Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Development at Lihir – An Overview

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Keywords: Geothermal power generation, open-pit mining

ABSTRACT

Gold bearing ore is mined from an open-pit mine within an active geothermal system at Lihir. The geothermal system consists of a deep liquid dominated reservoir overlaid by shallow steam zone located within close proximity to the ore bodies.

The mine pit floor will ultimately reach the shallow steam zone in some parts of the mine. Steam relief wells are drilled into this shallow steam zone to depressurize and cool the formation ahead of mining operation while dewatering wells are used to pump out water from depths below the mine pit floor for safe mining and pit wall stability.

A 6MW geothermal power plant was commissioned in 2003 and a further 30MW plant is under construction and due to be commissioned in mid 2005. Studies are underway to prove up an additional 20MW expansion. The mining environment limits access to the production wells and the steamfield. A number of considerations are incorporated into the steam supply strategy to enable geothermal power generation and safe mining operation concurrently.

1. INTRODUCTION AND BACKGROUND

The Lihir site is located in the New Ireland province of Papua New Guinea (PNG) about 800 km north east of the capital Port Moresby. The site is situated on the Island of Lihir on the eastern coast immediately adjacent to the sea. The site elevation ranges from about 50 to 100 meters above sea level. The open pit mine, currently one of the largest epithermal gold mines in the world, is located within a Caldera that has been breached by the sea. The northern and western parts of the mine falls within an active geothermal system.

Unlike the other geothermal projects around the world, the development of geothermal energy at Lihir commenced out of the need to dewater the pit and cool and depressurize the rock formation so that safe and efficient open-pit mining could be carried out at depth. The requirements for dewatering and depressurization were evaluated in the Lihir Feasibility Study (Kennecott, 1992).

Commercial operation of the gold mine started in mid-1997. The gold deposits currently under development consist of two ore bodies (Lienetz and Minifie) located inside the Luise Caldera. The current plan is to mine for the first 15 years followed by about 20 years of processing of the stockpile.

With increased drilling and better understanding of the resource, the geothermal development has evolved from playing the role of dewatering & depressurisation of the mine, to its current stage of generating power to supplement the power needs of the mining operation at Lihir. There is now a clear recognition that geothermal energy can deliver cheaper and cleaner source of energy to support its mine operation & processing plant by replacing the dependence on heavy fuel oil (HFO) fired power plants. Work has commenced on looking at ways to expand the geothermal generation to ultimately replace reliance on HFO fired power plants while at the same time achieving the dewatering and geothermal control requirements to enable safe mining.

Figure 1: Location of Lihir Island

2. MINING OPEARTION

Conventional drill and blast techniques are used for mining operations, with explosives that are designed for elevated rock temperatures. The mine plan comprises deepening and expanding the pit outwards in phases starting at the Minifie orebody and subsequently moving northwards through the Lienetz orebody (Figure 2). High-grade ore is crushed and processed into gold while low-grade gold is stockpiled for later processing.

To ensure safe operation, the mine has to be dewatered prior to mining. Dewatering of the pit is achieved by pumping from vertical dewatering bores, drilled on the seaward side of the pit, to reduce ground water and shallow geothermal inflows to the open-pit. The dewatering bores are nominally drilled to depth of around 300-400m. Currently, 11 downhole submersible pumps are in operation pumping a total of about 700 l/s of water at temperatures of up to 90ºC.

Continuous dewatering results in draw-down of the water table around the pit. Because of close to boiling-point-with-depth conditions in many areas around the pit, this draw-down increases the formation of steam in shallower zones.

The dewatering strategy thus included geothermal mitigation measures to reduce the risk of geothermal blowouts. To achieve the required level of dewatering the following methods are used:

- Horizontal drain holes drilled within the open pit
- Deep geothermal wells
- Shallow steam relief wells
- Pumped dewatering wells

The geothermal environment presents a very unique and challenging situation to the mining operation at Lihir. On one hand it serves to depressurize and cool the shallow zone around the ore bodies to enable safe mining operation. On the other hand, geothermal steam produced from the deeper formation is used to support the power requirements of the mining and processing operations.

Mining operation takes place on a 24-hour basis. While some of the geothermal production wells are located within the current mine pit others will be affected as the mine expands in future. This necessitates the need to plug the wells from time to time and cut the exposed casing near the surface to the next mine bench. The casing is plugged with a temporary drillable packer so that once the mine reaches the final bench, the wellhead can be reinstated and the well reopened.

3. THE GEOTHERMAL RESOUCE

Shallow temperature exploration wells were drilled down to 200-300m depth in the early to mid eighties to investigate the viability of open pit mining. Extensive testing of the shallow aquifer near the planned mine area was done during this time.

In 1999 eight deep geothermal wells were drilled with standard 9-5/8" production casings and 7" slotted liners. Because of restricted access due to mining operations, and to keep the wellheads outside the pit boundaries, all the initial wells were drilled directionally from two drill pads located on the southwest corner of the mine.

The wells were drilled from the edge of the mine to pass under the bottom of the Minifie and Lienetz pits (Figure 2) to determine permeability and temperature at depth and to establish whether such wells could successfully intercept the recharge flows into the bottom of the pit and hence reduce the temperature and pressure. Measured well depths ranged from 1260m to 1790m with true vertical depth ranging between 1120 to 1400m. This deep drilling program helped to characterize the deep pressure profile and define the area of high temperature upflow.

Three of these wells (drilled northwards) have encountered highly permeable zones and are large producers and three more wells (drilled southwards) produce at smaller flow rates. The produced fluid has high pH and high chloride and sulphates. Separated water at atmospheric pressure has a pH of about 9 and chloride concentration of 30,000 ppm and sulphate of 40,000 ppm. Non-condensable gas content of the reservoir fluid is about 0.6% by weight of which 98% is CO_2.

The high mineral composition of the fluids has resulted in calcite deposition in the wellbore and silica scale in the discharge pipelines. Due to the severity of the calcite deposition, some of the wells could only sustain discharge for a period of several months before the wellbore is completely blocked by the deposition.

Scale inhibitor trials have been conducted on two of these wells. The results of these trials indicates that more work is necessary before these wells could be committed for long-term steam production.

Table 1: Output of the Deep Geothermal Wells

Well	Mass (t/h)	Enthalpy (kJ/kg)	Gas in Total Fluid (% Wt)
GW1	320	1100	
GW2	65	2000	
GW4	95	2750	
GW5	150	2700	2
GW6	180	2700	0.6
GW7	100	2400	0.6
GW8	400	1200	0.7

Following the deep drilling program, close to twenty shallower wells (400-800m) were drilled within the pit boundaries in order to accelerate the cooling and depressurisation of the mine. Most of these wells encountered high temperature fluids and produced steam that was suitable for power generation.

Table 2: Output of Intermediate Depth Geothermal Wells

Well	Mass (t/h)	Enthalpy (kJ/kg)	Gas in Total Fluid (% Wt)
GW14	320	1100	
GW16	65	2000	1.3
GW17	320	1100	0.5
GW21	95	2750	1.9
GW24	150	2700	2.0
GW26	180	2700	1.8
GW27	100	2400	1.3
GW28	400	1200	0.5

The down hole temperatures in these intermediate depth wells were close to boiling point conditions from depths of about 200 down to 700 meters. These wells produce higher enthalpy fluids and have less scaling and rundown behavior than the deeper wells.

Due to this favorable fluid characteristic, some of the wells were selected for power production. The first 6MW geothermal power plant is connected to four of these wells to supply the required steam.

4. GEOTHERMAL POWER GENERATION

4.1 Current Status

A 6MW backpressure unit has been in operation since May 2003. The purpose of this plant was to utilize the steam from the existing wells and assess the viability of generating geothermal power & gain operational experience.

The steamfield of the 6MW plant is composed of four wells connected to a common header delivering fluid to a cyclone separator with a bypass to atmospheric vent silencer. The separated steam is piped to the turbine through a main steam line. A steam scrubber is used to remove any carryover in the steam. The power plant is composed of a 6MW conventional steam turbine and generator set generating power at 11kV.

The plant has been operating reliably since commissioning. To-date, except for shutdowns caused by external factors, the plant has been operating at very high plant availability of greater than 95%.

A 30MW geothermal power is under construction with expected commissioning in mid 2005. Steam for the power plant will be supplied by four intermediate depth wells located on the margins of the existing mine pit. These wells were originally drilled as depressurisation wells however, because of their very good productivity they were proposed for power generation. It is expected that steam from some of these wells would be affected as they fall within the mine pit as mining expands outwards. Make-up wells would be drilled ahead of time to ensure that the power plant is supplied with sufficient steam.

Computer simulation of the geothermal reservoir model is carried out on an ongoing basis, to determine the optimum fluid withdrawal rate that will enable sufficient depressurisation in the shallow aquifer for safe miming and also enable sustained steam supply for power generation.

4.2 Future Plans

Currently LMC is carrying out exploration works to prove additional reserve that will enable generation of geothermal power to support all the power requirements of the mine operation. A geophysical study was carried out in early 2004 to define the northern and western boundaries of the geothermal resource. Based on the results of the geophysical work, a slim-hole geothermal drilling program is currently underway to accurately define the extent of the geothermal resource and its potential for power generation.

Based on the experience of other sites, which have adopted geothermal power generation and, given a reliable long-term source of steam, it is known that such power can be provided more efficiently and cheaper than hydrocarbon based power generation. Lihir's power generation is provided by 12 heavy fuel oil (HFO) fired machines and a series of small diesel-fired generators. Considering the future power requirements at Lihir, it is evident that geothermal power is likely to play a major role in supporting the power needs of the mine operation and process plant with reduced carbon emissions. The ultimate goal is to prove sufficient geothermal reserve to replace all the HFO fired power plants.

CONCLUSION

The work completed to date demonstrates that geothermal energy can be harnessed for power generation at Lihir.

This being the first geothermal power development in PNG there is significant benefit to the local population in gaining experience in exploration and development of geothermal energy and also would have the benefit of serving as a model for future geothermal projects in the region.

Replacing the existing diesel fired power plants with geothermal plant has significant cost saving and the added benefit of less emission of green house gases such as CO_2 to the environment.

Other environmental benefits include, due to geothermal wastewater having alkaline nature with high pH, it has the potential of neutralizing run-off from the stockpiles.

With proper monitoring and filed management, the project will achieve the dual purpose of providing cheap geothermal power and also enable a safer mining environment to enable safer mining in the shallower zones.

ACKNOWLEDGEMENTS

The support of Lihir Management Company (LMC) to publish this paper is acknowledged. Thanks are due to Garrick Mendham for reviewing the draft of this paper.

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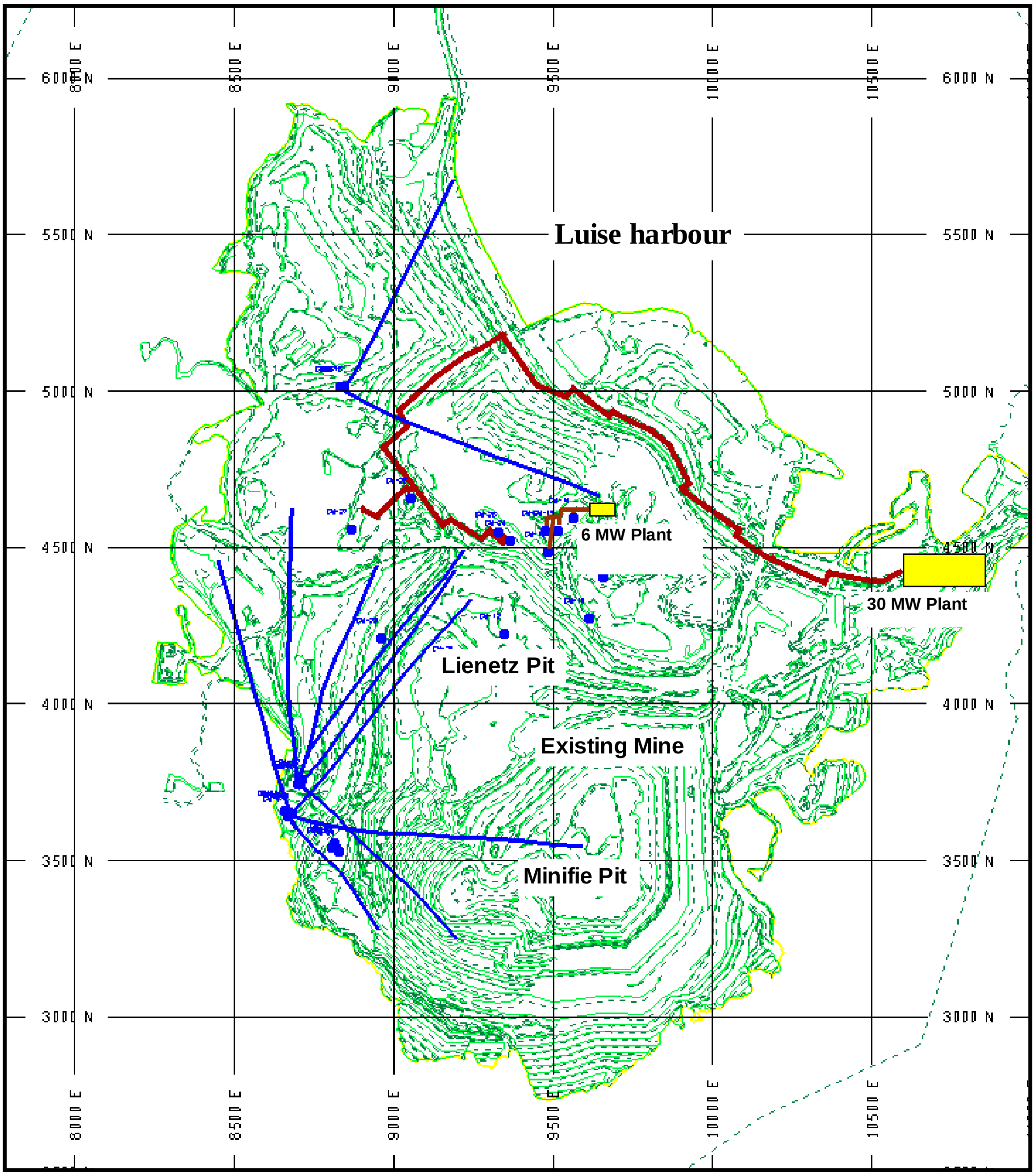

Figure 2: Site Layout Showing Approximate Footprint of the Mine Pits and Current Location of Geothermal Wells Used for Power Generation – for the Existing 6 MW Plant and the New 30 MW Plant Under Construction.