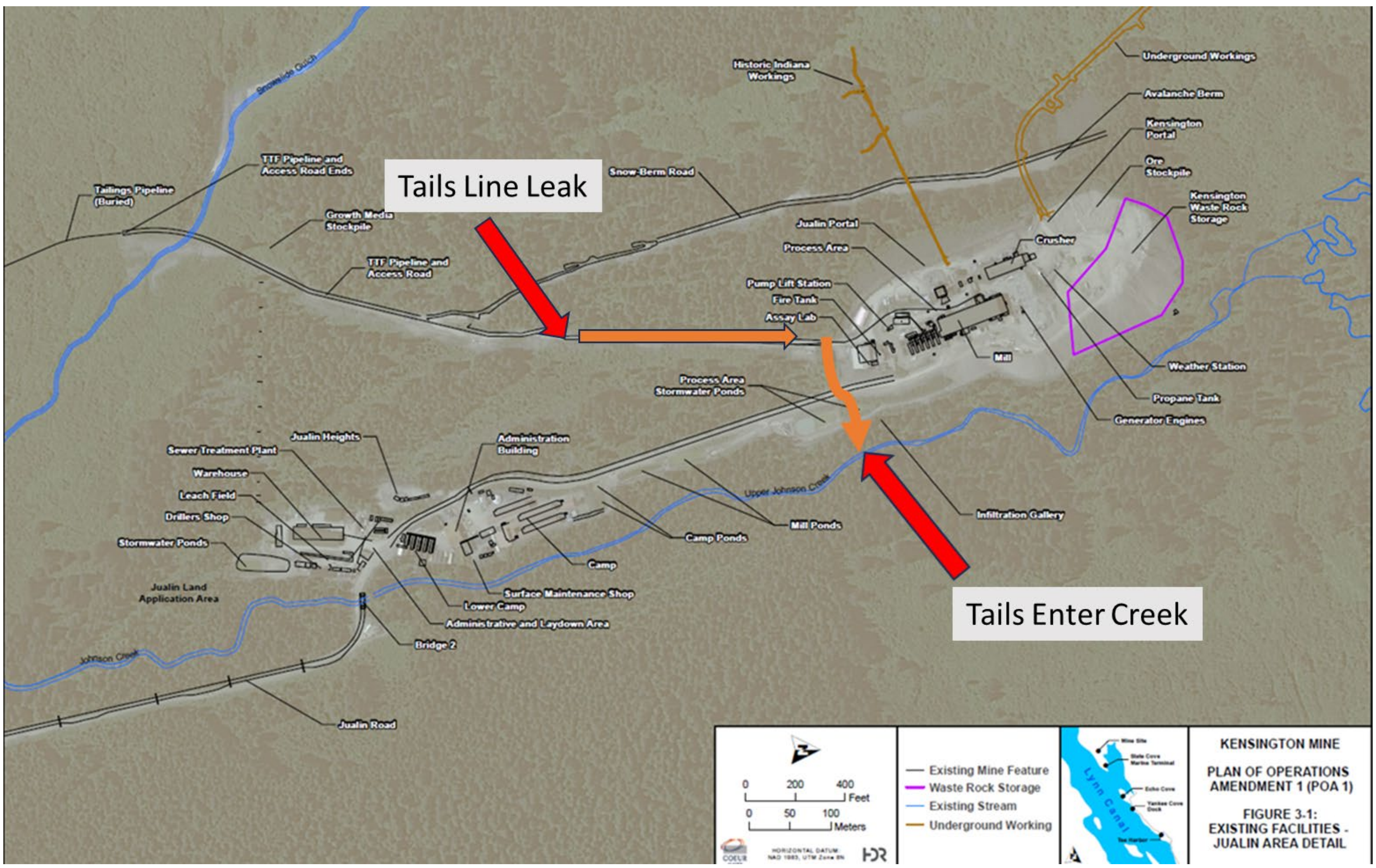


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Photo 1: Tailings leak from buried tailings line on Pipeline Rd.

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Photo 2: Tailings in freshwater drainage along Pipeline Road leading to Johnson Creek.

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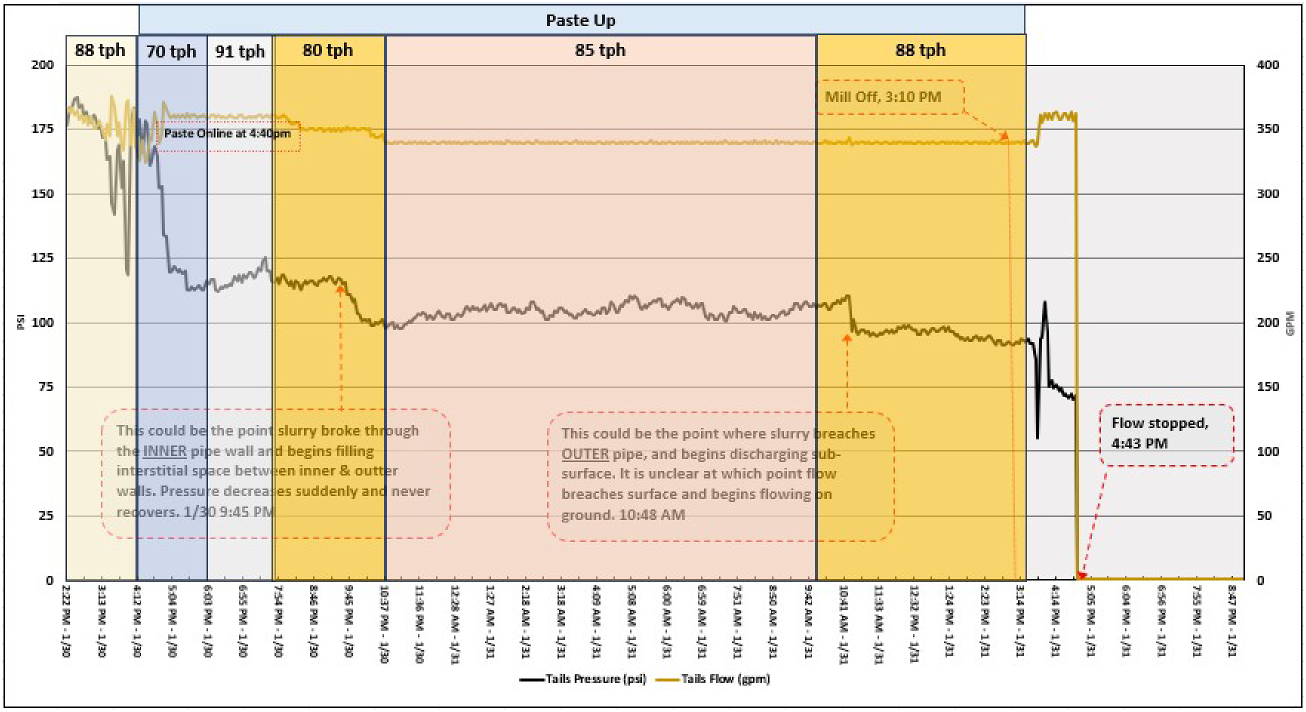
Photo 3: Johnson Creek during tailings spill.

Figure 4. Tailings line pressure and flow on the day of the incident:



Chronology of events following the incident:

1. 1/31 3:00 PM: A leak was identified in the tailings pipeline.
2. 1/31 3:10 PM: Upon discovery of the leak in the tailings pipeline, the mill control room initiated shutdown of the mill to stop the flow of tailings through the pipeline.
3. 1/31 3:20 PM: A response team was assembled and heavy equipment deployed to the scene to stop the flow of tailings to freshwater. Stormwater wattles were placed in the drainages to prevent tailings from reaching Johnson Creek.
4. 1/31 3:40 PM: Water quality samples taken in Johnson Creek directly downstream of the entry point where tailings entered the creek. The water quality sample analysis suite consists of total and dissolved metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, nickel, selenium, silver, sodium, zinc and low-level mercury), general chemistry parameters (total suspended solids, total dissolved solids, sulfate, ammonia, chloride, hardness, alkalinity & turbidity) field parameters (temperature, dissolved oxygen, pH & conductivity)
5. 1/31 4:12 PM: A call to ADEC Spill Prevention and Response was made to inform them of the release and provide initial information.
6. 1/31 Approximately 5:00 PM: Johnson Creek was observed to be running clear and there was no indication of elevated turbidity.
7. 1/31 6:00 PM: Incident Response Team meeting held to further assess the situation and plan next steps.
8. 1/31 approximately 7:00 PM: further agency notifications initiated, Alaska Department of Fish and Game and National Response Center (EPA and Coast Guard)
9. 2/1 Day-long comprehensive water quality sampling conducted at APDES permit established water quality sites on Johnson Creek. Further investigation conducted to determine if tails were present in the lower reaches of Johnson Creek – no evidence of tailings found indicating tailings did not reach Berners Bay.
10. 2/1 At approximately 11:00 AM: Alaska Department of Natural Resources and the USDA Forest Service notified.
11. 2/1 At approximately 4:00 PM: Submitted to ADEC the most recent tailings geochemistry data and tailings slurry water analytical data to demonstrate the inert quality of the tailings.

Cleanup Actions

Immediately after the leak's discovery, straw wattles were placed in the freshwater drainage next to Pipeline Road and in the riparian area of Johnson Creek to capture any residual tailings and prevent migration to the creek (Photo 4). Following the placement of wattles heavy equipment was deployed to the scene. The equipment was used to remove tailings from the Pipeline Road. Also, the freshwater drainage next to Pipeline Road was diverted to prevent residual tailings from reaching Johnson Creek.

A vacuum trailer was used to remove residual pockets of tailings from the freshwater drainage leading to Johnson Creek (Photo 5). An in-stream cleanup of the tailings was conducted to remove tailings from Johnson Creek (Photo 6). All recovered tailings were either disposed of underground or in the TTF, both permitted disposal methods. Once the snow melts and the ground is exposed further cleanups are scheduled to remove any remaining tailings.

Photo 4. Straw wattles capturing residual tailings.

Photo 5. Vacuum trailer removing tailings near Johnson Creek.

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Photo 6. Mine personnel removing tailings from Johnson Creek.

Monitoring Actions

To evaluate any impacts from the tailings entering Johnson Creek, water quality samples were taken during the incident and days following the incident. On the day of the incident, within 40 minutes of the discovery of the ruptured tailings line, water quality samples were taken. The samples were shipped that evening to a third-party lab for analysis. Sampling occurred at the entry point of the tailings into Johnson Creek and at APDES permit sample station JS-5, approximately 750 meters downstream of the tailings entry point. The results are presented in Table 1. Exceedances of Alaska Water Quality Standards did occur during the incident as indicated by the highlighted values. To be the most conservative the chronic water quality standard was used although the incident represents an acute scenario. Acute water quality results are also provided in Table 1 for comparison. The duration of the exceedances was short, Johnson Creek was running clear approximately 2.5 hours after the discovery of the tailings line rupture.

The day after the incident, February 1st, additional water quality sampling was conducted. The February 1st water quality sample results are presented in Table 2, all results are within Alaska Water Quality Standards. To further assess water quality, sampling was again conducted at all APDES permit receiving water sample sites one week later, on February 6th. The February 6th results are presented in Table 3. No exceedances of water quality standards occurred on February 6th. See Figure 5 for a map detailing the water quality sampling locations.

The presence of tailings in Johnson Creek was also investigated during the water quality sampling events. No tailings in Johnson Creek were found beyond sample site JS5, upstream of the creek's anadromous reaches. Note that the tailings are geochemically inert and are non-acid generating and do not leach metals.

Additionally, sediment sampling was conducted in Johnson Creek by the Alaska Department of Fish and Game (ADF&G) on February 6th. This sampling was conducted to determine any impacts to Johnson Creek with respect to sediment toxicity and evaluate any impacts to overall stream ecology pertaining to fish, benthic macroinvertebrates, and algae. Five sediment samples were taken at three locations within the creek. The locations are High Johnson Creek (HJC), Upper Johnson Creek (UJC) and Lower Johnson Creek (LJC). HJC is located 8 meters upstream of the tailings entry point. UJC is located approximately 570 meters downstream of the tailings entry point. LJC is approximately 500 meters from the mouth of Johnson Creek.

Sediment samples were analyzed for aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc. LJC results were compared to historic Johnson Creek sediment metal concentrations from the same sample location dating to 2011. When compared to historic concentrations the results show no marked difference, as shown in Figure 6.

Additionally, all sample results from the February 6th sampling were compared to the Threshold Effect Concentrations (TEC) guidelines. TEC is a concentration below which adverse effects are not expected to occur. All results remained below the TEC level, as shown in Figure 7. The sediment sampling locations can be found in Figure 8.

Future routine monitoring of Johnson Creek will continue as prescribed by the APDES permit. This monitoring will include monthly water quality monitoring for all parameters displayed in Table 1. Annual aquatic resource monitoring will be conducted as dictated by the APDES permit. This will include sediment monitoring, benthic invertebrate monitoring, anadromous fish monitoring and algae monitoring.

Table 1. Water quality results from the day of the incident.

COEUR ALASKA KENSINGTON MINE					
Tailings Line Release - Johnson Creek Samples					
	Date:	1/31/2024	1/31/2024		
Parameters	Units	Tailings Point of Entry into Johnson Creek	CAK-JS5	Chronic Water Quality Limit	Acute Water Quality Limit (where applicable)
Aluminum	ug/L	29900	12700	87 ug/L	750 ug/L
Ammonia, Total	mg/L	0.313	0.146	1.6 mg/L	1.6 mg/L
Cadmium	ug/L	0.118	<0.063	0.06 ug/L	0.31 ug/L
Chlorine - In House	mg/L	0	0	11 mg/L	19 mg/L
Copper	ug/L	40.1	18.2	1.7 ug/L	2.2 ug/L
Iron	mg/L	46.3	17.6	1 mg/L	N/A
Lead	ug/L	2.71	1.49	0.30 ug/L	7.61 ug/L
Manganese	ug/L	2420	889	50 ug/L	N/A
Nickel	ug/L	6.41	2.9	10.3 ug/L*	92.5*
Selenium	ug/L	<0.24	0.5	5 ug/L	N/A
Zinc	ug/L	93.5	43.5	23.3 ug/L*	23.1*
Sulfates	mg/L	6.9	5.35	250 mg/L	N/A
Chloride	mg/L	1.26	1.14	250 mg/L	N/A
Turbidity	NTU	369	279	5 NTU**	N/A
TDS	mg/L	53	55	500 mg/L	N/A
TSS	mg/L	319	198	N/A	N/A
pH - Field	pH	8.64	8.33	6.5-8.5	N/A
Dissolved Oxygen - Field	mg/L	13.6	13.8	> 4.0 mg/L	N/A
Temperature - Field	oC	2.2	2.3	< 15 oC	N/A
Nitrate as N	mg/L	1.56	1.10	10 mg/L	N/A
Conductivity - Field	umhos/cm	36.8	41.3	N/A	N/A
Hardness, Total	mg/L	14.7*	14.7*	N/A	N/A
Color	Color Unit	10	15	N/A	N/A
Low Level Mercury	ug/L	0.00982	0.00609	0.77 ug/L	0.77 ug/L
*Hardness based limits calculated using hardness from JS-2 on 1/10/2024.					
**WQ limit for turbidity based on background site turbidity from JS-2 on 1/10/2024.					

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Table 2. Johnson Creek water quality sampling one day after the incident.

COEUR ALASKA KENSINGTON MINE						
Tailings Line Release - Johnson Creek + Lower Johnson Sample Results						
	Date:	**2/1/2024**	**2/1/2024**	**2/1/2024**	**2/1/2024**	
Parameters	**Units**	**CAK-JS2**	**CAK-JS5**	**CAK-JS4**	**Lower Johnson**	**Chronic Water Quality Limit**
Aluminum	ug/L	76.1	47.9	76.6	78.1	87 ug/L
Ammonia, Total	mg/L	<0.030	<0.030	<0.030	<0.030	1.6 mg/L
Cadmium	ug/L	<0.063	<0.063	<0.063	0.072	0.06 ug/L*
Chlorine - In House	mg/L	0	0	0	0	17 mg/L
Copper	ug/L	1.11	0.63	0.68	1.42	1.7 ug/L*
Iron	mg/L	0.153	0.067	0.103	0.11	1 mg/L
Lead	ug/L	<0.14	<0.14	<0.14	<0.14	0.29 ug/L*
Manganese	ug/L	5.17	6.68	7.22	6.53	50 ug/L
Nickel	ug/L	<0.12	<0.12	<0.12	0.31	10.2 ug/L*
Selenium	ug/L	<0.24	<0.24	<0.24	<0.24	5 ug/L
Zinc	ug/L	<2.0	<2.0	<2.0	2.8	23 ug/L*
Sulfates	mg/L	1.79	4.94	7.17	11.8	250 mg/L
Chloride	mg/L	0.85	0.95	0.98	1.05	250 mg/L
Turbidity	NTU	<0.200	0.508	0.275	0.536	5 NTU
TDS	mg/L	20	38	42	54	500 mg/L
TSS	mg/L	<5.0	<5.0	<5.0	<5.0	N/A
pH - Field	pH	7.16	7.20	7.23	7.41	6.5-8.5
Dissolved Oxygen - Field	mg/L	13.67	13.90	14.06	14.52	> 4.0 mg/L
Temperature - Field	oC	2.7	2.1	1.7	1.6	< 15 oC
Nitrate as N	mg/L	0.318	0.758	0.821	0.889	10 mg/L
Conductivity - Field	umhos/cm	19.3	32.8	42.6	51.7	N/A
Hardness, Total	mg/L	14.5	25.4	35.9	42.4	N/A
Color	Color Unit	5	5	5	5	N/A
Low Level Mercury	ug/L	0.00056	0.00058	0.00081	0.000931	0.77 ug/L
*Hardness based limit, hardness value from 1/10/24 sampling for JS2 (background site) used to calculate limit						

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Table 3. Johnson Creek water quality sampling 7 days after the incident.

COEUR ALASKA KENSINGTON MINE					
Tailings Line Release - Johnson Creek Sample Results					
	Date:	**2/6/2024**	**2/6/2024**	**2/6/2024**	
Parameters	**Units**	**CAK-JS2**	**CAK-JS5**	**CAK-JS4**	**Chronic Water Quality Limit**
Aluminum	ug/L	8.1	71.70	47.80	87 ug/L
Ammonia, Total	mg/L	<0.030	<0.030	<0.030	1.6 mg/L
Cadmium	ug/L	<0.063	<0.063	<0.063	0.06 ug/L*
Chlorine - In House	mg/L	0	0	0	17 mg/L
Copper	ug/L	<0.36	0.62	0.61	1.7 ug/L*
Iron	mg/L	0.014	0.09	0.06	1 mg/L
Lead	ug/L	<0.14	<0.14	<0.14	0.29 ug/L*
Manganese	ug/L	1.17	8.47	5.42	50 ug/L
Nickel	ug/L	<0.12	<0.12	<0.12	10.2 ug/L*
Selenium	ug/L	<0.24	<0.24	<0.24	5 ug/L
Zinc	ug/L	<2.0	<2.0	<2.0	23 ug/L*
Sulfates	mg/L	1.93	5.83	9.11	250 mg/L
Chloride	mg/L	0.83	1.09	1.03	250 mg/L
Turbidity	NTU	<0.200	0.80	1.00	5 NTU
TDS	mg/L	16	48.00	53.00	500 mg/L
TSS	mg/L	<5.0	9.00	<5.0	N/A
pH - Field	pH	6.91	7.34	6.87	6.5-8.5
Dissolved Oxygen - Field	mg/L	14.13	13.98	14.44	> 4.0 mg/L
Temperature - Field	oC	3.0	2.8	2.3	< 15 oC
Nitrate as N	mg/L	0.331	0.87	0.97	10 mg/L
Conductivity - Field	umhos/cm	21.9	44.8	58.8	N/A
Hardness, Total	mg/L	14.5	32.3	44.7	N/A
Color	Color Unit	<5.00	5.00	5.00	N/A
Low Level Mercury	ug/L	0.000179	0.00043	0.00087	0.77 ug/L
*Hardness based limit, hardness value from 1/10/24 sampling for JS2 (background site) used to calculate limit					

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Figure 5. Johnson Creek water quality sample locations, indicated in green.

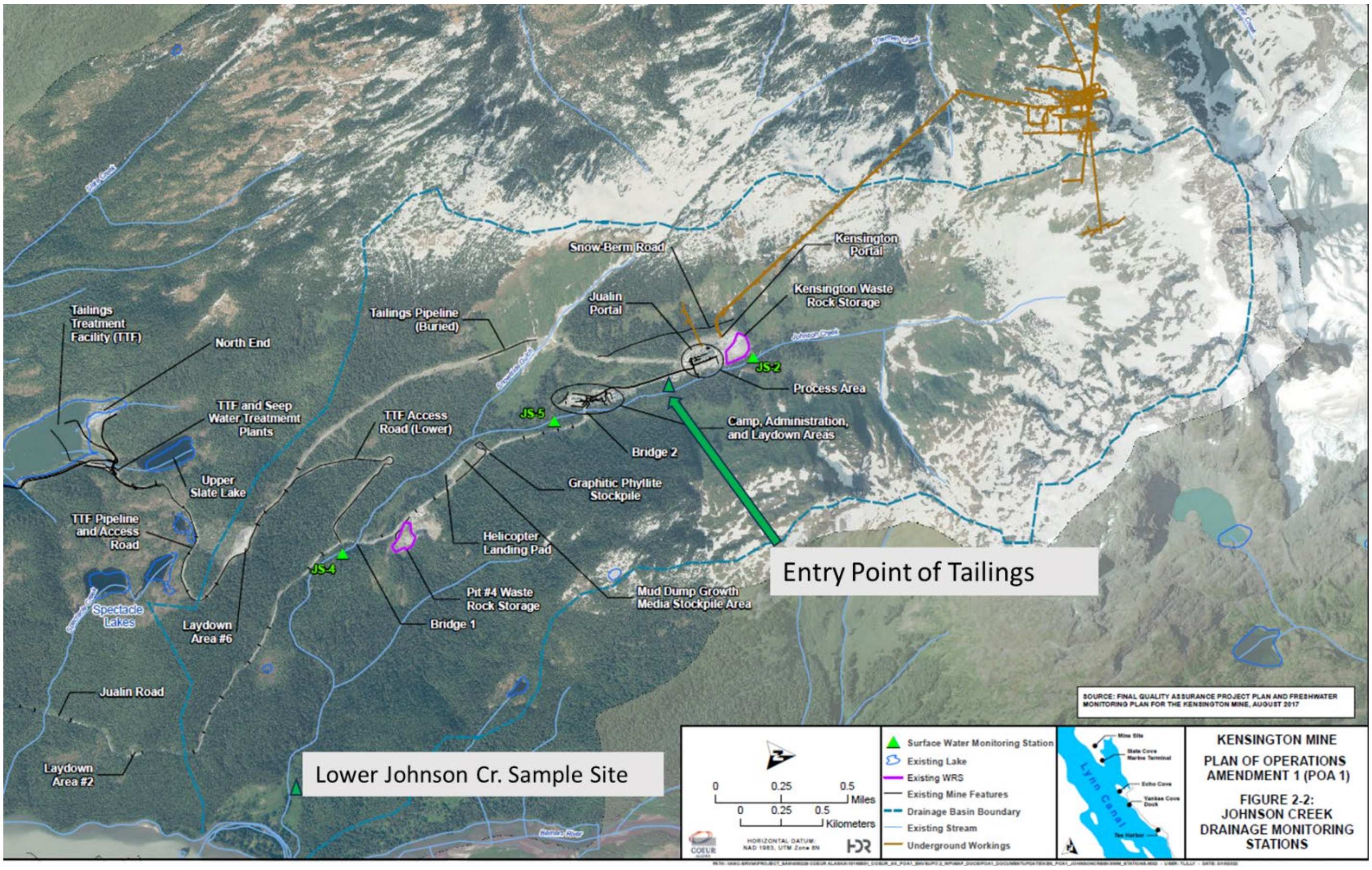

Figure 6. Sediment sampling results compared with historic values – 2024 results represent post spill.

Kensington Mine Tailings Spill Sediment Analysis

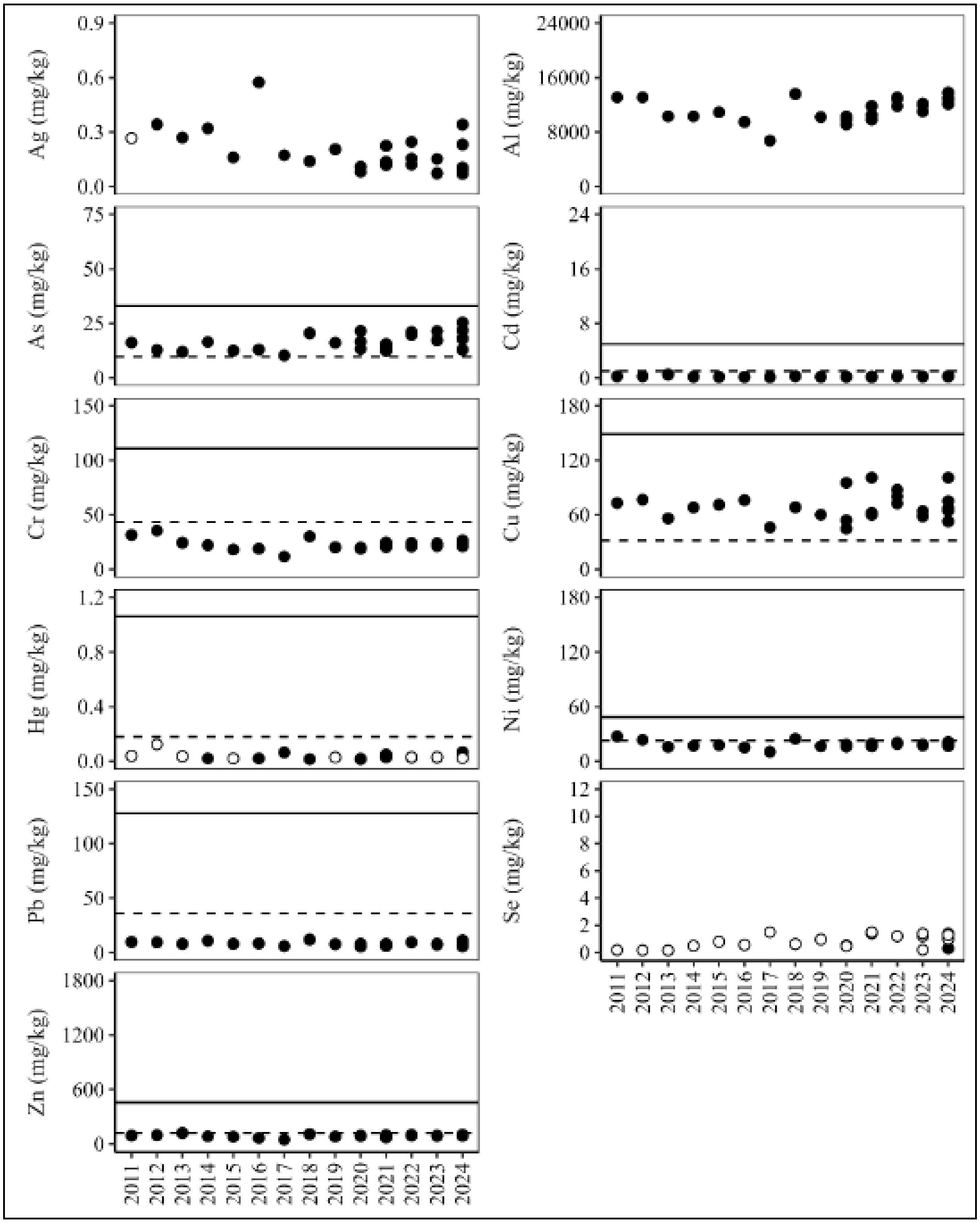

Figure 1.–Lower Johnson Creek element concentrations.

Note: Elements undetected (o) are presented at the method reporting limit. TEC and PEC guidelines are not published for Ag, Al, or Se (Buchman 2008).

(Figure source: Erika King ADF&G)

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Figure 7. Sediment sampling results compared with the TEC guidelines.

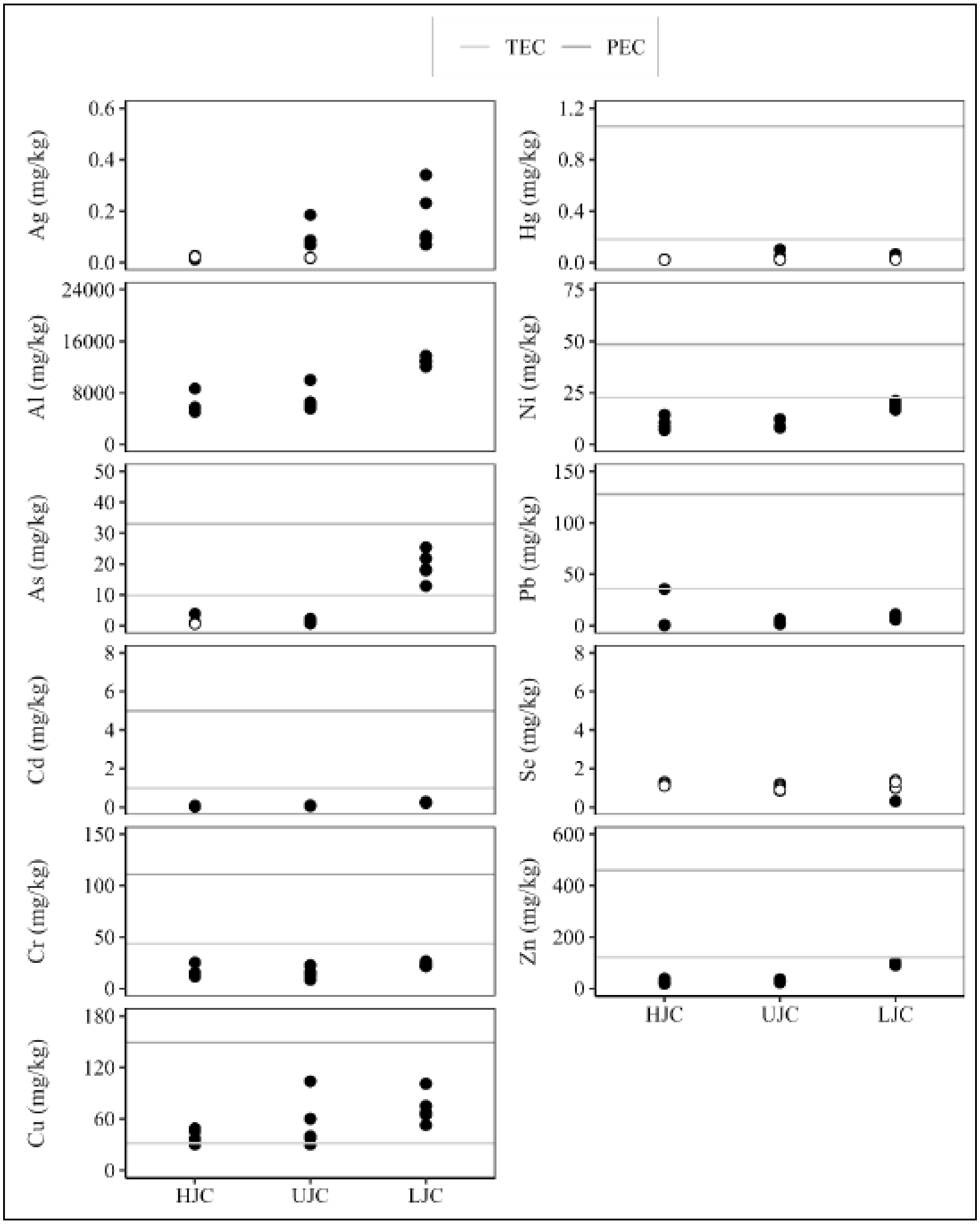

Figure 2.–High Johnson Creek (HJC), Upper Johnson Creek (UJC), and Lower Johnson Creek (LJC) element concentrations on February 6, 2024, with TEC and PEC guidelines.

Note: Elements undetected (o) are presented at the method reporting limit. TEC and PEC guidelines are not published for Ag, Al, or Se (Buchman 2008).

(Figure source: Erika King ADF&G)

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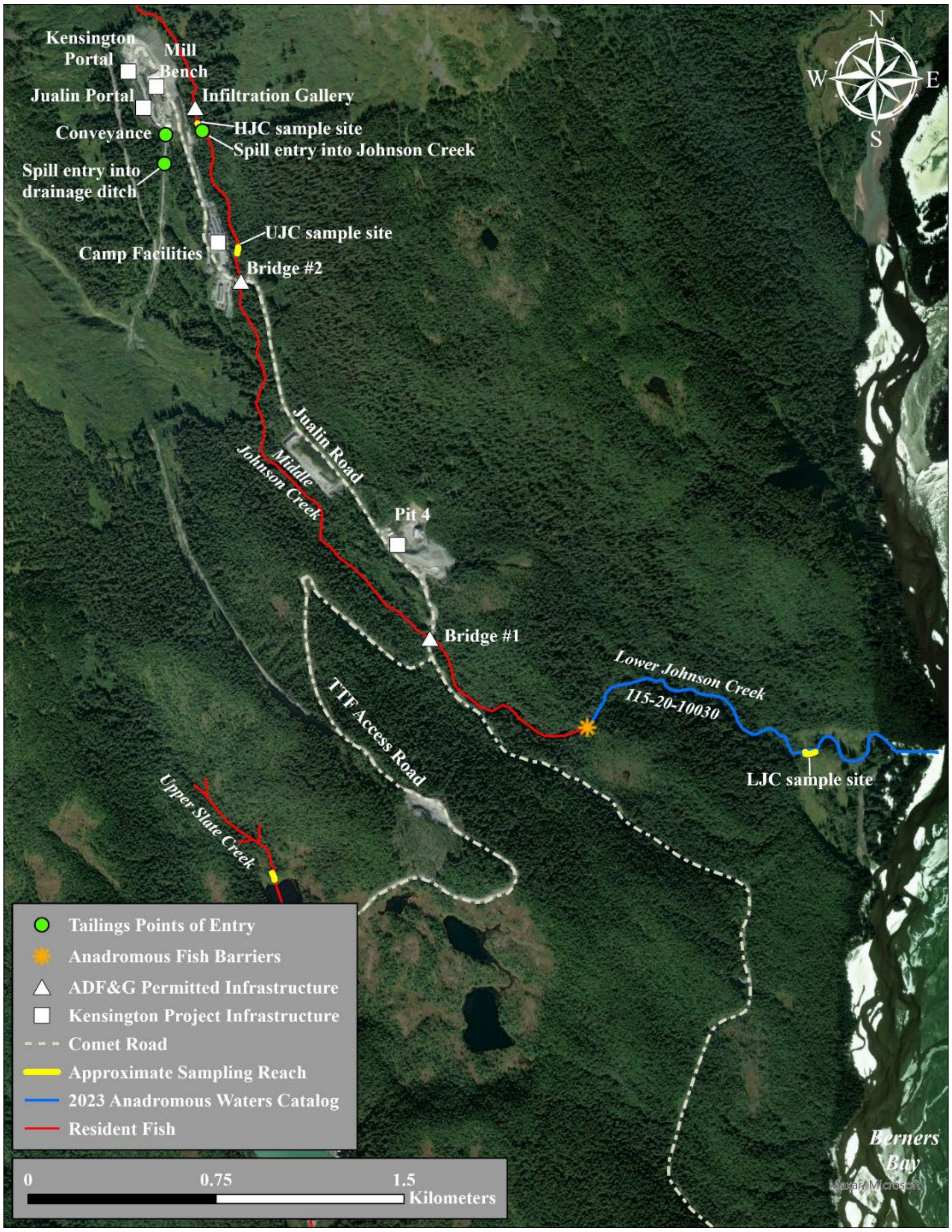
Figure 8. Sediment sampling locations.



(Figure source: Erika King ADF&G)

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Spill Volume

The estimated total volume of tailings and slurry water spilled is 105,581 gallons. It is important to note that tailings slurry by volume is 16% tailings and 84% water. The total estimated volume of tailings spilled is 16,787 gallons. Of the 16,787 gallons, approximately 8,111 gallons of tailings have been recovered. The recovery volume accounts for the volume removed from Pipeline Road, residual pockets of tailings removed from drainages and tailings removed from Johnson Creek. As mentioned previously, future cleanups are planned to remove remnant tailings from both the spill path and in the margins of Johnson Creek. This will be conducted once the snowpack recedes. Also important to note, as shown in Figure 3, the distance tailings traveled before reaching Johnson Creek; the large surface area of the spill path helps provide retention of remnant tailings.

Spill Volume Calculations Summary

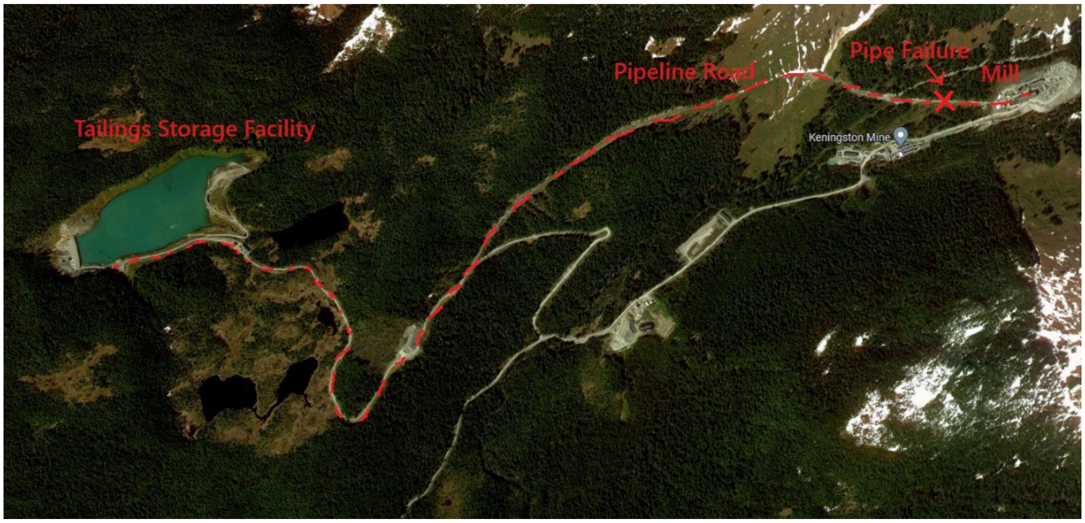
The calculations are based on the estimated duration of the spill determined by analyzing pressure and flow changes within the pipeline to assign a start time to the event. The hole in the pipeline enlarged over time, to determine flow rates, three separate pressure regimes were used in the calculations. The three separate flow rates over a given period were correlated with the three separate pressure regimes. The flow rates were then summed to estimate a total slurry volume released. The total slurry volume is broken down into a water component and tailings component.

Detailed Analysis of Calculations

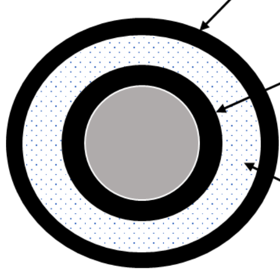
This section shows the method and calculations used to estimate the quantity of slurry discharged into the environment. To accomplish this the:

1) Tailings pipeline system setup was defined.
2) Relevant process data and site condition information was collected and evaluated.
3) The duration of the leak was determined based on the process data.
4) The volume of slurry discharge was estimated using an orifice plate approximation of the hole that formed.

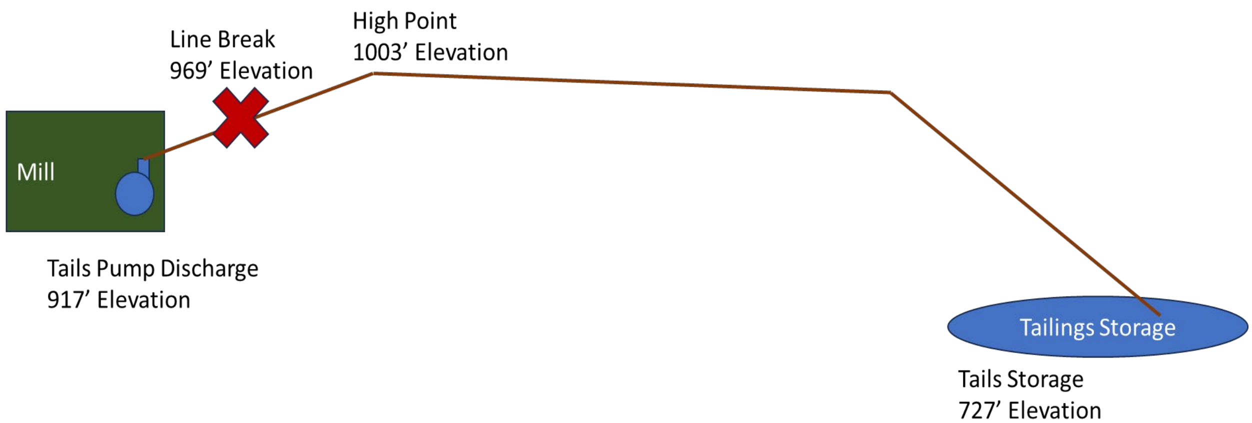
System Setup Overview



Tailings are pumped from the Mill to the Tailings Storage Facility through a buried, double walled HDPE pipeline.



Double Wall HDPE Pipeline. 10-inch Outside Pipe and 6-inch Inside Pipe



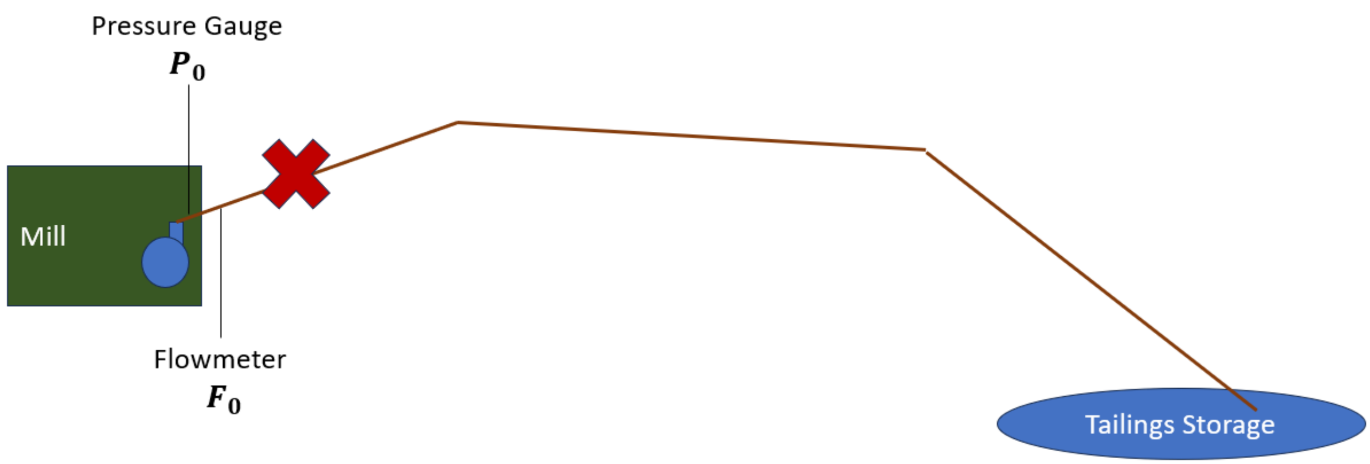
Elevation Profile of Tailings Pipeline

Failure Event

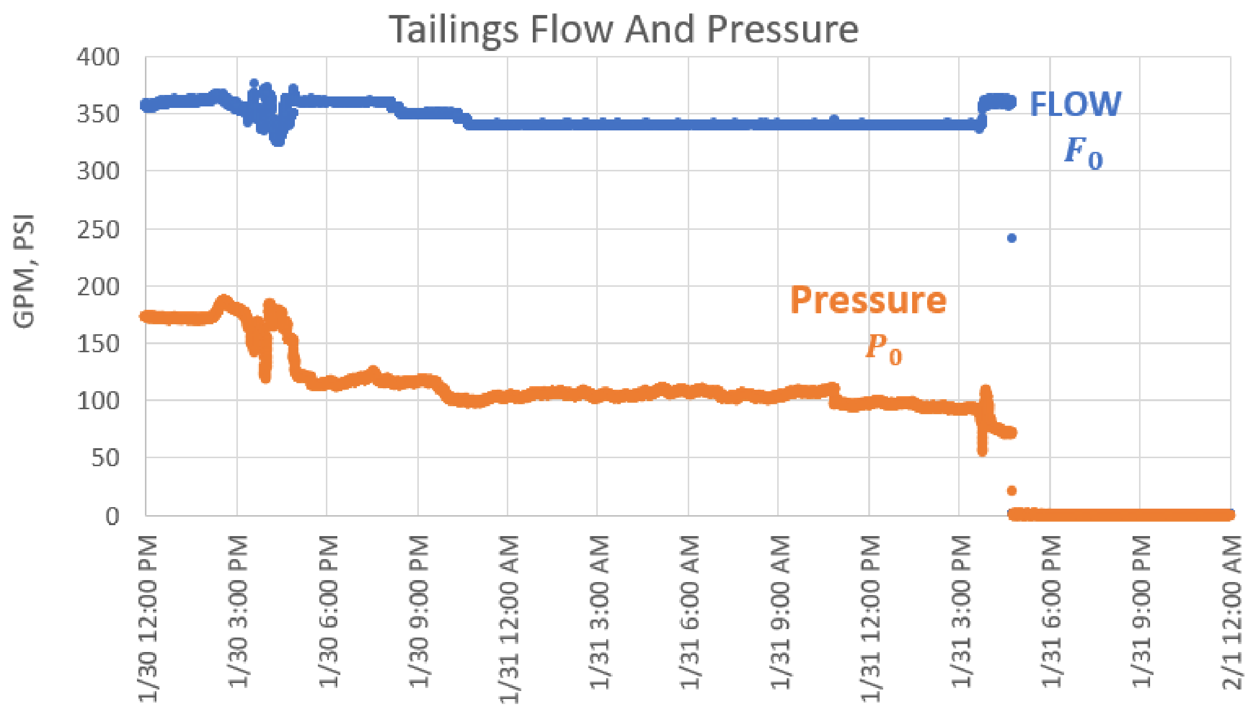
The tails pipe failed by abrasion; this suggests a pinhole failure in the inner pipe allowed a thin jet of tails slurry to exit and erode both the inner and outer walls of the pipe. There were no signs of a failure due to bursting (excessive pressure/plugged line).

Leak Estimation: Duration

To estimate the volume of tailings slurry, mill process data was analyzed to determine flow rate and duration of the leak event.

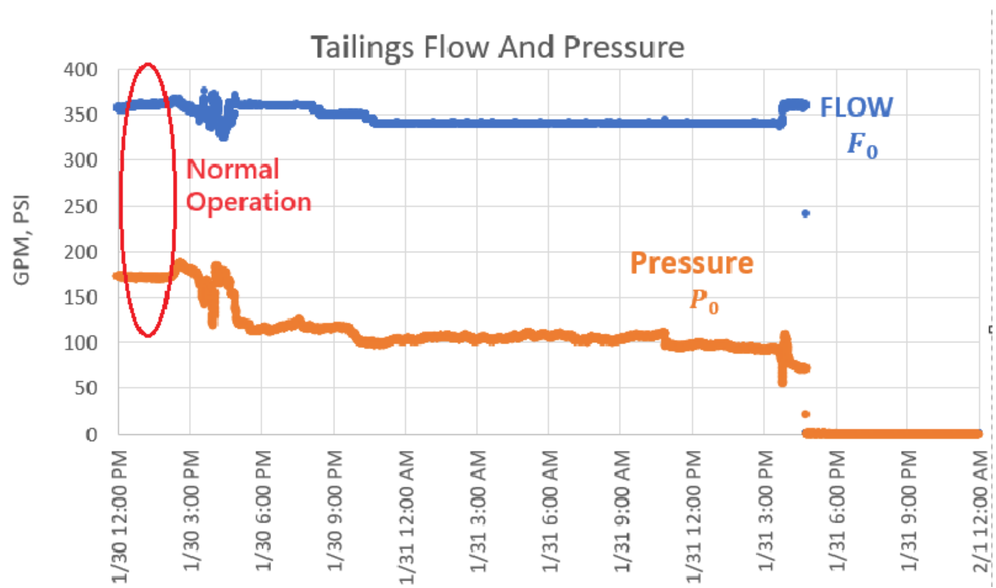


Mill Process Data Instruments



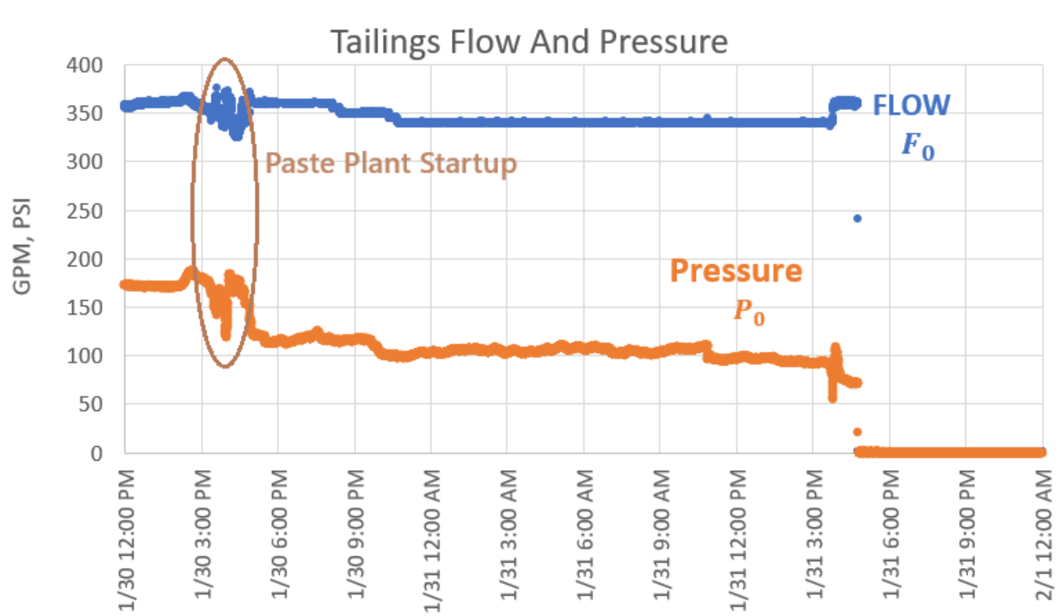
Raw Mill Process Data

Prior to 1/30 at 3pm, the pressure and flow measured at the mill correspond to a normal tails slurry pumping operation.



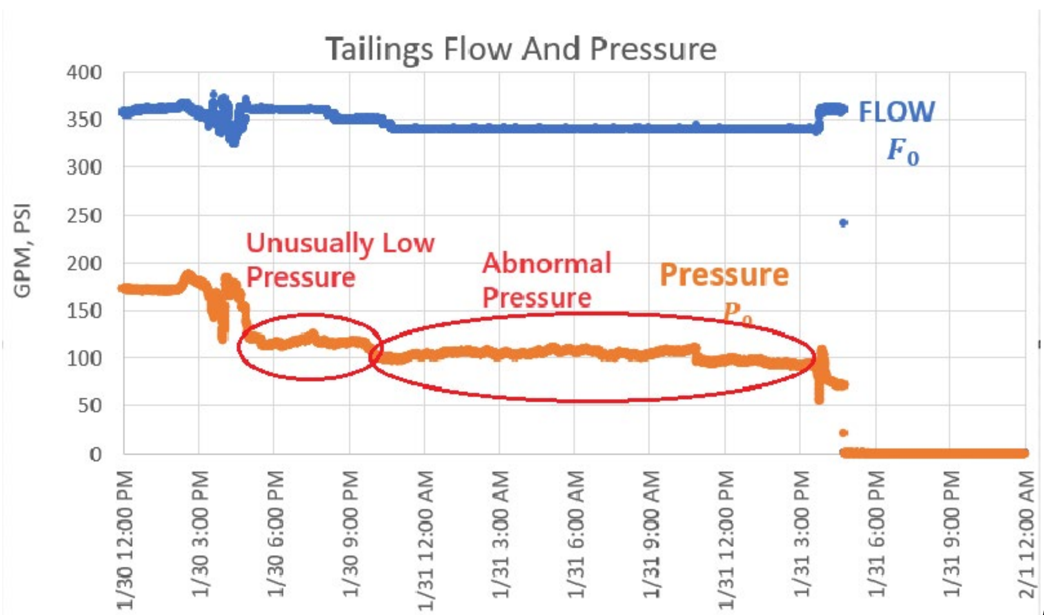
Normal Operation Pressure

The next event corresponds to a typical change in mill conditions. During this time, mill tonnage changed and the paste plant was started up at 4:40 pm.



Normal Process Change

Coming out of the process change, the tails line pressure is unusually low. These pressures are possible with a normal line, but only under extremely low % solids. To be conservative, the leak time was estimated to start after 5 pm on January 30th. The mill shut down before 5pm on January 31st after the leak was detected.



Unusually Low Pressure Followed by Abnormal Pressure

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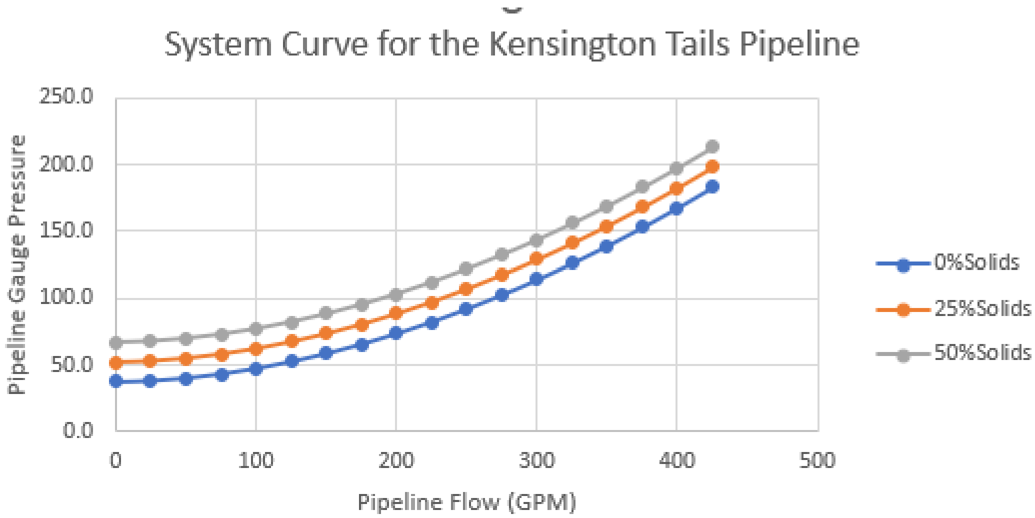
How do we know the pipe is OK before 3pm?

For a given pipeline geometry, fluid type, a given pressure will correspond to a certain flow.



Kensington Tails Pipeline Theoretical Pressure Vs. Flow curve for various tails slurry densities

Pipe pressure is a function of the system elevation gain, system pressure due to fluid friction, and system pressure due to velocity at discharge.

$$P_{total} = P_{elevation} + P_{friction}$$

Pressure due to the elevation is based on the density of the fluid and the elevation gain of the pipeline. For our tailings density of $2.6\frac{g}{cm^3}$ and a maximum elevation gain of 86 feet.

Pressure due to friction is calculated using the Hazen-Williams friction loss model:

$$P_{friction} = .002083 * L * \left(\frac{100}{C}\right)^{1.85} * \frac{gpm^{1.85}}{d^{4.8655}}$$

Where L = the length of the pipeline line, C is the friction coefficient of the pipeline material, gpm is the fluid flowrate, and d is the inside diameter of the pipeline.

For $L = 12{,}000\ FT, C = 150\ (typical\ for\ hdpe\ plastic\ pipe)\ gpm = 365\ d = 5.3\ inches$

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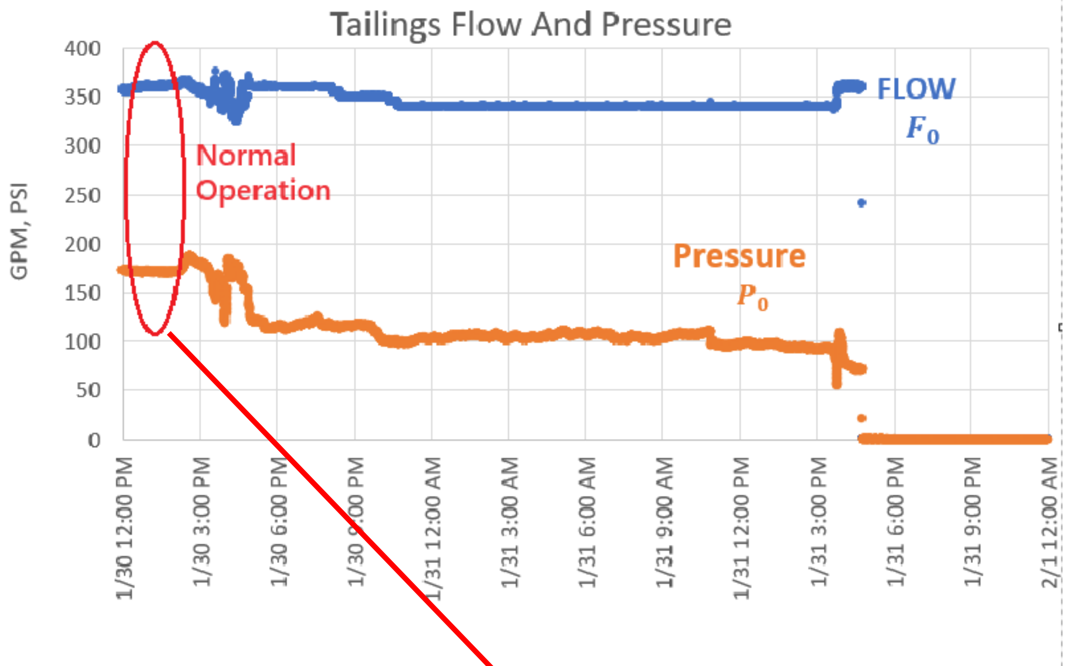
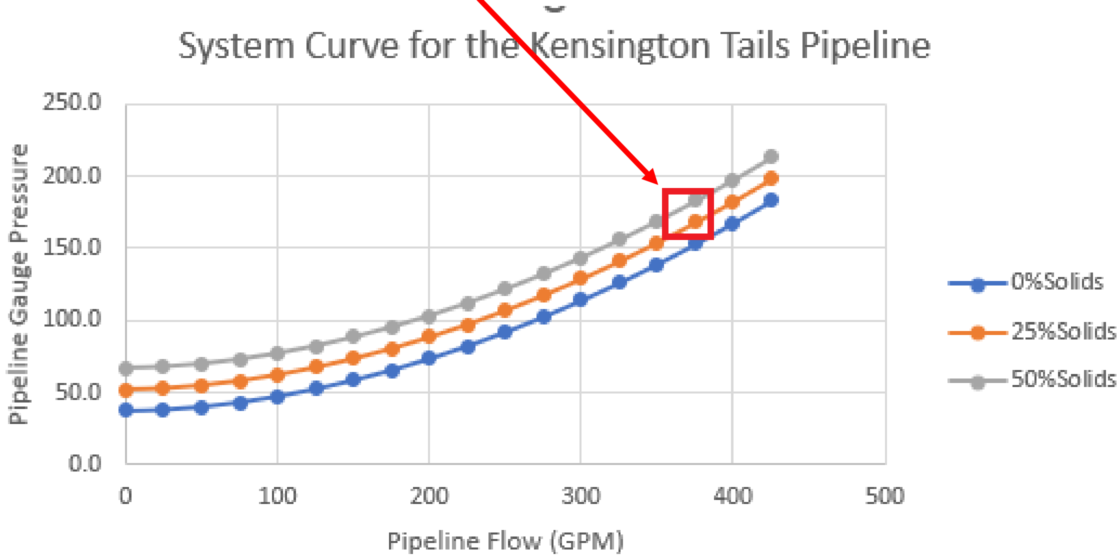
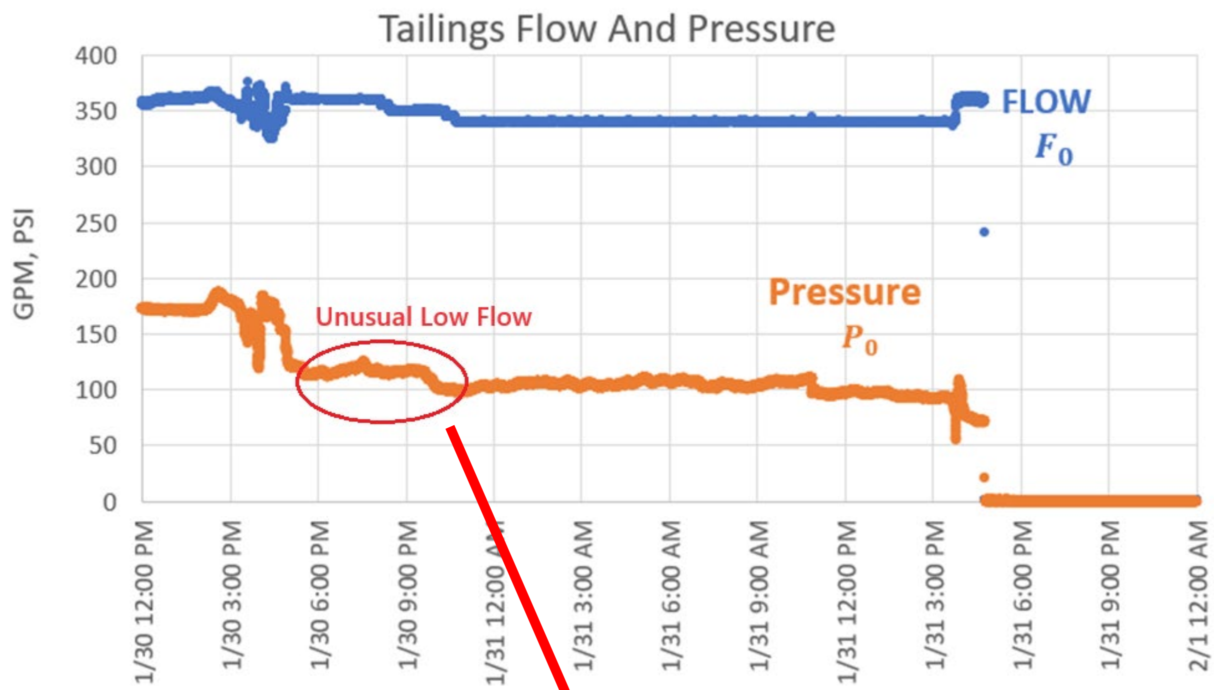
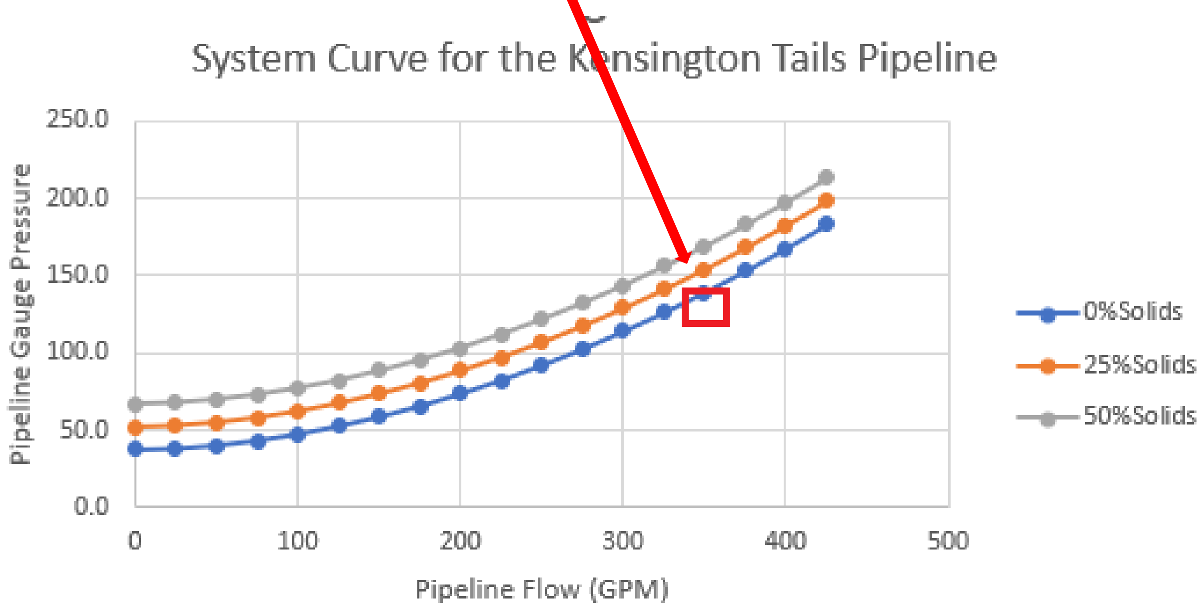
Before 3pm January 30th, the indicated pressure of 170 PSI corresponds to a Flow of 360-365 GPM. This reasonably matches the system curve for a 25-50% solids slurry, typical for a No Paste Plant Operation





After 5pm, we are now operating at very different pressure and flow parameters.





While it is not impossible to be running under 15% solids in the tails slurry after a paste startup, it is unlikely. 5 PM was tagged as the likely start time of the event.

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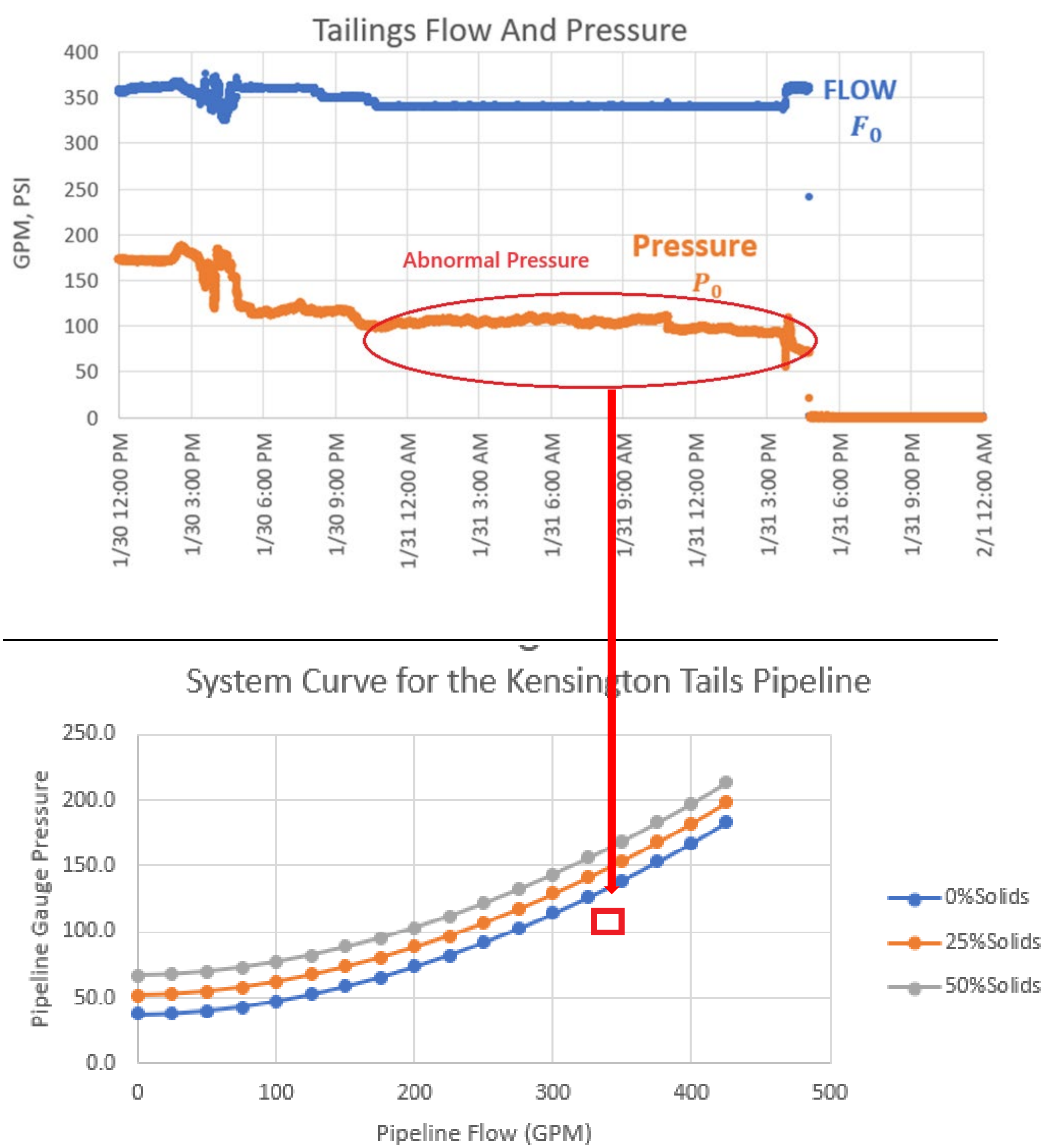
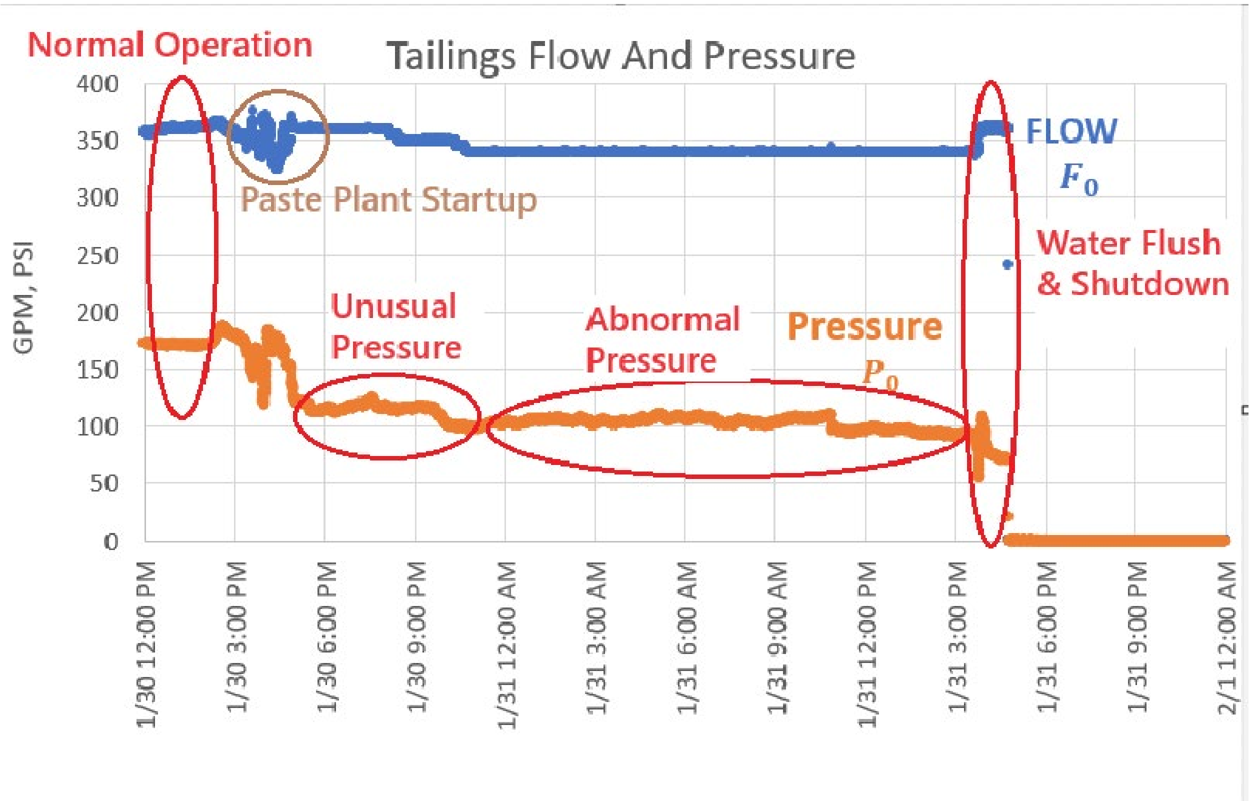
After 10 PM, our pressure readings indicate we are no longer operating with the same “System Curve” or the same pipeline.



Assumptions:

- It is estimated that suction plays an insignificant role in the pressures.
- Velocity head pressure is ignored, <1psi
- Pipeline is 12,000 ft long. Somewhere in the last 2,000 ft this converts to “slack flow”, AKA gravity takes over without being able to pull a syphon/suction



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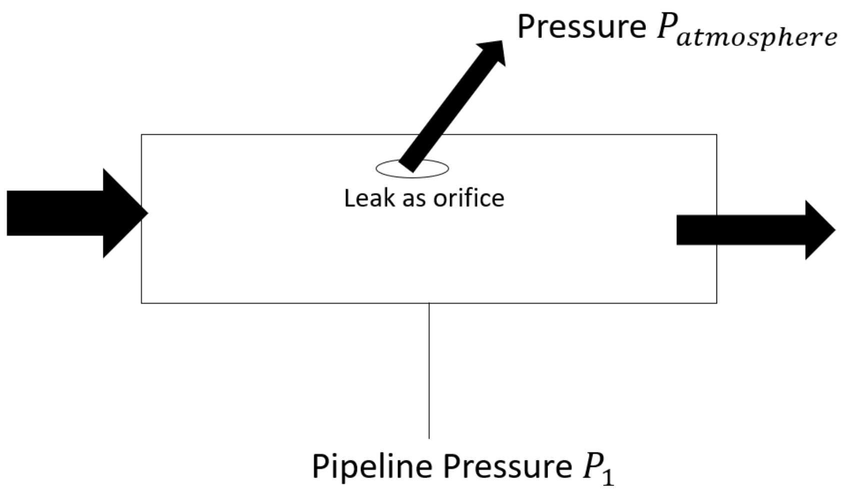
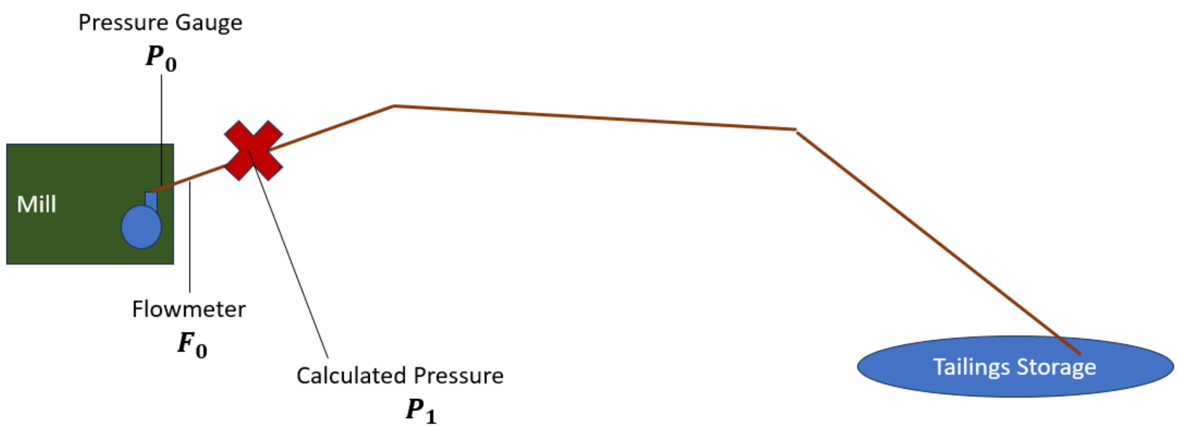
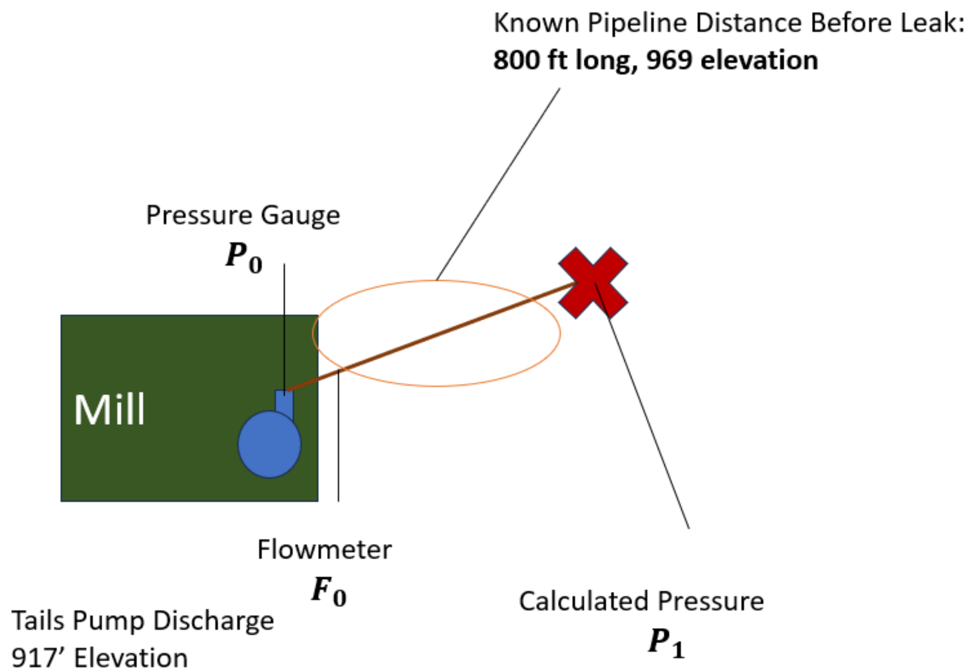
Flow Estimation

After shutdown of the pipeline, a hole leaking tails was found to be about 1.5 inches long and 5/8th inches wide. This hole was modeled as a perpendicular orifice with no pressure drop.





Pressure P_1 can be calculated knowing the Flow F_0, the initial Pressure P_0, and knowing the pipeline geometry.



$$P_1 = P_0 - P_{elevation} - P_{friction}$$

Pressure due to the elevation is based on the density of the fluid and the elevation gain of the pipeline. For our tailings density of $2.6\frac{g}{cm^3}$, 33% solids in the slurry by weight, and elevation change of 52 feet.

Pressure due to friction is calculated using the Hazen-Williams friction loss model:

$$P_{friction} = .002083 * L * \left(\frac{100}{C}\right)^{1.85} * \frac{gpm^{1.85}}{d^{4.8655}}$$

Where L = the length of the pipeline line, C is the friction coefficient of the pipeline material, gpm is the fluid flowrate, and d is the inside diameter of the pipeline.

For $L = 800\ FT, C = 150\ gpm = various\ (see\ chart)\ d = 5.3\ inches$

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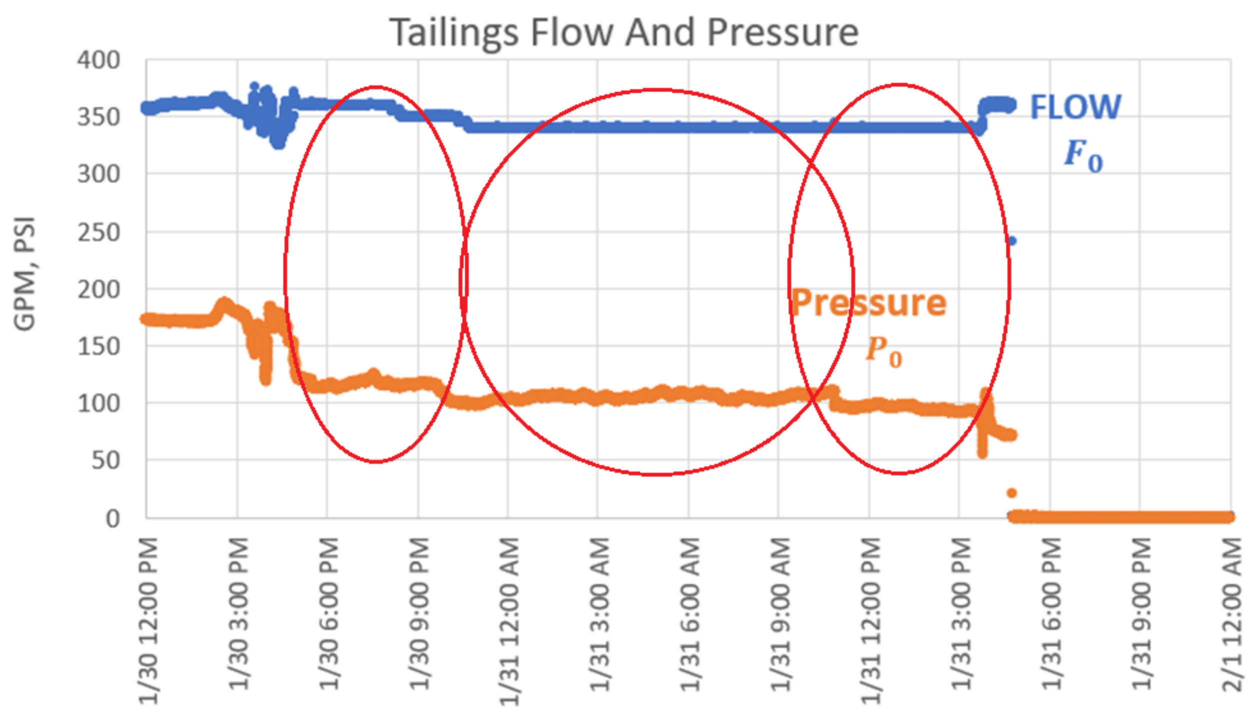
P_0	F_0	P_1
Indicated Pressure	Indicated Flow	Calculated Orifice Pressure
PSI	GPM	PSI
120	360	80.3
104	340	64.8
95	340	55.8

These 3 pressure and flow combinations correspond to these three time frames.



Flow through an orifice can be calculated exclusively from pressure P_1 and the orifice size:

$$Q = 19.636 * C * d^2 \sqrt{\frac{P_1}{0.662}}$$

C is the nozzle discharge coefficient (0.7), d is the diameter of the orifice and Q is the resulting flow in GPM.

Based on these parameters, tails slurry flowrates and total volumes were calculated as follows:

P_0	F_0	P_1	d	Q		
Indicated Pressure	Indicated Flow	Calculated Orifice Pressure	orifice diameter	leaked flowrate	***Leak Duration***	***Slurry Gallons***
PSI	GPM	PSI	Inches	gpm	minutes	gallons
120	360	80.3	0.55	45.8	277	12,681
104	340	64.8	0.7	76.5	795	60,807
95	340	55.8	0.9	102.2	314	32,094
					Slurry Total Gallons	**105,581**

Finally, this total discharge volume was broken down into dry tails and process water components:

Slurry Total	**% solids Weight**	**% Solids Volume**	**dry tails**	**dry tails**	**Liquid Only**
Gallons	%	%	gallons	metric tons	Gallons
105,581	33%	16%	16,787	165	88,794

Cause of Pipeline Failure

The hole in the pipeline occurred at a joint where two sections of the pipe are joined by an Electrofusion weld. The leak likely started as a pinhole and increased over time due to the abrasive nature of the tailings and the high-pressure environment within the inner pipe. Once the inner pipe was breached a second hole in the outer pipe formed due to the high-pressure jet exiting the inner pipe.

The section of the pipeline where the hole is located was excavated and the damaged portion of the pipeline was cut and removed. The removal of the damaged section allowed for further investigation. At the junction of the two sections of pipe it was found that the two pipes were slightly misaligned when they were Electrofused. Misalignment of this section during original pipeline installation would cause a weaker weld joint, see Photo 6. At this weld joint a lip formed in the inner pipe, this lip would create an area of turbulence at the weld and would promote a wear channel in the pipe. Over time the tailings would wear through the inner pipe and cause a pinhole to form, then a larger hole would propagate over time. Photo 7 shows the hole in the inner pipe and Photo 8 shows the corresponding hole in the outer pipe.

Photo 6. Misaligned Electrofusion weld at failure point.

Photo 7. Inner pipe breach.

Photo 8. Outer pipe breach.

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Corrective Actions

Below is a list of corrective actions to be taken to prevent future tailings line failures.

1. A full internal pipeline inspection will be conducted using non-destructive methods such as cameras or pigs. A specialist is needed to assist with the assessment. A pipeline pigging specialist is scheduled for a site visit on April 8-9.
2. Once an internal pipeline inspection process has been established, internal inspections will be routinely conducted.
3. Add a pressure indicator alarm for the outer 10-inch line which would enable detection of a leak within the inner 6-inch line.
4. A tailings flow meter will be installed near the end of the tailings line at the TTF. This will enable monitoring of flow near the outlet of the pipeline to ensure flow rates are equal at both the inlet and outlet of the tailings line. An alarm will be installed on the outlet flow meter which will be tied to the Mill Process Control Room. This will allow operators to shut down the mill in the event a drop in flowrate is detected.
5. Establish a formalized response protocol specific to a tailings line release, this will aid a quick response and cleanup.
6. Provide training and equipment to perform certified HDPE pipeline repairs on site.
7. Create an SOP for a tailings release and leak response for the Mill Control Room operators.