Boliden Summary Report

Resources and Reserves | 2018

Maurliden

Front page: Maurliden mine: view towards ESE before the last blasting, photo Roger Backman

Prepared by
Lena Albrecht

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1 SUMMARY

Maurliden is an open pit mine located approximately 50 km north-west of the Boliden Area Operations Process Plant in Boliden. Maurliden is a massive sulfide deposit with zinc being the primary metal. Mining started in 2000 and up to 2018 3.8 Mt @ 1.4 g/t Au, 51 g/t Ag, 0.3 % Cu, 4.0 % Zn and 0.4 % Pb has been produced. The ore will be mined out in 2019 and closed down.

Table 1. The Maurliden mineral resources

			2018			
Classification	kt	Au (g/t)	Ag (g/t)	Cu (%)	Zn (%)	Pb (%)
Mineral Reserves						
Proved	**73**	**1.45**	**56**	**0.56**	**4.40**	**0.37**
Probable						
Total	**73**	**1.45**	**56**	**0.56**	**4.40**	**0.37**

2 GENERAL INTRODUCTION

This report is issued annually to inform the public (shareholders and potential investors) of the mineral assets in Maurliden held by Boliden. The report is a summary of internal reports for Maurliden. Boliden method of reporting Mineral Resources and Mineral Reserves complies with the Pan-European Standard for reporting of Exploration results, Mineral Resources and Mineral Reserves (The PERC Reporting standard 2017). It is an international reporting standard that has been adopted by the mining associations in Sweden (SveMin), Finland (FinnMin) and Norway (Norsk Bergindustri), to be used for exploration and mining companies within the Nordic counties.

This report is the first Mineral Resources and Mineral Reserves summary report for Maurliden based on the PERC Reporting standard. Until 2017 Boliden used the FRB standard (Fennoscandian Review Board) which will be no longer updated. Many of the estimations summarized in this report was made before the change from FRB to PERC. Boliden consider these estimations accurate enough to directly be reported under PERC although the process of replacing them with PERC compliant reported estimations have started. This is for Maurliden confirmed with reconciliation of productions data.

2.1 Pan-European Standard for Reporting of Exploration Results, Mineral Resources and Mineral Reserves – The PERC Reporting Standard

PERC is the organisation responsible for setting standards for public reporting of Exploration Results, Mineral Resources and Mineral Reserves by companies listed on markets in Europe. PERC is a member of CRIRSCO, the Committee for Mineral Reserves International Reporting Standards, and the PERC Reporting Standard is fully aligned with the CRIRSCO Reporting Template.

The PERC standard sets out minimum standards, recommendations and guidelines for Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves in Europe.

2.2 Definitions

Public Reports on Exploration Results, Mineral Resources and/or Mineral Reserves must only use terms set out in the PERC standard.

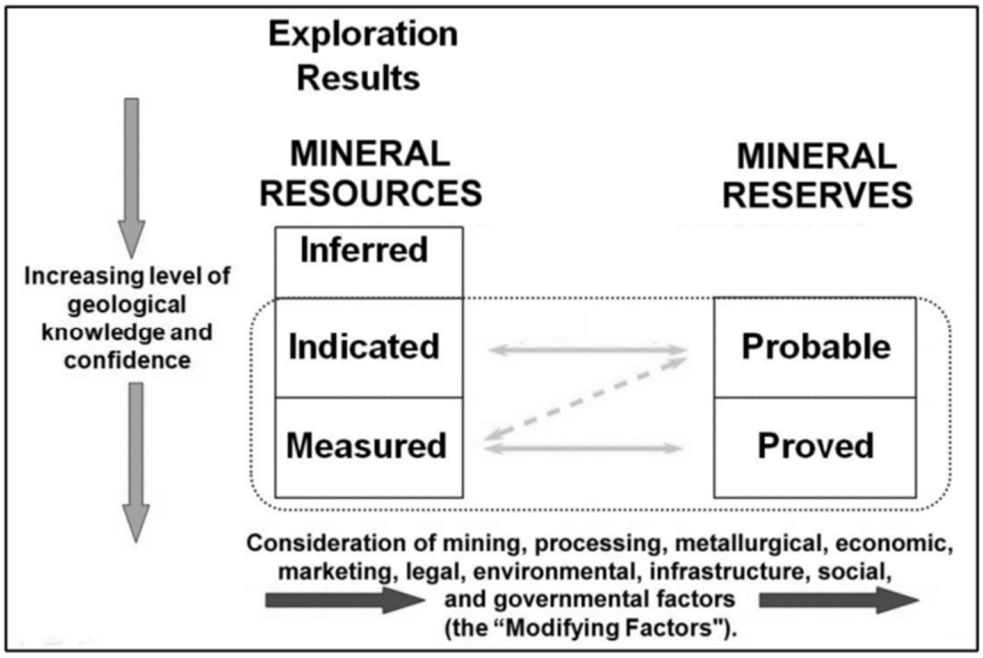


Figure 1. General relationship between Exploration Results, Mineral Resources and Mineral Reserves (PERC 2017).

2.2.1 Mineral Resource

A Mineral Resource is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction.

2.2.2 Mineral Reserve

A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource.

It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.

2.3 Competence

Table 2. Contributors and responsible competent persons for this report

Description	Contributors	Responsible CP
Compilation of this report	Lena Albrecht	Gunnar Agmalm
Geology	Lena Albrecht	
Resource estimations	Gunnar Agmalm	
Reconciliation	Bertil Holmqvist	
Mineral processing	Marie Lundberg	
Mining	Sami Ojanen	
Environmental and legal permits	Linnéa Hisved	

Gunnar Agmalm is Boliden's Ore reserves and Project Evaluation manager and a member of AusIMM[1] and FAMMP[2], Lena Albrecht, Ph.D. is District Geologist, and Project geologist for Maurliden Near Mine Exploration project.

[1] Australasian Institute of Mining and Metallurgy
[2] Fennoscandian Association for Metals and Minerals Professionals

3 MAURLIDEN

3.1 Major changes

During 2018 it was decided to abandon the ideas for underground mining and instead continue to mine as an open pit. This since we don´t see any reasonable prospects to mine the quantities left below.

3.1.1 Technical studies

No technical studies has been carried out during 2018.

3.2 Location

The Maurliden mining area is situated in the central part of the Skellefte field, in Norsjö municipality, approximately 50 km from the concentrator in Boliden, Västerbotten county (figure 2). The mining area hosts four mineralizations of which two have been mined in open pits: Maurliden and Mauliden Östra. The Maurliden mine was the first mine in operation in the area and is the only mine with on-going production. In order to avoid confusion it is sometimes called Maurliden (w) mine.

3.3 History

The deposit was discovered in the mid-1940s through geophysical measurements made by the Swedish Geological Survey (SGU). However it was not until the end of the 1950s that any diamond drilling was carried out in Maurliden (Agmalm, 1999, Claesson & Isaksson, 1981, Claesson, 1984). In 1998, Boliden Mineral AB submitted an application for an exploitation permit. In 1999, resource estimation was conducted and mining of the initial pit began in 2000. Pushback 1 began in 2005 and was completed down to 264 m.a.s.l. (196 m, MAUz) during 2007 (Årebäck 2008). A new resource estimation for Maurliden (west) was made and at the beginning of 2008 the decision was taken to begin pushback 2 (Årebäck 2008). The tonnage contained in this pushback was then entered in the ore reserves. Along with waste rock mining for pushback 2, during 2008 approximately 28000 t of ore was taken from the stockpile for processing (Agmalm, 2009). During 2009 and 2010, 2094 kt was mined, less than planned mainly due to problems with water in the open pit (Platt, 2011). In 2012 was 55660 t of ore production was planned, but due to problems with water in the open pit only 16439 t was mined (appendix, this report and Rilinger, 2013). In 2013 the mine design was partially changed and a re-calculation of the ore volume was done (Rilinger, 2014). In 2014, 219 889 t ore was mined and infill drilling was carried out (Rilinger, 2015). At the end of 2014 a new block model and an adjusted mine design was created (Agmalm, 2015). In 2015, 277 000 t of ore was mined (Albrecht, 2016). In 2016, 399 950 t was mined (Albrecht, 2017). In 2017, 396 800 t was mined and one infill hole drilled (Albrecht, 2018). Plans for underground mining of the lowest level were approved in 2017 (Isaksson, 2016, Bergman&Peterson, 2017). But in 2018 the underground plans were reconsidered and subsequently abandoned. Tonnages and grades mined in Maurliden are listed in appendix 1 and 2 in this report.

3.4 Ownership

The deposit is 100% owned by Boliden Mineral. Boliden was granted a renewed environmental permit in June 2010. A separate environmental permit for mining of the ongoing pushback was granted in August 2007.

3.5 Permits

Maurliden is covered by the mine concession, Maurliden K no.1, valid until 2024-05-27.

3.6 Geology

3.6.1 Regional

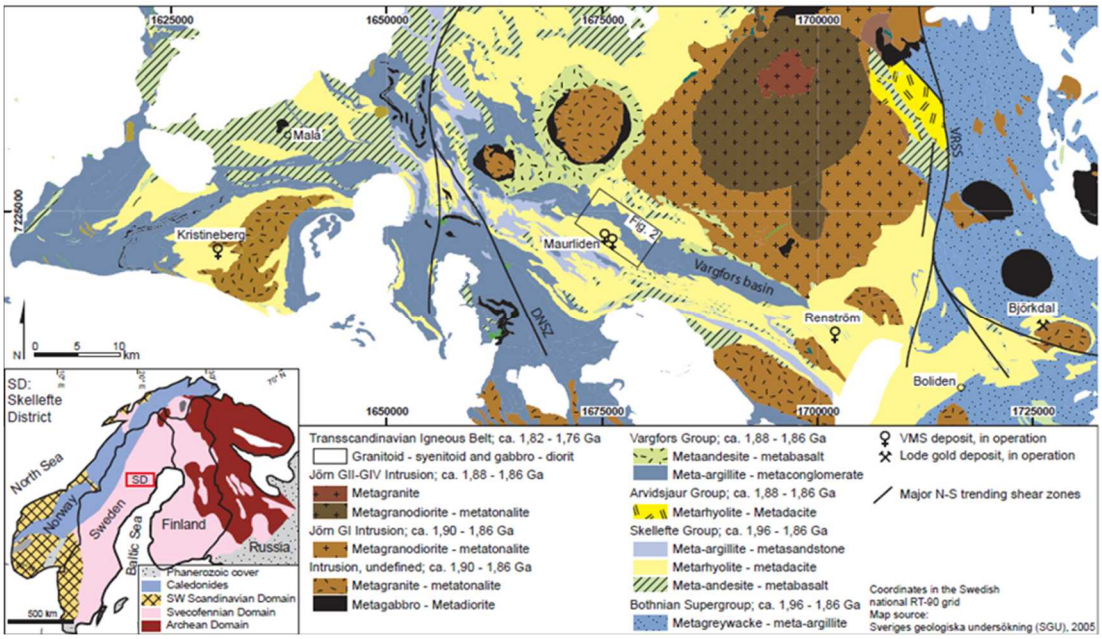


Figure 2. General relationship between exploration results, mineral resources and mineral reservers (PERC 2017)

The Maurliden area, covers an area approximately 8 km by 6 km, which is dominated by volcanic rock rocks with primarily rhyolitic composition, (Allen et al.1996, Montelius 2005), (figure 2). These volcanics belong to the Skellefte group, which is a sequence of volcanic rocks in the Skellefte field, that were deposited on the seafloor about 1,89 Ga ago. The majority of the known ores in the Skellefte field occur in the upper parts of the Skellefte group (Allen et. al.1996).

3.6.2 Local

All four sulphide mineralizations in the Maurliden area are hosted by a quartz-feldspar porphyritic volcanic rock (yellow in figure 3) which was deposited as a series of pumicious mass-flows (Montelius 2005). The deposit is surrounded by strongly quartz-sericite altered and intensely brecciated rocks (hyalocastic breccia) often hosting pyrite veins, particularly in the footwall on the northern side (white in figure 3). A weakly porphyritic ryholite intrusion occurs on the south side of the orebody. A pyritic mudstone interfingers with the ore and the quartz-feldspar rhyolite on the north side of the deposit.

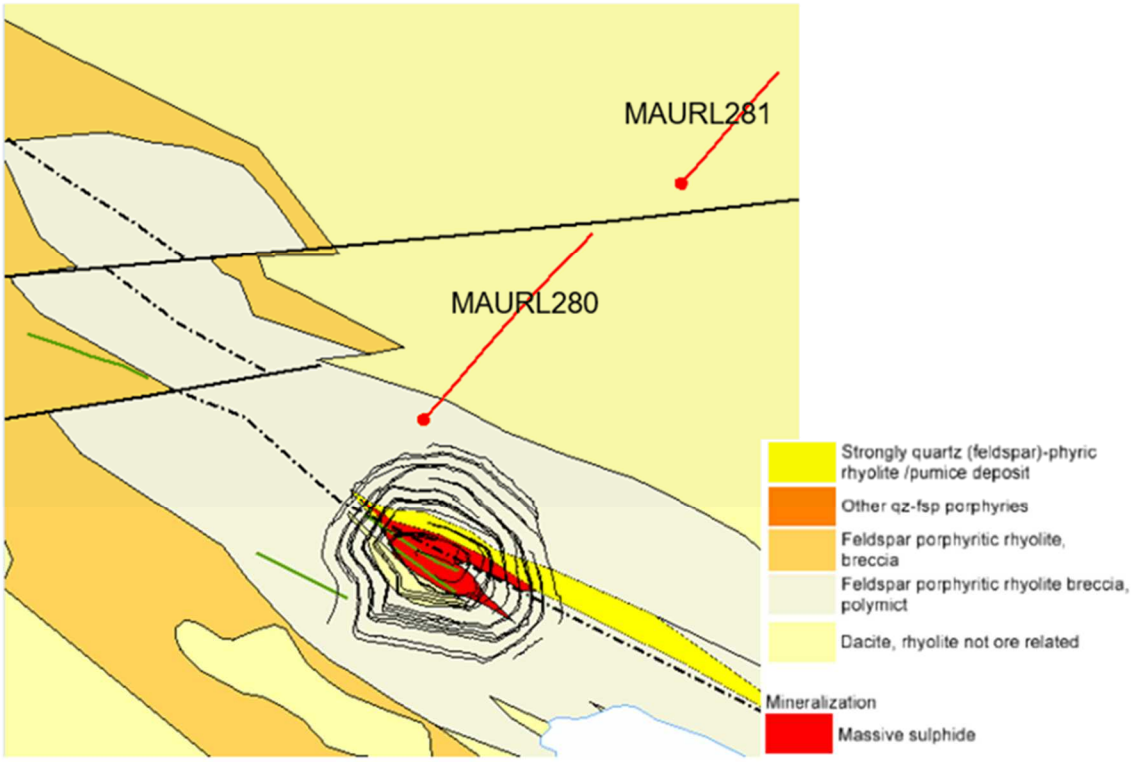


Figure 3. Local geology and the recently drilled exploration holes north of Maurliden open pit. One fault earlier discovered east of the mine, has been intersected in MAURL280, black solid lines: faults, green lines: andesitic dykes, stippled line: axial plane of Maurliden syncline, north is upwards, length of open pit: 301m.

3.6.3 Mineralization

Maurliden (West) is a massive, pyritic sulfide deposit with zinc being the primary metal. The ore is tabular, dips vertically and is oriented sub-parallel to bedding. The central part of the orebody consists of massive pyrite with minor streaks and bands of sphalerite. In the upper part, the margins of the body tend to have higher sphalerite content. Downwards, two distinct high grade zinc zones can be distinguished at the southern and northern margins of the body (figure 4). Chalcopyrite occurred in the upper part at the northwestern tip and at the northeastern end of the orebody. Downwards it increases and is concentrated in a region between the high-grade sphalerite-zones, extending along the whole orebody. Chalcopyrite occurs both as impregnation in massive pyrite and in stringers of pyrite, interpreted to represent a footwall stringer zone. Silver follows the sphalerite-zones and occurs within tetrahedrite and most of the antimony in Bournite (Bohlin 2009). Gold is present in electrum (Au-Ag-Hg-alloy), and occur as micro inclusions and small fracture fillings in pyrite (80%). Electrum is also associated with and included in primary arsenopyrite and intergrown with antimony minerals (Brising, 2016). Gold recovery is low (Johansson 2003).

Figure 4 Lowest level in the Maurliden mine: Massive sphalerite zones within orange and yellow shapes, copper rich zone within green shape, thin black lines: position of drillholes used for modelling shapes, north is upwards, length of outlined pit bottom: 95m.

3.7 Exploration procedures and data

3.7.1 Drilling techniques

Exploration and infill drilling has been carried out using core drilling, diameter size: NQ.

3.7.2 Downhole surveying

Holes were all Gyro-surveyed. Exploration holes were also surveyed with Boliden´s dowhole electromagnetic sond (BHEM).

3.7.3 Sampling

Cores were cut with a diamond saw and one half was kept as reference. Sample length varied from 0.5 to 3m, occasionally up to 5m where mineralization was weak. Samples were analysed at ALS Chemex and to MS Analytical. In total, 125 samples including standards and blanks were analysed. Assays for two infill holes MAURL278 and 279 were received during 2018.

3.7.4 Density

Density of the Maurliden ore can be described by this formula:

Density = 2.70 + 0.0043Cu + 0.004Zn + 0.02Pb + 0.0375S + 0.027As (Hedén, 2000). For wasterock density=2.7 t/m3 has been used (Larsson&Agmalm 1994, Hedén 2000).

3.7.5 QAQC

Quality control followed Boliden´s standard QAQC routine: 1-2% standard samples were submitted, at least one standard/batch. Boliden internal standard, BSBM4 was used. Blanks were inserted after high grade samples, representing max 2% of samples. Issues: Samples of

MAURL279 had to be re-analysed since the results not passed the QAQC-test. No other QAQC issues have been encountered.

3.8 Exploration activities

One infill hole, MAURL279, and two exploration holes, MAURL280 and 281, were drilled. Infill drilling to confirm resources and since deviation of an old hole, 60103, not could be trusted. New assays confirm earlier models. High grade sections are located almost exactly within modelled high Zn-zones. Planned underground drilling under the present pit was cancelled since there was no ramp to drill from. Drill metres were reallocated to surface drilling to investigate the area north of the mine. Earlier drilling did not fully penetrate into unaltered rock. Exploration holes MAURL280 and 281 were drilled in a profile towards the north under the waste pile (figure 3). Both unaltered rock and zones of intense sericite alteration with pyrite stringers were intersected, representing typical footwall alteration. Assays and lithogeochemical results are pending but no ore grade zones are expected.

3.9 Mining methods, processing and infrastructure

3.9.1 Mining methods

Maurliden has been mined as an open pit using traditional drill and blast techniques. Ore and waste are blasted separately. Bench height is 8.7 m. Loading is conducted by backhoe and rock is hauled to surface using articulated trucks. Ore is stockpiled before further transport to processing plant. Grade control has been carried out through continuous XRF-measurements of drill cuttings from production holes. During 2017 a Conceptual Study for underground mining of mineral resources below the open pit was made (Isaksson, 2016). This study indicated that economically mining was possible and complementary Pre-feasibility studies regarding water handling, rock mechanics and an updated mine design was made. However, results from this study were not presented in a way that they could be converted to mineral reserve and the underground plans were abandoned.

3.9.2 Mineral processing

Ore is delivered by truck to the industrial area where each truck is weighed on a truck scale in order to determine the tonnage arriving to the industrial area. The ore arriving at the industrial area is either taken into the processing plant or stored in a stockpile. Separate stock piles are kept for each of the individual mines in the Boliden area. Ore from the different mines is processed in campaigns where fresh ore from the mine is combined with ore from stockpiles. The feed tonnage to the processing plant is determined using a weighing system with a stationary belt scale. Feed tonnage and weights from the trucks scale are used to determine current tonnage on the stockpiles.

In the processing plant the ore is ground in two stages (figure 5). The primary mill is a fully autogenous mill and the secondary mill is a pebble mill fed with pebbles extracted from the primary mill. The ground ore is classified using screens and hydrocyclones. A gravimetric concentrate containing coarse grained gold bearing minerals is produced in the grinding circuit and a flash flotation cell is used to extract mainly copper minerals with high flotability. The gravimetric concentrate is packed in big bags and delivered by truck to the Rönnskär smelter. Flotation is done in a three-stage process: copper-lead bulk flotation, copper-lead separation and zinc flotation producing three concentrate qualities, copper, lead and zinc. The mineral concentrates are dewatered using thickeners and vertical plate pressure

filters. The concentrates are transported by truck to the Rönnskär smelter and shipping port. Lead and zinc are transported by boat to Boliden smelters in Norway and Finland or to external buyers. Metallurgical accounting where a sum of products calculated using assays from daily composite samples of main process streams and assays and tonnage for delivered products together with feed tonnage is used to determine the head grade of the ore.

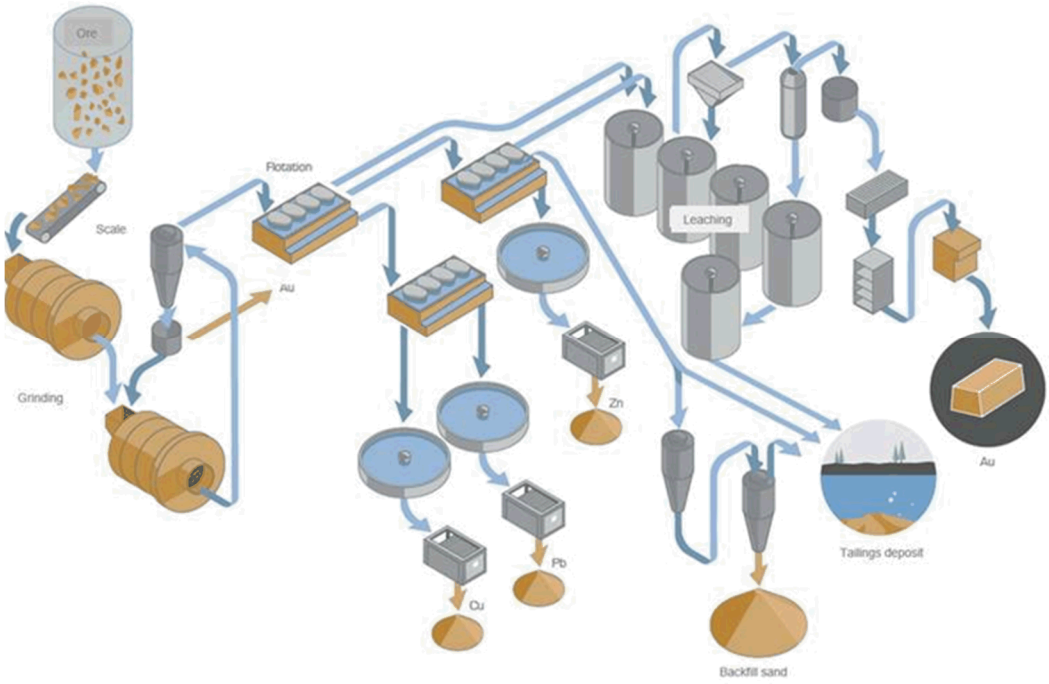


Figure 5. Flow chart for mineral processing, leaching is not applied to the Maurliden ore

3.9.3 Infrastructure

Ore is transported to Boliden by truck.

3.10 Prices, terms and costs

Table 3. Short term planning prices currently used in Boliden

	Planning prices, 2018
Copper	USD 5,984/tonne
Zinc	USD 2,414/tonne
Lead	USD 2,072/tonne
Gold	USD 1,227/tr.oz
Silver	USD 14.8/tr.oz
USD/SEK	8.90

The cut-off for the Maurliden mine is currently 200 SEK/t, corresponding to the incremental cost of transport and processing (Nordström, pers. com.). This value has also been used for resource calculation in the block model (Agmalm, 2015).

3.11 Mineral resources

Previously classified measured and indicated mineral resources were written off (Albrecht, 2018). This since they are not possible to mine economically as an open pit with the present pit design. We don´t see any reasonable prospect that they can be economically mined underground.

3.12 Mineral reserves

Remaining reserves are planned to be mined early 2019 (figure 6).

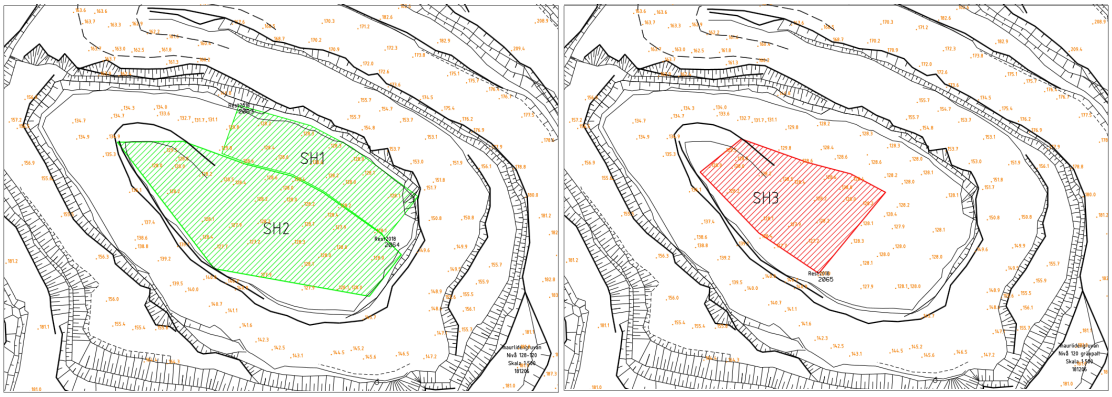


Figure 6. During 2018 it was decided to abandon the ideas for underground mining and instead continue to mine as an open pit. This since we don´t see any reasonable prospects to mine the quantities left below. Two alternatives to mine the last reserves: left, common open pit mining, right, goodbye cut, north is upwards, width of pictures: 140m.

Table 4. Grades and tonnages for unclassified quantity below final pit that there are no reasonable prospects for economically mining and thus **not** Mineral Resources

				2018					
Unclassified	**kt**	**Au (g/t)**	**Ag (g/t)**	**Cu (%)**	**Zn (%)**	**Pb (%)**	**As (%)**	**S (%)**	**NSR (Kr/t)**
Below final pit	**415**	**1.0**	**38**	**0.65**	**2.47**	**0.16**	**1.08**	**40**	**631**

Table 5.Mineral Resources and Mineral Reserves, Maurliden 2018-12-31

	2018						2017					
	kt	**Au**	**Ag**	**Cu**	**Zn**	**Pb**	kt	Au	Ag	Cu	Zn	Pb
Classification		**(g/t)**	**(g/t)**	**(%)**	**(%)**	**(%)**		(g/t)	(g/t)	(%)	(%)	(%)
Mineral Reserves												
Proved	**73**	**1.45**	**56**	**0.56**	**4.40**	**0.37**	172	1.5	49	0.39	4.23	0.32
Probable												
Total	**73**	**1.45**	**56**	**0.56**	**4.40**	**0.37**	**172**	**1.5**	**49**	**0.39**	**4.23**	**0.32**
Mineral Resources												
Measured							618	1.1	41	0.57	2.77	0.20
Indicated							222	0.7	20	0.36	1.47	0.06
Total M&I												
Inferred							840	1.0	35	0.51	2.42	0.17

3.13 Comparison with previous year

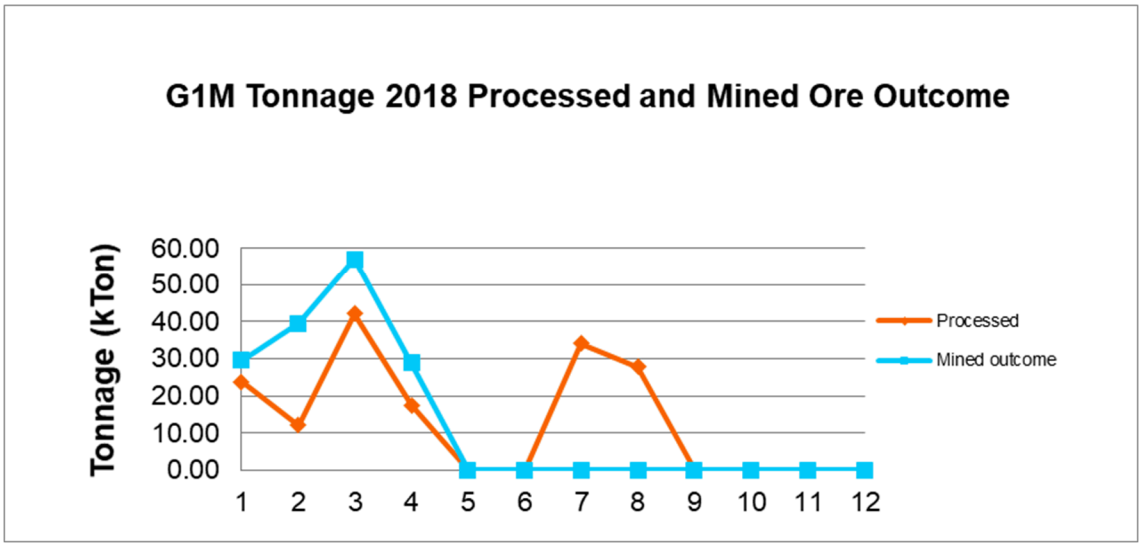
Since the ideas for underground mining were abandoned, the reserve decreased to what is possible to mine as a last bench in an open pit.

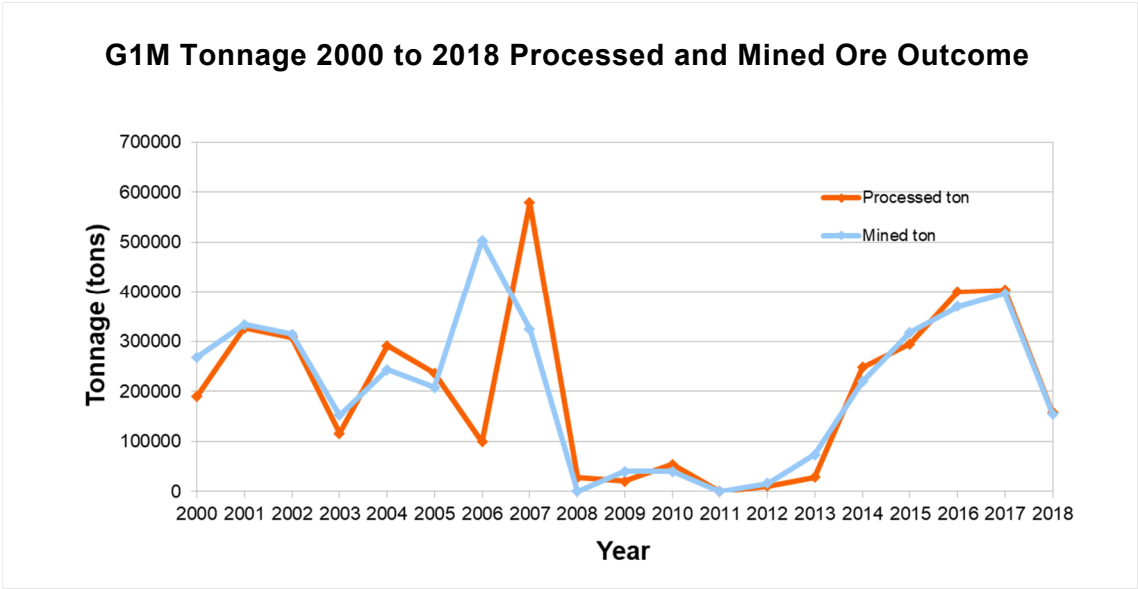
3.14 Reconciliation

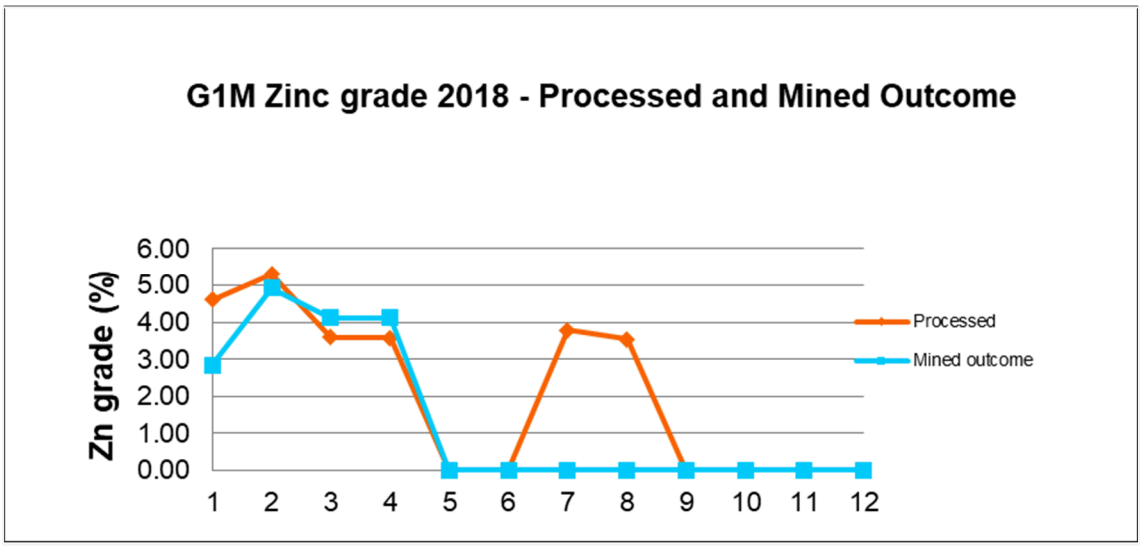
Mined tonnes from mine survey and grades from block model are compared with final results from the processing plant in the reconciliation tables and diagrams below.

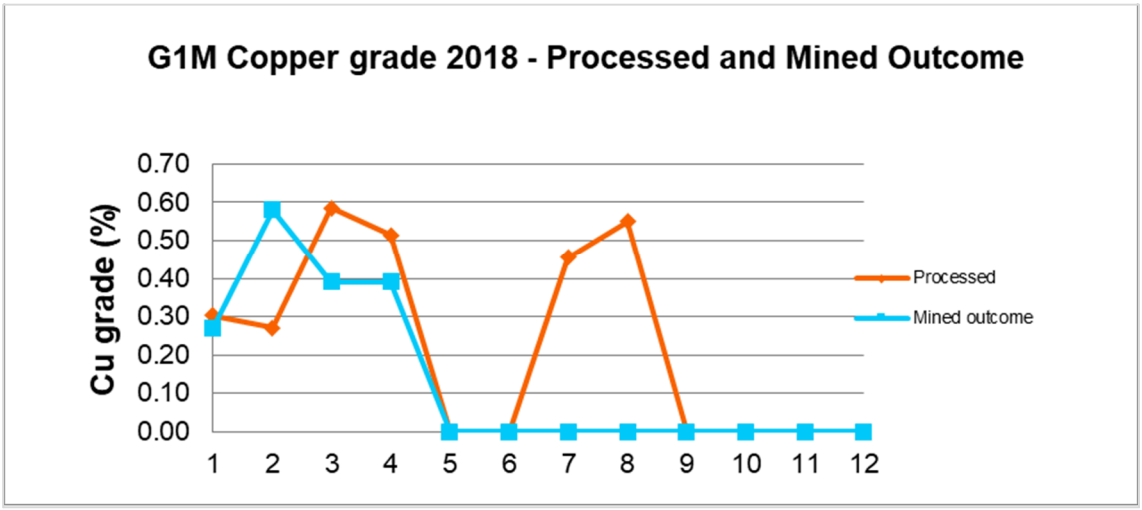
Table 6. Reconciliation table

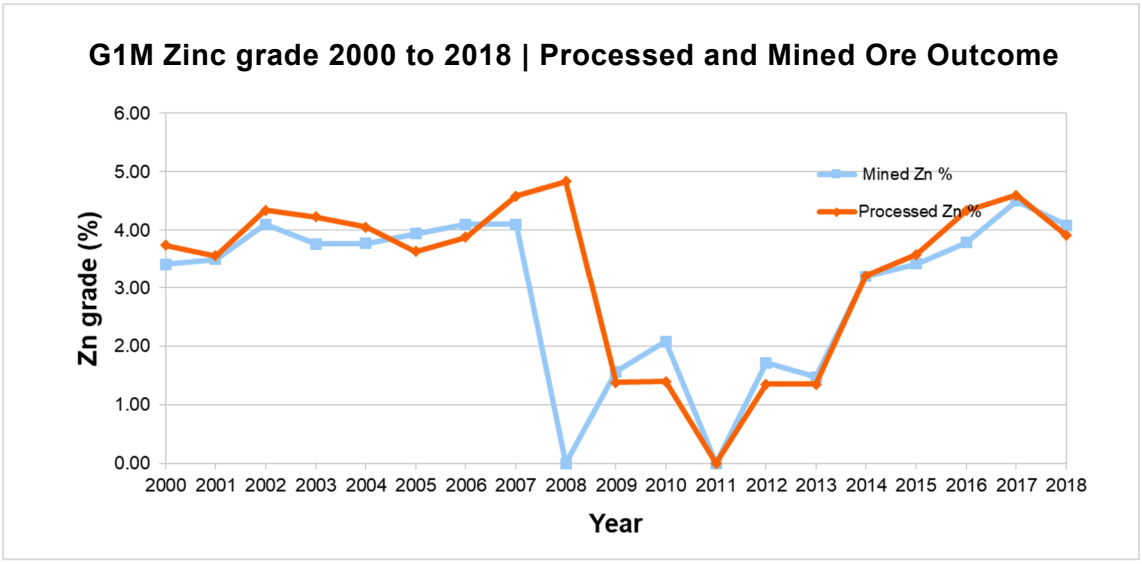
G1M 2018 Reconciliation	**Ore t**	**Au g/t**	**Ag g/t**	**Cu (%)**	**Zn (%)**	**Pb (%)**	**S (%)**
Processed acc.	157.7	1.3	42.3	0.5	3.9	0.4	41.8
Mined acc.	155.1	1.5	52.2	0.4	4.1	0.3	39.8
Difference	2.5	-0.2	-9.9	0.1	-0.2	0.0	2.0
Difference (rel%)	2 %	-15 %	-19 %	15 %	-4 %	15 %	5 %

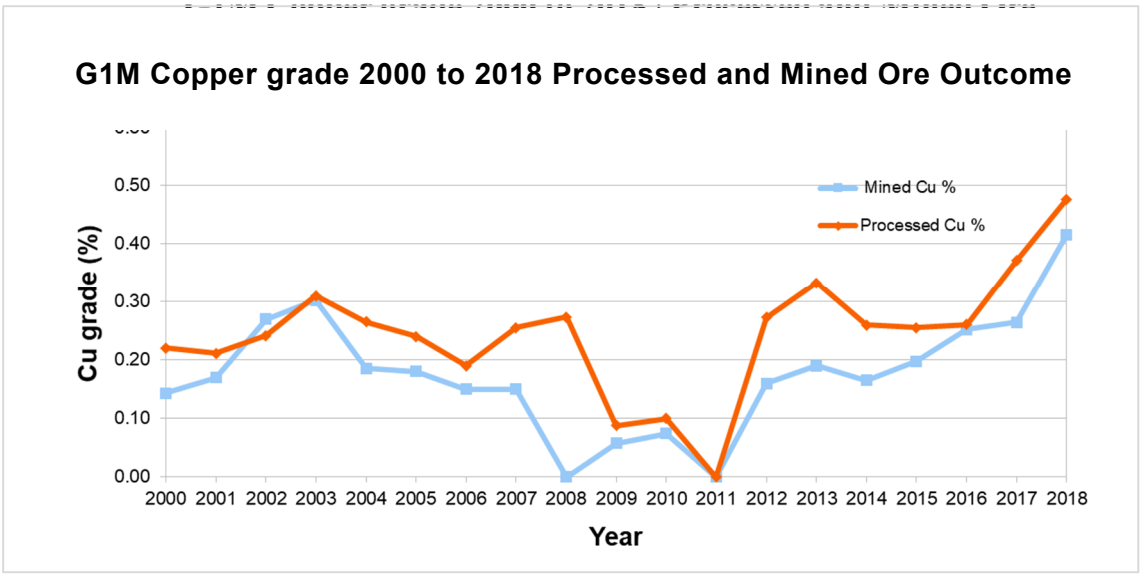

G1M Tonnage 2018 Processed and Mined Ore Outcome
Tonnage (kTon)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12
Processed
Mined outcome


G1M Tonnage 2000 to 2018 Processed and Mined Ore Outcome
Tonnage (tons)
700000
600000
500000
400000
300000
200000
100000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year
Processed ton
Mined ton


G1M Zinc grade 2018 - Processed and Mined Outcome
Zn grade (%)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12
Processed
Mined outcome


G1M Copper grade 2018 - Processed and Mined Outcome
Cu grade (%)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1 2 3 4 5 6 7 8 9 10 11 12
Processed
Mined outcome


G1M Zinc grade 2000 to 2018 | Processed and Mined Ore Outcome
Zn grade (%)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year
Mined Zn %
Processed Zn %


G1M Copper grade 2000 to 2018 Processed and Mined Ore Outcome
Cu grade (%)
0.50
0.40
0.30
0.20
0.10
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year
Mined Cu %
Processed Cu %

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4.2 Appendices

1 Annually mined tonnages and grades from 2000 to 2018 (table)
2 Annually processed outcome tonnage and grades from 2000 to 2018 (table)

Annually mined tonnages and grades from 2000 to 2018

Year	Mined ton	Au g/t	Ag g/t	Mined Cu %	Mined Zn %	Pb %	S %	Waste %
2000	268700	1.09	47.66	0.14	3.42	0.40	39.91	7.00
2001	334400	1.09	56.88	0.17	3.50	0.44	39.07	7.00
2002	314373	1.31	57.73	0.27	4.10	0.43	43.20	7.00
2003	153000	1.14	54.07	0.30	3.77	0.39	43.00	0.00
2004	243596	1.03	55.74	0.19	3.77	0.45	43.45	0.00
2005	208244	1.10	59.00	0.18	3.94	0.40	45.70	0.00
2006	504208	1.10	52.00	0.15	4.10	0.40	38.00	0.00
2007	325158	1.10	52.00	0.15	4.10	0.40	0.00	0.00
2008	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	40000	0.26	10.64	0.06	1.57	0.08	11.63	0.00
2010	40550	0.32	10.75	0.07	2.08	0.09	21.56	14.20
2011	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	16439	0.60	19.00	0.16	1.72	0.10	24.50	8.90
2013	73930	0.61	19.04	0.19	1.47	0.11	24.70	18.66
2014	219889	0.92	39.45	0.16	3.20	0.32	33.14	18.16
2015	318050	1.24	45.01	0.20	3.42	0.32	35.78	1.10
2016	370320	1.44	63.93	0.25	3.79	0.38	35.14	0.00
2017	396840	1.65	59.47	0.26	4.51	0.38	38.79	0.00
2018	155140	1.51	52.17	0.42	4.08	0.31	39.77	0.00
Total	**3982837**	**1.19**	**52.27**	**0.21**	**3.76**	**0.38**	**35.15**	**3.23**

Annually processed outcome tonnage and grades from 2000 to 2018

Year	Processed ton	Au g/t	Ag g/t	ocessed Cuocessed Zn		Pb %	S %
2000	191000	1.12	54.00	0.22	3.74	0.51	42.00
2001	327300	1.48	56.24	0.21	3.56	0.51	41.11
2002	308477	1.54	56.55	0.24	4.34	0.45	42.28
2003	116069	1.50	43.80	0.31	4.23	0.52	42.60
2004	291323	1.59	53.02	0.26	4.05	0.47	44.35
2005	237077	1.36	49.60	0.24	3.64	0.41	44.80
2006	99892	1.14	55.10	0.19	3.88	0.44	35.90
2007	579003	1.47	59.69	0.26	4.58	0.48	0.00
2008	27920	1.68	58.80	0.27	4.84	0.47	0.00
2009	20428	0.49	10.28	0.09	1.38	0.06	0.00
2010	54338	0.53	12.00	0.10	1.40	0.07	16.00
2011	0	0.00	0.00	0.00	0.00	0.00	0.00
2012	10750	0.56	18.65	0.27	1.36	0.07	27.60
2013	28386	0.64	20.50	0.33	1.36	0.10	28.71
2014	248340	1.19	40.49	0.26	3.22	0.33	35.19
2015	295189	1.41	43.35	0.25	3.59	0.38	37.53
2016	399951	1.49	52.34	0.26	4.34	0.42	38.04
2017	404323	1.64	55.92	0.37	4.60	0.44	41.23
2018	157661	1.27	42.30	0.48	3.91	0.36	41.76
Total	**3797427**	**1.42**	**51.31**	**0.27**	**3.99**	**0.43**	**33.41**