ABSTRACT

The Kimberley region of northern Western Australia presently supports two diamond, one nickel, and one lead/zinc mine. Lennard Shelf Pty Ltd, a joint venture partnership between Teck Cominco and Xstrata Plc, own and operate the Lennard Shelf lead and zinc mining, concentrating and exporting operations in the West Kimberley. The operations, when purchased by Teck Cominco in November 2003, comprised two operating underground mines (Pillara and Kapok), two decommissioned underground mines (Cadjebut and Goongewa), one operating concentrating mill at Pillara, one decommissioned concentrating mill at Cadjebut, a shipping export facility at Derby and approximately 2100 square kilometres of mining and exploration tenements across the West Kimberley. Since November 2003 Lennard Shelf has decommissioned the third mine (Kapok), reclaimed the three decommissioned mine sites plus the Cadjebut concentrating mill and is now planning for closure and reclamation of the remaining Pillara mine, concentrating mill and Derby Export Facility in 2009. The reclamation of these mines and tailings storage facility has been the first of their kind and unique in the Kimberley region of Western Australia.

INTRODUCTION

The Lennard Shelf is the geological name for the Devonian carbonate reef formation running north-west to south east along the northern margin of the Canning Basin in the Western and Central Kimberley of northern Western Australia. Several Mississippi Valley Type deposits of Pb and Zn were identified in the carbonate Pillara and Emanuel Ranges of the Lennard Shelf during the 1970s to 1990s. A joint venture between then BHP Minerals Ltd and Billiton Australia saw the deposits defined and in 1988 an underground mine and a concentrating mill commissioned at the Cadjebut site approximately 80km south east of Fitzroy Crossing. In 1994 the Lennard Shelf operations were purchased by a junior mining company; Western Metals Ltd. Western Metals continued mining the Cadjebut deposit and over the following three years developed the satellite Goongewa and Kapok underground mines to feed the Cadjebut mill. Mining at Cadjebut ended in 1997, feed to the mill continued from the Goongewa and Kapok mines until 2001 when the Cadjebut mill was decommissioned. In 1998 Western Metals Ltd commissioned the Pillara underground mine and mill approximately fifty kilometers north-west of Cadjebut. Mining at Goongewa also ceased in 2001; the remaining ore mined at Kapok was transported and processed at the Pillara mill approximately 80 km to the north-west. Please see Figure 1.
Western Metals Ltd went into voluntary administration and then receivership in July 2003. The Lennard Shelf operations were bought by Teck Cominco (Western Australia) Pty Ltd in November 2003 and placed on care and maintenance. In January 2004 Teck Cominco WA Pty Ltd formed a joint venture with Noranda Incorporated. Noranda Inc was subsequently acquired by Falconbridge in March 2005; Falconbridge Ltd was subsequently acquired by Xstrata Plc in mid 2006.
The Kimberley region of Western Australia has a tropical climate, the year being divided into two seasons, the dry season (May to November) and the wet season (November to May). Average temperatures in the dry season range from 15\(^\circ\)C to 30\(^\circ\)C, average temperatures in the wet season range from 25\(^\circ\)C to 40\(^\circ\)C with daily maximums during November in the mid forties. The Lennard Shelf receives an average of approximately 550mm of rain annually, the bulk of which falls during the wet season months of February, March and April. Average annual evaporation is 3.2 metres.

Pillara is located between the towns of Fitzroy Crossing (40km to the north-west) and Hall’s Creek (240km to the south-east); these towns have populations of approximately 1400 and 1300 people respectively and are comprised 80 percent of Indigenous Australians (Aborigines). The Kimberley is widely used for pastoral cattle grazing, mineral and petroleum exploration and production and tourism. The major towns are Broome 450km west (population 14,000) Derby 250km north-west (population 3,400) and Kununurra 830km north-east (population 5000). The Lennard Shelf Pillara workforce is comprised of approximately twelve percent aboriginal employees from local communities and towns, sixty five percent fly in-fly out from Perth and the remainder fly in-fly out from Broome, Derby, Kununurra and interstate.

**INTEGRATED LAND USE**

The majority of the Lennard Shelf exploration and mining tenements coexist on ground covered by pastoral leases (Bauhinia Downs, Christmas Creek, GoGo, Brooking Springs, Fossil Downs and Napier Downs) and various pending Native Title claims.

**Pastoral Land Use**

Pillara is located on the 400,000 hectare GoGo pastoral lease (station). The GoGo station boundary also encompasses seven Aboriginal communities and three schools. The GoGo station runs approximately 30,000 head of beef cattle which are exported through the port of Broome. The workforce on GoGo varies in size from approximately four people in the wet season to over twenty in the dry season when most of the stock work including mustering, branding and drafting (separating breeding cattle from sale cattle, yearlings from mothers etc) is performed. The workforce is partly sourced locally however the majority are employed from interstate and overseas (primarily New Zealand). Pastoral lease holders pay an annual fee to the state government, administered by the Pastoral Lands Board of Western Australia. All pastoral leases in Western Australia are due to expire in 2015.

Although the GoGo station is operated independently of the Lennard Shelf operations a positive relationship between the two is well maintained. No compensation is paid between the two enterprises. The benefits gained by having a mining operation on the GoGo station appear to balance out the 252 hectares lost by GoGo to the mining operations. Benefits include:

- Approximately 14km of sealed roads from the adjacent main highway enables all year access to pastoral grounds otherwise restricted in the wet season
- Surplus mine dewatering water (approximately 80 litres per second) is discharged to a natural drainage channel providing stock with water.
- New water sources are identified by exploration drilling.
• Earth moving equipment is available if needed.
• Mechanical assistance is available if needed.
• Bush fire fighting assistance is on hand when needed.

The benefits to the mining operations from the positive relationship with the GoGo station includes:
• Assistance with water supplies for exploration drilling.
• Bush fire fighting assistance when needed.
• Access to station equipment when needed.

The GoGo station is investigating using the mine dewatering discharge water for cattle feed irrigation; this is covered later in the section, ‘Future Reclamation & Integrated Land Use’.

Indigenous Land Use

Indigenous land use in the Kimberley region of Western Australia is primarily that of occupancy, hunting and ceremonial. Several indigenous enterprises including tourism operations and art production are also facilitated on indigenous lands.

Ninety eight percent of Western Australia is currently subject to Native Title claims of various types. The majority of the Lennard Shelf Pty Ltd mining and exploration tenements were issued prior to the establishment of the Native Title Act 1993. Only new tenements applied for after 1993 are subject to Native Title claims. So far, due to the complexity and cost associated with the native title determination process very few of the 504 (Australia wide) native title claims have been determined and granted, of these, nine are in the Kimberley.

The Lennard Shelf mining operations are all situated on land recognized as being traditionally owned by the Gooniyandi aboriginal group. Traditional Gooniyandi lands cover approximately 12,000km2 to the east of Fitzroy Crossing and the Fitzroy River. The Gooniyandi group is one of approximately two hundred recognized indigenous language groups in Australia. Although no compensation payment is legally required to be made by the exploration or mining tenement holder a ‘Regional Agreement’ was developed between the Gooniyandi people and Western Metals Ltd in 2002 regarding access to and exploration on Gooniyandi land and to establish a heritage protection protocol. This agreement was transferred to Teck Cominco WA Pty Ltd upon purchase of the Lennard Shelf assets. This agreement states the conditions and procedures for Teck Cominco WA Pty Ltd’s (now Lennard Shelf Pty Ltd) exploration access to Gooniyandi land and requires an annual payment to the Gooniyandi based on exploration activity and tenement area held.

RECLAMATION

Following the purchase of the Lennard Shelf assets from the receivers of Western Metals Ltd. in November 2003, Teck Cominco WA Pty Ltd placed all operations on care and maintenance. A care and maintenance crew was retained at Pillara to maintain underground mine dewatering pumps and power station until July 2006 when mining resumed at Pillara. During this time reclamation of the Cadjebut, Kapok and Goongewa sites was undertaken.
Reclamation at Cadjebut
The Cadjebut site covered 91 hectares and included a one million tonnes per annum floatation concentrator mill, a 54 hectare tailings storage facility (TSF), underground mine, workshops, power station, offices and a two hundred person camp. The concentrator mill, associated workshops and camp buildings were sold and removed by the purchaser between June and October 2004. Reclamation of the site began in September 2004. Please see Figure 2.

Geochemical studies and TSF cover design reports were produced between 1992 and 2003 for the Cadjebut operations. Following discussions between Teck Cominco WA Pty Ltd and the Western Australian state government Department of Industry and Resources (DoIR), environmental consultants MBS Environmental were engaged in 2004 to undertake further geochemical analysis and to substantiate the previous reclamation studies for the Cadjebut site and TSF. The reclamation was to achieve the following outcomes;

- Create a physically stable, free draining non erosive landform.
- Cover the tailings surface to permanently contain all tailings.
- Vegetate the covered surfaces with self sustaining, low palatability local vegetation.
The Cadjebut TSF was a conventional perimeter discharge paddock type consisting of two cells with central causeway and decant ponds for process water recovery. The perimeter embankments had been raised by upstream lifts to a final maximum height of eleven metres.

The Cadjebut, Kapok and Goongewa ores processed in the Cadjebut mill were all limestone hosted galena and sphalerite sulphide deposits. Tailings density when discharged was approximately 40% solids; discharge was by means of perimeter spigots. The tailings particle sizes varied from less than 40 microns to 2.0mm. Representative samples were collected at 36 sites (sample sites CT1 to CT36) at varying depths to 1.5 metres across the TSF surface, the samples were analyzed for alkaline metals, alkaline earths and possible pollutant metals. Results showed the tailings to be predominantly non acid producing (NAP) and were becoming non-saline with an almost neutral pH. Tailings in the central decant pond areas were Potentially Acid Forming (PAF) but tests indicated that being surrounded by large volumes of NAP coarser tailings any acid generated would be neutralized. Please see Table 1.

The perimeter discharge of non-thickened tailings with a central decant caused depositional segregation of tailings particle size. The coarser particles (0.25-2.0 mm) deposited first on the outer slopes within the TSF, the finer tailings (less than 80 microns) carried towards the central decant area. To mitigate this segregation, an internal bund was built in 1999 within the north western cell, this achieved a cover of coarse tailings cover closer to the central decant area.

Having established the predominantly NAP properties of the tailings a relatively thin cover over the tailings surface appeared appropriate which would serve as a capillary break and provide a growth medium for cover vegetation. To establish a free draining surface on the reclaimed TSF the lower levels of the central decant areas required filling to prevent ponding; the maximum amount of fill required in the decant ponds was 1.4 metres. The central causeway, constructed of competent gravel, provided an ideal structure in which to construct a storm water discharge drain to the north eastern perimeter. (Rainfall events of up to 326mm overnight have been recorded at Cadjebut). Storm-water draining from the north eastern perimeter is channeled into a natural creek system. The high evaporation rates (3.2m per year) worked to dry the tailings surface sufficiently to enable forty tonne tip trucks and swamp-track bulldozers to travel on the TSF. The filled surface of the TSF was covered with a 200mm thick layer of calcareous stony sub soil from adjacent gravel pits. This layer was then covered with a 50mm layer of gravelly topsoil removed from the site prior to the construction of the TSF in 1987 and 1992 and placed in stockpiles around the perimeter. Stock piled topsoil provided thirty percent of the topsoil required, the remainder was ‘harvested’ from nearby suitable areas. Topsoil harvesting involved removing and stock piling the surface vegetation then removing the surface 200mm of soil material. The topsoil harvested areas were later ripped and the remnants of the original vegetation re-spread to promote re-growth. No additional seed or seedlings were imported to the area to augment the vegetation growth, no fertilizer was used. The seed bank in the stockpiled topsoil proved to be still viable after up to seventeen years. Subsequent fauna surveys in 2007 of both the topsoil harvested areas and the reclaimed TSF show:

- that the percentage cover on the reclaimed TSF and topsoil harvest areas is approximately 70% compared to undisturbed control quadrats,
- species numbers compare well to the control quadrats,
- low numbers of weeds were present
all native species present were of local provenance.

Table 1: Potential for Acid Generation Sample Data

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<th>Sample No.</th>
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<th>Fe</th>
<th>Pb</th>
<th>Zn</th>
<th>As</th>
<th>EC</th>
<th>TDS</th>
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<th>MPA kg</th>
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</table>

The reclamation of the TSF started in late 2004 and was completed in mid 2006.

Following the removal of the concentrating mill, workshops and associated mine infrastructure in 2004, reclamation of the mine/mill site commenced. This required; sealing of the portal and box-cut, removal of concrete foundations and pads, removal of potentially contaminated hardstand and Run of Mine pad, disposal of mill scats, closure of an industrial tip, closure and filling of dewatering sedimentation ponds, contouring and ripping of the final land form. All non contaminated concrete and hardstand was used to seal the mine portal, contaminated concrete, hardstand and mill scats were used as fill in the TSF central
decant ponds. All other non-hazardous waste was placed in the industrial land fill within the TSF, compacted, covered with tailings followed by a 200mm layer of sub soil and 50mm layer of topsoil. Due to the monsoonal wet season rains reclamation works were suspended in December 2004 and 2005 and resumed in April 2005 and 2006.

Reclamation at Goongewa
Goongewa, a satellite mine located eighteen kilometres west of Cadjebut was closed in 2001. Remaining at the 27 hectare site in 2004 was the limestone waste rock pile, mine portal and box-cut, sedimentation and de-leading ponds, a 2.4km long mine dewatering discharge channel, two vent rises and various concrete footings and pads.

Goongewa is situated on the margin of a black soil plain characterized by dark cracking clays which set hard and cracked in the dry season and become saturated in the wet season. At approximately three metres depth the soils turn to calcareous rubble and then limestone at approximately ten metres depth.

The initial Goongewa Reclamation Plan involved removing all concrete to seal the mine portal, removing all waste rock limestone hardstand to partly fill the box-cut, reshaping the waste rock pile to form a safe and stable form, filling the sedimentation and de-leading ponds, discharge channel and vent rises. The reshaped waste rock pile and the partly filled box-cut were sheeted with a 100mm layer of topsoil stockpiled prior to the construction of the mine site; these were then contour ripped to anchor the topsoil. The rains of the 2005-06 wet season showed the walls of the part filled box-cut and black soil sheeted waste rock pile to be unacceptably erosive. In 2006 the black soil sheeting was removed from the box-cut and waste rock pile and the box-cut was filled to natural ground level with material from the waste rock pile. The remaining waste rock pile was further reshaped to reduce the batter slopes and a concave water soak formed over the top of the pile. The waste pile and filled box-cut were re-sheeted with black soil cover. Subsequent wet season rainfall has caused negligible erosion.

Reclamation at Kapok
Kapok, a second satellite mine located two kilometres east of Cadjebut was held on care and maintenance until being decommissioned in May 2004. Remaining at the 21 hectare site was a diesel fuelled power station, workshop, waste rock pile, underground crusher and conveyor, three vent rises, rubbish tip and sedimentation ponds. Following decommissioning all infrastructure including workshop, conveyor and crusher were sold and removed by the purchasers. As Kapok is situated on outcropping limestone at the base of the Emanuel Range site reclamation was able to commence mid wet season in February 2006.

The Kapok Reclamation Plan involved filling and covering the sedimentation and de-leading ponds, sealing and filling of the portal and box-cut, sealing of the vent rises, burial of the rubbish tip, reshaping the waste rock pile, removing all hardstand and re-vegetating the site. All concrete footings and slabs were removed and used to seal the mine portal. Any remaining scrap was buried in the land fill at the base of the waste rock pile; the waste rock pile reshaped to cover the land fill and to reduce the batter slopes. All hardstand was removed and used as fill in the box-cut. Due to the rocky nature of the site little topsoil was able to be stripped and stockpiled prior to construction of the mine site. Additional well vegetated topsoil was sourced from an adjacent plain and spread over the site at a thickness of 100mm; this was
then contour ripped to anchor it into the reshaped site. As with Cadjebut and Goongewa, no seed or seedlings were brought onto site, relying on the native seed bank within the harvested topsoil. No fertilizer was applied. Following two wet seasons, some erosion has become evident; the choice of topsoil used to augment the existing stockpiled material now appears to have been less than ideal. Deeper ripping will be trialed in selected sections.

**FUTURE RECLAMATION and INTEGRATED LAND USE**

All currently economically viable ore at Pillara is expected to be depleted by November 2009. Closure and reclamation planning is underway. Lennard Shelf aims to leave behind a positive legacy.

**Integrated Land Use**

The GoGo pastoralists are investigating establishing an irrigated cattle feed growing operation adjacent to the Pillara mine-site. Lennard Shelf is assisting in establishing this enterprise. Cattle in the Kimberley graze on naturally available feed; towards the end of the dry season most feed has either been eaten, is unpalatable or has been lost to fires, resulting in the cattle loosing condition. The supply of imported feed from outside the West Kimberley is unreliable, costly and risks spreading weeds. A significant volume of potable quality ground water is available from a depth of approximately six metres below ground level at Pillara. An average of approximately 120 litres per second of water is abstracted from the Pillara underground operation, a further 30l/s is drawn from the potable water bores; this abstraction rate has lowered the surrounding water table over the past ten years since mining commenced by only five metres. Once mining and de-watering ceases it is expected that the water level in the mine will return to pre-mining levels in less than two years. (Water levels at the 580 m deep Kapok mine returned to pre mining levels, of three metres below ground level, within ten months of dewatering ceasing.)

The GoGo irrigation enterprise aims to:
- establish one hundred and fifty hectares of irrigation for sorghum hay production
- utilize the Pillara TSF storm water surge dam to store wet season rainfall
- build additional storage dams for wet season rainfall
- possibly use the decommissioned Pillara underground mine as additional water storage
- establish timber crops including sandalwood (*Santalum album*)
- develop vegetable production
- establish fish farming in the irrigation water

Success of this enterprise will:
- produce cattle feed to maintain stock in good condition throughout the year
- eliminate the reliance on imported cattle feed from out-side the West Kimberley
- create long term employment and training opportunities for the local community
- reduce Lennard Shelf reclamation costs

Reclamation at Pillara will be planned to accommodate these initiatives. Infrastructure useful to the GoGo Irrigation enterprise may be transferred to the GoGo irrigation enterprise including workshops, storage sheds, water bores, pipelines, power lines and all season bitumen roads. Transfer of such assets from a
mining to a pastoral lease is managed by the Western Australian Pastoral Lands Board and The Department of Industry and Resources.

Reclamation at Pillara
The Pillara site covers 252 hectares including the 162 hectare tailings storage facility, concentrating mill, mine box-cut and portal, ore pad, waste rock pile, explosives facility and magazine, sedimentation and de-leading ponds, workshops, diesel fuelled power station, fuel storage, administration offices and 21 hectare camp. Of the 162 hectares of TSF it is anticipated that twenty two hectares will be retained for the GoGo irrigation enterprise water storage.

The Pillara TSF is a central thickened discharge stack with a maximum outer embankment height of 4.8m. Tailings density target is 65% solids to achieve a 1.5% beaching angle. Tails bleed water is collected in a decant pond and returned to the mill for process water. Evaporation in the dry season commonly reduces the volume of return water to nil. The tailings deposition is low segregating.

Filling of the TSF has been in a clockwise direction starting at the southern extent of the oval shaped facility; this method is intended to enable progressive reclamation whilst the TSF is still in use. Environmental consultants MBS Environmental who co-designed the TSF are now developing the reclamation plan for the TSF and mine site. Tailings samples are currently under geochemical assessment. As with the Cadjebut TSF, reclamation of the Pillara TSF aims to achieve the following:

- Create a physically stable, free draining non erosive landform.
- Cover the tailings surface to permanently contain all tailings.
- Vegetate the covered surfaces with self sustaining, low palatability local vegetation.

Preliminary TSF reclamation planning indicates that all waste rock from the mine waste rock pile, ore pad and hardstand (approximately 350,000m³) will be used to create a 250mm capillary-break cover over the TSF surface; above this will be placed a 200mm sub-soil/gravel layer, covered by approximately 50mm of topsoil suitable for low palatability vegetation establishment. Sub soil/gravel will be sourced from within the TSF storm water storage dam effectively increasing the storage capacity for future use by the GoGo irrigation enterprise. Additional gravel material may be sourced from the construction of a stormwater diversion channel by the GoGo irrigation enterprise. Topsoil was stripped from within the TSF footprint at the time of construction and stockpiled around the TSF perimeter; this volume will need to be supplemented by topsoil harvested from within the storm water storage dam area. It is anticipated that reclamation earthworks at Pillara will take two years.

CONCLUSION

Three main challenges faced the Lennard Shelf reclamation; the remote location, the climate and being the first. Being over 2500km from the Western Australian capital, Perth, where machinery, personnel and supplies were sourced caused significant mobilization, transport and logistical challenges. The extreme heat of the Kimberley climate challenged both personnel and machinery; the ensuing monsoonal rains reduce temperatures but increase humidity. The Lennard Shelf reclamation plan had to be original; there was no reclamation of this kind completed in the Kimberley to use as a model.
One stand out error made was failing to adequately assess the topsoil harvested to cover the Kapok waste rock pile which proved, after placement, to be unsuitably erosive.

Factors contributing to the successful reclamation included:
- full support from the corporate level
- planning for mine closure at the time of construction
- having environmental consultants (Perth based MBS Environmental) who had been involved with the sites since being operational to plan and oversee reclamation appropriate to the area
- the diligence and amenability of the selected earth moving contractor
- the resilience of the native vegetation and it’s seed bank in stockpiled topsoil.

The Pillara site will be the Kimberley’s most challenging mine closure and reclamation project to date. If completed successfully, it too will be evidence that mining, pastoralism and indigenous interests can co-exist to a mutually beneficial effect providing continued employment and sustainable economic benefits whilst maintaining environmental integrity.

REFERENCES


MBS Environmental. February 2006. Kapok Site Rehabilitation Plan: Lennard Shelf Operations, West Kimberley, Western Australia. 23 p + Appendices.

