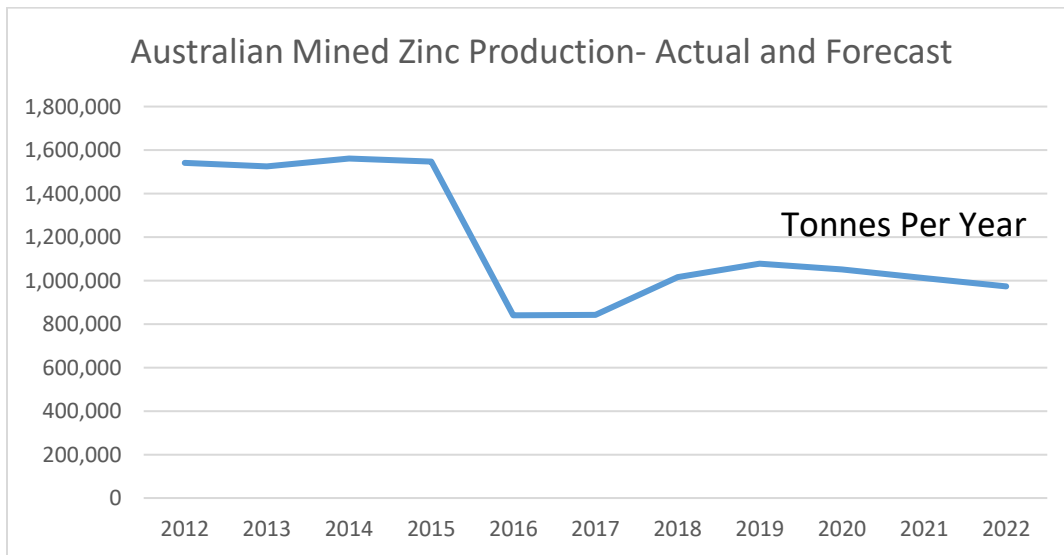


PART I- ZINC MINING IN AUSTRALIA

The purpose of this module is to get an understanding of the zinc mining production potential in Australia. By looking at numerous significant zinc mining countries it is then possible to form educated opinions on the relative health of the industry to determine whether the market is heading for oversupply or deficit assuming steady or increasing demand. Summary findings are illustrated below in Table 1. Zinc mine production levels have fallen by over 40% and will only partially recover from there.

Table 1 Actual and Forecast Zinc Mine Production in Tonnes of Zinc in Concentrate

	2015	2016	2017	2018	2019	2020	2021	2022
Mt. Isa Mill	478,200	296,835	309,680	425,810	413,170	413,170	413,170	382,360
McArthur River	272,700	185,250	195,000	195,000	195,000	195,000	195,000	195,000
Century	392,667	16,457	-	-	-	-	-	-
Rosebery	92,104	78,750	74,813	70,875	66,938	63,000	63,000	59,063
Golden Grove	55,131	39,160	39,160	39,160	39,160	39,160	-	-
Dugald River	-	-	-	42,000	125,568	167,424	172,656	177,888
Cannington	83,870	94,113	91,151	99,891	102,185	95,985	89,186	80,367
Endeavor	40,000	11,340	22,680	39,690	39,690	-	-	-
Rasp	34,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000
Perilya	50,000	38,000	35,000	35,000	35,000	35,000	35,000	35,000
Jaguar/Bentley	42,000	37,410	31,320	26,100	18,270	-	-	-
Hera	7,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total	1,547,672	840,315	841,804	1,016,526	1,077,981	1,051,739	1,011,012	972,678



Projects on the drawing board and exploration prospects will be covered in Part II but the impact of these projects is likely to only have a minor effect on +2020 production levels.

Zinc mining in Australia is a bit of a good news, bad news story. The good news is, unlike Canada, the zinc mining industry remains somewhat vibrant. The bad news is that a lack of exploration in the past twenty years has meant that what is currently being mined was almost exclusively discovered before 1990. The potential to find more deposits in Australia is still excellent in my mind and the logistics and operating conditions for a mine there are generally very good providing there is good access to water. Mines in Canada spend a huge amount of capital on ensuring they can survive a harsh winter whereas in Australia, the mill, for instance, can be outdoors exposed to the elements. This is a huge competitive advantage.

As a young snot nosed engineer, I moved to Australia in 1988 to take a mining engineering job with Mt. Isa Mines Ltd (later bought by Xstrata, now themselves part of Glencore). My role there was to help get the Hilton silver/lead/zinc mine off the ground production wise and then figure out what we were going to do with Hilton North. The Hilton Mine is now called George Fisher (P49) and Hilton North is now called George Fisher (L72). So essentially I laid out many kilometers of tunnels and designed blasthole stopes up to 400,000 t each and spent some time supervising miners underground. After we hit our stride at Hilton and had the plan in place to access Hilton North from underground, I was transferred to Brisbane to supervise the underground design for the McArthur River zinc mine in the Northern Territory. I left Australia before this plan was implemented but essentially they followed what I laid out for many years. The mine has since converted to an open pit mine once the mill got more confidence treating the other numerous fine grained and high pyrite ore zones and permission to move the river was obtained from the Northern Territory government.

George Fisher and McArthur River are now the two largest zinc mines in Australia and are firmly planted in the top 10 for the world. I also had the opportunity to travel around Australia and the world to see what many of the other zinc miners were up to. So, unlike India, I feel uniquely qualified to discuss zinc mining in Australia.

A common thread in the Australian zinc mining industry, and indeed in other nations, is that many of the operations were at one time considered to be lead/silver mines since this is where the profits were. Zinc was of secondary importance. Where it was possible to mine lead and silver rich orebodies in preference to zinc rich zones, such as at Broken Hill and Mt. Isa, this was done. The Australian zinc mining industry is now dominated by companies that own zinc smelters (or feed state owned smelters such as in China's case). Zinc is now the primary metal extracted and it must now be the profit center due to generally lower lead and silver grades. This is a very important transition that has occurred. However, what has not changed is the relationship between zinc, lead and silver commodity prices. This has deteriorated. As illustrated in the graphs below the relationship between the three commodities has actually turned away from zinc's favour.

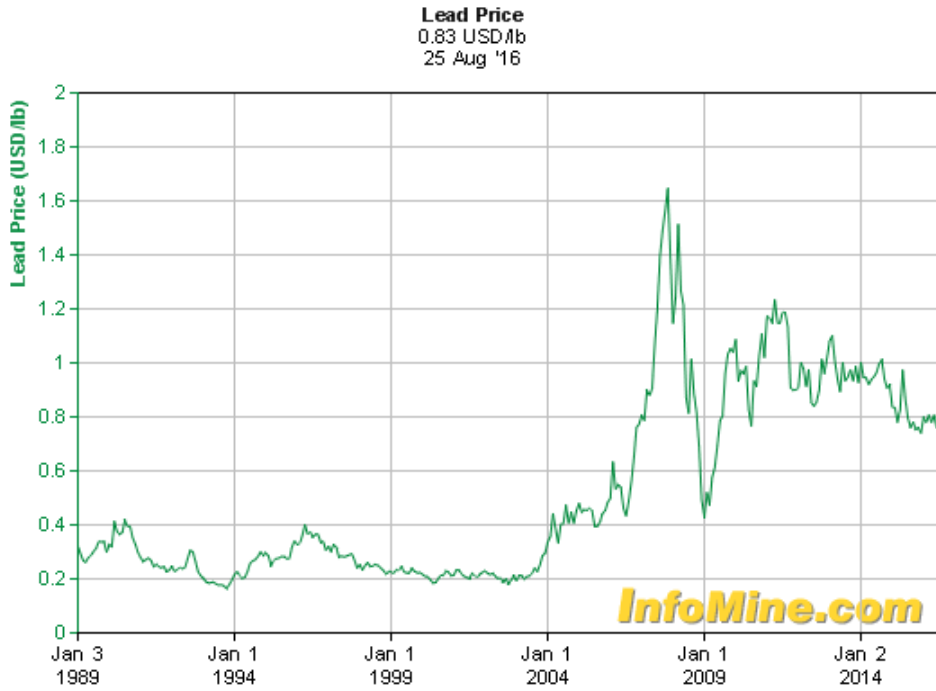
Prior to 2005 zinc traded at twice the price of lead and this ratio is now closer to 1:1. One ounce of silver typically traded at 12 times the price of a pound of zinc but this ratio is now closer to 16:1.

The net result of this is that a mine which now must survive on zinc may very well find itself bankrupt as we have seen in numerous cases. It is one of the primary reasons why there has been very little investment in the industry. It is also a key reason why smelters have had to get into the mining business

and run mines at considerable losses on occasion. They would not have a guaranteed source of zinc concentrate supply otherwise.

I am sure zinc miners are grateful for the fact that the zinc price has stabilized post-2009 at a level twice that of prior to 2004. But the fact of the matter is, this is grossly insufficient to incentivize an industry to seek out and develop new production centers. Consumers have failed to recognize that zinc is no longer a byproduct at most mines. It is the primary metal mined. This therefore provides an opportunity for those who realize this cannot persist.

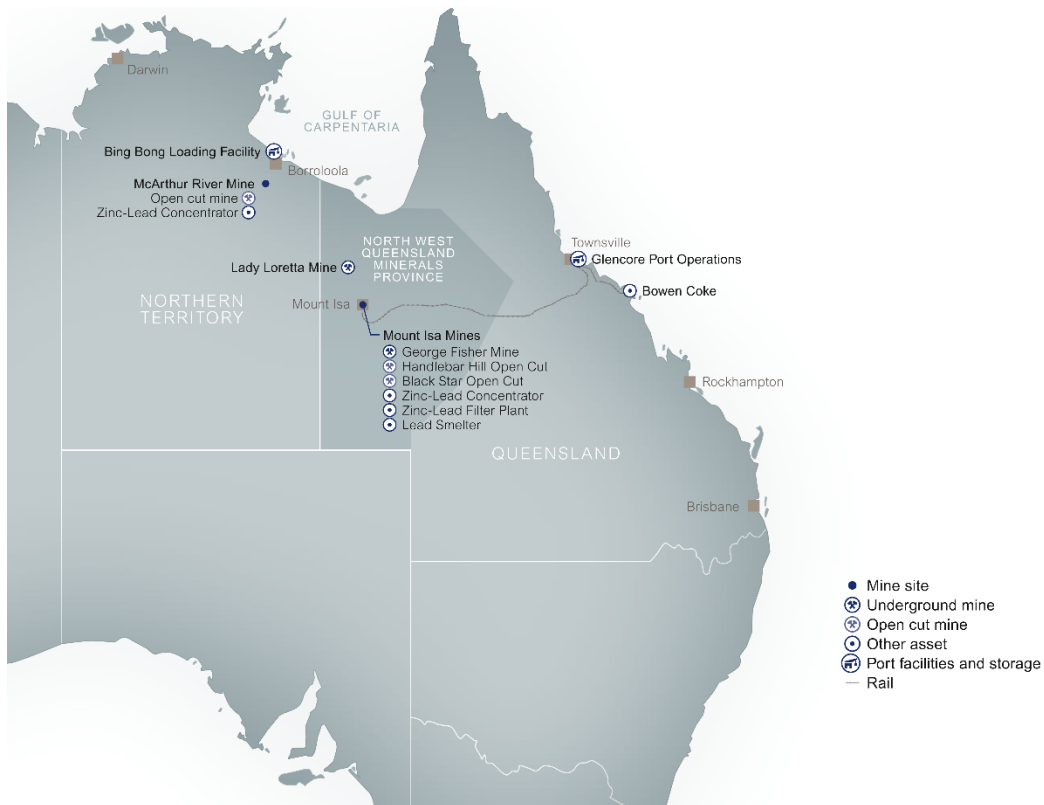




Existing Operations

Glencore

It is instructive to note that the silver/lead/zinc deposits at Mt. Isa were always referred to by the original owner, Mt. Isa Mines Ltd, as lead deposits. Glencore now refers to remaining ore as zinc deposits. With a lead smelter on site and silver reporting to the lead concentrate, it was far more profitable in the past to focus on lead rich deposits. These are now largely mined out. Glencore’s motivation for mining the zinc rich remaining deposits appears largely due to the fact that they have a number of hungry zinc smelters to feed around the world. This does not mean it is necessarily more profitable than mining which occurred in the past. Indeed, the cutback announcement made in October 2015 acknowledges this fact. Illustrated below are the locations of Glencore’s Australian zinc assets.



Mt. Isa

Next month marks a milestone that will go largely unnoticed, even by those intimately associated with the base metal mining world. Lead/zinc mining, that commenced in 1929, at Mt. Isa will cease.

Underground lead/zinc mining ceased in 2005. The Black Star Open Cut, which mined the up dip extension of the underground deposits, commenced in 2004 but ceases in September due to ore exhaustion. Figure 1 is a cross section through the numerous lead/zinc orebodies. Table 2 lists 2015 production and remaining reserves as of January 1, 2016. Forecast production is discussed later.

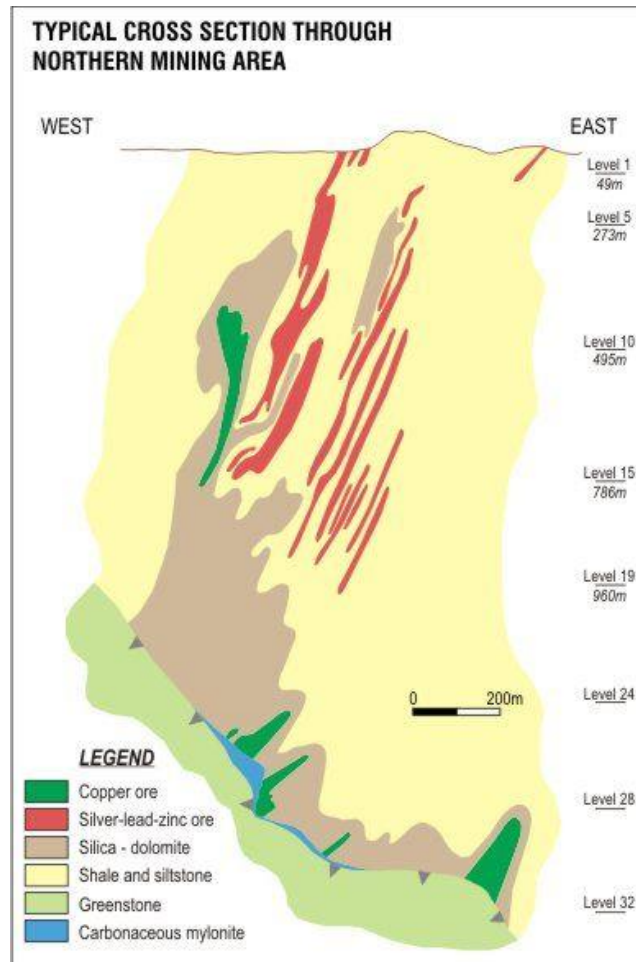


Figure 1 Silver-lead-zinc Orebodies at Mt. Isa

Table 2 Black Star Open Cut Reserves as of Jan. 1, 2016 and 2015 Production

	Tonnes	Zn%	Pb%	Ag (g/t)
P+P Reserves	3,000,000	5.6	2.9	51
2015 Production	3,200,000	4.8	2.3	55

One of the key issues with the mining of this pit has been the location of infrastructure on surface. Glencore lists a measured and indicated resource for an expansion of this pit of 236 MT grading 3.7% Zn plus copper, lead and silver but this entails the relocation of the lead/zinc concentrator and other infrastructure to proceed as illustrated in the photo below. The big stack in the photo is the lead smelter. I used to live across the street in behind my favorite watering hole, the Barkly Hotel. If I had something to discuss with the General Manager but could not get his attention during the day, I knew what bar stool he would be sitting on at 5 PM.



George Fisher

As illustrated in Figure 2, George Fisher is really two separate deposits located about 20 km north of Mt. Isa. Both deposits are similar to the Mt. Isa lead/zinc deposits (Figure 1) though much more deformed. A series of orebodies are stacked like pancakes with waste shale between. The Hilton Mine (since renamed George Fisher P49) consists of seven orebodies and the George Fisher L72 area (which we used to call Hilton North) has roughly a dozen zones of ultimate interest though mining is likely confined currently to half of these. The P49 shaft can hoist in excess of 1.5 MT a year and my understanding is the L72 hoisting shaft (not illustrated in Figure 2) can hoist in excess of 3.0 MT a year.

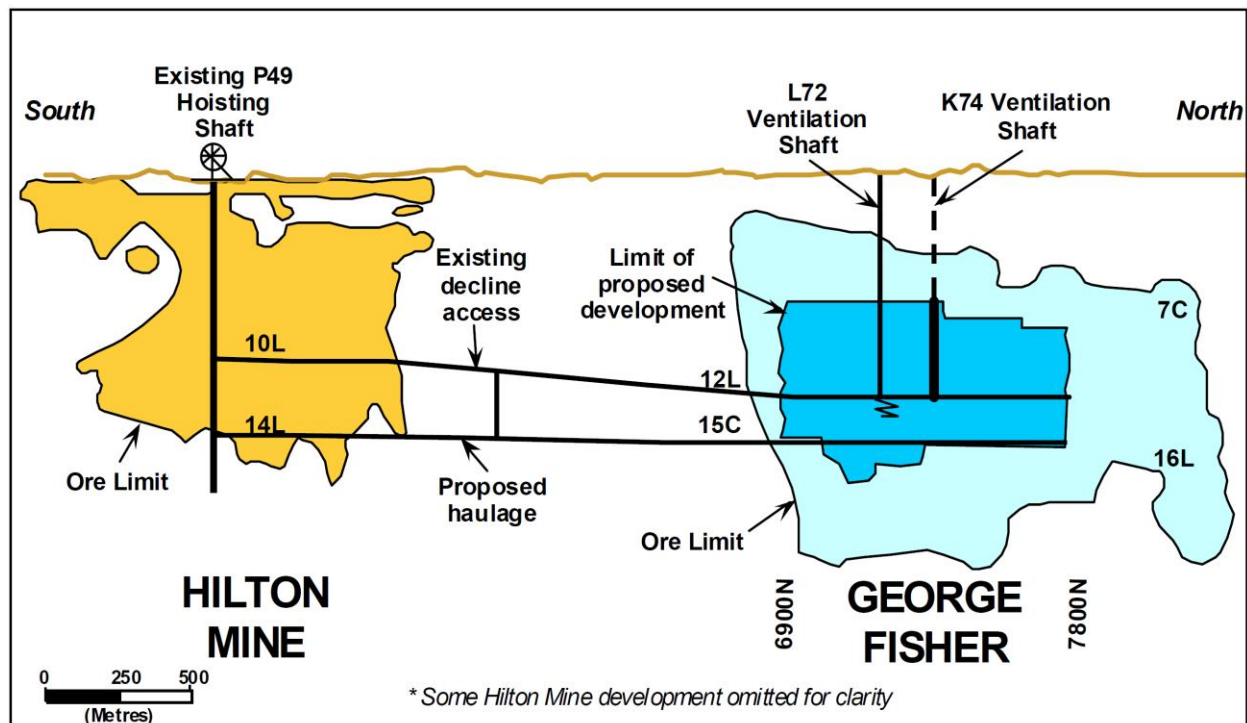
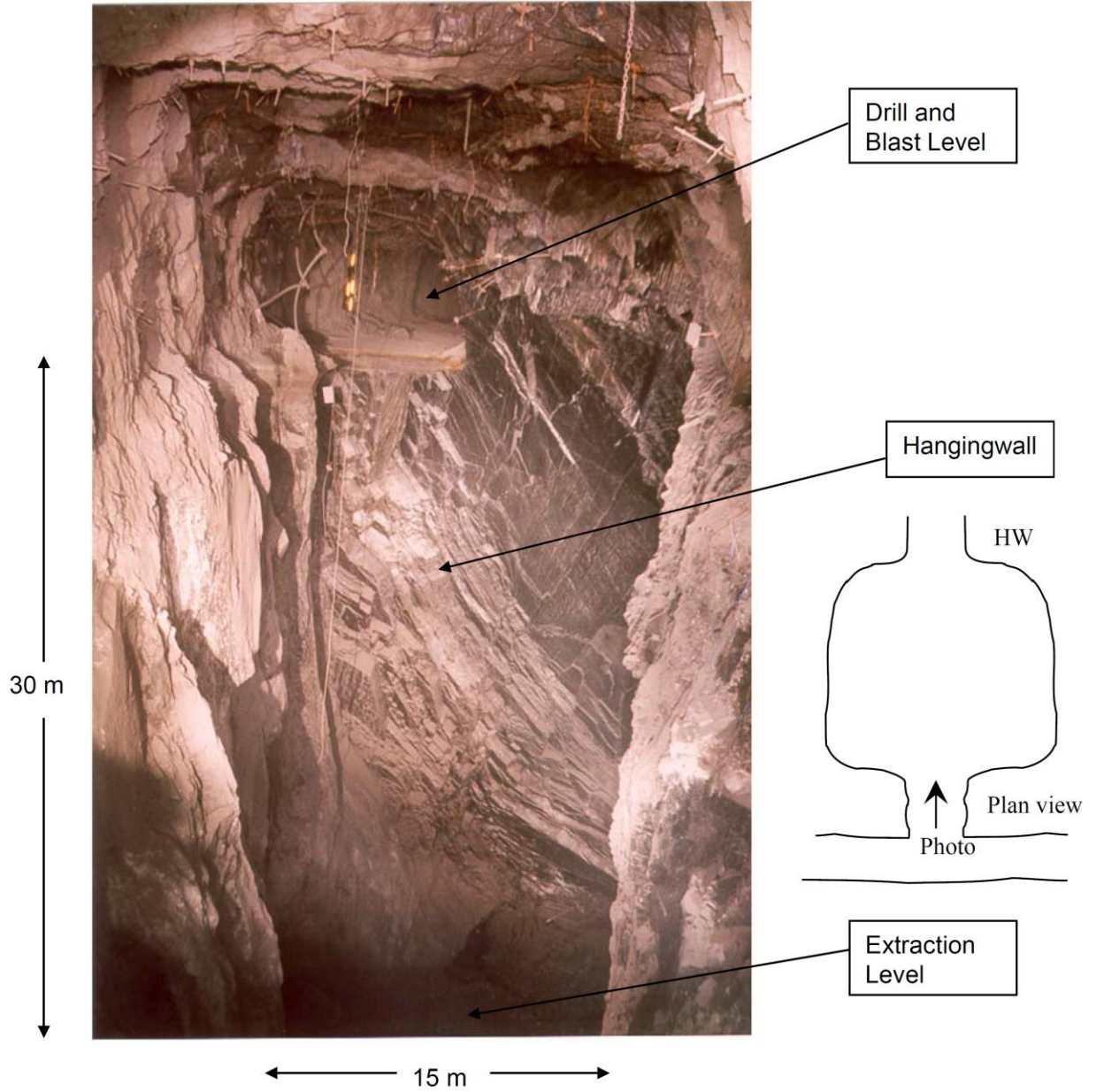


Figure 2 Longitudinal Section Showing the Relationship between George Fisher P49 and L72 mines.

Most orebodies are from 3 m to 25 m wide, dip around 60-65 degrees and can extend laterally for +500 m and down dip for +500 m. There is no lack of ore at George Fisher, it just needs to be mined carefully to avoid excessive dilution. Blasthole stoping and a variant known as bench mining are the standard methods used. I have mentioned blasthole stoping in the Modules often and to get a sense of what it actually is I have included below a picture of a mined out stope from George Fisher. This photo is from a PhD thesis found [here](#). I guess you can say this is largely what I did for a living, making big holes in the ground up to a thousand metres below surface in some very inconvenient places around the world. It was lots of fun actually.



George Fisher was ramped up to a production rate of 4.5 MT per year in 2015 and then quickly knocked back to 3.5 MT per year as part of the cutbacks announced in October 2015 when zinc hit the price of \$0.72/ lb.

Table 3 illustrates 2015 production and reserves as of January 1, 2016.

Table 3 George Fisher Reserves as of Jan. 1, 2016 and 2015 Production

	Tonnes	Zn%	Pb%	Ag (g/t)
P+P Reserves- P49	16,000,000	6.3	4.9	95
P+P Reserves- L72	49,000,000	7.2	3.6	59
2015 Production	3,800,000	6.9	3.0	56

When this asset was owned by Mt. Isa Mines Ltd in the 1980's and 1990's our typical annual production grades were 7% Zn, 7% Pb and 120 g/t Ag. So it is readily apparent that this asset has transitioned to being a predominantly zinc asset since then. Below is the P49 production shaft where I used to work.

It is also important to note that previous decisions to expand George Fisher from ~3.8 MT to 4.5 MT a year (and McArthur River from 2.5 MT to 5.5 MT a year and Lady Loretta from 1.0 MT to 1.6 MT a year) were made by Xstrata and not Glencore. Glencore has reversed these decisions and in the case of Lady Loretta, shut it down entirely. Glencore may take plenty of time before they increase production once again.



Handlebar Hill

Near surface mineralization at George Fisher P49 was mined up to 2014 by open pit methods. This pit is now exhausted. Much of this mineralization was oxidized leading to poor mill recoveries. You can see the pit in the above photo just below the water tanks.

Lady Loretta

This deposit is located 140 km north of Mt. Isa and was discovered over 40 years ago but languished until 2012 when production commenced. It passed through a number of hands prior to Xstrata acquiring it in their Noranda acquisition.

It made little economic sense in the past to develop a full mine/mill site here so Glencore trucks the ore to the mill in Mt. Isa since it now has plenty of spare capacity. Blasthole stoping is used at Lady Loretta and for a sense of what the underground looks like there is a video [here](#) .

The mine is rated for 1.6 MT of ore a year. This mine was placed on care and maintenance in October 2015. Table 4 illustrates 2015 production and reserves remaining as of January 1, 2016. At full production therefore, there are only roughly five or six years of mine life remaining with poor prospects of discovering additional resources. This asset will therefore be likely treated as a contractor operated swing producer brought back into production when zinc prices increase markedly.

Table 4 Lady Loretta Reserves as of Jan. 1, 2016 and 2015 Production

	Tonnes	Zn%	Pb%	Ag (g/t)
P+P Reserves	8,500,000	13.0	5.1	87
2015 Production	1,200,000	15.5	5.1	80

Mt. Isa Mill

The above assets all feed the mill at Mt. Isa. Listed in Table 5 is the performance of this mill since 2012. Table 6 is a forecast to 2022 assuming the cutbacks are removed as of (say) July 1, 2017. If the cutbacks remain in place indefinitely, total annual production will be less than 200,000 T of zinc in concentrate since only the George Fisher mine will be in operation at reduced production rates.

Table 5 reveals however, that even bringing all production back still does not get production back to 2015 levels due to the loss of production from the Black Star Open Cut.

Messaging from Glencore will be very important. If they announce the removal of cutbacks, the zinc price at that time will likely be deemed by the market to be acceptable to Glencore and could put a ceiling on the zinc price. The proper message is likely to bring some production back but only to partially replace lost production from the Black Star Open Cut and to communicate such.

Table 5 Recent Mine and Mill Performance for Mt. Isa Area Assets

Year	Mine	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	Blackstar Open Cut	4,400,000	4.8%	211,200	390,400	68.4%
	Handlebar Hill	1,400,000	6.1%	85,400		
	George Fisher	3,700,000	7.4%	273,800		
	Mount Isa Mill	9,500,000	6.0%	570,400		
2013	Blackstar Open Cut	4,400,000	3.4%	149,600	405,100	70.3%
	Handlebar Hill	1,200,000	6.8%	81,600		
	George Fisher	4,200,000	6.9%	289,800		
	Lady Loretta	500,000	11.0%	55,000		
	Mount Isa Mill	10,300,000	5.6%	576,000		
2014	Blackstar Open Cut	3,300,000	3.9%	128,700	437,100	76.2%
	Handlebar Hill	480,000	7.7%	36,960		
	George Fisher	3,900,000	7.3%	284,700		
	Lady Loretta	970,000	12.7%	123,190		
	Mount Isa Mill	8,650,000	6.6%	573,550		
2015	Blackstar Open Cut	3,200,000	4.8%	153,600	478,200	79.5%
	George Fisher	3,800,000	6.9%	262,200		
	Lady Loretta	1,200,000	15.5%	186,000		
	Mount Isa Mill	8,200,000	7.3%	601,800		
2016	Blackstar Open Cut	3,000,000	4.8%	144,000	296,835	77.0%
	George Fisher	3,500,000	6.9%	241,500		
	Lady Loretta	-	0.0%	-		
	Mount Isa Mill	6,500,000	5.9%	385,500		

2012-2015 figures- actual. 2016 figures- projected based on Q1, Q2 performance. Recoveries are inferred from mining tonnes and grades reported along with zinc in concentrate output.

Table 6 Forecast Zinc in Concentrate Production to 2022

(assuming production cutbacks are reversed July 1, 2017)

Year	Mine	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2017	George Fisher	4,000,000	7.0%	280,000		
	Lady Loretta	800,000	14.0%	112,000		
	Mount Isa Mill	4,800,000	8.2%	392,000	309,680	79.0%
2018	George Fisher	4,500,000	7.0%	315,000		
	Lady Loretta	1,600,000	14.0%	224,000		
	Mount Isa Mill	6,100,000	8.8%	539,000	425,810	79.0%
2019	George Fisher	4,500,000	7.0%	315,000		
	Lady Loretta	1,600,000	13.0%	208,000		
	Mount Isa Mill	6,100,000	8.6%	523,000	413,170	79.0%
2020	George Fisher	4,500,000	7.0%	315,000		
	Lady Loretta	1,600,000	13.0%	208,000		
	Mount Isa Mill	6,100,000	8.6%	523,000	413,170	79.0%
2021	George Fisher	4,500,000	7.0%	315,000		
	Lady Loretta	1,600,000	13.0%	208,000		
	Mount Isa Mill	6,100,000	8.6%	523,000	413,170	79.0%
2022	George Fisher	4,500,000	7.0%	315,000		
	Lady Loretta	1,300,000	13.0%	169,000		
	Mount Isa Mill	5,800,000	8.3%	484,000	382,360	79.0%

McArthur River

The McArthur River mine was developed in the early 1990's not because of its wonderful economics. It was developed because the Northern Territory was putting pressure on Mt. Isa Mines to develop the asset or lose it. In other words, they were threatening us with expropriation although in a very polite typically Australian way. A fact known by only a handful of us. It also nicely coincided with a recession in Australia (Paul Keating's "The recession we had to have.") so the federal government was under great pressure to help kick start the economy again. So we fronted up in Canberra to kill two birds with one stone and everyone got great mileage from it. I still have the newspaper clippings.

My task was to put the underground design together. The fundamental problem to this day at McArthur River is the fine grained nature of the mineralization. If you held a piece of high grade drill core in your hand you would be very hard pressed to realize it was metallic ore except for its density. Hermann Radmuller ([page 6](#)) and I reopened an old bulk sample decline to get more ore and we shipped it off to Mt. Isa for testing. Those were good times, particularly at Campbell's Country Club (the camp bar) and the Heartbreak Hotel after work. The metallurgists indicated that they could only make a reasonable bulk concentrate with 2 orebody, 4 orebody and the upper part of 3 orebody. The IsaMill technology was specifically developed during the feasibility study to cost effectively grind the ore to a P₈₀ of 8 microns. Good ole German technology (Netzsch) from the paint industry was scaled up very successfully for the mining industry. (The Caribou mine in Canada can thank us for this adaptation since it is what has made that ore now millable.)

But, due to the metallurgy, my hands were tied to one mining method only, inclined room and pillar mining on two horizons (2 o/b and a 4 o/b 3 HW blend). A great way to sterilize the other orebodies present and not exactly the cheapest method around. This method was used successfully however for over ten years from the mid-90's during which time 2 orebody was largely mined out producing about 150,000 T of zinc in concentrate annually. During this timeframe, the metallurgists also realized they could mill other ore zones. So the push was made to convert from underground mining to open pit mining. Open pit mining has since been expanded. Final depth will be in the 400 m range. A 34 page description of this expansion can be found [here](#).

The other stumbling block in the past was the presence of the McArthur River itself right over top of the orebody. This was a dry channel for perhaps ten months of the year (and a good place to catch barramundi trapped in the billabongs) but could be a raging torrent over 1 km wide during the monsoonal wet season particularly if a cyclone was in the area. The end of the airstrip would actually be under water. The mill and mine portals to underground were located on Barney Hill safely above the floodplain. The river diversion channel and berm separating river from the open pit is illustrated in the photo below. It was the ability to open pit mine that really blew the doors off the production potential for this mine.



The various orebodies are illustrated in the photo below. The top 50 m of ore (the crown pillar essentially) was very steep before it subsequently flattened out for room and pillar mining.



The key to note is that open pit mining is now sending almost the entire ore package to the mill but much of it is rejected by a heavy media separation plant at the frontend. Table 7 illustrates 2012-2015 production and reserves as of January 1, 2016. However, based upon the zinc in concentrate reported, zinc recovery was only 64.5% in 2015. In other words, the mill has chosen throughput over recovery. Also note the drop in mined ore grade. A 100% increase in throughput since 2012 has only led to a 35% increase in zinc in concentrate. Performance is far short of what was announced in expansion plans.

Table 7 McArthur River Zinc in Concentrate Output, 2012- H1 2016

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	2,300,000	11.9%	273,700	202,100	73.8%
2013	3,000,000	10.1%	303,000	203,300	67.1%
2014	4,600,000	9.0%	414,000	224,300	54.2%
2015	4,500,000	9.4%	423,000	272,700	64.5%
H1 2016				89,200	
P+P Reserves	102,000,000 T	10% Zn	4.8% Pb	49 g/t Ag	

It is very important to note that the mine produces a bulk concentrate that less than 8% of smelters can treat using the Imperial Smelting process. The process is considerably more expensive than conventional smelters and is therefore reflected in treatment charges. The McArthur River bulk concentrate is unusual in that it has up to 46% zinc which is not far from being a suitable grade for electrolytic smelters. The lead content (roughly 10%) is too high however for electrolytic smelters.

There could be more than meets the eye therefore with respect to the announced cutback in production in October 2015. There may be little or no market for the additional concentrate despite what the price of zinc happens to be. The IZA states that Imperial Smelters are only in operation in China, India, Japan and Poland. Glencore could perhaps blend some of this concentrate with other zinc concentrate to make an acceptable feed for their European smelters. In 2012 Xstrata reported that less than 10% of McArthur River concentrate was used internally however. So my gut feel is that these guys have over run their market and we will not see this mine return to previous production levels since few want what they produce. Table 8 is therefore my estimate of production to 2022. But Ivan could always prove me wrong I guess.

Table 8 Forecast McArthur River Zinc in Concentrate Production- 2016-2022

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2016	3,000,000	9.5%	285,000	185,250	65.0%
2017	3,000,000	10.0%	300,000	195,000	65.0%
2018	3,000,000	10.0%	300,000	195,000	65.0%
2019	3,000,000	10.0%	300,000	195,000	65.0%
2020	3,000,000	10.0%	300,000	195,000	65.0%
2021	3,000,000	10.0%	300,000	195,000	65.0%
2022	3,000,000	10.0%	300,000	195,000	65.0%

MMG**Century**

Anyone who knows anything about the zinc industry will be able to tell you that this mine closed last year and this is a prime reason there is a shortage of zinc concentrate. I won't bother to elaborate on previous mining here at this open pit. Table 9 lists production from 2012 to closure. The mill was used to treat ore from the Dugald River test mining and this is also included in Table 9.

Table 9 Century Zinc Mine- Zinc in Concentrate Production 2012-2016

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	5,413,520	11.9%	644,209	514,707	79.9%
2013	7,096,282	8.9%	631,569	488,233	77.3%
2014	7,109,879	8.3%	589,489	465,696	79.0%
2015	6,811,181	7.3%	497,047	392,667	79.0%
H1 2016	118,951			16,457	

Notes: For 2014/15 milled grade was calculated based on an assumed 79% recovery.

2015/16 includes the milling of ore from the Dugald River test mining program.

Rosebery

This stalwart has been in operation since 1936 and continues to just keep on giving. A good summary of the operation is found in the Downloads area [here](#). There are some good photos and figures I won't reproduce here. Looks like a nice place to live and work. The ore zones dip at an awkward 43 degrees but they have still been able to apply variations of blasthole stoping. Mining is being conducted at depths up to 1,500 m. All ore is hauled to surface in 55-60 tonne trucks and this appears to be the site bottleneck. The shaft hoisting of ore to surface ceased in the early 2000's.

Proven and probable reserves as of June 30, 2015 are:

7.4 MT @ 7.4% Zn, 0.2% Cu, 2.6% Pb, 91 g/t Ag and 1.0 g/t Au

Production for 2012-2015 is listed in Table 10. As illustrated, mined zinc grades in 2015 were well above reserve grade and initial results for 2016 illustrate that zinc production is now trending down. Although the mine has been in operation for 80 years, I am uncertain about its future. There are ample reserves and resources but the ore haulage distance from the bottom of the mine to surface is exorbitant to say the least. Production during the period under assessment appears assured but beyond that it is a question mark. Table 11 illustrates my estimate of production to 2022.

Table 10 Rosebery Mine Zinc Production 2012-2015

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	812,595	9.6%	78,233	70,410	90.0%
2013	897,277	10.9%	98,188	88,369	90.0%
2014	879,288	10.6%	92,786	83,507	90.0%
2015	898,573	11.4%	102,338	92,104	90.0%

Notes: In order to determine milling head grade I have assumed 90% zinc recovery which is close to recent experience.

Table 11 Forecast Rosebery Mine Zinc Production 2016-2022

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2016	875,000	10.0%	87,500	78,750	90.0%
2017	875,000	9.5%	83,125	74,813	90.0%
2018	875,000	9.0%	78,750	70,875	90.0%
2019	875,000	8.5%	74,375	66,938	90.0%
2020	875,000	8.0%	70,000	63,000	90.0%
2021	875,000	8.0%	70,000	63,000	90.0%
2022	875,000	7.5%	65,625	59,063	90.0%
	6,125,000				

Golden Grove

MMG states that they have had a number of expressions of interest in this mine so I expect a sale of this asset shortly. It is typical that when a mine is down to its last five years or so of ore, the operation is sold by a big miner to a wannabe miner. The big miner extracts the remaining NPV without having to do any mining or rehabilitation work and the wannabe miner can now boast that they are actually a producer. So both backs are scratched.

Golden Grove is actually two separate mines a few kilometers apart: Gossan Hill and Scuddles. Information on these mines can be found in the Downloads section [here](#).

In the case of the Gossan Hill mine, most zinc stopes are greater than 1,000 m deep and the ore must be hauled to surface by truck. This is likely a haul over 8 km on a ~15% ramp which would take a truck the better part of two hours for a round trip. At Scuddles, remaining zinc stopes are over 1,200 m deep and must be hauled up to approximately 700 m depth to the shaft loading pocket (I assume this shaft is still operational). The long haulage distances are likely the production bottleneck. Table 12 illustrates 2012-2015 production figures. Note that these zinc grades are a combination of distinct copper and zinc zones so the grades listed are deceptively low. Copper rich and zinc rich zones are campaign milled separately and the portion of each zone milled annually varies.

Table 12 Golden Grove Mine Zinc Production, 2012-2015

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	1,668,080	2.5%	42,044	37,419	89.0%
2013	1,766,157	1.5%	26,538	23,619	89.0%
2014	1,739,111	2.4%	42,580	37,896	89.0%
2015	1,807,866	3.4%	61,945	55,131	89.0%

Notes: In order to determine milling head grade I have assumed 89% zinc recovery

Zinc rich reserves as of June 30, 2015 are:

2.0 MT @ 11.6% Zn, 0.4% Cu, 1.7% Pb 123 g/t Ag and 2.4 g/t Au

MMG announced recently that this mine is being “right sized” from 1.6 MT a year to 1.0 MT a year. This is likely tacit admission they can no longer get the more attractive ore at depth to surface quickly and what is near surface is uneconomic. Table 13 is my estimate of zinc production going forward assuming the zinc rich zones constitute 40% of annual mill feed. Against my better judgement I have assumed production continues to 2020 but this mine really is a tired dog that should be put out of its misery instead. This seldom happens though. Someone always comes along that thinks they know better.

Table 13 Forecast Golden Grove Mine Zinc Production, 2016-2022

Year	Tonnes	Zn%	Contained	Recovered	Recovery
2016	400,000	11.0%	44,000	39,160	89.0%
2017	400,000	11.0%	44,000	39,160	89.0%
2018	400,000	11.0%	44,000	39,160	89.0%
2019	400,000	11.0%	44,000	39,160	89.0%
2020	400,000	11.0%	44,000	39,160	89.0%
2021	-	0.0%	-	-	0.0%
2022	-	0.0%	-	-	0.0%
	2,000,000				

Copper tonnage not listed.



Dugald River

MMG is currently constructing the Dugald River mine after an extensive test mining phase. This deposit is located in the Mt Isa area and was discovered well before my time in the area. Being predominantly zinc rich it attracted only scant attention from an area traditionally steeped in lead/silver mining.

The Dugald River style of mineralisation is a sedimentary hosted base metal deposit. Mineralised widths vary from 3 m to 30 m. The mineralised zone extends approximately 2.4 km in strike length and up to 1.2 km down dip. The main Dugald lode is hosted within a major N-S striking steeply west dipping shear zone which cross cuts the strike of the Dugald River Slate stratigraphy at a low angle. Dip varies between 85° and 45° to the west. The mineralisation is open at depth. Blasthole open stoping will be used. Zinc recovery of 87.2% to a concentrate grading 51.6% Zn is expected. When I asked back in the 1980's why this deposit was not being mined, a relatively high manganese content in the ore was one answer offered up. Smelters have issues with this.

Proven and probable reserves as of June 30, 2015 are:

22.1 MT @ 12.3% Zn, 2.0% Pb and 50 g/t Ag

Resources are greater than 56 MT at similar grades.

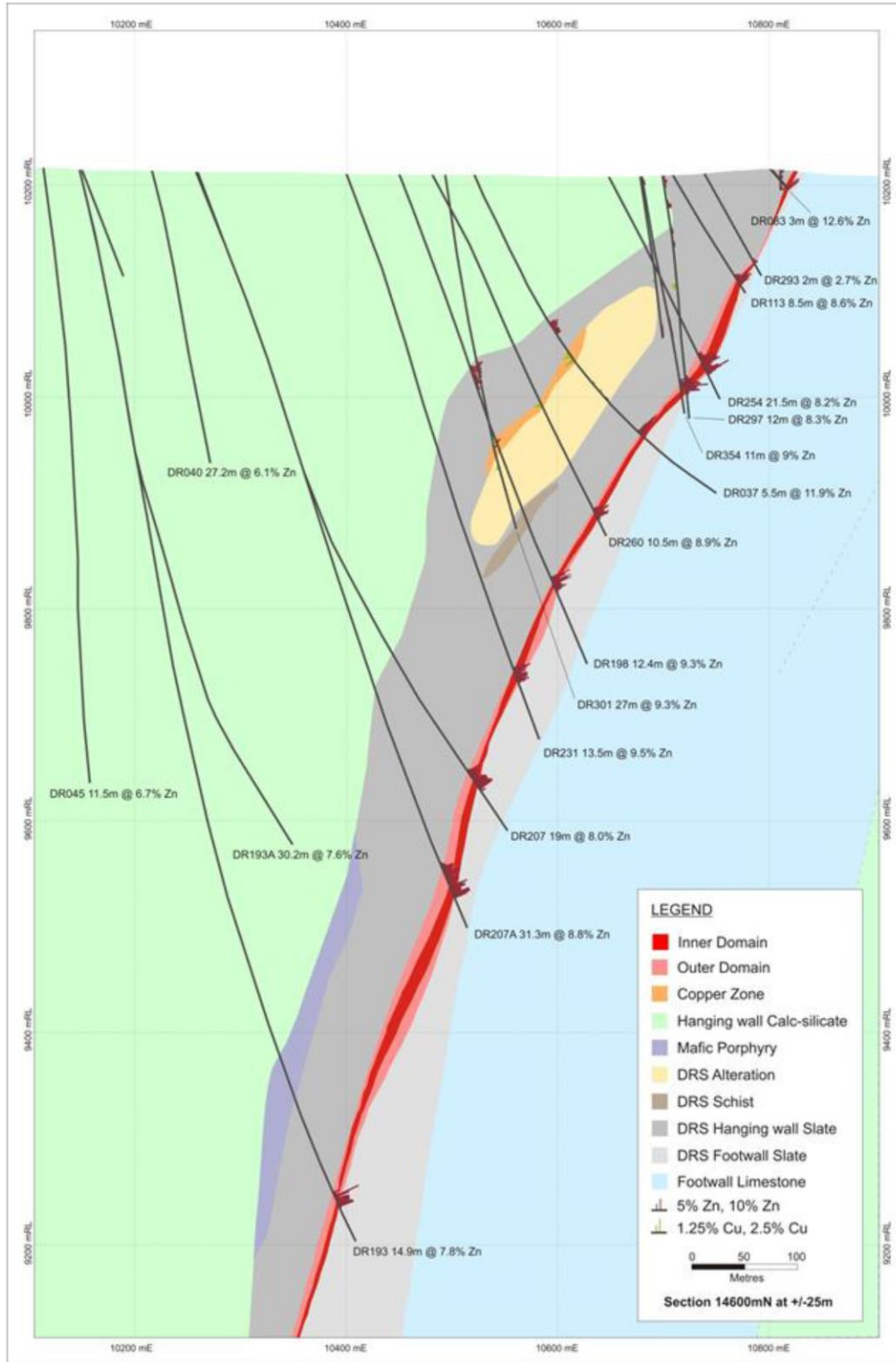
MMG expects to produce 1.7 MT of ore per annum with the ramp up commencing in mid-2018. Mill output at full production is expected to be 170,000 T of zinc in concentrate annually. It therefore represents Australia's largest new zinc mine development and will be one of the top 10 in the world.

The investment decision was made by MMG based on their projection of the price of zinc increasing to the \$1.75 /lb. range by 2017 and then sustaining \$1.50/lb. for subsequent years. This is a price range I agree with since the zinc price will need to be attractive enough for a new suite of mines to justify development.

Table 14 is my estimate of the production ramp up. MMG has conducted an extensive test mining program here so I have no doubt that they will achieve this. It is a shame however that Mark Adams, my former boss at Mt. Isa is not leading this show up having left as General Manager of MMG's Century mine last year when it closed. The beaches near Perth beckoned just like my golf clubs did I guess.

Table 14 Forecast Dugald River Mine Zinc Production, 2016-2022

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2016	-	0.0%	-	-	0.0%
2017	-	0.0%	-	-	0.0%
2018	500,000	12.0%	60,000	42,000	70.0%
2019	1,200,000	12.0%	144,000	125,568	87.2%
2020	1,600,000	12.0%	192,000	167,424	87.2%
2021	1,650,000	12.0%	198,000	172,656	87.2%
2022	1,700,000	12.0%	204,000	177,888	87.2%



A cross section through the Dugald River deposit.

South32

Cannington

BHP rolled Cannington into South32 likely due to its limited economic mine life using BHP commodity price assumptions. The mine has predominantly been considered a silver/lead mine yet its zinc production has been very significant. Blasthole stoping is used to produce over 3 MT of ore annually. Table 15 illustrates FY2015 production and reserves remaining as of June 30, 2015. This is yet another mine in the prolific Mt. Isa region. This mine was a huge money maker for BHP during its prime.

The South32 Information Memorandum filed with the ASX [here](#) provides mining and milling details (page 1186 onwards) and the zinc production schedule reproduced in Table 16 through to ore exhaustion in 2023.

The resources (at a \$90/t NSR) are roughly three times the reserve base. It is uncertain whether these resources are essentially sterilized by previous mining or readily accessible should it be decided to extend the mine life based on a rise in commodity prices. At one time BHP mulled open pit mining here at a 60% higher milling rate. By divesting of this asset to South32, I guess the ball is in their court now to determine whether they can convert resources into reserves. My suspicion is that the mine life will be much longer than illustrated in Table 16. For the geologists out there, there is a technical description of this type of deposit [here](#). (Us mining engineers just want to know where the ore is.)

Table 15 Cannington Reserves as of June 30, 2015 and FY2015 Production

	Tonnes	Zn%	Pb%	Ag (g/t)
P+P Reserves	21,300,000	3.8	5.9	225
FY2015 Production	3,289,000	3.4	6.7	257

Table 16 Actual and Forecast Cannington Mine Zinc Production, 2012-2023

Financial Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2012	3,337,000	2.84%	94,771	67,856	71.6%
2013	3,145,000	2.98%	93,721	67,292	71.8%
2014	3,203,000	2.96%	94,809	69,590	73.4%
2015	3,289,000	3.4%	111,826	83,870	75.0%
2016	3,458,000	3.6%	124,488	94,113	75.6%
2017	3,454,000	3.5%	120,890	91,151	75.4%
2018	3,160,000	4.1%	129,560	99,891	77.1%
2019	3,443,000	3.9%	134,277	102,185	76.1%
2020	3,112,000	4.0%	124,480	95,850	77.0%
2021	3,155,000	3.7%	116,735	89,186	76.4%
2022	3,102,000	3.4%	105,468	80,367	76.2%
2023	2,401,000	3.0%	72,030	55,391	76.9%



CBH Resources (Toho Zinc)

Toho acquired struggling CBH in 2010 apparently in order to internally source most of their concentrate requirements for a smelter in Japan.

Endeavor Mine

This mine used to be called the Elura Mine and I had the opportunity to visit it in the early 1990's. The orebody is now essentially mined out and only the mining of small stopes and remnants left in and around the previous mining areas is underway. Remnant mining can be very tricky business since it relies upon the good understanding of past activities, namely whether the previous mining areas nearby are backfilled adequately. High stress levels may also be present in some locations particularly sill pillars left between two previous mining levels.

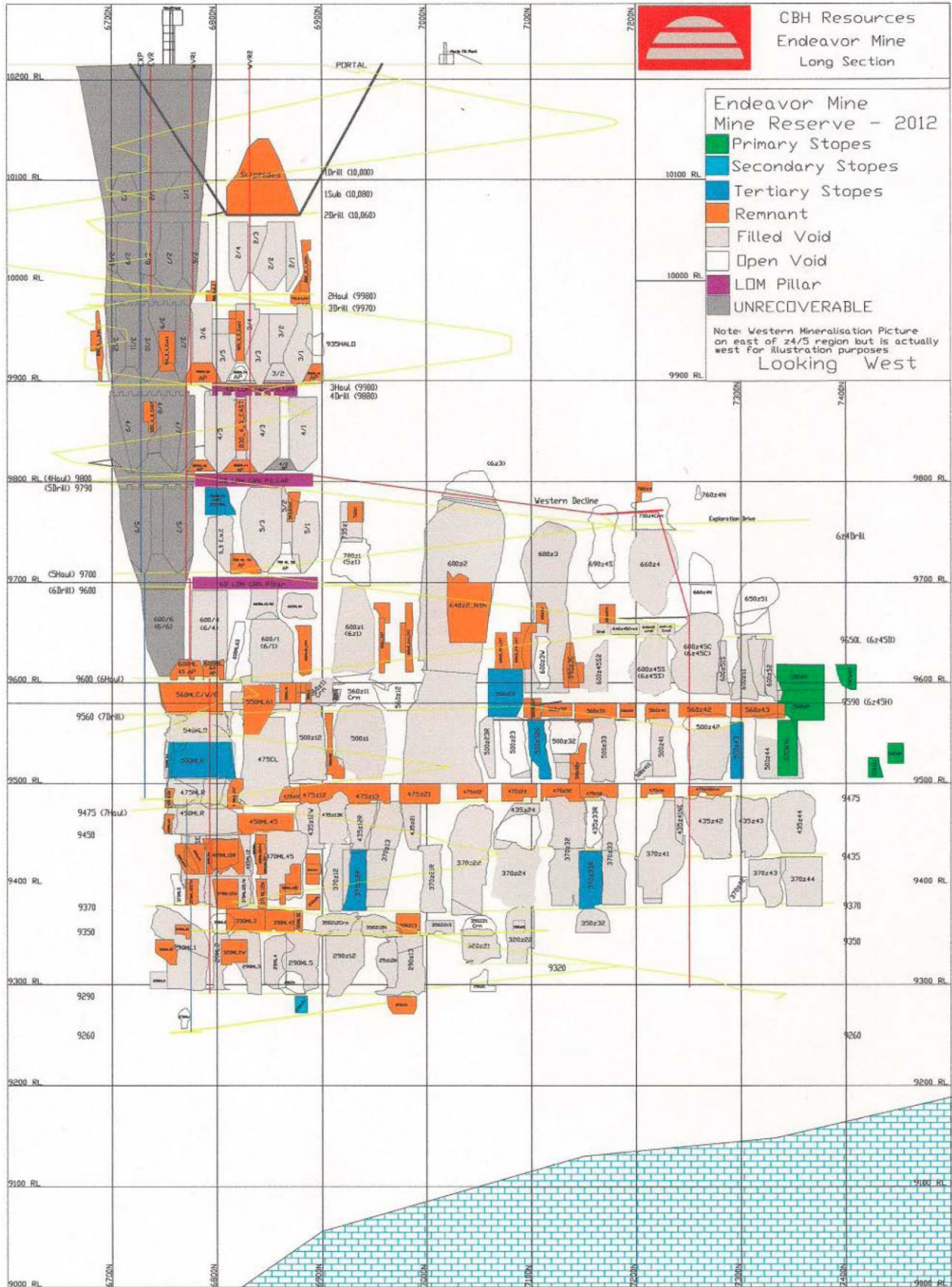
Variations of blasthole stoping are being used and production has averaged in the 700,000 T a year rate over the past few years. The location of these remnants as of 2012 in relation to previous mining is illustrated below.

Toho Zinc does not publish mining performance details (in English at least) but a good sense of the operation can be obtained from the NI 43-101 filed by Coeur in 2013 (they have a silver royalty). Coeur also publishes annual mining production and reserve figures (for silver grade only unfortunately from which I infer a ~7% Zn head grade and 40,000 T a year zinc output). Based upon the reserve situation, it is inferred that this mine would close in roughly three years' time. However, in February 2016 CBH announced [here](#) an 80% cut in production claiming weak commodity prices. CBH confirms that there are only 2-3 years of reserves left at previous production rates. I have assumed the mine returns to full production mid-2017 in Table 17 and the mine closes at the end of 2019. This may be overly optimistic.

Table 17 Forecast Endeavor Mine Zinc Production, 2016-2019

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Recovery
2016	200,000	7.0%	14,000	11,340	81.0%
2017	400,000	7.0%	28,000	22,680	81.0%
2018	700,000	7.0%	49,000	39,690	81.0%
2019	700,000	7.0%	49,000	39,690	81.0%

Reference: Coeur NI 43-101 Endeavor Mine Technical Report, March 28, 2013. www.sedar.com

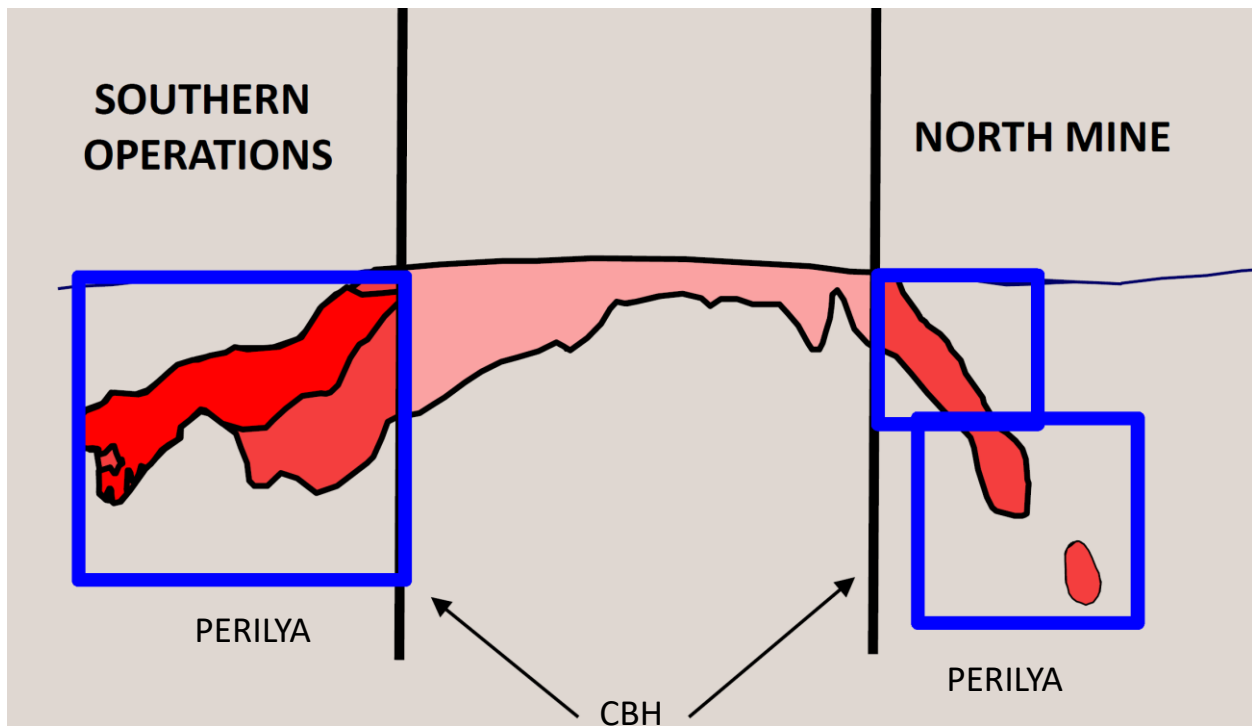


Rasp Mine

Old mining camps never die it seems. Broken Hill, New South Wales is a classic example of this. I bet there are some readers out there that have no clue what BHP stands for- Broken Hill Proprietorship. The Broken Hill mine was the cash cow that underpinned this mining empire. They had enough sense not to piss it away unlike most mining companies (but they are trying lately I guess). BHP was incorporated in 1885. Like Mt. Isa, Broken Hill was known as a silver/lead/zinc mine in that order of importance. The “Silver City”.

Charles Rasp is credited with the discovery of this deposit. The silver and lead rich portions were essentially mined out over one hundred years but there are a number of areas richer in zinc that are still exploited here. Unfortunately, I have been unable to find much information on current operations except to report that Toho expects to produce 34,000 T of zinc in concentrate annually and have not announced any alterations to plans.

The Rasp Mine mines remnants from the original BHP mine. The orebody is shaped like a boomerang as illustrated below. CBH mines remnants in the center and Perilya mines remnants currently in the Southern Operations. Both operations are classic swing producers that at times have lost considerable money and have been effectively subsidized by their Asian parent companies. This is one reason why zinc mining has been a crappy business more years than not for those that don't have an owner with deep pockets or an extraordinarily rich orebody.





Perilya- Southern Operations

Perilya acquired assets on the north and south limb of Broken Hill in 2002. Zinc rich zones and remnants are mined currently on the south limb at what is known as the Southern Operations. From 2002-2010 over 15 MT of ore was mined with grades in the range of 6% Zn, 4% Pb plus silver. Perilya was caught up in the 2008 financial crisis like many mining companies. Shenzhen Zhongjin Lingnan Nonfermet Co. Ltd of China acquired 50.1% of the company in 2009 as a result. This was increased to 100% in 2013.

Following the financial crisis operations on the north limb (Potosi development and North Mine) were suspended and production levels were reduced 50%. Due to low prices and deteriorating ore quality, Perilya announced further job losses in March 2016 [here](#). Production would be cut a further 30%. The mine apparently lost \$A30M during the previous year due to low lead and zinc prices.

Since the owner is a private company that does not report annual results, I have had to do considerable reading between the lines. I assume 2015 production levels were roughly 900,000 t grading 6% Zn for 50,000 T of zinc in concentrate and going forward this will drop to 35,000 T per year to 2022. Predicting the actual outcome is a real crapshoot since production could rise on a price increase.

Perilya is a classic swing producer. At high commodity prices it would be possible to restart the Potosi development (1.6 MT @ 13.0% Zn, 3.1% Pb and 43 g/t Ag) and perhaps even the North Mine Deeps project (3.7 MT @ 11.3% Zn, 13.5% Pb and 219 g/t Ag).



Jaguar (Bentley)

When I worked in Queensland and the Northern Territory much of the mining action was actually in Western Australia, underground gold mining mostly. We looked upon that mining as real cowboy stuff. Undercapitalized, unsafe, real hand to mouth contract underground mining with little science applied. So I was pleasantly surprised to investigate Independence Group NL for this report. Here is a mining company that can actually develop new underground base metal mines cost effectively in Western Australia, turn a profit and pay their shareholders a dividend. A rare combination these days.

IGO owns the Jaguar Operation which is adjacent to the previous producing Teutonic Bore mine. The Jaguar and Bentley deposits are on strike with this mine. Jaguar is now mined out with all ore coming from the Bentley deposit. Significant copper, silver and gold quantities are also recovered. The life of Bentley is a bit of a mystery since it relies upon successful exploration down dip. Production for FY2016 and reserves as of June 30, 2015 are listed in Table 18. Production from FY2012 to FY2016 is illustrated in Table 19 along with my forecast to 2022 assuming 50% of the resource base is converted to reserves after depleting FY2016 mining from reserves. Reserves are inclusive of resources. IGO is currently drilling another nearby deposit, Triumph, but whether there is sufficient economic mineralization here or not is uncertain. I therefore illustrate the mine closing in 2019.

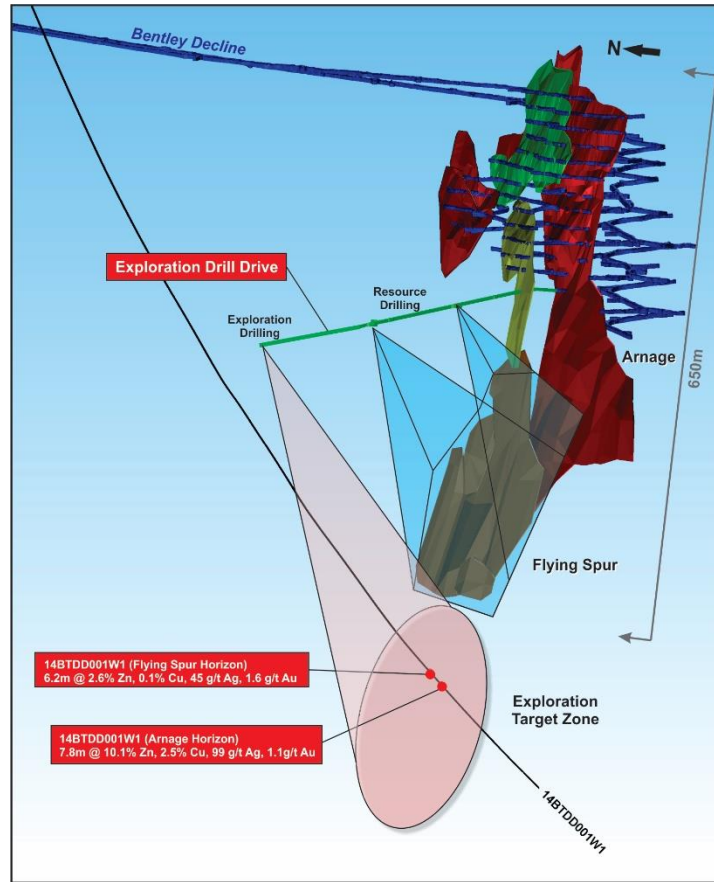
Table 18 Bentley Reserves and Resources as of June 30, 2015 and FY2016 Production

	Tonnes	Zn%	Cu%	Ag (g/t)	Au (g/t)
FY 2015 P+P Reserves	1,144,000	7.6	1.7	126	0.7
FY 2015 M+I Resources	2,907,000	8.6	1.5	138	0.9
FY2016 Production	505,578	8.9	1.7	128	0.75

Note: FY2016 reserves have not been announced. Production listed above would deplete the FY 2015 reserves and resources listed above. FY2016 ends June 30, 2016.

Table 19 Actual and Forecast Bentley Mine Zinc Production, FY2012 -2022

Year	Tonnes	Zn%	Contained Zinc	Recovered Zinc	Implied Recovery
FY2012	366,891	5.95%	21,830	16,569	75.9%
FY2013	392,125	10.10%	39,605	33,803	85.4%
FY2014	431,362	10.60%	45,724	41,163	90.0%
FY2015	485,302	10.6%	51,442	44,996	87.5%
FY2016	505,578	8.9%	44,996	39,336	87.4%
2016	500,000	8.6%	43,000	37,410	87.0%
2017	450,000	8.0%	36,000	31,320	87.0%
2018	400,000	7.5%	30,000	26,100	87.0%
2019	300,000	7.0%	21,000	18,270	87.0%
2021	-	0.0%	-	-	0.0%
2022	-	0.0%	-	-	0.0%



Hera

Aurelia Metals' Hera mine provides another cautionary tale of accepting financing from Glencore. Mine startups seldom go according to plan and cash can quickly drain from the treasury. A poor startup here left the company in dire straits and Glencore attempted unsuccessfully to place the company into Administration. They have since kissed and made up.

This Cobar area deposit is somewhat unique in that most gold and silver can be liberated by gravity concentration and dore is poured on site. The mine also produces a bulk Pb/Zn concentrate containing precious metals but it is predominantly considered a gold mine currently. Blasthole stoping with ramp access is used. Table 20 illustrates FY 2016 reserves, resources and production figures.

Table 20 Hera Reserves and Resources as of June 30, 2016 and FY2016 Production

	Tonnes	Zn%	Pb%	Ag (g/t)	Au (g/t)
FY 2016 P+P Reserves	979,000	3.85	2.84	16.3	5.11
FY 2016 M+I Resources	2,698,000	4.86	3.67	34	4.12
FY2016 Production	308,118	2.58	2.71	14.27	6.01

Note: FY2016 ends June 30, 2016. Mineral resources are inclusive of reserves.

Since annual zinc production is relatively minor I have assumed 9,000 T per year of zinc in concentrate through 2022 and that Aurelia will send Ivan a Christmas card annually.



Australian Zinc Mine Cost Competitiveness

Although the intent of this report is to look at total output potential for zinc, the question many likely have is what separates an economic deposit from an uneconomic deposit. I hope to have a spreadsheet based model shortly to help out but it should only be used in experienced hands with clear understanding of what concentrate precious metals report to in particular. The revenue side is only one aspect of the equation though.

Many of the miners assessed above have provided cost data or at least the cutoff Net Smelter Return (NSR) used to determine the threshold for differentiating between reserves (ore that covers site operating costs) and resources (mineralization that does not currently). These cutoff NSR's can be used to provide a quick assessment of the viability of potential producers going forward. If a company is promoting their project but has an NSR below or near the cutoff of other similar deposits it is likely that this project requires a considerable sustainable increase in commodity prices. Table 21 summarizes the cutoff NSR's used by some of the mines above. A new project would likely want an overall NSR at least 100% above the cutoff in order to cover the cost of mine construction, sustaining capital and other costs such as finance as well as to reward the long suffering owners (shareholders).

Table 21 Cutoff NSR's for Selected Mines

Mine	Reserve Cutoff Net Smelter Return or Ore Grade
Rosebery	A\$179/t
Golden Grove Zinc	A\$145/t
Dugald River	A\$134/t
Cannington	A\$120/t
Century	Zn% + 1.19 x Pb% > 4.5
Hera	A\$170/t

MMG mine NSR's also include an allocation for royalties.

To give you some indication of what this means from a grade perspective, the Cannington cut-off NSR of \$A120/t ore equates to an ore grade of 1.67% Zn, 1.36% Pb and 39 g/t Ag under their particular set of milling grades and recoveries, commodity pricing and exchange rate assumptions. So applying the 100% rule of thumb listed above suggests that grades of 6% Zn+Pb and 80 g/t Ag are likely the minimum grades possible for the development of a similar greenfield situation under these circumstances. I myself, would sleep better at night knowing my (underground) project was at least 10% Zn+Pb with some healthy silver credits. Obviously, having some payable copper and gold along for the ride greatly helps matters. This is a very crude way of looking at matters but at least it helps you focus on the better prospects. Below is how Rosebery determines the cutoff NSR annually for their reserve statements.

Cost Categories	YTD Cost June 2013 (A\$ M\$)
Total Mining Cash Costs	\$50.8
Mine Technical Services (excl. Geology)	\$1.6
Mine Technical Services - Geology	\$1.0
Asset Management - Mine Maintenance	\$8.9
Mining Costs Deferred (Capital Mine Development)	-\$14.8
Total Mining Costs (with Capital Mining Costs excluded)	\$ 47.6
Total Mill Operating Costs	\$ 9.5
Asset Management - Mill Maintenance	\$ 6.6
Total Mill Costs	\$ 16.1
Total Support Costs	\$10.1
Total Site Op. Cash Costs (with Capital Mining Costs excluded)	\$73.8
Ore Tonnes to Surface	419,117
Indicative Break-Even NSRAR \$/t (with Capital Mining Costs excluded)	\$176

Summary of Australian Zinc Production

I have reproduced below my summary of Australian zinc mine output to 2022 assuming recent cutbacks at George Fisher, Lady Loretta and Endeavor are reversed in 2017. I assume McArthur River will remain at reduced production rates. With respect to new production only Stockman and perhaps Woodlawn and Triumph will be developed prior to 2022 but total production would likely not amount to more than 100,000 T zinc in concentrate by that time. I will discuss their prospects in a very brief module next. For those whose money is burning a hole in their pocket, [here](#) is an alternate source for information on some of these prospects. Pretty damn thin gruel on the exploration front due to lack of funding.

	2015	2016	2017	2018	2019	2020	2021	2022
Mt. Isa Mill	478,200	296,835	309,680	425,810	413,170	413,170	413,170	382,360
McArthur River	272,700	185,250	195,000	195,000	195,000	195,000	195,000	195,000
Century	392,667	16,457	-	-	-	-	-	-
Rosebery	92,104	78,750	74,813	70,875	66,938	63,000	63,000	59,063
Golden Grove	55,131	39,160	39,160	39,160	39,160	39,160	-	-
Dugald River	-	-	-	42,000	125,568	167,424	172,656	177,888
Cannington	83,870	94,113	91,151	99,891	102,185	95,985	89,186	80,367
Endeavor	40,000	11,340	22,680	39,690	39,690	-	-	-
Rasp	34,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000
Perilya	50,000	38,000	35,000	35,000	35,000	35,000	35,000	35,000
Jaguar/Bentley	42,000	37,410	31,320	26,100	18,270	-	-	-
Hera	7,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Total	1,547,672	840,315	841,804	1,016,526	1,077,981	1,051,739	1,011,012	972,678

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