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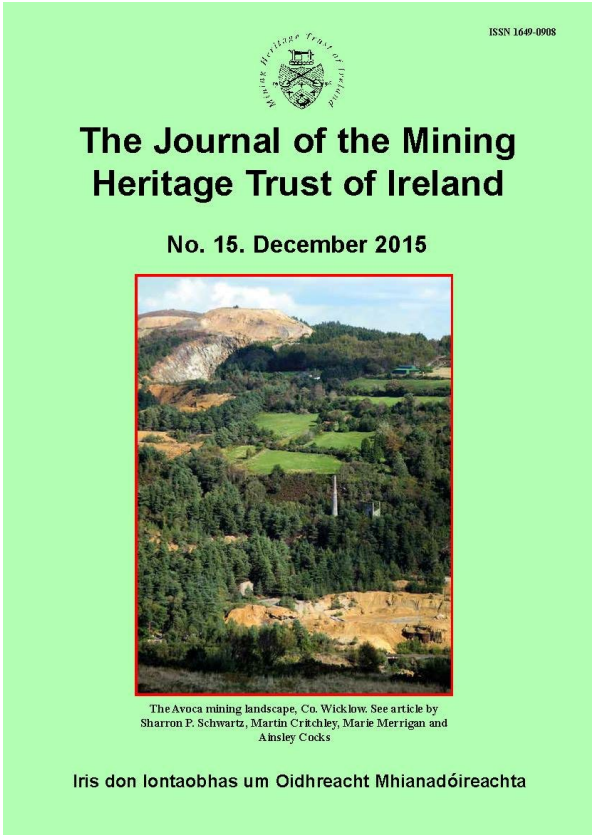


THE LISHEEN MINE CO. TIPPERARY: PLANNING A WORLD CLASS CLOSURE

Brendan Morris

Abstract: Production at the Lisheen Mine, situated in the heart of the Irish Midlands, ceased in December 2015 after 16 years of production due to depletion of ore reserves. The closure process, which will take several years, was planned well in advance and proper provisions were put in place to ensure that the mine, surface infrastructure and the environment is properly managed and in compliance with statutory and regulatory requirements well into the future. This descriptive paper outlines the closure process and provides a visual record of the rehabilitation of the tailings management facility.
Journal of the Mining Heritage Trust of Ireland **15***,* 2015, 93-103.

LOCATION AND DISCOVERY

Lisheen, located near Thurles in County Tipperary, is a mining/mineral processing company wholly owned by Vedanta Limited, a company that is a London Stock Exchange listed, globally diversified natural resources major, with interests in Zinc, Lead, Silver, Copper, Iron Ore, Aluminium, Power and Oil and Gas. Vedanta has mining operations in India, Africa, Australia and Ireland, with a strong organic growth pipeline of projects. Vedanta is committed to international standards for safety and sustainable development and works with stakeholders and local communities.

Lisheen Mine consisted of two distinct operating companies. The mining entity extracted zinc and lead ore from underground and the crushed ore from the mine was brought to surface via conveyor and stored in a surface stockpile ("Tepee"). The milling entity then took the ore and conveyed it via vibrating feeders onto a conveyor, which delivered it directly into the milling plant where it was processed into zinc and lead concentrates and sold to smelters and customers in Europe, North Africa and the USA.

The Lisheen site consists of an underground mine, a concentrator and a Tailings Management Facility (TMF). Mining was carried out at a rate of approximately 1.5Mt of ore per annum at an average grade of 11 % Zinc (Zn) and 2 % Lead (Pb). The concentrator recovered 90 % of the Zn and 70 % of the Pb and produced more than 300 Kt of Zn and 40 Kt of Pb concentrates annually at grades of 53 % Zn and 62 % Pb. The metal concentrate was then transported to the Port of Cork where it was shipped to smelters around the world. At peak capacity, Lisheen employed 374 people plus 26 permanent contractors and 65 % of the employees belonged to trade unions (SIPTU 50 % and TEEU 15 %).

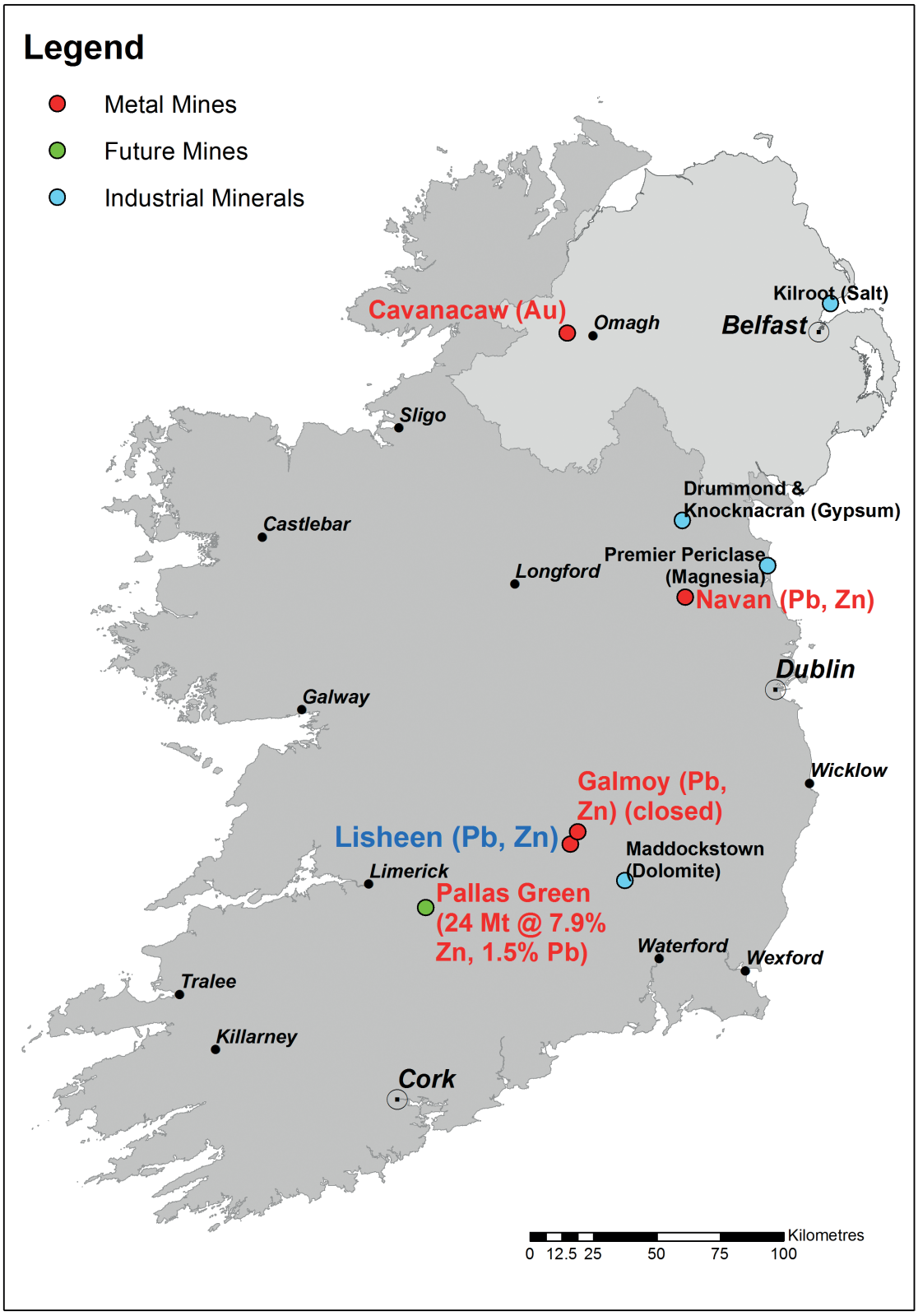
A backfill programme was completed following closure to complete the mining cycle and to minimise the potential of surface subsidence in the future. A fully funded 'mine closure' programme was put in place and will continue for several years into the future. The Lisheen management team and Vedanta are intent on ensuring that the mine closure is carried out to a world class standard.

Lisheen was one of the largest power consumers in Ireland, predominantly due to the large volumes of underground dewatering and the requirement to mill the ore material so finely. Up to 100 million litres of water per day were pumped from the mine to enable it to operate. The water was released into the local rivers under strict environmental conditions.

Lisheen is accredited with ISO 14001 (environmental systems - NSAI), OHSAS 18001 (occupational health and safety systems - NSAI) and with Excellence Through People (NSAI), where it holds a Gold Standard accreditation. Lisheen continues to operate under an Integrated Pollution Control Licence (IPCL) from the Environmental Protection Agency (EPA), which sets limits on discharges of noise, vibration, air emissions, water discharges, etc.

In 1984, Chevron commenced exploration in Ireland and two years later the Galmoy orebody was discovered. In 1987, Chevron started prospecting around the general area and in 1990 signed a joint venture (JV) agreement with Ivernia West. Over the next few years, two massive sulphide zones were intersected and drilled at the current Lisheen site, and in 1993 Anglo American, a multi-national mining company, took over Chevron's JV share.

A decision was then made to carry out an Environmental Impact Statement, and following approval, construction started in 1997 on the Lisheen mine site. Production commenced in 1998, but soon after, a major delay was encountered when the decline intersected a major water feature at a distance of 500m from surface. This was to hold up progress by almost a year. In 2003 Anglo American bought



Map 1: Irish metal mines and those worked for industrial minerals, showing the location of Lisheen in the Irish Midlands

out the Ivernia share-hold and the mine continued in production until 2010, when Anglo American sold Lisheen to Vedanta for US$308m. Vedanta also purchased other Anglo American zinc assets, including the Black Mountain mine in South Africa, the Skorpion mine in Namibia, and a large zinc prospect at Gamsberg in South Africa. At that stage the Lisheen mine was due to close in 2013, but with the full support of the new owners, Lisheen was able to extend the life of mine to the end of 2015.

GEOLOGY

More than 90 % of the orebody was extracted during the life of the mine. The Lisheen orebodies occur in a NE-SW

Fig. 1: The Lisheen Mine site, July 2010

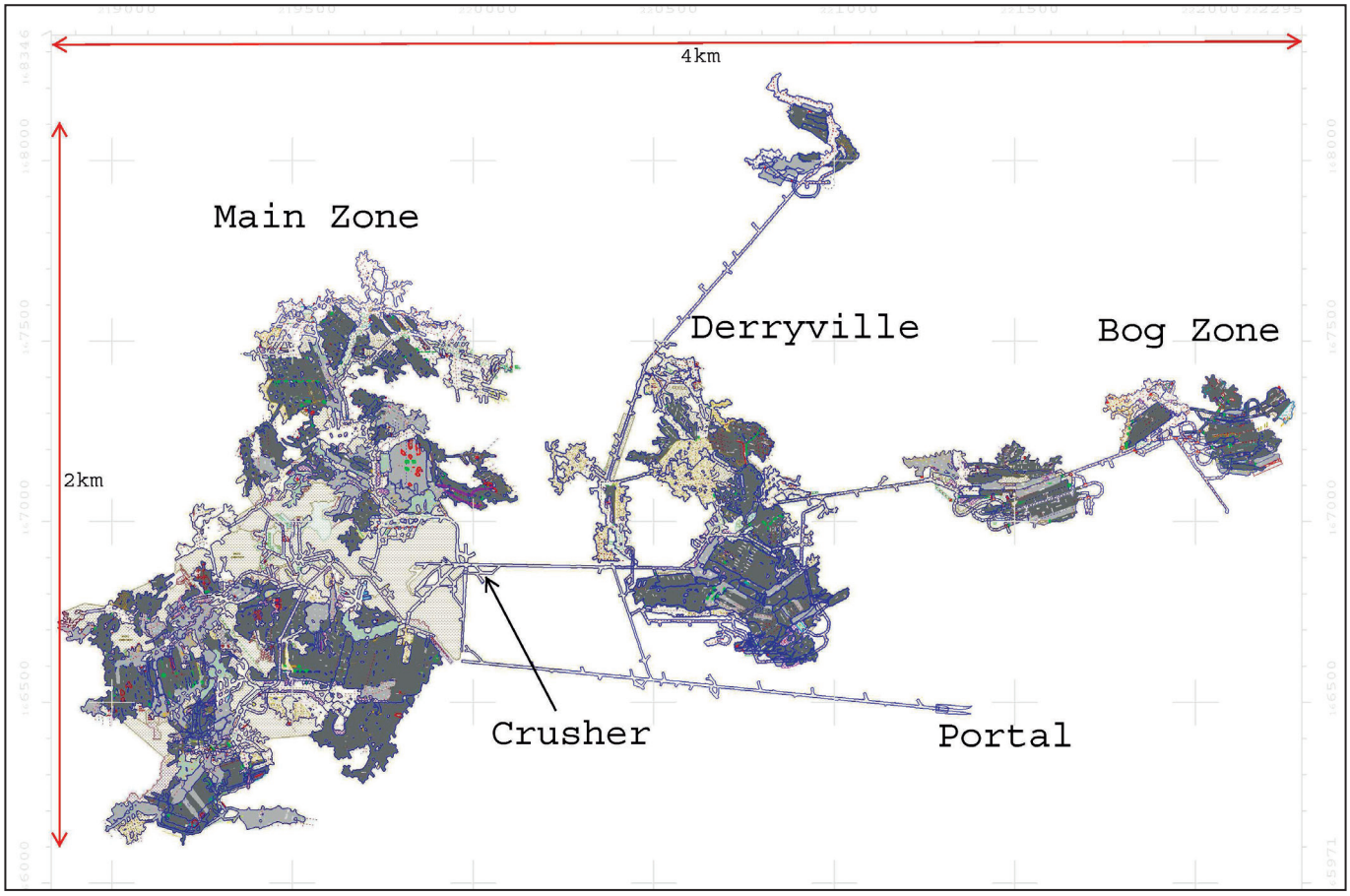


Fig. 2: Plan view of the mine

trending belt of Carboniferous aged carbonate rocks, commonly termed the Rathdowney trend. The ore is largely hosted within fault associated hydrothermal breccias, known as the Black Matrix Breccia (BMB), which is developed at, or proximal to, the base of a massive, fine grained dolomitised limestone unit, termed the Waulsortian Formation. This unit is underlain by the Argillaceous Bioclastic Limestone (ABL), a dark shaly limestone which forms the lithological footwall to the mineralisation. Minor mineralisation may also be present in the ABL, usually associated with normal faulting developed at the ABL-Waulsortian contact.

Complex geometry and grade variability required close-spaced drilling, combined with significant grade control and mine geology effort, to define the orebody adequately to a level suitable for productive mining.

SAFETY AND ENVIRONMENT

Lisheen had a comprehensive Safety Health and Environmental (SHE) policy in place. All major operational activities were controlled by procedures, which were continuously reviewed and briefed out to workers, supervisors and other stakeholders on a regular basis. Workers continually underwent training and reviews of the safety related systems.

Since the initial start-up of the mine, Lisheen was on a continuous journey of safety improvement towards Zero Harm, with many initiatives, standards, training courses and other factors put in place. The core principle of safety was based around high quality risk assessment and risk management, and ensuring that adequate layers of control were put in place.

MINING PROCESS

Ore was produced from the development cycle (tunnelling within the orebody) and the production cycle (massive ore mining) within the mine. The ore was drilled using a variety of large drilling machines and then blasted using an ammonium nitrate based emulsion explosive combined with non-electric detonators. Using Load-Haul-Dump (LHD) machines, the ore was then loaded onto 40 and 50 tonne trucks for transportation to the underground crusher, where it was crushed to <150mm and transported to the surface storage tepee via a conveyor system. The tepee held a live storage capacity of approximately 15,000 tonnes, with a series of feed chutes located at its base; this live storage enabled the concentrator to operate on a continuous basis. The mine produced between 1.35 and 1.5 million tonnes of ore per year with an average grade of 11 % Zinc (Zn) and 2 % Lead (Pb). The mine operated on a two shift basis, six days per week.

Mining Methods

Lisheen has utilised three different mining methods throughout the mining cycle. Room and Pillar mining was carried out in areas where the ore was less than 5 metres thick and where the local geometry was complex. This method provided flexibility as mining, geological and geotechnical conditions changed. Rooms were cut between parallel drifts leaving pillars in place. On retreat, the pillars were extracted resulting in a high extraction ratio. Any waste areas were left in place and the ore mined from around them.

Drift and Fill mining was used in areas where the ore was 5-15m and when the orebody complexity was low. Drifts were driven along the hanging wall, the roof was supported, and then the lower bench mined on the second pass.

Longhole Open Stope mining was carried out where the ore was greater than 10 metres, and up to 30 metres. Open stoping has predominantly been from an uphole retreat style of mining from a single footwall drive. Several stopes with hanging wall and footwall access have also been mined successfully. The upper and lower accesses were required in stopes where the orebody was too thick for uphole retreat mining with the mobile equipment fleet (greater than 30m), or where the hanging wall of the orebody was anticipated to be poor.

Ventilation

The Lisheen mine is located at an average depth of 170m with no major geothermal gradient. Ventilating air was delivered using a negative pressure system, whereby fans were located at the exhaust raises. All fans were located underground in order to reduce noise, as part of the Integrated Pollution Control Licence. Air was supplied to, and returned from, the

Fig. 3: Load Haul Dump machine in operation on remote control

underground workings via eight ventilation shafts which were connected to surface, and also via the main decline from surface. Four of the shafts were used for exhausting return air to surface, and five of the shafts and the main decline were used to draw fresh air into the working areas. The mine utilised four major underground fans to achieve the required ventilation levels, with a total power requirement of 860kW, with the fans ranging in size from 2.5 m to 3 m in diameter. The mine had a volumetric air throughput of approximately 500 m3/s, distributed between 4 major mining zones: Main Zone, Main Zone North, Derryville, and the Bog Zone.

Backfill

A system of backfill was used at Lisheen to fill voids which were made as a result of the extraction of ore from mining areas. Backfill was also used to provide the necessary strength fill material to facilitate extraction of secondary and tertiary mining areas. Backfill also provided support to the overlying strata in order to prevent surface subsidence.

When a section was mined, the area was sealed and backfill pumped in a liquid state to fill the void. Backfill at Lisheen was made from the tailings (finely crushed rock with the economical metal removed), which was produced at the concentrator. The tailings was then mixed with a binder, Ground Granulated Blasting Slag and Ordinary Portland Cement. The backfill then hardened over a period of 28 days to a strength of approximately 500kPa, and at this stage the adjacent secondary or tertiary mining areas were available for mining. The concentrator produced more than 1Mt of tailings per annum and approximately 43 % of the tailings material from the concentrator was pumped underground as backfill.

Water

Lisheen Mine produced between 60-100 million litres of water per day depending on rainfall conditions in the preceding months. The water comes from natural aquifers in the region and entered the mine through a series geological fractures and faults. On entry to the mine, the water was classified as ‘clean’ or ‘dirty’ and pumped through separate systems to the surface. ‘Dirty’ water was that which had come into contact with mineralised rock and was likely to contain metal contaminants and suspended solids. The ‘dirty’ water was pumped to a treatment plant on the surface where it was cleaned and then mixed with the ‘clean’ water before being discharged into local rivers. Water discharge was carried out under very strict environmental conditions which are covered in the Integrated Pollution Control Licence, issued by the Environmental Protection Agency.

Geotechnical

The experience gained in managing the ground conditions at Lisheen over the 16 years of production gave a progressively good understanding of the ground behavior, and the development of support techniques and methodologies; as a result, geotechnical and mining personnel were able manage the poor ground conditions.

The ore body at a depth of between 70 and 230 m is extensively faulted, with deep karstic weathering causing degradation of the strong limestone into sand and clays, and eroding sections of the massive sulphide ore body. The occurrence of major water inflows along the faulting at times created hazards such as pressure build up in sand filled features, and the removal of cohesion from the intensely jointed rock mass.

Fig. 4: Backfill Plant

The use of paste backfill and shotcrete to stabilise sidewalls, and long bulbed cable bolts to pre-support the roofs, facilitated large spans allowed for longhole open stopes and aggressive pillar mining. Critical stope assessments incorporating modified stability graph techniques, span management, blasting control and strategic paste fill placement with robust risk evaluations, has resulted in large stopes in extremely poor ground being successfully mined.

In extremely poor ground, shotcrete arches and spiling bars were used during the development process. In some cases, this method was not sufficient to consolidate the ground, and the use of spiling bars followed by pressure grouting allowed both the consolidation and reinforcement of ground ahead of the face. This support technique combined with good blasting design, allowed the mine to access areas that previously were considered unmineable.

Mobile Plant and Maintenance

The fleet of mobile equipment which was used to operate

underground is shown in the table 1. Most of the maintenance work on underground equipment was carried out in a modern underground workshop where maintenance personnel worked on both an extensive planned maintenance programme and unplanned breakdowns. The fleet of mining equipment included the following units;

Equipment	No.	Make
Drill Rigs	4	Atlas Copco – twin boomed jumbo
	3	Tamrock/Atlas Copco – long hole rig
Load haul dump units	9	Tamrock (6m3), remote controlled (6)
Dump trucks	10	Tamrock (40t & 50t capacity)
Roof bolters	3	Atlas Copco
Mechanical scalers	3	Jama
Shotcrete	1	1 Active & 1 backup (Normet)
Cable Bolters	1	Tamrock

Table 1: Equipment in use at the Lisheen Mine

Mines Rescue Team

A mines rescue team consisting of 16 highly trained employees were available in the event of an emergency. The team carried out emergency drills, competed in international competitions and had a mutual assistance arrangement with Tara mine for emergency situations and with the Air Corps for transportation in the event of an emergency.

MILLING PROCESS

The mining process ended with the delivery of ore to the surface stockpile. The milling process then commenced with the concentrator plant receiving the crushed ore from the tepee storage where it was fed into the concentrator mill, and was processed into zinc and lead concentrate on a 24 hour per day basis. The crushed ore was ground to 80 % passing 75 micron in a semi-autogenous mill (SAG) and a ball mill. The ore was then mixed with reagents and passed through a lead flotation circuit, followed by a zinc flotation circuit. In each circuit, the specific reagents cause the lead and zinc minerals to float. The floated product was then skimmed from the top, thickened and filtered, with the resultant concentrate fed to a storage outlet. The concentrate was then transported to the Port of Cork where it was loaded onto ships and sold to smelters across the globe. The resultant waste product from the process was pumped to a Tailings Management Facility (TMF), where it is now stored in an environmentally secure entity.

ENVIRONMENTAL MANAGEMENT

Lisheen remains highly regulated by the Integrated Pollution Control Licence which was issued by the Environmental Protection Agency (EPA). The key environmental aspects are:

- Water discharges offsite
- Tailings management
- Mine closure
- Dust
- Noise
- Blast vibration

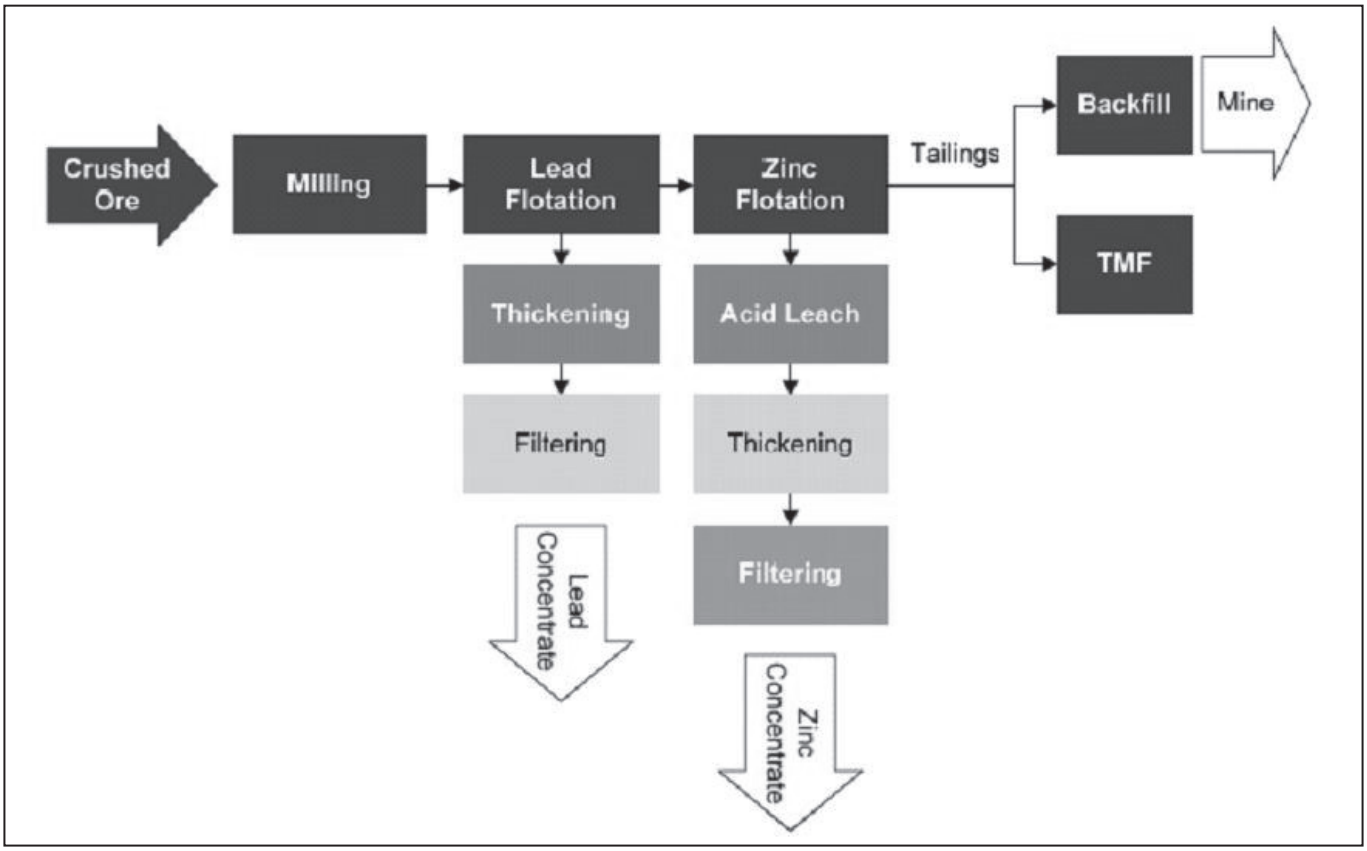


Fig. 5: Concentrator Processing Circuit

A self-contained environmental laboratory remains on site to manage all of the key testing requirements. A compliance level of >99 % has been achieved during mining operations for all conditions of IPCL.

Regular meetings are held with the EPA, the Department of Communications, Energy and Natural Resources, local County Councils, and other key stakeholders, to ensure that all parties are aligned on the environmental process and progress towards closure.

Windfarm

Lisheen facilitated the planning and development of a windfarm on the site with generation of power from 18 turbines, with a total capacity of 36MW, starting in 2009. The windfarm is owned and maintained by a third party, and the energy is fed directly to the national grid through a sub-station located on site.

VEDANTA EXPLORATION

Vedanta Exploration Ireland Limited (VEIL) was established in July 2014 and currently has 3 full-time employees and 5 part-time/temporary employees, based at Lisheen Mine. VEIL is currently exploring on 30 prospecting licence areas in the Irish Midlands for carbonate hosted lead and zinc. The company has drilled more than 17,000 m to date, and is intent on building a licence portfolio through applications and JV's. The dominant position for drilling is on the Rathdowney Trend which hosts the Galmoy and Lisheen ore bodies.

Community Engagement

Lisheen has engaged in regular sponsorship of the local community's events and projects since 2008, with excess of €1.5 million spent on local community projects;

- Moyne Templetuohy GAA Stadium
- Moyne Indoor Athletics track
- Upgrade of Moyne hall
- Hurling Wall in Thurles
- Playground in Thurles
- Many other small projects

Over the past few years, Lisheen has held an Annual Safety EXPO over a two day period at the mine site, where local community and employee families are invited. Up to 1,700 people have attended on a single day.

A Community Engagement Programme was formalised in 2007, and there have been very positive interactions and good relations since its inception. This group continues to meet regularly with members of the Lisheen management team to discuss and agree progress with site closure and rehabilitation. Any major changes to the closure plan are agreed with the group in advance.

Employment at the mine provided more than €30 million per annum to the region, and financial contributions to the Government and County Councils through royalties amounted to more than €6.5 million per annum.

People and Closure

A significant redundancy package was put in place in 2010, when Vedanta acquired Lisheen from Anglo American. Redundancies started in 2014 and continued throughout 2015 and into 2016 on a phased basis.

An 'Outplacement Programme' was put in place for all employees, part of which has been run in conjunction with SIPTU, one of the workers unions. The programme included:

- Training grant to all employees, to improve their skill levels prior to closure
- CV preparation and interview skills for all Lisheen personnel and onsite contractors
- Start your own business courses
- Train the Trainer courses
- Basic IT skills courses

There was significant interest in all of the programmes by the employees of Lisheen.

End of Production – Mine and Mill

The last day of production from the mine was on 11 December 2015 when the final tonnes were sent to surface on the conveyor belt. Following the completion of backfilling from underground locations and the stripping of assets, the water pumps were turned off on 30 December, allowing the mine to re-water in line with a detailed hydrogeology model which is a part of the closure plan. Monitoring wells are in place to assess the re-watering rates and chemistry of the water at the mine site.

Some backfilling of mining workings from surface locations was carried out in January 2016. The mill ceased production on the 23 December 2015 and the final shipment of zinc ore from Lisheen to the Port of Cork was carried out on 4 January 2016.

Closure Initiatives

A Task Force was put in place with the intention of finding alternative solutions for the site post-closure. The Task Force includes members from the mine management team and semi-state bodies and former government minister Liz O'Donnell. The Lisheen site is being promoted as a Bio Energy Hub, and there are currently confidential agreements in place with a number of companies who intend to establish business entities on the site. The Lisheen application to the European Union (EU) to become a Model Demonstrator Site, has recently been approved and this may provide an incentive to companies within the energy business to consider the site for new business ventures. Any agreement on the future use of the site will include input from the local community.

A new independent company, Lisheen Technical and Mining Services - LTMS Limited, has been established by a small number of Lisheen mining personnel, offering technical consultancy and mining contracting services to both Vedanta

Fig. 6: Lisheen Mine prior to rehabilitation. Note the tepee centre left and large tailings management facility in normal use which the company has planned to rehabilitate in line with strict environmental controls after closure

and other international mining operations. LTMS are at the advanced stages of negotiation for a two year contract for high speed mine development which includes a mining contracting team of 30 ex-Lisheen personnel at Vedanta's Sindesar Khurd mine in Rajesthan, India. Additional contracts for technical assistance and training are being discussed.

An asset disposal team was put in place early in 2015 to ensure that all assets from the site are accounted for, managed properly, and either sold or disposed of in a responsible manner. All assets that were required to be removed from the mine have been taken out prior to the mine being allowed to re-water. The mill and associated buildings have been sold and will be dismantled and re-located to a newly constructed mine.

Site Closure and Rehabilitation

A Lisheen Mine Closure and Aftercare Management Plan has been in place for a number of years with a fund of €25M to ensure that closure is completed responsibly and in line with best practice. A further €3M is set aside for after-care for a 30 year period. The mine access and ventilation shafts will be plugged in early 2016 to an agreed standard.

The original plan for the full site if no other use is found, was for the wind farm to be retained on the site post closure, and all other surface buildings to be demolished. This may now change based on the new site status and the potential for use as a Bio Energy Hub.

A major part of site closure and rehabilitation is the Tailings Management Facility (TMF). A phased process of closure was started in 2011 when a part of the TMF was rehabilitated by covering the tailings surface with a geotextile layer, followed by capping with rock and topsoil and then grassing. Cattle were reared on the rehabilitated TMF under a strict testing regime to ensure that there was no contamination from the tailings material. The TMF rehabilitation has undergone several phases, with the final phase expected to be completed in 2016. Further environmental testing will continue for several years to ensure that the highest standard is maintained.

Both the Vedanta and Lisheen management teams are fully committed to closing the Lisheen operation to a world class standard utilising the 'best practice' available in the safest, most environmentally responsible manner possible. The whole closure process at Lisheen has, and continues to be, carried out to the very highest standard, and involves significant input from Lisheen management, Vedanta Limited, the local community, government departments, local county councils and the EPA.

Lisheen would like to thank all of the stakeholders who have supported the mine from start-up to closure and particularly Vedanta, who have been fully supportive of the many new initiatives since acquisition of the mine in 2010.

Fig. 7: First phase rehabilitation. Image, Peter Barrow 2010

Fig. 8: Second phase rehabilitation. Image, Peter Barrow 2015

Fig. 9: Third phase rehabilitation

Fig. 10: Fourth phase rehabilitation

Fig. 11: Original Plan for Post Closure Site Rehabilitation