การศึกษาความเป็นไปได้เบื้องต้นของเหมืองแร่ดีบุก: กรณีศึกษาเหมืองดีบุกในประเทศไทย

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PRE-FEASIBILITY STUDY OF TIN MINE: A CASE STUDY OF TIN MINE IN THAILAND

Mr. Chanthaphone Milamith

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Georesources Engineering
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งานวิจัยนี้ศึกษาความเป็นไปได้เบื้องต้นของโครงการเหมืองแร่ดีบุกสำหรับกรณีศึกษาโครงการเหมืองแร่ดีบุกซึ่งมีแหล่งแร่อยู่ในพื้นที่ อำเภอบ้านคา จังหวัดราชบุรี โดยมีวัตถุประสงค์หลักของการศึกษาคือ (1) การประเมินปริมาณทรัพยากร ปริมาณสำรองแร่ที่สามารถทำเหมืองได้ การออกแบบวางแผน และการพัฒนาเหมืองแร่ (2) การเปรียบเทียบการขนส่งแร่ระหว่างระบบรถบรรทุกกับรถตักและระบบสายพานลำเลียง และ (3) การวิเคราะห์ทางการเงินจากแบบจำลองกระแสเงินสด และใช้เกณฑ์ต่างๆเพื่อประกอบการตัดสินใจ เช่น มูลค่าปัจจุบันสุทธิ (NPV) อัตราผลตอนแทนภายใน (IRR) และระยะเวลาคืนทุน (PP)

ในการประเมินปริมาณทรัพยากร ปริมาณสำรองแร่ที่สามารถทำเหมืองได้ การออกแบบวางแผน และการพัฒนาเหมืองแร่ โดยใช้โปรแกรมประยุกต์ Mincom Minescape 5.7 ในสร้างแบบจำลองแหล่งแร่และออกแบบเหมืองแบบบ่อเปิด (Open pit) สามารถประเมินปริมาณสำรองแร่ที่สามารถทำเหมืองได้ 2,795,468 เมตริกตัน และจากแผนการทำเหมืองมีอัตราการผลิตแร่ต่อปีประมาณ 700,000 เมตริกตัน ซึ่งสามารถประเมินอายุของเหมืองได้ประมาณ 4 ปี และจะได้โลหะดีบุกต่อปีประมาณ 2,510 เมตริกตัน ทั้งนี้จากผลการศึกษาจะเลือกใช้ระบบสายพานลำเลียงในการขนส่งแร่ โดยจากการวิเคราะห์แบบจำลองทางการเงินแสดงให้เห็นว่าโครงการมีมูลค่าปัจจุบันสุทธิ (NPV) ประมาณ 447,779,678 บาท มีอัตราผลตอนแทนภายในประมาณ (IRR) 79% ต่อปี และระยะเวลาคืนทุนประมาณ (PP) 1 ปี 1 เดือน

ภาควิชา	วิศวกรรมเหมืองแร่และปิโตรเลียม	ลายมือชื่อนิสิต	....
สาขาวิชา	วิศวกรรมทรัพยากรธรณี	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2558	ลายมือชื่อ อ.ที่ปรึกษาร่วม	....

5770485221 : MAJOR GEORESOURCES ENGINEERING
KEYWORDS: MINE DESIGN / CASSITERITE / MINE PLANINING / FINANCIAL MODEL / ENVIRONMENTAL / REHABILITATION

CHANTHAPHONE MILAMITH: PRE-FEASIBILITY STUDY OF TIN MINE: A CASE STUDY OF TIN MINE IN THAILAND. ADVISOR: ASSOC. PROF. SOMSAK SAISINCHAI, M.Eng, CO-ADVISOR: SONGWUT ARTITTONG, Ph.D., 101 pp.

This research conducted a pre-feasibility study of a cassiterite mining project location at Bankha district, Rachaburi Province, Thailand. The main purposes of this project were (1) resource/reserve estimation, mine design and planning and mine development (2) comparison of ore transportation systems between truck-loader and belt conveyor system and (3) the project financial analysis by using cash model.

The resource/reserve estimation and mine design and planning were carried out by using the software “Mincom Minescape 5.7”. The open-pit mining method was chosen and the mineable reserve was estimated at 2,795,468 metric tons. The mining capacity is 700,000 metric tons per year, and the mine life is estimated at 4 years. This resulted in the tin metal production of 2,510 metric tons for the project. The belt conveyor system was used for the main ore transportation system. The result of the project financial analysis showned that the Net Present Value (NPV) was 447,779,678 Baht, the Internal Rate of Return (IRR) was 79% and the Payback Period (PP) was 1 year and 1 month.

Department:	Mining and Petroleum Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Georesources Engineering	Co-Advisor's Signature	....
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CHAPTER I
INTRODUCTION

1.1. Background

In the past, tin has been an important commodity, and there have been more tin mines or mining activities than for any other material. Thailand has potentially large tin resources. Tin is found mainly as placer deposit (eluvial or alluvial). Mining methods are chosen according to type and occurrence of the tin deposit. Two methods are commonly used: dredging and hydraulicking. The latter is considerably cheaper than other tin recovering methods (MacDonald, 1983). Most of tin found in Thailand is in the form of cassiterite (SnO_2). The occurrence of cassiterite is normally related to the western granite formation extending from the north to the south of Thailand. There are two types of cassiterite deposits: primary and secondary.

1. Primary: hard rock, without weathering of the source rock
2. Secondary: weathered rock, either in-situ or transported by stream (river: synonym) to form eluvial deposits (tin and other associated heavy minerals) (Aranyakanon, 1969).

The first historically proven tin mining industry in Thailand was located on Phuket, about 450 years ago. Phuket, the first known trading post for tin, amber and pearls in Asia, was then largely controlled by Dutch, Chinese, French, British and Portuguese tradesman. The island is situated off the southwestern shore of Thailand in the Indian Ocean (Suchit, 1979).

The major part of the tin production is derived from the southern peninsula, extracted mostly by placer mining. Since 1985, there have been more than 696 mines in the western part of the country along the Tanaosi. Mountains which cover the area of Kanchanaburi, Ratchaburi, Petchaburi, and Prachuap Khiri Khan Province as well as Phang nga and Phuket province in the south. Therefore, tin mining became the main occupation of local people around those areas. There are many methods to carry out mine operations (or mining operations) depending on the classification of mineral, geological characteristic, percent grade, and tin ore deposits, including capital costs for mine operation. Tin mining methods can be classified such as Gravel pumping, Hydraulicking, Ground Sluicing, Open pitting, Shaft Shinking, Gophering, Tunelling, Dredging, and Suction Boat (Nuannat, 1981).

Tin is one of the most significant minerals for industries, it can be produced coats with metal such as the iron and copper and other metal. As a result, there is a high demand of it. There are two important factors that impact the price of tin to fluctuate. Firstly, the mining sectors are limited and tin ore reserves decreasing. Secondly, the demands of tin by the industry has a tendency to increase. The tin price is fluctuating according to consumption in the industry during in 2000-2015 as shown in figure1.1

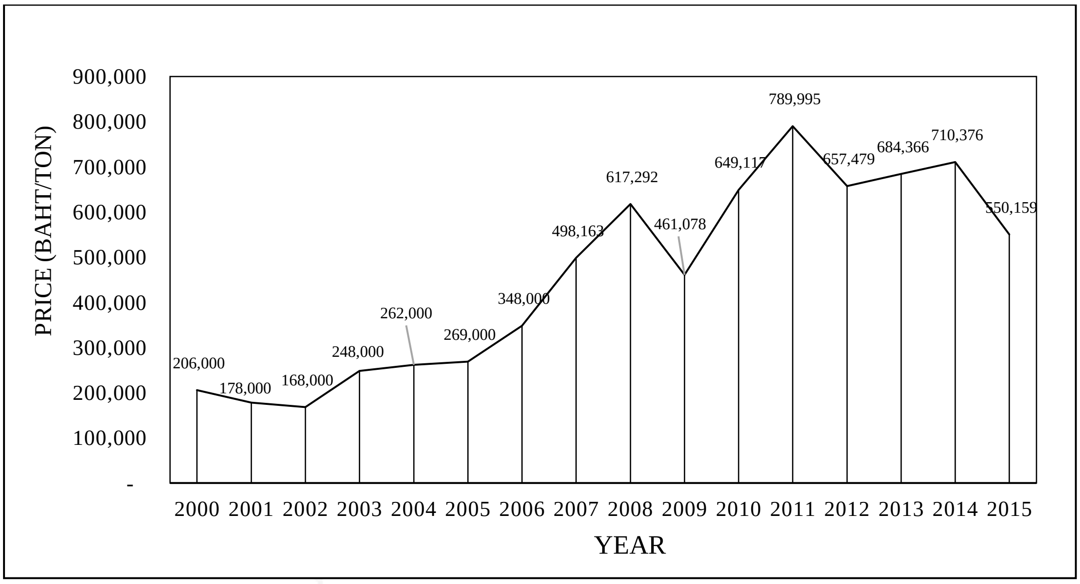


Figure 1. 1 Tin metal price in 2000-2015
***Sources**: Department of Primary Industries and Mines 2015*

Due to the industries high demand for tin. Producer have been interested about tin mine development. This research focuses on conducting a pre-feasibility study of tin mine design at the Ban Kha district, Ratchaburi province, Thailand. Tin is found as secondary, eluvial deposits, inserted to pegmatite and quartz-muscovite veins, associated with other minerals. Tin ore reserves are expected to be sufficient for mine development.

1.2. Status of the import-export-production and tin consumption in Thailand (2001-2014)

Result of the estimation of the Department of Primary Industries and Mines about the import-export-production and consumption of tin in Thailand are displayed in detail in table 1.1. It can be summarized total of quantity and value from 2001-2014 such as tin ore import was 189,669 tons and 34,537 million baht, tin metal export was 251,506 tons and 122,408 million baht, tin concentrate products was 7,501 tons and 1,828 million baht and tin metal consumption was 55,161 tons and 24,364 million baht respectively. The quantity and value of tin in every year depend on the price and demand used to material industries in the domestic and external.

Table 1. 1 The import-export-production as well as quantity and value of tin consumption in Thailand (2001-2014)

-	Tin imports (Ore)		Tin exports (Metal)		Tin products (Concentrate)		Tin consumption (Metal)	
Year	Quantity (tons)	Value (million baht)	Quantity (tons)	Value (million baht)	Quantity (tons)	Value (million baht)	Quantity (tons)	Value (million baht)
2001	40,147	4,004.8	18,575	3,602.3	2,384	346.9	4,115	806.7
2002	26,578	2,274.4	12,621	2,223.6	1,384	175.7	4,809	841.4
2003	18,409	2,179.4	10,390	2,157.1	980	142.4	4,667	945.8
2004	12,753	2,670.5	14,566	5,046.5	724	176.2	5,807	1,993.9
2005	20,018	3,937.9	26,636	8,237.9	188	40.1	4,337	1,296.8
2006	6,545	1,247.3	22,397	7,352.4	225	54.5	4,915	1,614.8
2007	12,974	3,980.3	19,636	9,995.4	149	53.9	3,210	1,593.9
2008	18,771	5,965.6	17,407	10,939.1	235	235	4,080	2,525.9
2009	17,985	4,272	16,661	7,890.1	167	57.3	2,603	1,216.5
2010	3,432	685	19,363	12,694.3	292	134.3	3,707	2,346.8
2011	2,716	257.2	20,015	16,387.6	286	172	3,321	2,648.3
2012	2,842	397	19,628	13,248	199	94	3,321	2,176.1
2013	648	280.4	19,721	13,483.4	132	65.7	3,012	2,044.3
2014	5,851	2,385.5	13,890	9,150.4	156	80	3,257	2,313
Total	189,669	34,537	251,506	122,408	7,501	1,828	55,161	24,364

The total amount of tin products exported in between 2001 and 2014 accounts for 7,501 tons. Therefore, 189,669 tons of tin ore have been imported from foreign countries. In this situation, Thailand needs to develop tin mine for tin industry to strike a balance of domestic using and reduce the import quantity form foreign countries.

Figure 1.2 and 1.3 illustrate fluctuation of quantity and value of the import-export-production and tin consumption in Thailand. The fluctuations are due to changes in demand and supply of tin at domestic and global levels.

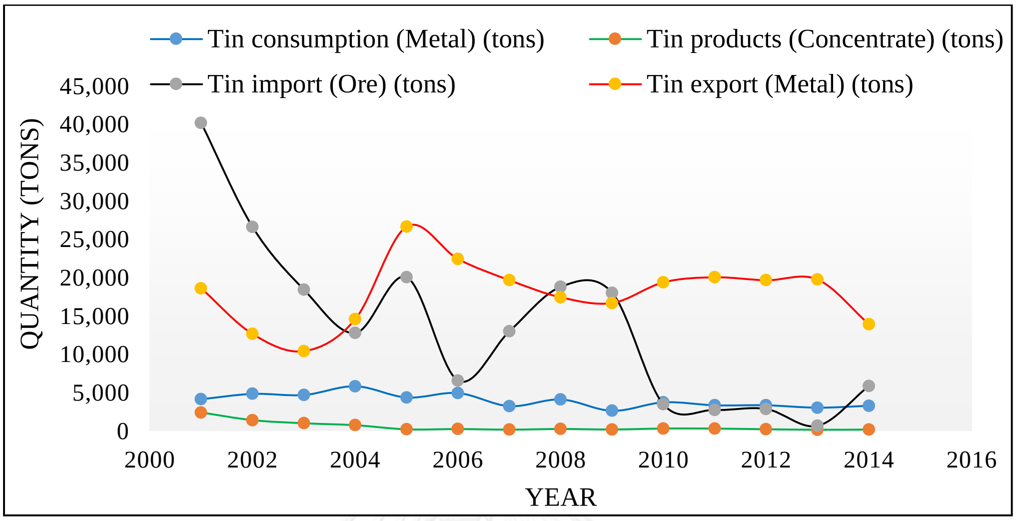


Figure 1. 2 Quantity of import-export-production and consumption tin in Thailand (2001-2014)

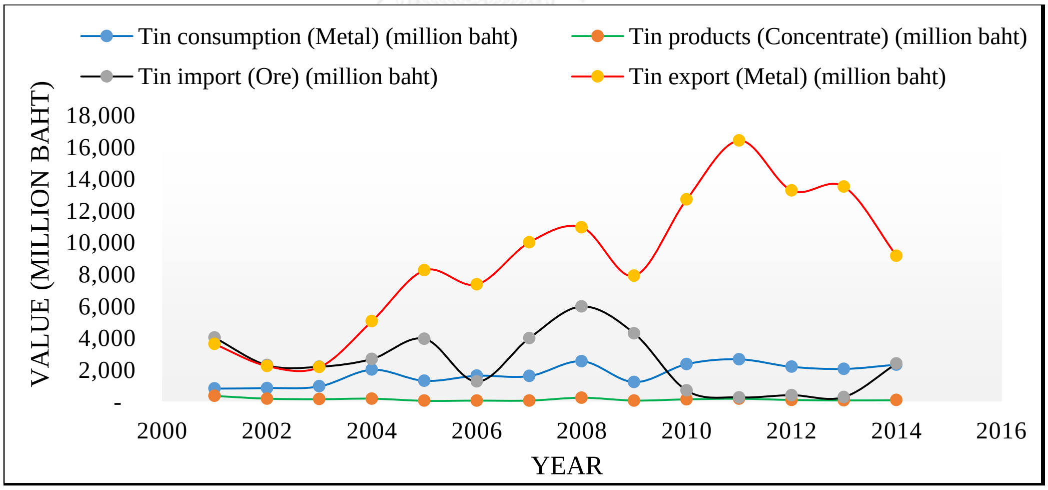


Figure 1. 3 Value of import-export-production and consumption tin in Thailand (2001-2014)

1.3. Statement of the problem

Mining Industry plays a very important role in economics growth. It attracts foreign investments, creates jobs and therefore helps people to earn more income. For Thailand, as a developing country, the using of tin metal was very important to industries, and tin products is decreasing. To solving the problem of not having enough tin ore for the industry, tin deposits in the country are considered to mining development especially mining sector. Tin mine development involves geological exploration, resources estimate, mine design, mine operation, financial analysis, environment and mine rehabilitation consideration and to effectively undertake the tin mining development.

This research provides a framework of tin mine development at Ban Kha district, Rachaburi Province, Thailand. It emphasizes 3 stages of pre-feasibility study which are technical, financial and environmental.

1.4. Literature Review

According to (Komar, 1954) Pemali open pit mine is the largest primary tin mine in Indonesia. If tin ore is mined in an open pit mine, there are two mining processes: dry and wet. This research focuses on selecting equipment and working system to make tin production more effective. There are many factors which are related with equipment selection part such as overburden, ore deposit, volume of tin ore, distance of transportation and hardness of the material. The equipment selection is aimed to production capacity. At Pemali open pit mine, there are two formulations for mine operation such as wet process, which is carried out by using hydraulicking, and dry process, which is excavated by backhoe. Dump trucks and belt conveyor are used for transportation. The transporting distance is 1,500 meters. Tin production capacity is about 500 tons (Sn) per year. Thus, sustainable mine development should consider safety, equipment and production.

(Somkiat, 1983) conducted a research related to trends in tin mining of on-land alluvial deposits in Thailand. This paper gives more detail on technological change made on traditional mining practice for on-land deposits in Thailand. The economic aspects are also discussed in some detail. By the end of 1983, there were 1,154 active mining operations in the country, 737 of these were tin mines. There were several traditional methods of mining tin ore in alluvial deposits in the country. Among others, the gravel pump method has been very popular over a long period of time. There were used gravel pump about 353 gravel pump mines. From an economic point of view you have to compare the cost per unit volume of the two major mining methods: gravel pump and dry stripping. As the result, if transporting distance is higher 500 meters, total production cost by gravel pump is cheaper than the total production cost by dry striping. However if transportation distance higher than 500 meters, total production cost of dry stripping is cheaper than total production cost by gravel pump. The same concept does also apply for the transporting cost as shown in figure 1.4.

It should be noted that, for the simplification of illustration, the graphs only represent some basic information of case study in a few mines. In practice, more factors should be considered in detail.

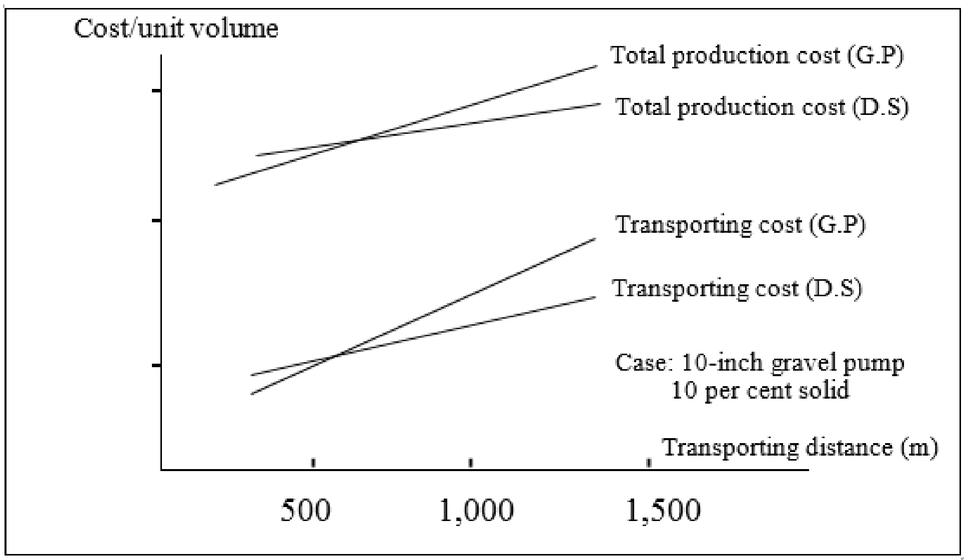


Figure 1. 4 Comparison of cost per unit volume between gravel pump and dry stripping methods

(Smith L.D., 1995) The studying of Discount Cash Flow Analysis Methodology and Discount Rate at Canadian Institute of Mining-Mineral Economics Society (CIM-MES) about mining project, that gives to more detail to define the discount rate percent in range of investment. Mining companies use discount rate for evaluations in constant capital investment, at 100 percent equity, after tax. This based on a survey conducted by the CIM Mineral Economics Society members which indicated the usage of the following rates for mining industry as base metals and Gold. As a result of discussions with mining companies, figure 1.5 shows the relationship between discount rate and production. There are 4 main production stages such as early exploration, pre-feasibility, feasibility study and mine operation. Each stage uses a different discount rate. In addition to this, mining investors also use this discount rate to make decisions that involve capital investment and cash flow analysis models.

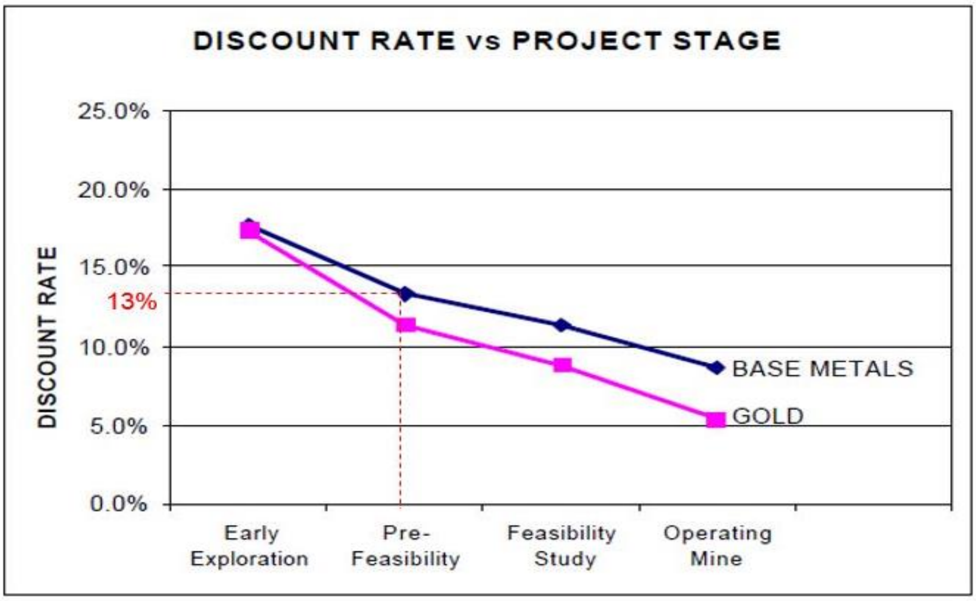


Figure 1. 5 CIM MES Survey-Discount Rate and Project Stage

(Kem, 2013) This paper is focuses on the Pre-feasibility study of limestone quarry which research area is located at Prey Ta Pret Village, Banteay Meas District, and Kampot Province, Cambodia. The research focusses mainly on the technical development of limestone quarry as geology and resource estimate, which is provided for quarry operation and design. The formulation of quarry development involves ore model, mineable reserve estimation, pit design, mine operation and mine rehabilitation, and develop financial analysis involving the discounted cash flow (DCF) model, the net present value (NPV), the internal rate of return (IRR). The result of the resource estimation, using the invert distance square method, is about 204 million tons. The minable reserve is designed for one million tons per year of limestone production covering 25 years mine life. Five trucks, one loader and two excavators are required to handle 550 tons per hour of limestone production. In term of financial analysis are 19.3 million dollars of NPV estimated with the IRR of 45%.

(Aus tin mining, 2014) The concept of the pre-feasibility study provides information for investors about tin mine development. The result show a mineral resource estimate of 36.3 million tons at 0.16 percent (Sn) for contained tin 57,200 tons, probable ore reserve 22 million tons at 0.16 percent (Sn) for contained tin 35,600 tons. Life of mine average 2,815 tons per year of tin concentrate and overall recovery tin is 70 percent. Mine life is about 9.3 years. The method of mine developing is open cut mining. The financial analysis, operation cost in year 1 to 9.3 is AU$ 16,553 per ton, tin price US$ 25,000 per ton and AU$: US$ 0.9. Discount rate at 8 percent are used for calculation net present value, the capital costs AU$ 87.8 million. The result of financial estimation are the net present value (NPV) of AU$ 63.2 million, the internal rate of return (IRR) of 27.3 percent and the payback period of 3.1 years.

1.5. Objectives of this study

This research conducted a pre-feasibility study of a cassiterite mining project location at Bankha district, Rachaburi Province, Thailand. The main purposes of this project were;

1. Resource/reserve estimation, mine design and planning and mine development
2. Comparison of ore transportation systems between truck-loader and belt conveyor system.
3. The project financial analysis by using cash model involving the discounted cash flow model (DCF), Net Present Value (NPV), The Internal Rate of Return (IRR), and the Payback Period (PP).

1.6. Procedure of this research

Figure 1.6 shows a flow sheet to know about a carry out of this research in this as bellowing.

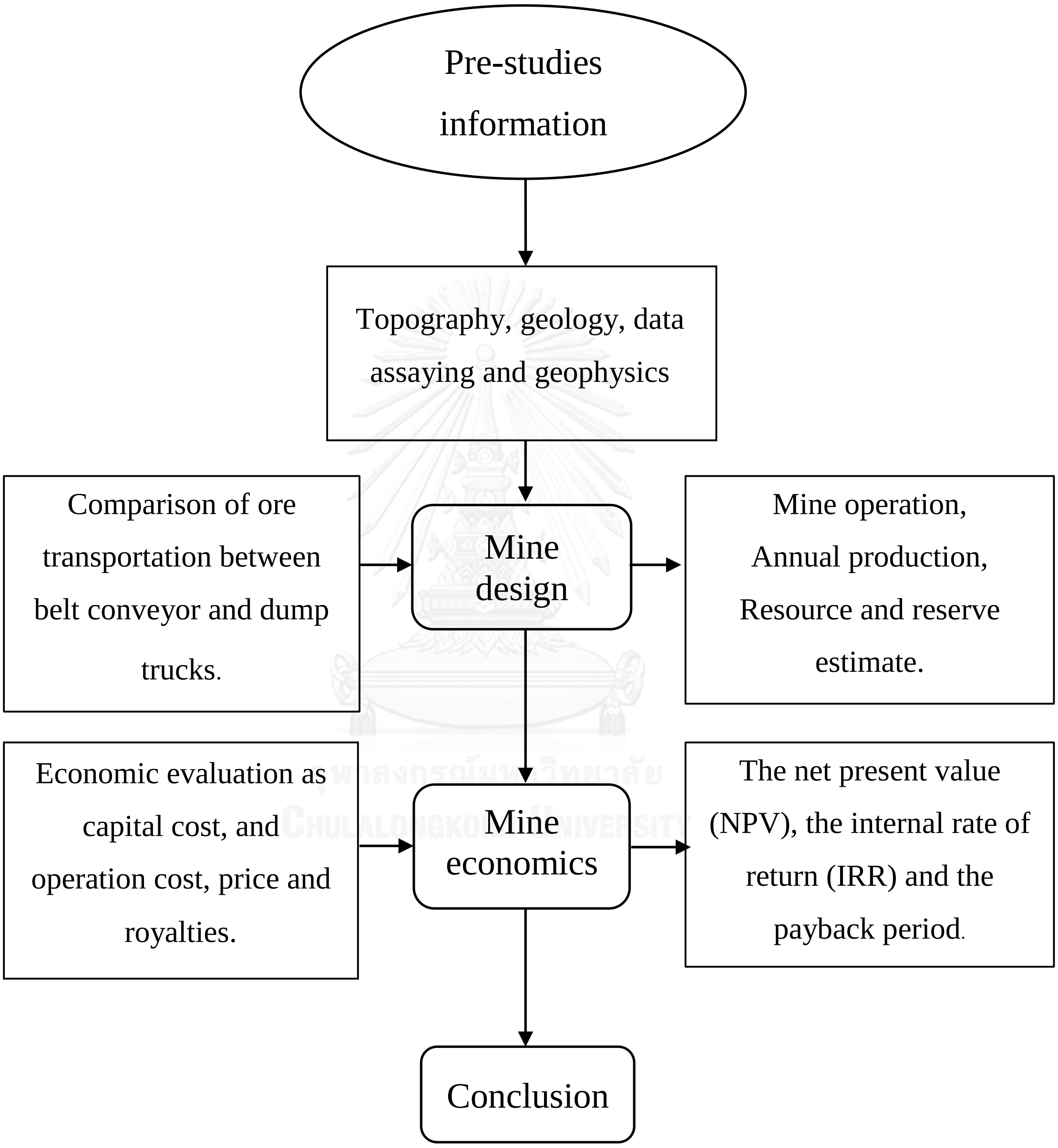


Figure 1. 6 Outline of this research

1.7. Expected benefits

The goal of this research is to improve mine management and mine development in many aspects:

1. To provides the framework for pre-feasibility study of tin mine in Thailand by taking a full consideration of local factor (infrastructure, cost factor, environmental issue, etc.)
2. To indicate the technical requirement and its designed parameter for resource estimate, mine optimization, mine planning and design, mine operation, loading and hauling, mine environment and rehabilitation

CHAPTER II
BASIC INFORMATION

2.1. Basic information

2.1.1. Tin

Tin is a chemical element with the symbol Sn (for Latin: stannum) and atomic number 50, (group IV in Europe), and atomic weight 118.69. Crystal international travel global systems 6-7 million strong resistance to corrosive well specific gravity 6.8-7.1 beady non-metal or a diamond semi. The color of the tin found is most often black or dark, brown honey yellow colors like red, purple color and powder white.

Tin metal, as featured in the resistance to corrosive and solvent are noncorrosive material mixed with other metals well, and not toxic to the body, it has been used in the coating of metal food containers that are made mainly of mixed-use money or lead solder copper metal and other metal such as pin that Peter and bronze, mixed with mercury and money do dental tooth filled material also used in electronics and electrical industry, other industries are much more in the flesh translucent glass, flat glass, plastic paints eliminate worms in animal medicine and toothpaste etc.

Figure 2. 1 Tin ore

***Sources**: Department of Primary Industries and Mines 2015*

2.1.2. Tin found in Thailand

In Thailand tin is found 2 different types: Cassiterite and Stannite.

1. The first type is Cassiterite (SnO_2), which is found only economic mineral. It formula is SnO_2 with chemical compounds of Sn and O of approximately 78.6% and 21.4% respectively, iron might have slightly approximated to 3 % and Niobium (Nb) and Tantalum (Ta).
2. The second types is Stannite rare (Cu_2FeSnS_4), often contains chemical compound of copper Cu 29.56%, Iron Fe 12.99%, Tin Sn 27.61% and Sulfur S 29.83% and not produced.

2.1.3. Tin occurrence in Thailand

Generally, tin in Thailand is associated with other high-temperature minerals in the granite rock or insert them. In sedimentary rocks above the granite again, and a piece of crystal or pay a small rock, with features strong resistance to the corrosive long which has been accumulated to bring in ore eluvial plug or blow to accumulate in the ground mineral. Usually, tin is associated with other mineral such as, Tawrsmalin (Tourmaline), Fluorite, and other including wolframite, Scheelite, tantalum, ilmenite, Monazite, Xenotime and Zircon. Moreover, tin deposits have been found along the border of Myanmar in the southern province and the central part of Thailand. (Aranyakanon, 1969). Figure 2.2 illustrates the potential map of heavy and rare minerals, which enable us to divide Thailand into three parts as:

1. Northern part: Uthai Thani, Kamphaeng Phet, Lampang, Chiang Mai, Chiang Rai, Mae Hong Son and Tak Province.
2. Western part: found in Chanthaburi, Ratchaburi, Chumphon, Nakhon Si Thammarat, Muang Yala, Trang, and Songkhla province.
3. Southern part: found in provinces as central Suphanburi, Ratchaburi, Kanchanaburi, Phetchaburi, including on seacoast of the Andaman Sea.

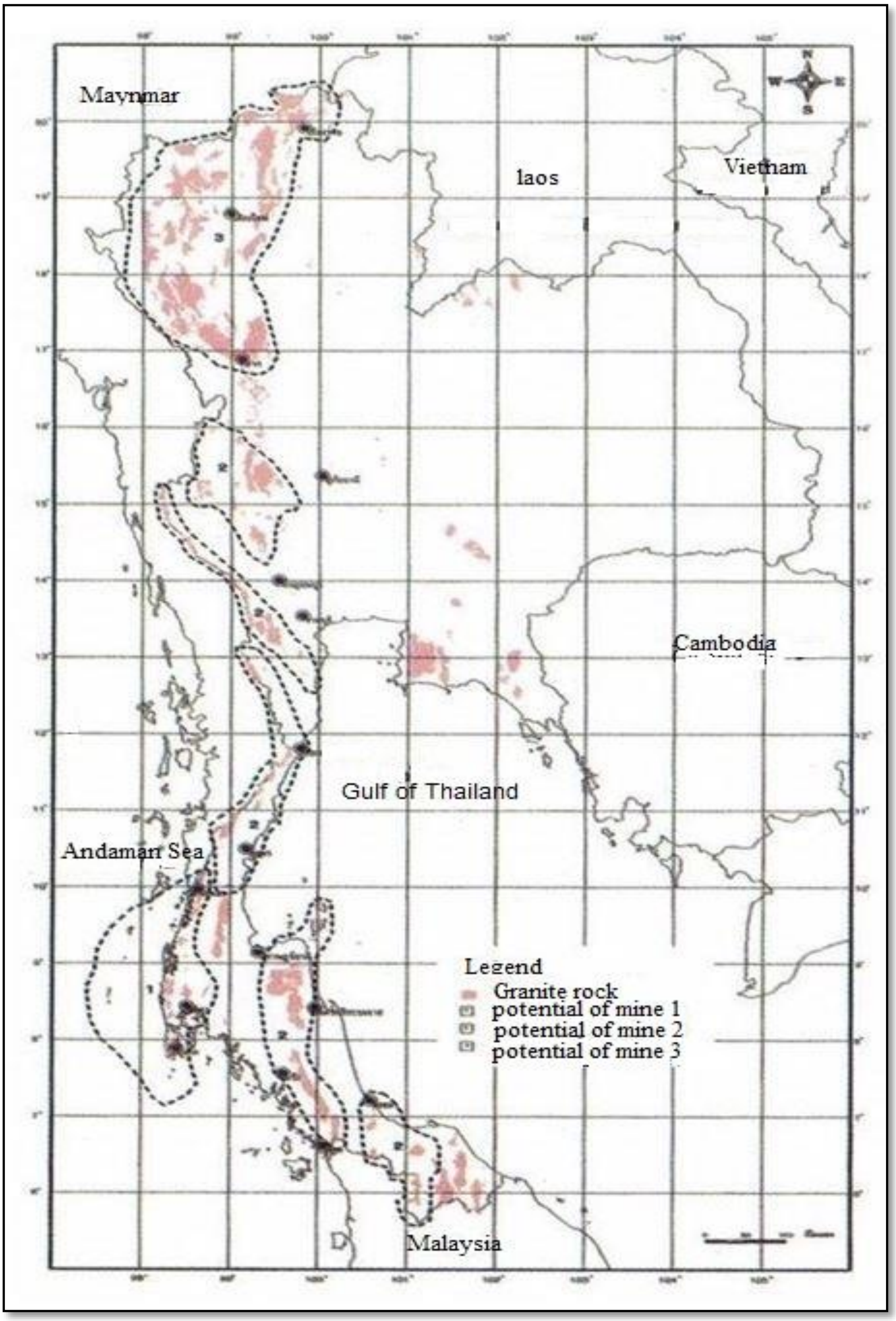


Figure 2. 2 Potential map of heavy and rare mineral, Thailand

2.2. Geology of tin deposits

In Thailand, tin deposits are associated with granite, especially mountains around western and northern to southern part. Tin deposits can be divided into two types: primary and secondary.

2.2.1. Primary deposits

Primary deposits are typically associated with granite intrusive rocks which magma bodies are embodied into the earth's surface, as the result of these processed can be divided tin occurring as:

a) Associated with quartz veins, inserted to granite and host sediment rocks, occurring in many different colors as brown, dark, orange, and yellow etc.

b) Associated with pegmatite veins, inserted to granite or parallel to host sedimentary. Pegmatite is an exceptionally coarse-grained plutonic igneous rocks. Main mineral are Quartz, Mica and Tourmaline, Garnet, Cassiterite, Columbite-Tantalite, Lepidolite, Beryl, Topaz along with rare mineral as Monazite and Xenotime.

c) Occurred into dissemination types inserted to granite, which is around periphery deposits of dissemination types in granite, it was low grade but more quantity and important to placers deposits.

d) Occurred in form of metasomatic deposits which is contracted between granite and calcareous sediments rocks, there are calcium silicates mineral.

2.2.2. Secondary deposits

Secondary deposits (placers deposits) are derived from the weathering and erosion of primary deposits. Cassiterite is a chemically resistant and heavy mineral. Therefore, tin deposit is developed from a primary deposit to eluvial and colluvial deposits, and it may be transported to a streams, and concentrate into placer deposits. Also, submerged streams as tin deposit. More than half of the world's tin production is from deposits in Malaysia, Indonesia and Thailand.

2.3. General geological characteristics of the project area

Geological characteristics in boundaries of this project as displayed in geological map by scale 1:250,000, between Nakhon Pathom province (ND 47-11), in

1985 by Pisit Wise Dilok and Geology Division of the Department of Mineral Resources. They found that geological characteristics of a project area composited of Carboniferous era and granite group in Cretaceous Era. Figure 2.3 illustrates the geology of the surrounding area. Detail information is described subsequently:

2.3.1. Sedimentary rocks

Carboniferous era (Ckp) includes the Khao Phra category of Khaeng Krachan rocks, composited by pebbly mudstone and sandstone, there are various size of quartz grained, quartzite, granite, feldspar, slates, phyllite and limestone. The texture was inserted by mudstone, sand and sandy clay. They connected together by calcareous cement. Mostly, they were massive rocks shown sliding a structure, traces of water flow, ripple marks and sole marking. The weathering surface was gray to dark gray, white to grayish brown as shale, gray to reddish gray, conchoidal fracture and slates cleavage. These category of rocks appeared in the eastern part of the project area.

2.3.2. Granite rocks

Cretaceous Era (Kgr) includes the porphyritic-phaneritic texture as tourmaline, muscovite inserted to pegmatite, quartz and aplite quartz veins. This category rocks appeared on the western of the project area.

2.3.3. Structural geology

Structural geology around this project area included linear structure. It indicated a major fault and fracture/joint. Mostly, it demonstrated to group rocks in Carboniferous Era. Which a fault and fracture/joint was alignment to northeast-southwest part. It found in around the eastern part of the project area. Figure 2.3 illustrates to geological map around project boundary.

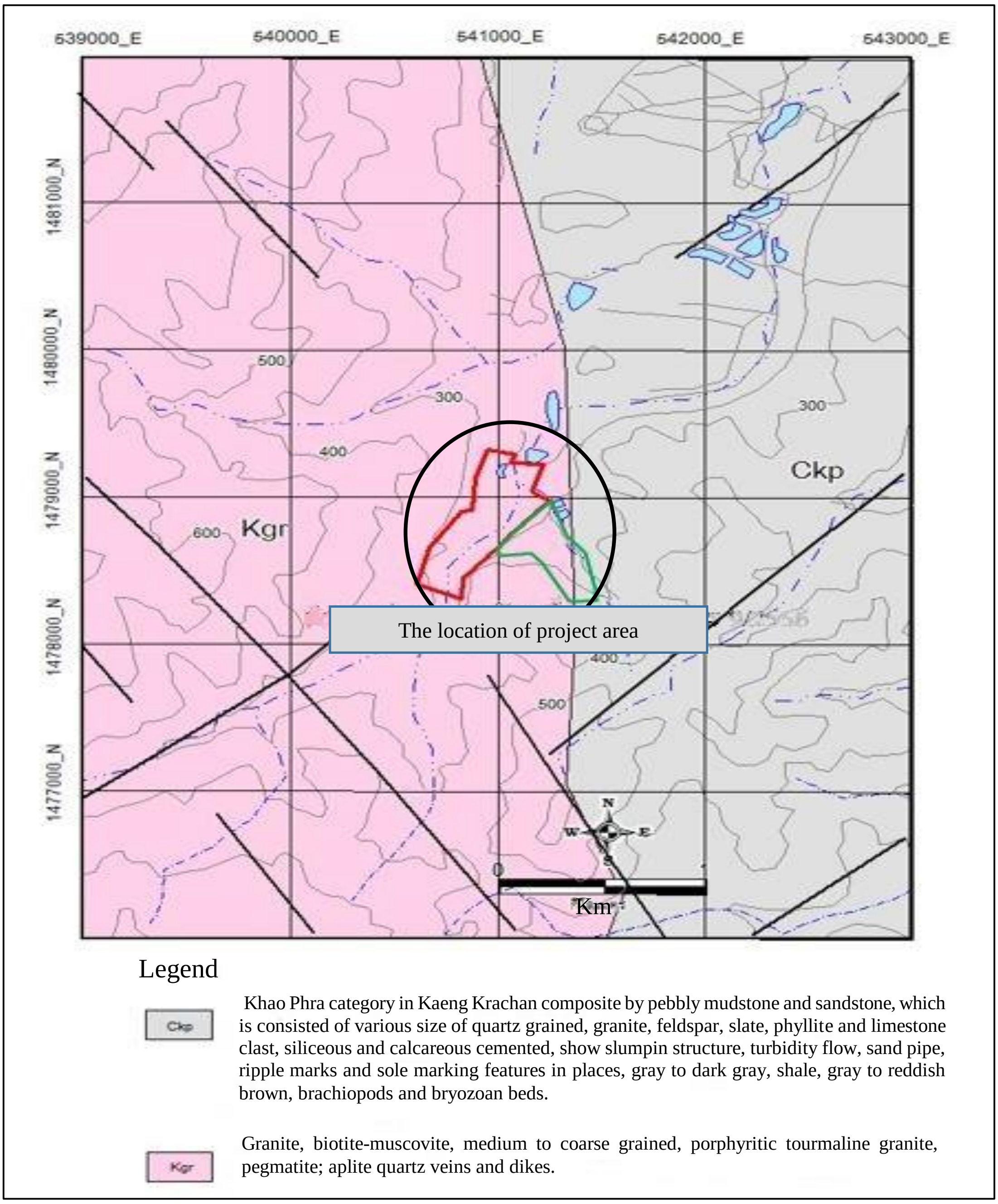


Figure 2. 3 Geological map around the project boundary

2.4. Geological characteristics around the project area

The general information about the geology characteristics around the project area has been edited for corrected, this information is obtained from around project area. Figure 2.4 illustrates the geology of the project area. Detailed information of the geological characteristics are found below.

2.4.1. Sedimentary and quaternary sedimentary rocks

Carboniferous Era (Ckp) is composed of sand, shale, sand gravel, sandstone Wagg and sand. They are greenish gray, greyish brown. The weathering of these rock is reddish brown which are category rocks distributed on medium part to eastern part and the southeastern of the project area as around the coordinates 542450 E and 1481920 N.

Eluvial deposits (Qc) are composed of silt and shatter rocks, which have been weathered from host rocks on higher level or around slopes then blow to accumulated on lower level or eluvial deposits, this category is composed of quartz, silt sand, clay and shatter rocks. These rocks are found in the medium part of the project area. It appeared on around plains low-level. Eluvial deposits posing covered area but not continues to Carboniferous era and Cretaceous Era.

Alluvial deposits (Qa) are composed of stream sediments including gravel, silt sand and clay. They accumulated in the stream and on plains. This category rocks appeared on northern of the project area.

2.4.2. Granite rocks

Cretaceous era (Kgr) was granite. There are texture characteristics porphyritic and medium to coarse grain. Composed of tourmaline mineral, biotite-muscovite inserted to the pegmatite and quartz veins. This category of rocks covers the southern part of the project area such as a outcrop around Lambuathong stream, around coordinates 540939 E and 1478638 N and 540782 E and 1478866 N. Around southern part of eluvial deposits continues to the Cretaceous Era, it can be found biotite-muscovite, and whitish gray granite.

2.4.3. Structural Geology

In around project area was composited by the linear structure that indicated a fault and fracture/joint. These structure was appeared in sediment rocks included granite alignment in northeast-southwest or about 320 degree and alignment into northwest-southeast or about 050-070 degree and in northern to southern that connected to the Cretaceous and Carboniferous Era.

2.5. Geological characteristics of tin deposits and around the project area

Tin deposits in around project area was secondary deposits (placer deposits) which found in form of eluvial deposits. Mostly, it was sediment layer composited by sandy gravel about 20-50 percent of granite rocks. Conglomerate characteristics without covered of clay layer and accumulated on the top crust to bottom of sediments and granite layers. Figure 2.4 illustrates to geological map of the project area.

The evidence indicates that tin occurred from primary deposits. There are two characteristics of tin deposits such as associated with quartz-muscovite and pegmatite as following:

a) Associate with quartz and muscovite veins. Tin found in quartz veins inserted to host rocks included sandstone, silt sand and shale, on the Carboniferous Era around the coordinate 541441 E and 1478899 N. that is contracted with the category rocks as sandstone inserted the quartz-muscovite veins.

b) Associate with pegmatite veins such as around coordinates 540797 E and 1478725 N, which is found pegmatite veins about 2 m large and 3 m long, it an alignment in the northern to southern part of the project area. The mineral composited of quartz and feldspar mineral about 5 × 8 cm inserted to biotite-muscovite rocks, granite fine to medium texture in around the coordinates 540897 E and 1478990 N.

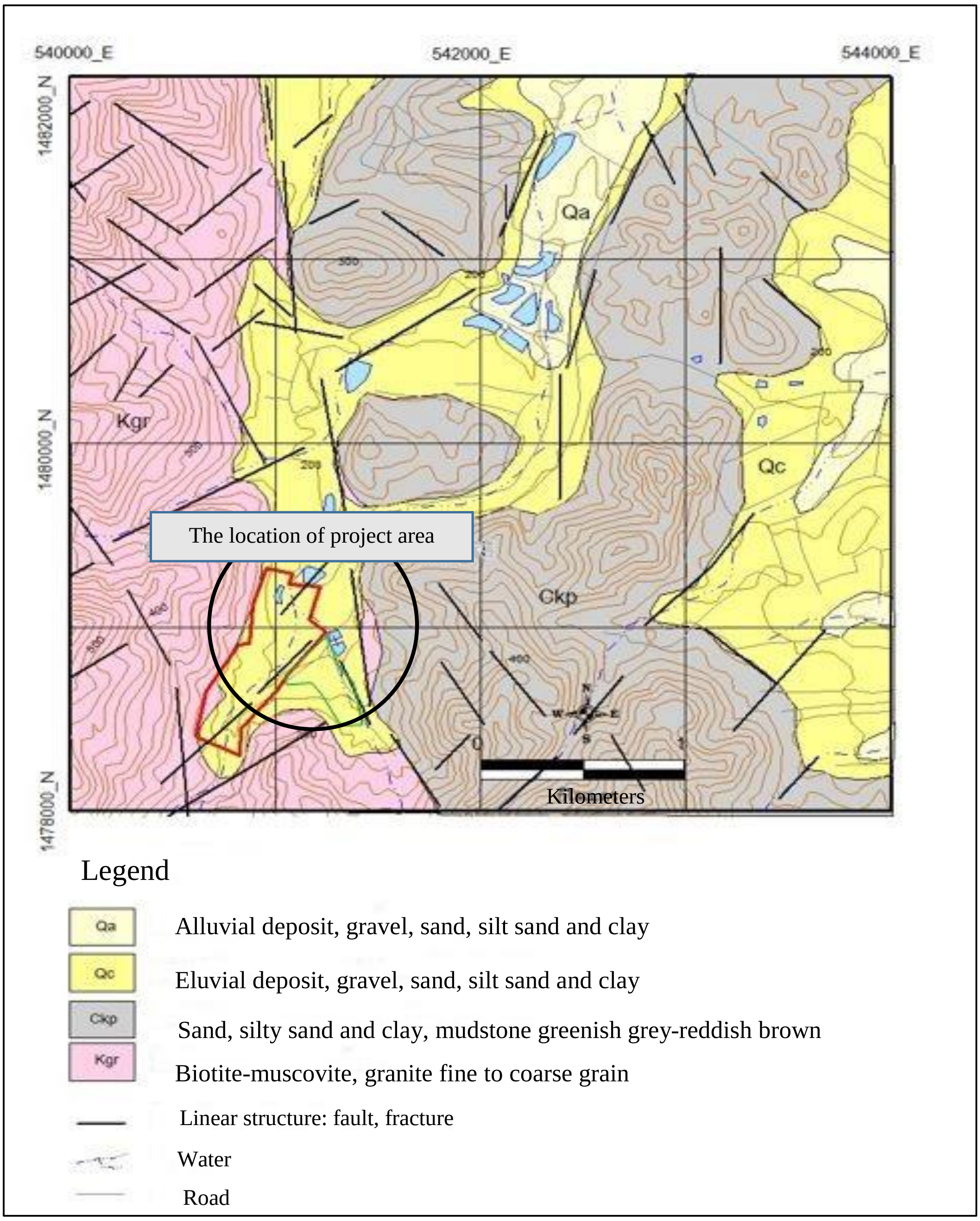


Figure 2. 4 Geological map of the project area

2.6. The formulation model of tin deposits

The geological characteristics of the tin deposits, is illustrated in Figure 2.5.

a) Host rocks were group rocks in Carboniferous Era. Mostly, they were composed of sandstone and mudstone, these rocks inserted by the granite in the cretaceous era which contain biotite-muscovite mineral. There are a fault and fracture/joint structure in the northern-southern of the project area around argillic alteration of wall rocks, and they have occurred at low temperature. In this case, finely textured granite occurred.

b) When fractures occurred in granite rock (host rock), the hydrothermal solution at low temperature, there are bring the quartz and pegmatite veins inserted to the fractures, which cassiterite inserted to granite, granite finely textured and host rocks in a fault and other fracture.

c) There are weathering and surface alteration in around fault and fracture/joint structures, cassiterite was deposited in eluvail ore placer deposits as the second deposits.

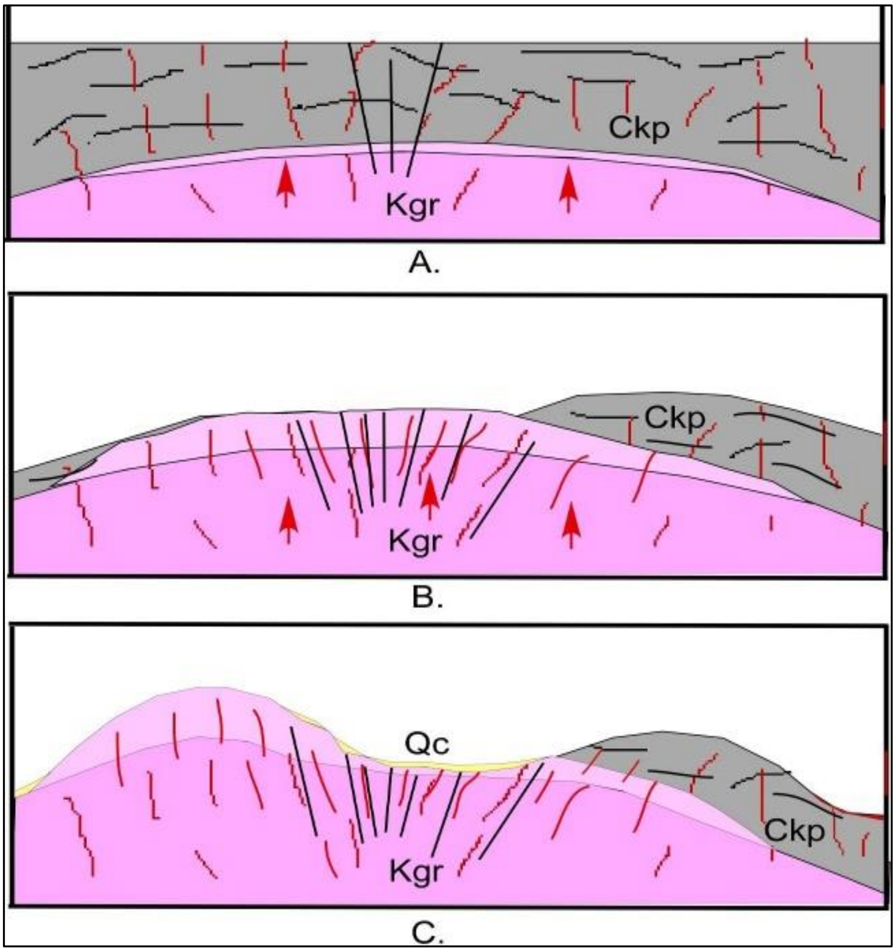


Figure 2. 5 The model of eluvial deposits of this project area

2.7. Location of the project

The project is located at the BanKha district, Ratchaburi province, in the western part of Thailand. It is situated about 160 kilometers from Bangkok. First, the point is Bangkok city. Then, traveling directly to the Lam Bua Thong village, Bankha sub-district, then, turn left at the road of department of Rural Road No: 5079 (Pu Khi Lex village road and the end of road, there is the SubTery waterfall). After that, travelling go on the gravel road about 5 kilometers before arriving at the location. Figure 2.6 shows the location and topographic map of the study area.

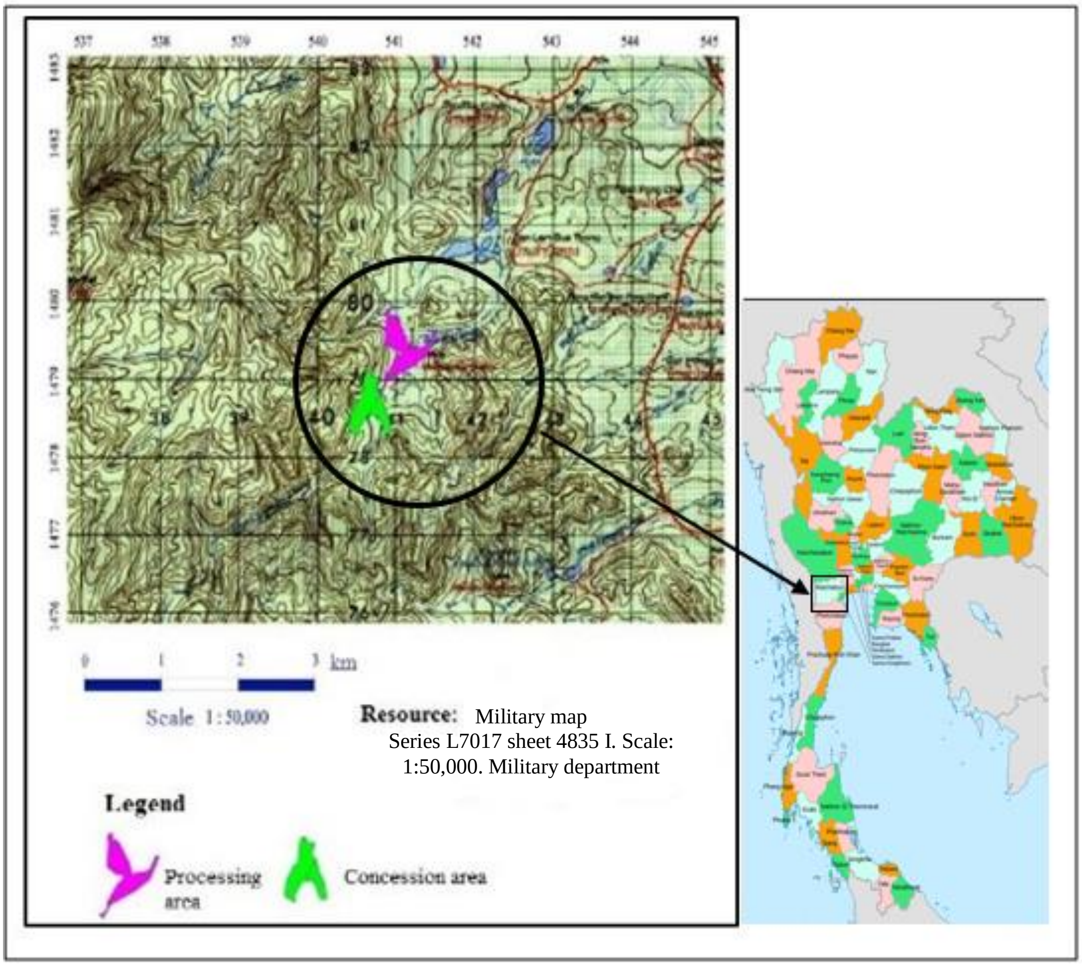


Figure 2. 6 Map of the project area in Bankha district, Ratchaburi province, and western part of Thailand. The green boundary is the concession area and the pink one the processing plant area

2.7.1. Topographic characteristics

Topographic characteristics around the location of the project area, there are a small valley between the basins of the mountain groups in the southern. There are slopes posing a moderate tilt to northeast and an altitude about 210-260 meters above sea level. The major stream is Lambuathong stream that flow from southwest to southeast, and continue to northeast of the project area.

2.7.2. Physical characteristics

The project area, there are bedrocks occurred from sediment rocks which posing on the top layers. The conglomerate was a variety of composed of rocks, and less soil layer on the top layers. In this case, there is no forest around this area, except the northern.

2.7.3. The utilization of a project area and connected area

The project area is located in the national conservation forests. Left bank of Phachi River is an agriculture area (Zone E), outside of preserves forests (Zone C). The good conditions of this area are the connection with the national conservation at the north, and there are forests on left part of Phachi River and public road. The east part, it connected to the national conserved forests on left part of Phachi River. The south part, it connected to the national conserved forests on left part of Phachi River, and the west was connected with the national conserved forests on the left part of Phachi River.

2.7.4. Transportation to the project area

Transportation to the project area is possible via the main road No: 4 (A-2) from Bangkok and then continue passed to these districts before arriving the project area such as Sam Phran District, Nakhon Chai Si district, the Mueang district, Nakhon Pathom province, Photharam district and Ratchaburi Province. Also, continues from Mueang district, Ratchaburi province to ChatPaWai sub-district, Suanphueng district, on the main road No: 3208. After that, traveling to the Ban kha district by following the main road No: 3206 approximately 15 km. Thus, turn right to the department of Rural Roads No: 4041 (Ban Kha district road to Wang Krok village) about 2 km arrived to moo 9 of the Pou Khi Lex village and Ban Kha sub-district, then turn left to the department of Rural Road No: 5079 (Pu Khi Lex village road, the end of road is SubTery water fall). Finally, traveling is arrived at the project area. The total distance from Bangkok to the project area is about 160 km.

CHAPTER III
METHODOLOGY

The goal of this study is a pre-feasibility study of a tin mine (or tin mines). There is a lot of information that needs to be considered such as topography, which is mapping or charting of the features of a relatively small area, large-scale detail or locality about the mine location. Then, there are geological information about ore deposit and percent grade. Geophysical data was obtained from resistivity electrical measurements of the rock types and thickness of eluvial deposit.

For mine design, can be used the program to formulate the optimum of tin mine. The main data input for mine design is obtained from the pre-studies information and distance of the transports. The production capacity is obtained from comparison between belt conveyor and dump truck. Then, the result for the mine design can be defined technically into mine operation, annual production and mine development including mine rehabilitation.

Mine economics is main concept of pre-feasibility studies of this project. It's crucial for the confidence of potential investors, willing to invest in mining projects, because mine operation costs a lot of money. These capital cost is invest on the equipment (machines), for operation cost and royalty. The result of economic analysis will show break-even point of the project. This depends on the Net Present Value (NPV), the Internal Rate of Return (IRR), and the Payback Period (PP).

3.1. Introduction to resistivity survey

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and voltage (V) values, an apparent resistivity (p_a) value.

The measured apparent resistivity values are normally plotted on a log-log graph paper. To interpret the data from such a survey, it is normally assumed that the subsurface consists of horizontal layers (Loke, 2001).

3.2. Geometrical Consideration

For open pit mining operation, the ore body is the main purpose of mining development. The ore body is mined from the top down in a series of horizontal layers called benches. Factors like safety, life, assets and especially slope stability should also be considered. Mining development starts from the top to the bottom of benches, and continues to the next layer. This process continues until the bottom bench elevation, also called final open pit, is reached. A road or ramp should be created to access to other benches. The width and steepness of the ramp depends on the type of the selected equipment. Overall slopes angle is an important geometric parameter that is significant for the mine configuration. In open pit mining, the equipment selection should be related to the physical size and space requirement to enhance the efficiency of mine operation. Loading and hauling equipment require an amount of working space.

3.2.1. Basic Bench Geometry

The bench height is the vertical distance between the highest point (crest) to the lowest point (toe) or the vertical distance between each horizontal level of the pit. All benches should have the same height.

The benches height should be as high as possible within the limits. The benches size and the equipment selection should fit with the desired production. The benches should not be so high that they will present a safety problem and their width should suitable with distance of working such as excavating, road and rocks etc. Figure 3.1 illustrates that part of bench geometry. The bench face angle is the horizontal angle of the line connecting bench toe and bench crest. It varies from 23 to 37 degree for sand mining.

3.2.3. Pit Slope Geometry

In the pit design stage slopes stability should be considered. The information used for slope design involved the characteristic of soil and rocks, structural geology, ground water condition, the depth below the surface, the model overall slopes as width, height, slopes angle and slopes stability stage.

The slopes and benches are connected from crest to toe of each bench. The angle measured from lower most toe to upper most crest is called overall pit slope angle. If there are more angle that must not stainable to desired operation and safety. The slope stability in each open pit mine depends on wall height or depth of open pit mine.

The overall slope angle obtained from general statistics estimation of the real mining operation for a clay mine is approximately 16-45 degrees depending on water content (wet or dry), for sand mines approximately 22-37 degree, for weathered rock mines approximately 35-50 degrees and for rock strength mines approximately 45-80 degrees. (Annels, 1991) Figure 3.2 illustrate the overall pit slope angle with 2 benches 30 degrees.

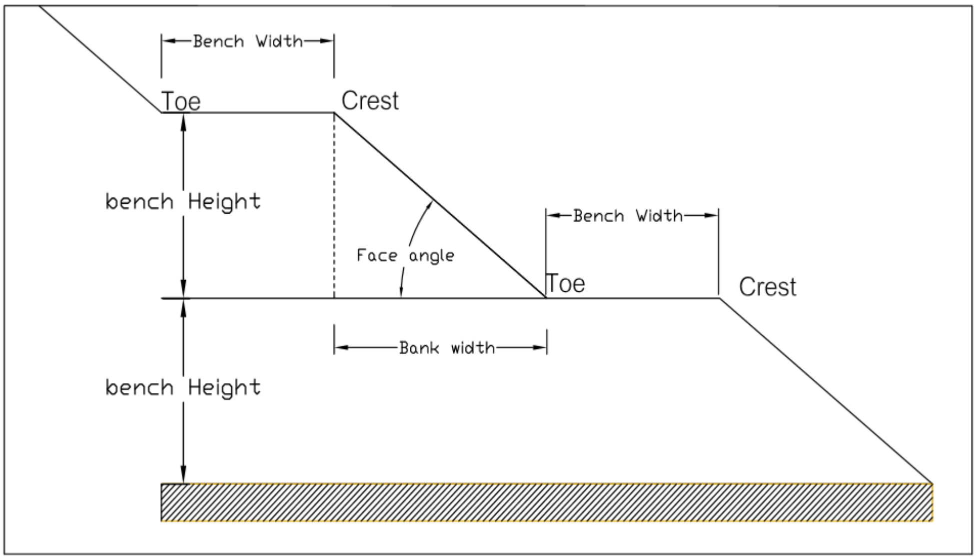


Figure 3. 1 Bench configuration

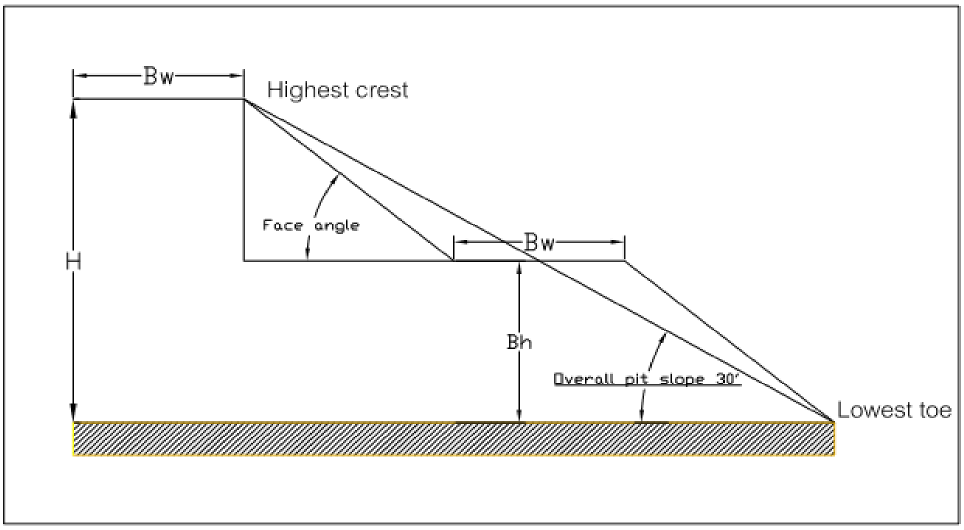


Figure 3. 2 Overall slope angle with 2 benches

The formula to calculate the angle of overall slope is;

$$\emptyset = \tan^{-1}\left[\frac{\text{No. Bh} \times \text{Bh}}{\text{No. Bw} \times \text{Bw} + \left(\frac{\text{No. Bh} \times \text{Bh}}{\tan\beta}\right)}\right] \qquad (\text{eq. } 3.1)$$

Where:

$\emptyset$ is the angle of overall slope

β is the bench face angle

No.Bh is the number of bench height

Bh is the bench height

No.Bw is the number of bench width

Bw is the bench width

3.3. Financial Analysis

Financial analysis concerns about the discounted cash flow (DCF) calculation, the net present value (NPV), and the internal rate of return (IRR).

3.3.1. Discounted Cash-Flow (DCF)

The criterion most commonly employed in the mining industry when evaluating the rate of return an investment proposal is called the discounted cash flow rate of return (DCF-ROR) (Main, 2002). It is referred to the net cash flow or out flow of money, which occurred during a particular time period. The elementary cash flow calculation is:

Gross profit = Gross revenue - Operation expense

Net profit = Gross profit (taxable income) - Tax

Cash flow = Net profit + DD&A - Capital Cost

The DCF method is widely accepted and used in the industry for all types of capital investment evaluation. It recognizes the time value of money. This is critical when assessing the profitability of long-term investments. Future and past values of money can be converted into their present value equivalent by using the time value of money concepts.

3.3.2. Internal Rate of Return (IRR)

IRR is another important and widely reported measure of profitability of the project. IRR is reported as a percentage rather than a dollar figure such as the NPV. IRR is the discount rate at which the net present value is exactly equal to zero, or the present value of cash inflows is equal to the present value of cash outflows. Another definition of IRR is the interest rate received for an investment consisting of payment (negative values) and income (positive values) that occur at a regular period. The equation for calculating IRR is:

$$\sum_{t=1}^{n} \frac{NCF_t}{(1+IRR)^t} = 0 \qquad \text{(eq. 3.2)}$$

NCF_t is the net cash flow.

IRR is the internal rate of return

The investment decision when using IRR is whether to accept the investment if the calculated IRR is greater than the return on the alternative use of funds or cost of capital and to reject the investment if calculated IRR is less than the return on the alternative use of funds or cost of capital.

3.3.3. Net Present Value (NPV)

NPV is the present value of cash surplus or present worth, which is obtained by detracting the present value of periodic cash outflows from the present value of periodic cash inflow. The present value is calculated using the average cost of capital of the investor, also referred to the discount rate or minimum acceptable rate of return (Main, 2002).

When NPV of investment at a certain discount rate is positive, it pays for the cost of financing the investment or the cost of the alternative use of funds. The investment generate revenue that is equal to the positive present value. It also indicates the rate of return on the investment is at least equal to the discount rate. The NPV method of evaluating the desirability of investment is mathematically represented by the following equation:

$$\mathrm{NPV} = \frac{S_1}{(1+id)} + \frac{S_2}{(1+id)^2} + \frac{S_3}{(1+id)^3} + \cdots + \frac{S_n}{(1+id)^n} - Io$$

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{St}{(1+id)^t} - Io$$

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{NCF_t}{(1+id)^t} \qquad (eq.\,3.3)$$

Where

S_t is the expected net cash flow (gross revenue-LOE-taxes) at the end of year t

l_o is the initial investment outlay at time zero.

id is the discount rate

n is the project’s economic life in years.

NCF is the net cash flow

If the NPV is positive, the project is acceptable. If the NPV is negative, the project is rejected. If the NPV is zero, the analyst will be indifferent because the proposal is generating the same return as the alternative use of funds will generate. The

NPV decision criterion follows directly from the assumption that the analyst is required to maximize the value of the project. This criterion result in optimum choice of project.

3.3.4. Discounted Payback Period

The discounted payback period in capital budgeting refers to the period of time required to recoup the funds expended in an investment, which is defined as the expected number of year required for recovering the original investment.

The payback period criteria of the project estimation to business corporate that should be targeted, how long will take to get money back from investment. If the result of calculated the payback period is shorter than or equal to targeted payback period, business organization might invest in that project, and if the calculated the payback period is longer than the targeted payback period an investment is very unlikely.

3.4. Mine planning and design consideration

The major engineering design task in the development of a surface mine is the planning of the open pit. There are three groups of factors involved such as:

a) Natural and geological factor that concern about geologic condition, ore types, hydrologic condition, topography and metallurgical characteristic.

b) Economics factors involving ore grade, ore tonnage, operating cost, desired profits, production rate and market condition.

c) Technological factors are important concerning the selection of the equipment, pit slope, bench height and pit limits.

The planning process is an important stage of the mining project involving the collection of all available data related to the deposit, resource and reserves estimation, mine design and annual production capacity should enough with the marketing demand or life of the project.

The Mine planning divided 3 characteristics of the mine planning phase such as: firstly, long stage is the final open pit design including reserves estimate, stripping ratio, definition the feasibility of project. Secondly, Short stage is separation the sub-mining area for suitable with working and reaches to area of the equipment (machine). Finally, operational planning is used the machine phase, define the area for development, and according to definition of long stage and short stage planning, mineral quantity measurements, and grade control that define the monthly plan or yearly plan.

3.4.1. Mine Life

The life of the mine is determined by dividing the quantity of ore in the ground which is to be extracted by the quantity of ore to be mined per year to meet the market requirements for the products. For a constant rate of production:

$$\text{Mine life} = \frac{\text{Ore Available}}{\text{Annual production Rate}} \qquad \text{(eq.3.4)}$$

To be able to calculate the mine life, the economic limited of the open pit must be known in order to determine the quantity of ore available for mining. This involves optimizing the pit limits which is part of the mine planning process.

3.4.2. Working Hours

Some decision must be made regarding the hours to be worked at the mine site. The factors to be taken into consideration, include industry practice, award conditions, plant maintenance and plant utilization. The possible production per year can be considered from possible working day which is deducted less public holidays, less rain days, and less provision for stoppage. Also, the available operation hours are given total available production days per year multiple with the available operating hours. The available hours include downtime or non-productive time which will result from equipment breakdown, alteration change-over time, and other break, etc.

3.5. Mining methods and equipment selection

The selection of an appropriate mining method primarily depends on: ground condition, required production rate, ore grade distribution requiring possible selective mining techniques, haul distance to concentrator waste dump, and topography of the mine site. These mine site characteristics will generally limit the choice of mining methods. The equipment selected for the operation must be compatible with the site characteristics and the adopted mining method.

3.6. Mining operation development

In mining operation, technique development is the main point and also the role to enhance the eluvial mining or mining successfully. In this step, it will describe the main process of mine operation that is operated on the daily basis, the eluvial mining operation revolves to loading and hauling sequences.

Mining operation is the concept following the planning stage which is concern about soil and rocks will be excavated in each year, mine site, amount cell of working, production capacity of equipment, bench size must relationship with the equipment, main road planning for ore transportation, and drainage included. Mining operation plan required more data such as marketing, price, grade, geological information, ore deposits, sustainable technic, ground water, information about regulation and environmental. These information are applies into target of mining operation plan, which must be alteration changed depending on condition of the mine operation (Micheal & Terry, 1993).

3.6.1. Belt Conveyor

In the manufacturing industry, raw materials and products need to be transported from one manufacturing stage to another. Belt conveyers are used to fulfill this task. which the manufacturing industries is depending on the speed of handling, height of transportation, nature, quantity, size and weight of material to be transported. However, infrequent halt or accident occur while loading and unloading in the industry are source of concern. Also, efficient belt conveyor system is reduced cost and enhance productivity while concurrently reducing dangers to workers operating them. Conveyor system is a mechanical system used in moving materials from one place to another. Which the materials has been reduced size already form surface mine before transports to processing plant or dumpsite (Daniyan, 2014).

3.6.2. Loading and Hauling

A surface mine contains pits with mineral endowed rock or ore. The surface mine extracts ore that lies within the upper layer of the mine boundary. The process of eluvail mining starts with using the excavating equipment remove vertical layers (benches) of material. Over time, these benches themselves are excavated and remove, making the pit wider and deeper. Mining engineers categorize the mined material into ore and waste material, with sub categories depending upon the quality or grade of ore. Trucks transport this material to a number of dumpsites, which can include crushing, stockpiles, and waste dumpsites. Figure 3.3 illustrates the process for creating a pit in sequentially manner.

The mine planning optimizes the timing of bench development depending on the products demand and value of the mine is maximized. The plan, alongside the optimization of the shape of the pit provides required productivity rates, bench sequences, and the shape of the mine. The bench height is varied and dictates the types of the equipment that can remove material. Using the equipment, there are alternate practices for conducting material movement in mine. However, for large-scale open pit mining, in particular, the truck and loader material movement practice is the preferred method of material handling.

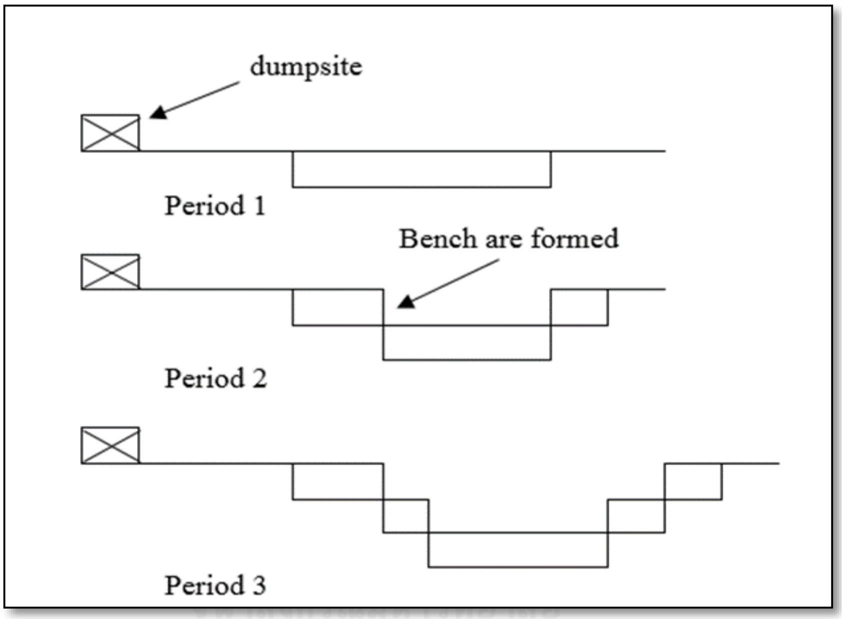


Figure 3. 3 Mining schedule and planning

3.6.3. Loading

Loaders are used to transport ore and waste material to the dump trucks to remove from the mine to stockpile or production plant. In the mining development, loader types are used to develop open pit mine including the backhoe excavator, hydraulic excavator, and front-end loader (wheel loader). Most of the equipment manufacturers publish performance data which can be used to estimate machine productivity. Each machine has characteristics which make it more suitable for one application over another. In this section different, types of machines will be briefly described and a method will be given for the determination of the number of machines to be purchased for a given mining operation.

The loader selection is depending on the type of mineral to be excavated, specifications of the mine geometry such as bench height, particularly, the compatibility of the loaders with selected truck fleets, and others factors must be considered in the equipment selection process, For example, some loaders cannot reach the top of the tray on the larger trucks. Conversely, some loader capacities exceed the capacity of the truck. The highly effective the truck and loader set are determined from of product capacity. Then, the dump truck and loader types will be selected simultaneously (Chritina, 2013). The equation to estimate the production per hour of a wheel loader is:

$$O = \frac{BC \times BF \times D \times MA \times JF \times 3600\,sec}{(1 + SF) \times CT} \qquad (eq. 3.5)$$

Where: O is the production in, ton/hour.

BC is the bucket size in, cubic yard (CY).

BF is the bucket fill factor in, percent

D is the density in place in, ton/CY.

MA is the mechanical availability in, percent.

JF is the job factor in, percent.

SF is swell factor in, percent.

CT is average cycle time in, second.

The number of trucks can be estimated by this equation;

$$N_{truck} = \frac{\text{Truck cycle time}}{\text{Loading time}}$$

Where: N_{truck} is the number of trucks

3.6.4. Cycle time of the truck

The truck cycle time itself comprises load time, haul time (full), dumping time, return time (empty), queuing (and other delays) and spotting time. A cycle may begin at a loading site where the truck receives its load from the excavating equipment. The truck travels full of ore to the dumpsite or stockpile through a designated route along a haul road. After dumping the material to the stockpile, the truck turns around and travels empty back to the loader. The spotting is the act of maneuvering the truck under the loader for serving. This can take several minutes. In a large mine, the truck cycle time may be 20-30 minutes in total, and can vary significantly over time if the stockpiles move and as the mine deepens (Chritina, 2013). Figure 3.4 illustrates the cycle time of the truck from the loader and dumpsite.

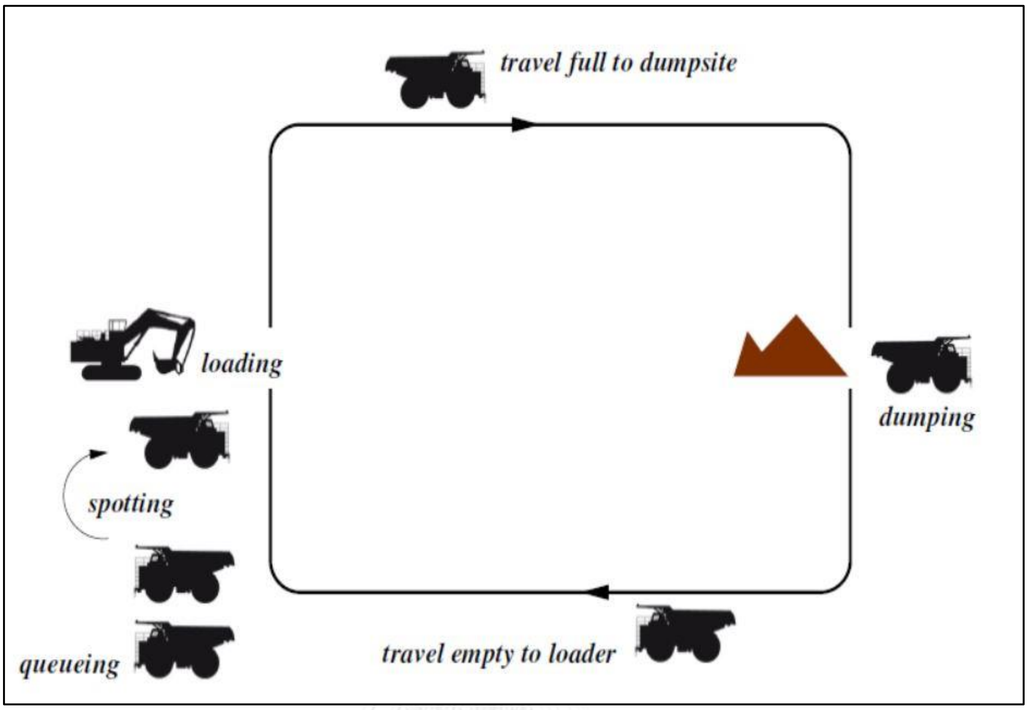


Figure 3. 4 Cycle time of the truck

The truck cycle time plays an important role with respect to loading and hauling into transports material to production plant. In addition to the average cycle time (C) one parameter needs to be considered to determine the production capacity in each cycle time of the equipment. (Cateriller Performance Handbook, 1979-2004) Table 3.1 shows the average cycle time increasing with the size of the equipment.

Table 3. 1 Average cycle time

Loader size (cubic yard)	Cycle time (minute)
1.5-4.5	0.45-0.50
5.0-8.5	0.50-0.55
8.5-12	0.55-0.60
12-16	0.60-0.65
16-22	0.65-0.70

CHAPTER IV
THE RESULT OF THE STUDY

In parallel with the adopted methodology for application to open pit develop into process optimization about pre-feasibility study, this chapter displayed the result of data preparation and the result of the project study such as resistivity electricity that is measurement to increase confidence the sediment thickness, mine boundary, the contour lines, and bedrock contour lines. The results of mine planning and design, and financial analysis are also discussed in detail.

4.1. The electrical resistance geophysics

The electrical resistance geophysics principle is used Ohm's law for identify the direct current. Which is low frequency alternating current electricity and homogeneous ground. The working principle of 4 terminals is current flow 2 terminals through the ground layers and there are the receiver 2 terminals to calculate the current. The geophysical measurement method of the electrical resistivity is used to determine sediment layers and bedrocks. Figure 4.1 illustrates the information of the electrical resistivity measurement of the line 1 (L1) to line 7 (L7). According to the resistivity result appeared on line from measurement in process of a model form, which can be interpreted the line and the distance is 1,890 meters. The interpretation of resistivity to identify the sediment layer was depending on the electrical resistance as Red color > 500 ohm-meters, is quartz sediment, dry sand or granite. Green color 100 to 500 ohm-meters, is shale rock layers, and Blue color 10 to 100 ohm-meters, is clay layers with contain more moisture, and there are pitting on the field to check about confidents of the sediment layers. Which enable to divide the sediment layers as;

a) The sediment layers composite of quartz, dry sand and including to layers expected that was eluvial deposits. Generally, cassiterite was accumulated on the bottom of sediment layers. The thickness approximately 15 meters and the average thickness approximately 5 meters which distribution of all the area.

b) Weathered rocks are the bottom layers of sediment, which consist of clay, mudstone and granite layers.

c) Bedrocks is a layers support the bottom layers, some a range has a fracture, it made some a range of weathered became to the trenches.

This area contracted with some a range of granite, mudstone, and sand. Which has alteration of structure geology such as fault, fracture, and fold. These alteration are important for ore deposits and mineral weathering from source rocks. Also, from interpretation of the information can be summarized the average sediment layers approximately 5 meters. The color display the thickness of sediments layers and outcrop rocks as pink is outcrops rocks, Red is a range of top soil to the bottom approximately 1 to 1.5 meters depth. Yellow is a range 1.5 to 3.87 meters depth. Green is a range 3.87 to 7.06 meters depth, and Blue is a range 7.06 to 12.51 meters depth. The result of the electrical resistivity is provided in Appendix C.

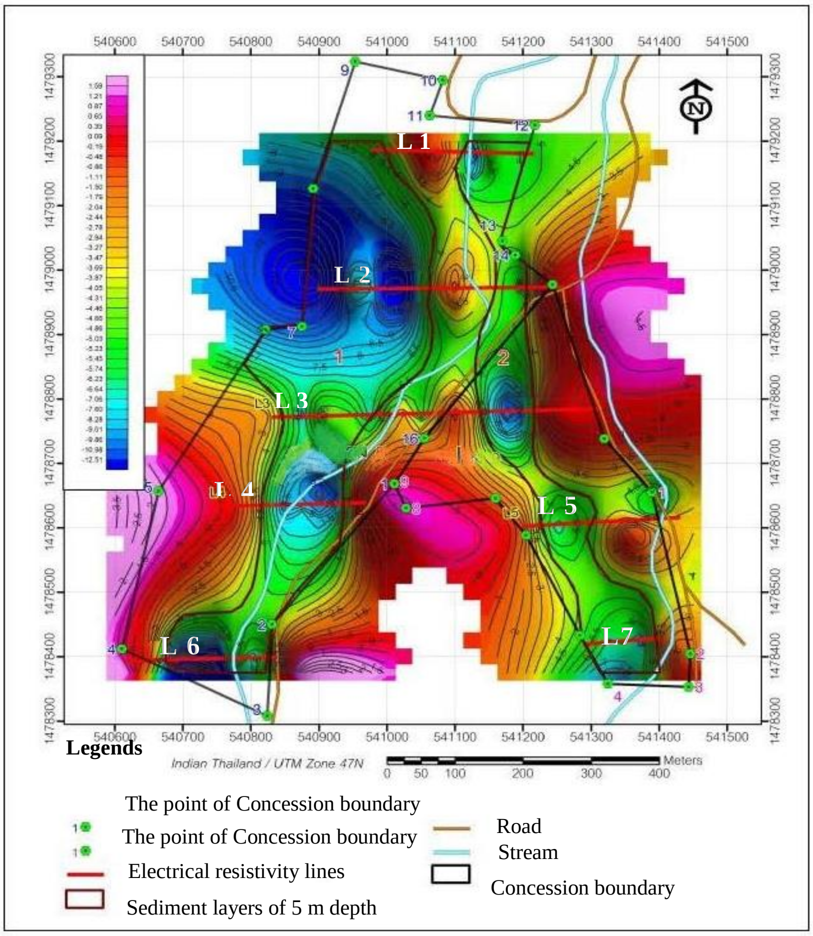


Figure 4. 1 Model of the electrical resistivity measurement of line 1 (L1) to line 7 (L7).

4.2. Data preparation

Prior to entering the data into the MineScape software, it was adjusted using AutoCAD. The main data was minable limit, topographic and bedrock contour lines. Details of the data are found below.

4.2.1. Mine boundary of the project study

The project selected study area covers an approximate area of 242 Rai (387,200 Square meters). Figure 4.2 illustrates the mine boundary, road, conveyor line, stream and buffer zone.

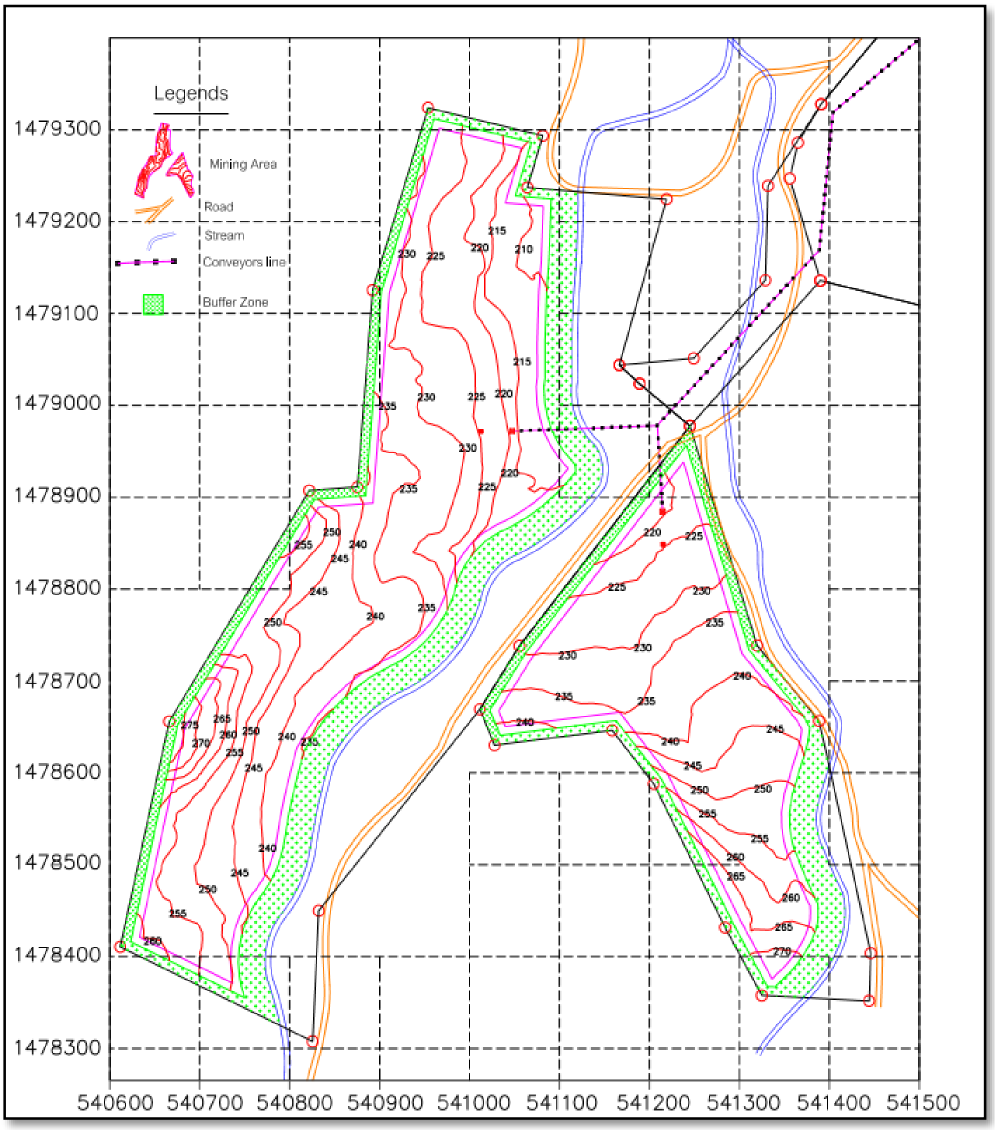


Figure 4. 2 Mine boundary of the project area

4.2.2. Topographic map

The topographic map contour lines was the most important data for indicated to accuracy about the detail of ground characteristic and appropriate to the scale of the map. Topographic mapping was conducted using ground survey methods (total station) tied to existing survey control benchmark point, this area has a moderate slope, posing quite tilted to the northeast. Figure 4.3 illustrates the topographic map around the project area which served as input for the Mincom Minescape software.

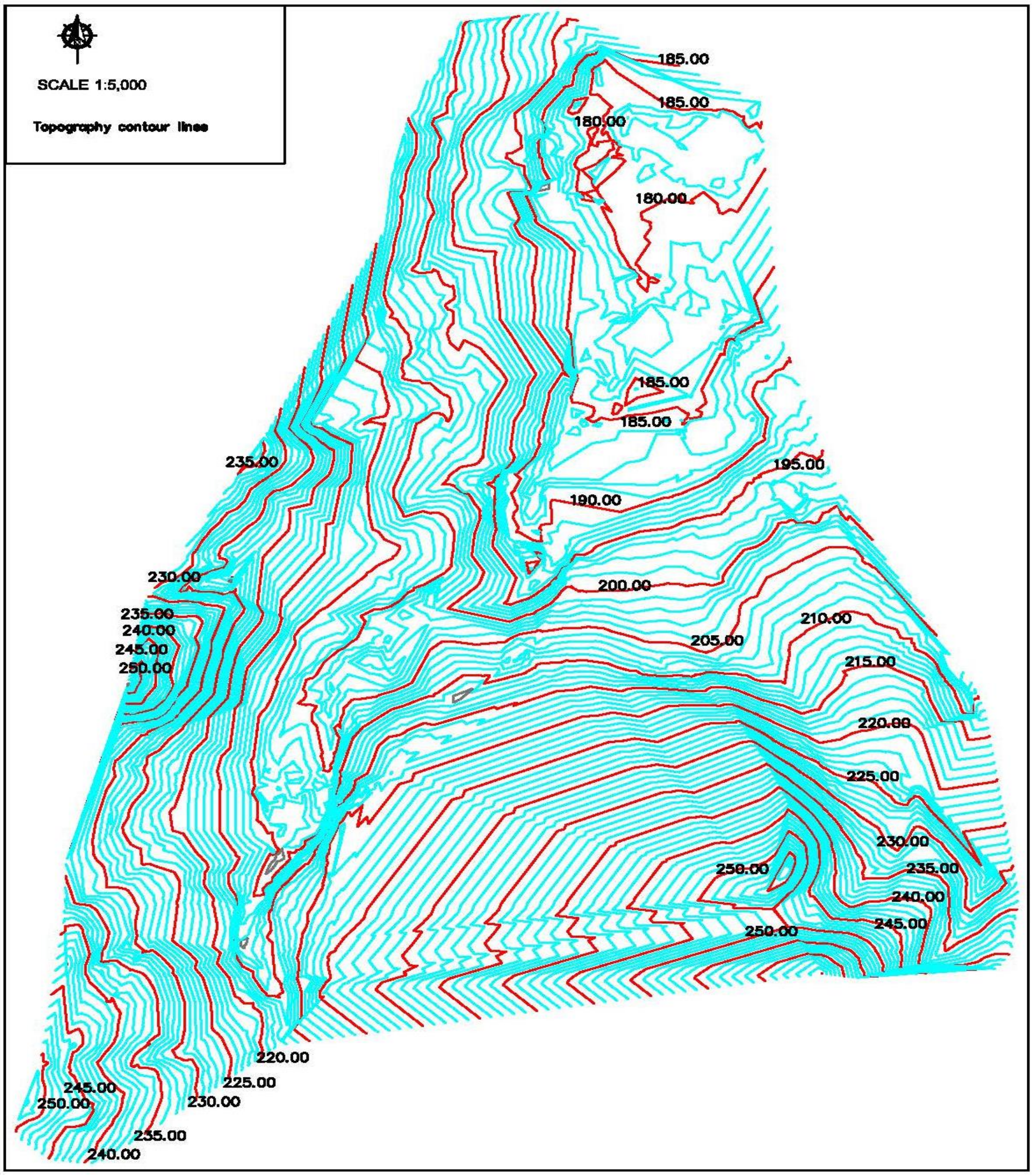


Figure 4. 3 Topographic map with contour lines

4.2.3. Bedrock contour lines

The electrical resistance measurement can be identified to the bedrock that was the layers supported the bottom of eluvail layers. The bedrock contour lines are important data because they are an indicator of the thickness of the eluvial layers. Figure 4.4 illustrates the bedrocks contour lines, which are the data format input to the Mincom MineScape software.

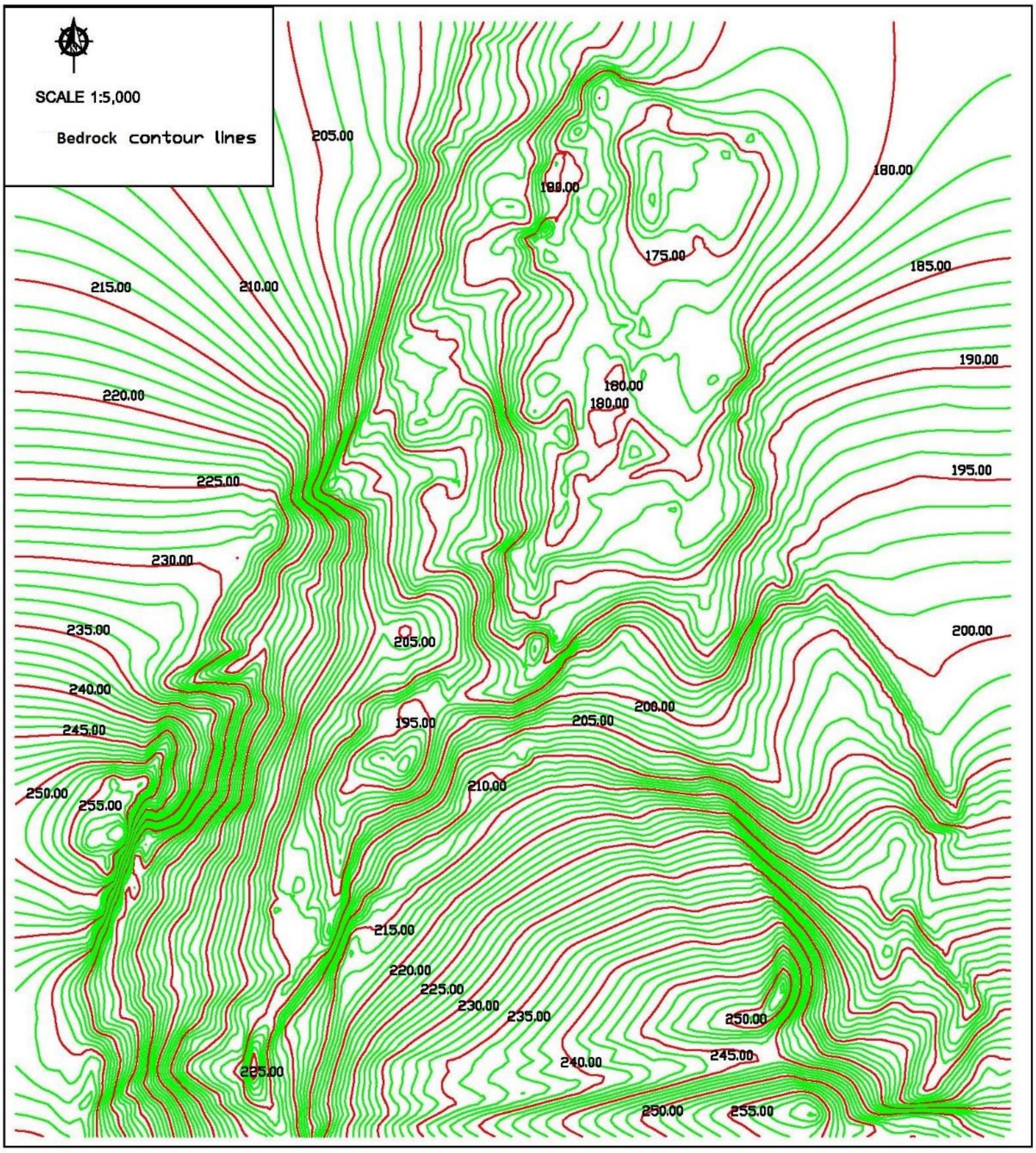


Figure 4. 4 Bedrock contour lines

4.2.4. Minable boundary

The minable boundary of this project covers an area of approximately 242 Rai (387,200 square meters) as mention above. According to the regulation of the government for minable boundary which are excluding the buffer zone (10 meters from road, stream and mining concession boundary), the minable boundary is approximately 154 Rai (246,400 square meters). Figure 4.5 illustrates the minable boundary for input to the Mincom MineScape software for mine design.

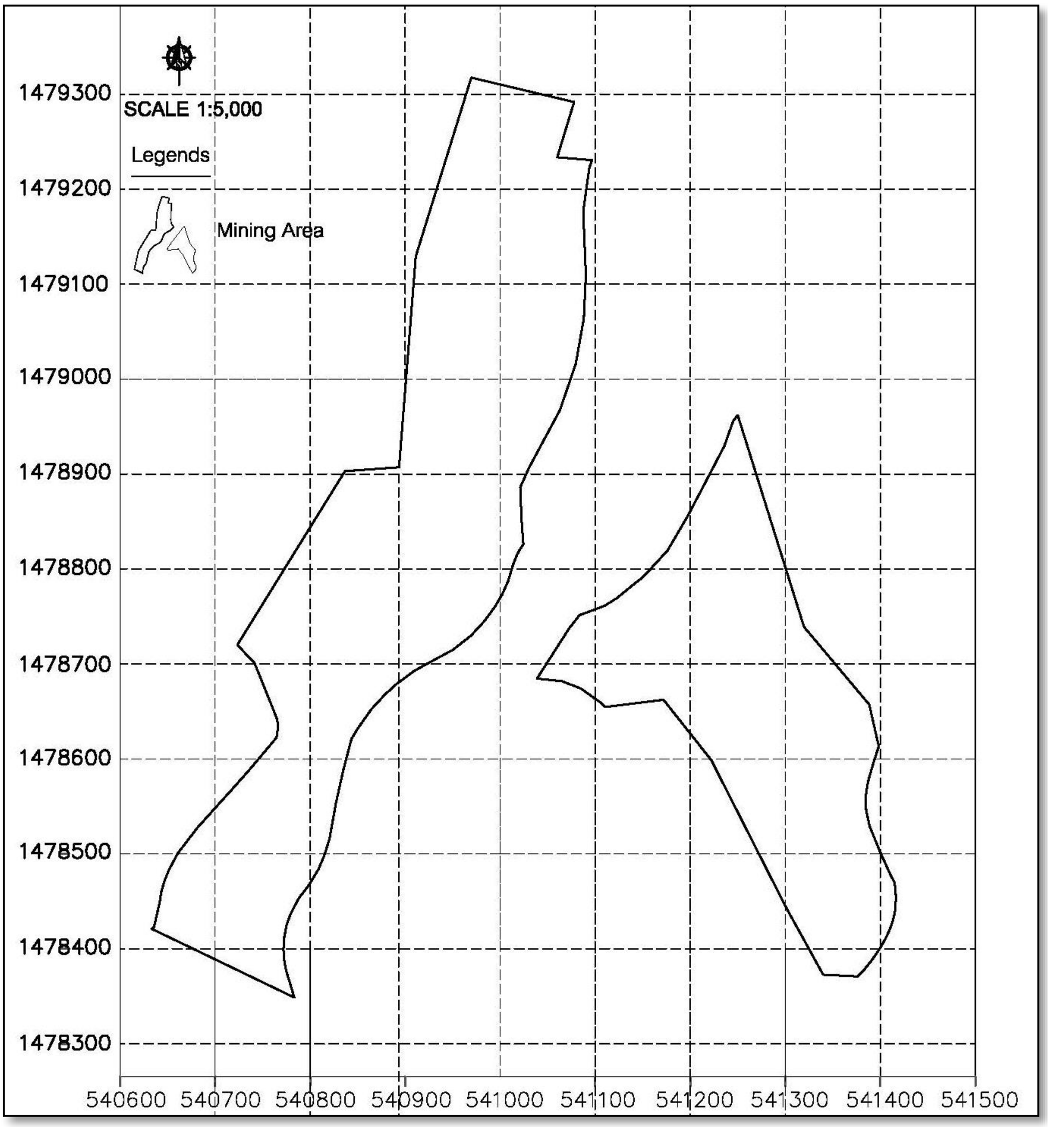


Figure 4. 5 Minable boundary input to MineScape software

4.3. Mine planning and mine design

Based on the ultimate reserve estimation, mine planning is considered from the characteristics of the tin deposits, mining reserve of the tin ore with sand, annual production capacity, environment impact and mine safety. In this project tin ore with sand is transported to processing plant using the belt conveyor.

The data for mine design is the topographic map and geological characteristics of the tin deposits. The electrical resistivity was conducted to rise confidence about the thickness of eluvial layers of the tin deposits. The total area of this project is 38.83 hectares. Due to the government regulation for exclude buffer zone (10 meters from road, stream and mining concession boundary) which is the area approximately 154 Rai (246,400 square meters). Figure 4.6 illustrates the minable area of the project study (help in pink). Table 4.1 illustrates the parameters for mine design.

Table 4. 1 Parameters for mine design

Parameters	Values
Overall pit slope (Annels, A.E., 1991)	30 degree
Bench height	5 meters
Bench width	5 meters
Average tin ore grade (from testing at laboratory)	0.1 percent
Specific gravity (SG) of sand (from testing on the field of company)	2.6
Buffer zone from road, stream and concession boundary	10 meters

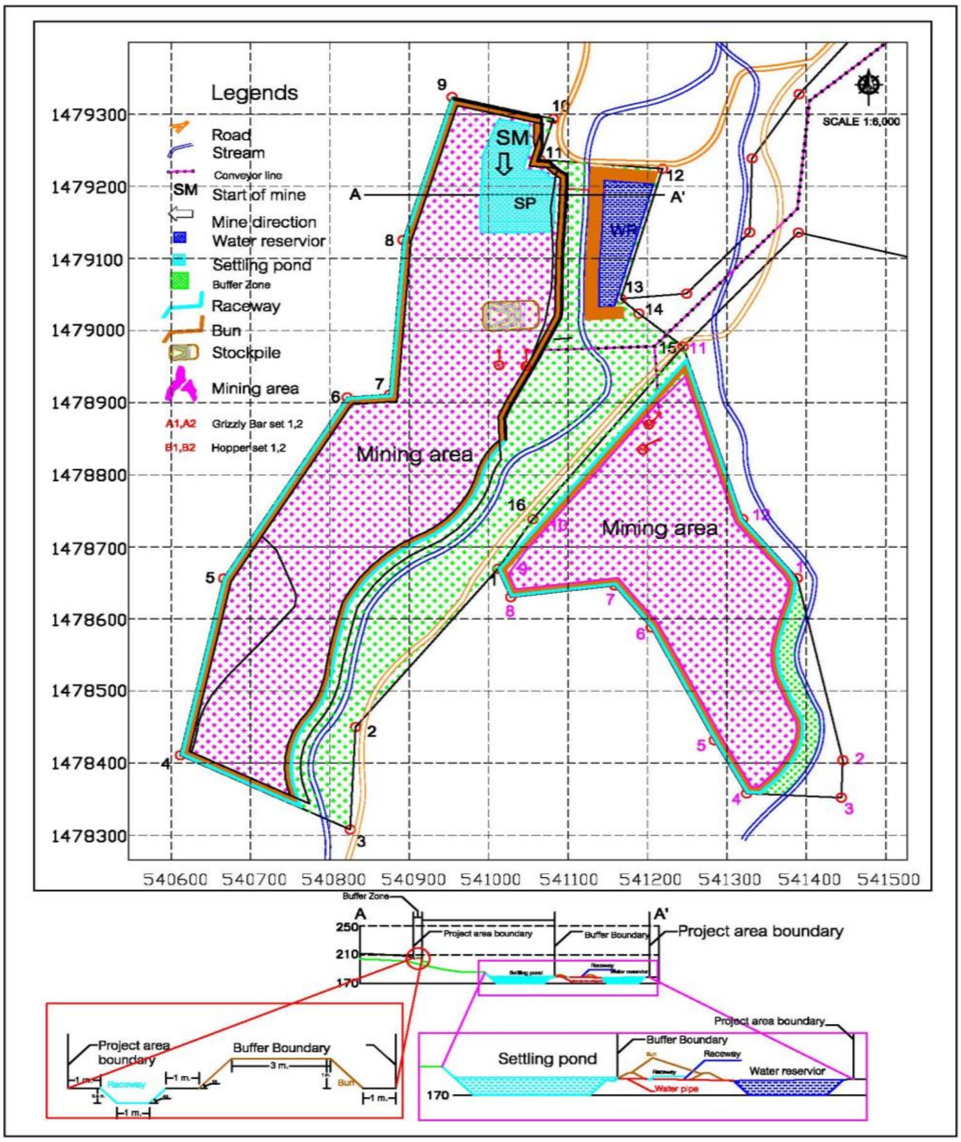


Figure 4. 6 Minable area of the project study

According to the geological condition, government regulation and other parameters used for benches and slope design in the mine development phase. This ultimate pit geometry 2 benches of 5 meters height and 5 meters width are designed. The calculation by using the equation 3.1 the result equal to 30 degree of the overall slope angle with the benches face slope of 39 degree as shown in figure 4.7.

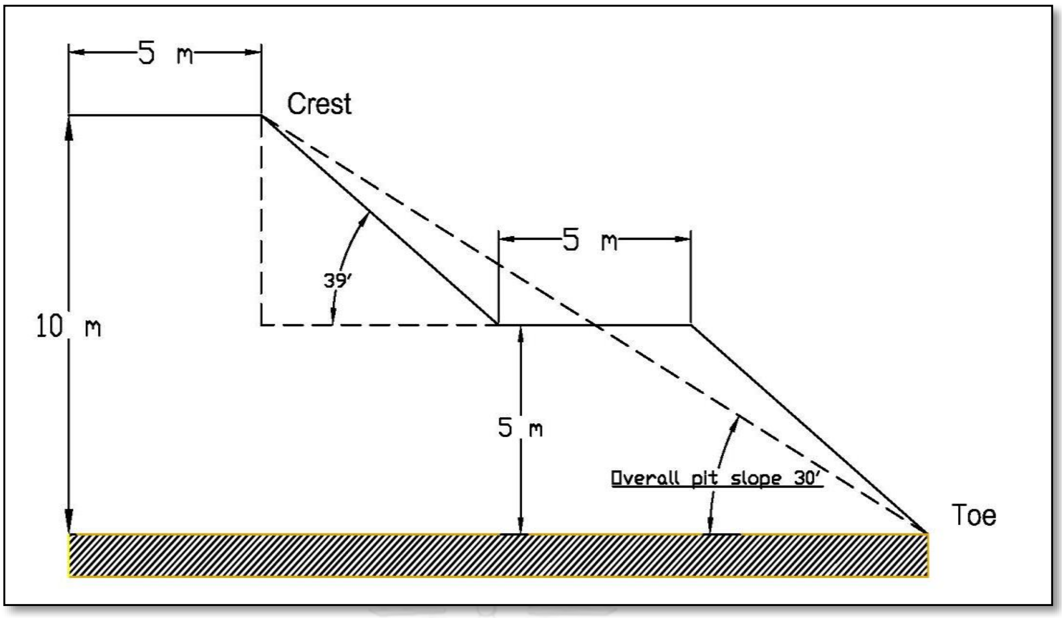


Figure 4. 7 The ultimate geometry with bench configuration

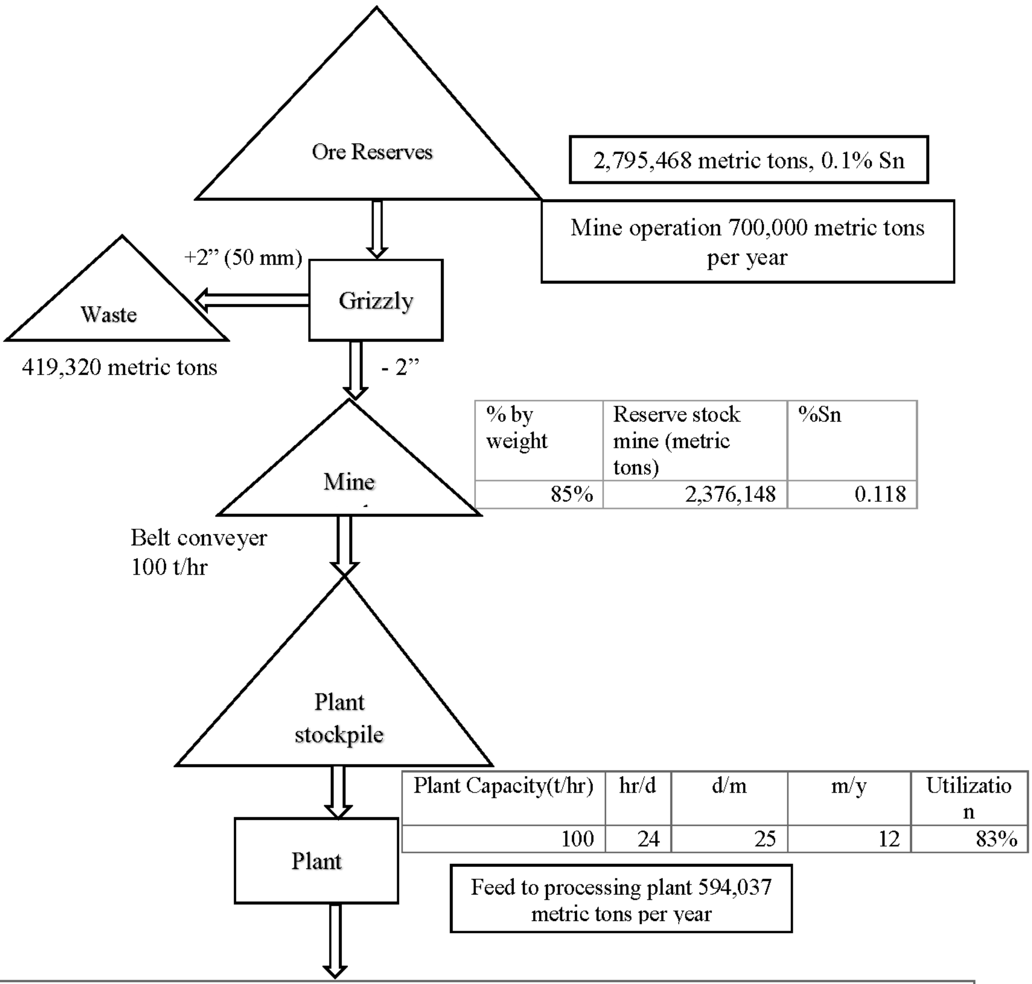
4.4. Reserves Estimation

In this study, reserves calculation used data mention above such as topographic map, bedrock contour lines and minable limit. The volume calculation of this software are used the function to project drown of the minable boundary on the topographic, and the bedrock contour lines that is support layers of the tin ore deposits. The Mincom MineScape software can be calculated the volume around inside minable boundary. The parameters considered for reserve estimate such as specific gravity of sand equal to 2.6 (specific gravity of sand obtained testing on the field of company). The eluvial deposit is distributed covers all of the area with the thickness about 5 meters. They are measured by using electrical resistivity.

The Mincom MineScape software can be calculated volume was 1,075,180 cubic meters multiply with specific gravity of sand 2.6. Then, reserve of tin ore with sand is 2,795,468 metric tons. The 3 D model of running the Mincom MineScape software is provided in Appendix D.

4.5. Mining operation

The result of reserve estimated and comparison ore transportation cost which belt conveyor was selected for ore transport from mine stockpile to the processing plant. The mine operation (operation line) of the project as shown in this flow sheet.



% by weight	Reserve stock mine (metric tons)	%Sn
85%	2,376,148	0.118

Plant Capacity(t/hr)	hr/d	d/m	m/y	Utilization
100	24	25	12	83%

Result from mine operation of this project.									
Soil		**Aggregate**		**Sand**		**Tin concentrate**			
% by weight	Metric tons/year	% by weight	Metric tons/year	% by weight	Metric tons/year	% by weight	Metric tons/year	%Sn	%Recovery
4.88%	29,070	15%	89,106	80%	475,230	0.118%	630	74%	90%

Figure 4. 8 The mining operation from site to the processing plant

The ore with sand reserve 2,795,468 metric tons are estimated by used the Mincom MineScape software. The planning for mine operation was 700,000 metric tons per year. The mining development phase which separates out the larger material fraction (bigger than two inches). The ore with sand reserve after separates big size is 2,376,148 metric tons and tin grade 0.118 percent. The tin ore with sand are transported by belt conveyor 100 ton per hour. The plant capacity is 100 ton per hour, working phase 24 hour per day, 25 day per month, 12 month per year, and utilities 83 percent. The final products feed to the processing plant 594,037 metric tons in each year, and obtained the tin concentrate was obtained from calculation of amount feed to the processing plant multiple with tin grade (0.118 percent) and %Recovery. The sand and aggregate products was obtained from the amount feed to processing plant multiple with percent by weight (percent by weight obtained from testing at the laboratory).

Mining operation is an important process tin mining. According to the information and reserve estimate mentioned above one is able to define annual planning of mining operation, which divided annual production into fourth years. The detail are shown in Table 4.2. Figure 4.8 illustrates the mining operation from site to the processing plant. Figure 4.8 to 4.11 illustrates the mine layout of mining operation in each year and cross section displaying the thickness of the eluvial layers.

Table 4. 2 Mine production plan

Year	Tin ore reserve with sand		Tin (metric tons)	Note
	Cubic meters	Metric tons		
1	0	0	0	Mine development
2	269,230	700,000	630	figure 4.9
3	269,230	700,000	630	figure 4.10
4	269,230	700,000	630	figure 4.11
5	267,490	695,468	620	figure 4.12
6	0	0	0	Mine rehabilitation
Total	1,075,180	2,795,468	2,510	-

The first year is the mine development phase. The activities in this year are the preparation of the infrastructures, installation of the equipment (machines) and the belt conveyor, preparation of the road, construction of the setting pond and water reservoir.

The second to fifth year is the mine operation phase. The activities in this phase are excavation of the tin ore with sand by using hydraulic excavator and transport by using dump trucks from mine site to the Grizzly screen, which separates out the larger material fraction (bigger than two inches). The tin ore with sand which is less than two inches is feed into a hopper by a wheel loader. Then, the tin ore with sand is transported to the processing plant using a 2,077 meters long belt conveyor. The mine operation phase is shown in Figure 4.8, 4.9, 4.10 and 4.11.

The mine operation phase starts from the northern part and expand to the southern part of the project area, following the arrow direction. According to the mine plan, the production plan for tin ore with sand is 700,000 metric tons per year to be sent to the processing plant and the finished production of tin is 630 metric tons per year.

In the fifth year, the mine production is 695,468 metric tons per year and the processing plant production of tin product is 620 metric tons per year as shown in figure 4.11. As a result, the total tin ore with sand mining production of the project is 2,795,468 metric tons and the total tin finish product from the processing plant is 2,510 metric tons.

In the sixth year, the project goes into the mine closure phase. The activities include landscape adjustment and mine rehabilitation by following the environmental regulation.

According to the mine planning of annual production capacity and tin ore with sand reserves, which is able to consider the equipment capacity and suitable with each really function of working. The main equipment (machine) used into tin mining. There are detail in Table 4.6

Table 4. 3 Mine equipment and screening

No.	Equipment	Units
1	Hydraulic excavator (bucket capacity 0.52-2.3 cubic meters)	2
2	Dump truck 15 tons	8
3	Wheel loader (bucket capacity 2.7-4.0 cubic meters)	1
4	Fuel truck 5,000 liters	1
5	Water spray truck 5,000 liters	1
6	Grizzly screen and Hopper	2

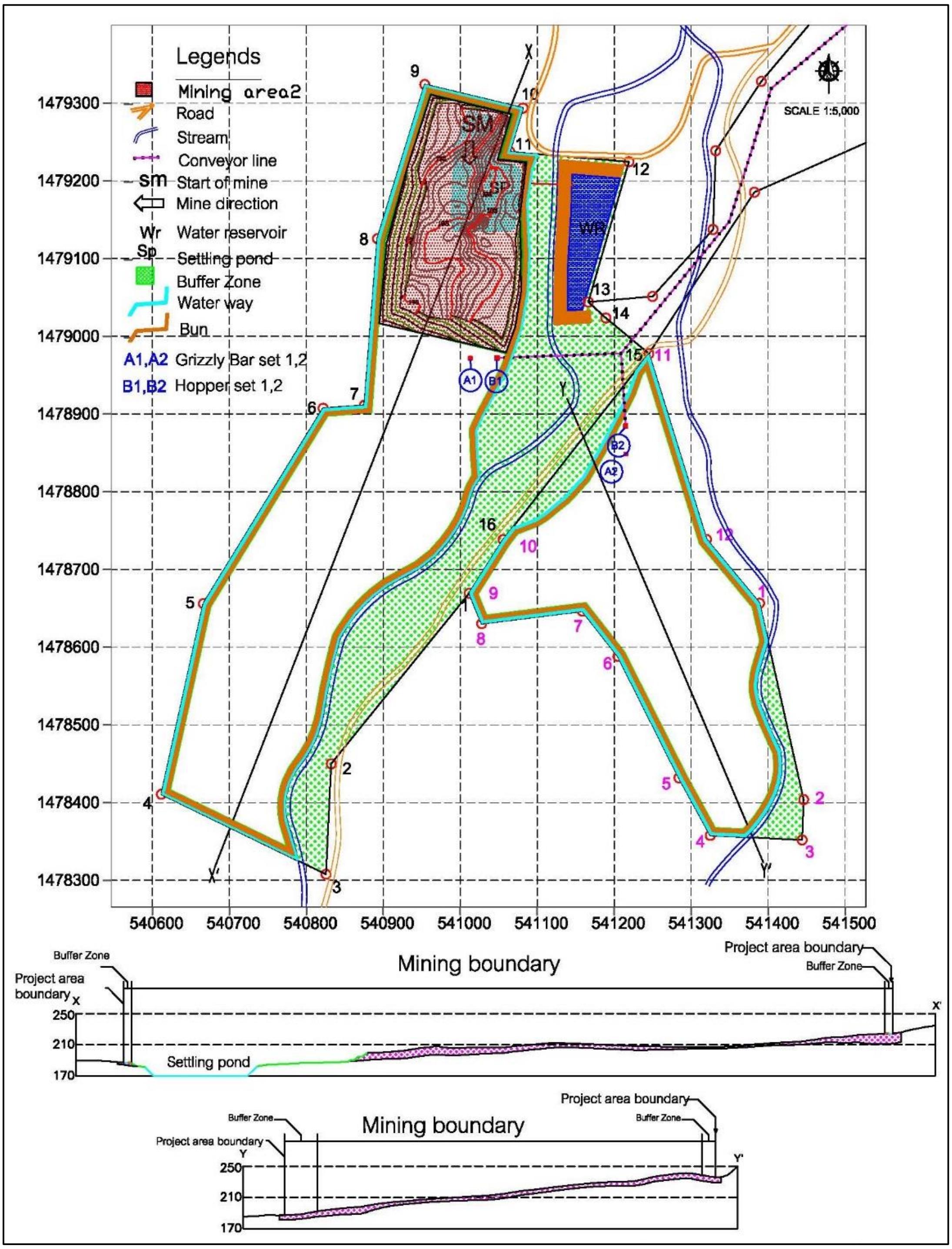


Figure 4. 9 Mine layout at the end of the second years

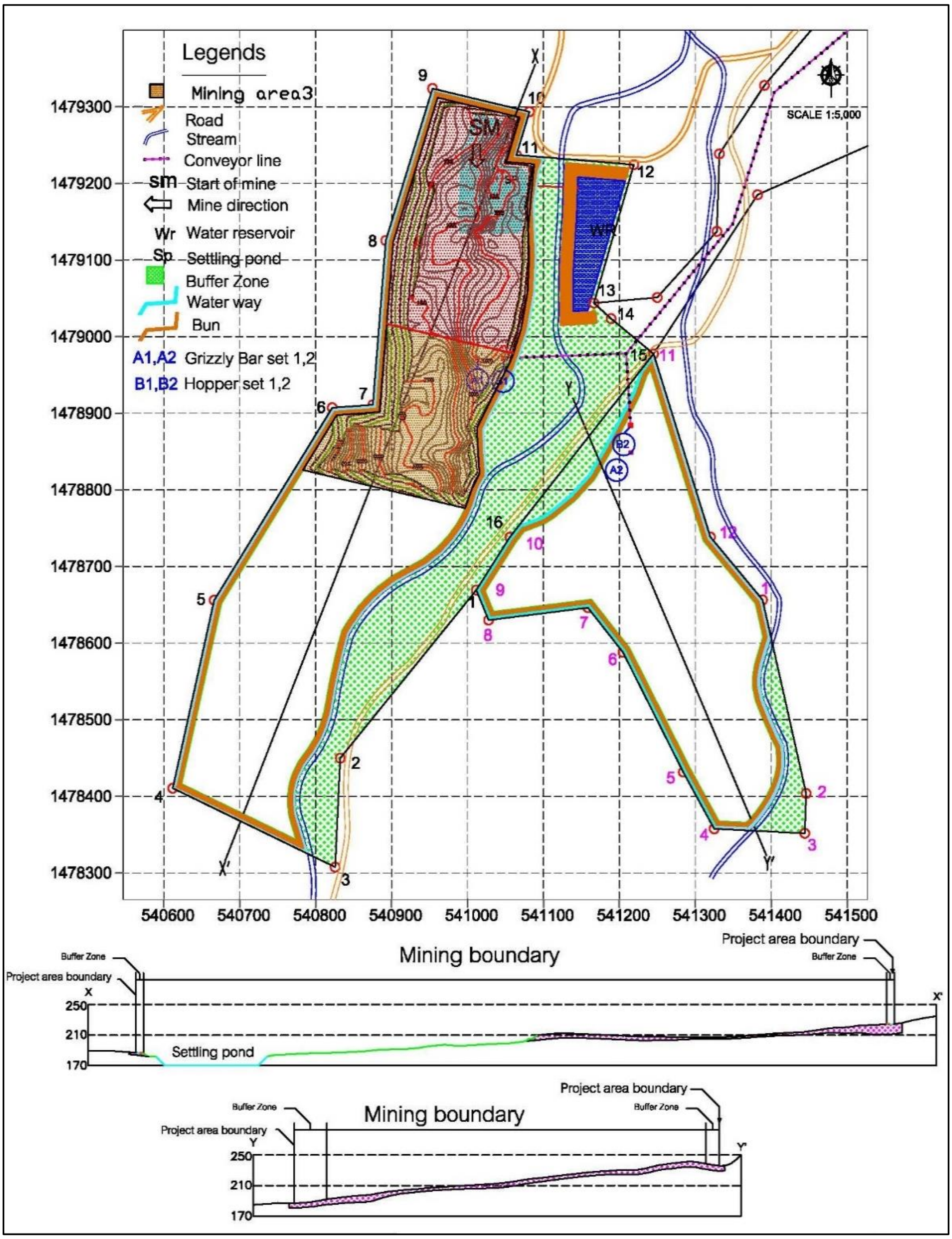


Figure 4. 10 Mine layout at the end of the third year

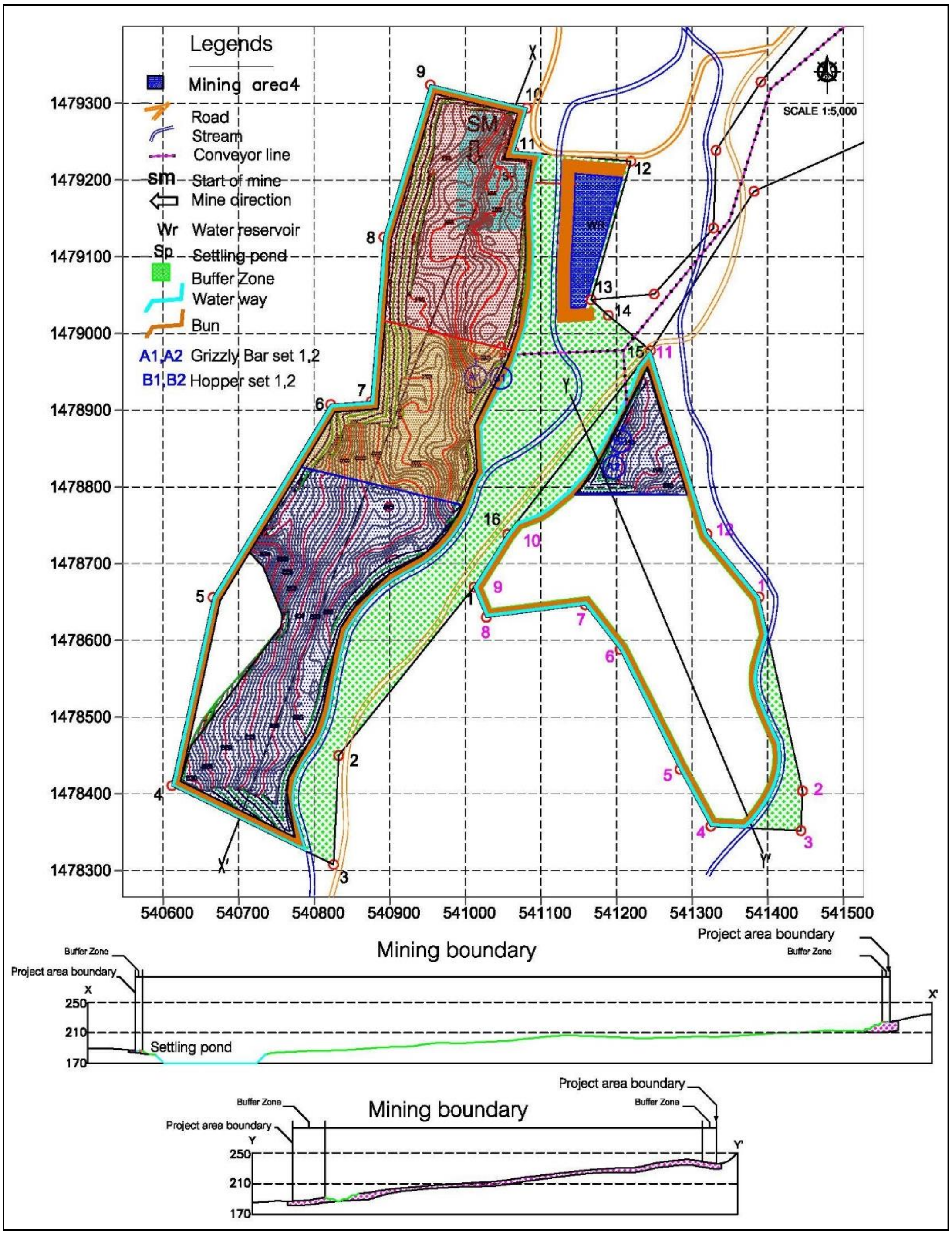


Figure 4. 11 Mine layout at the end of the fourth year

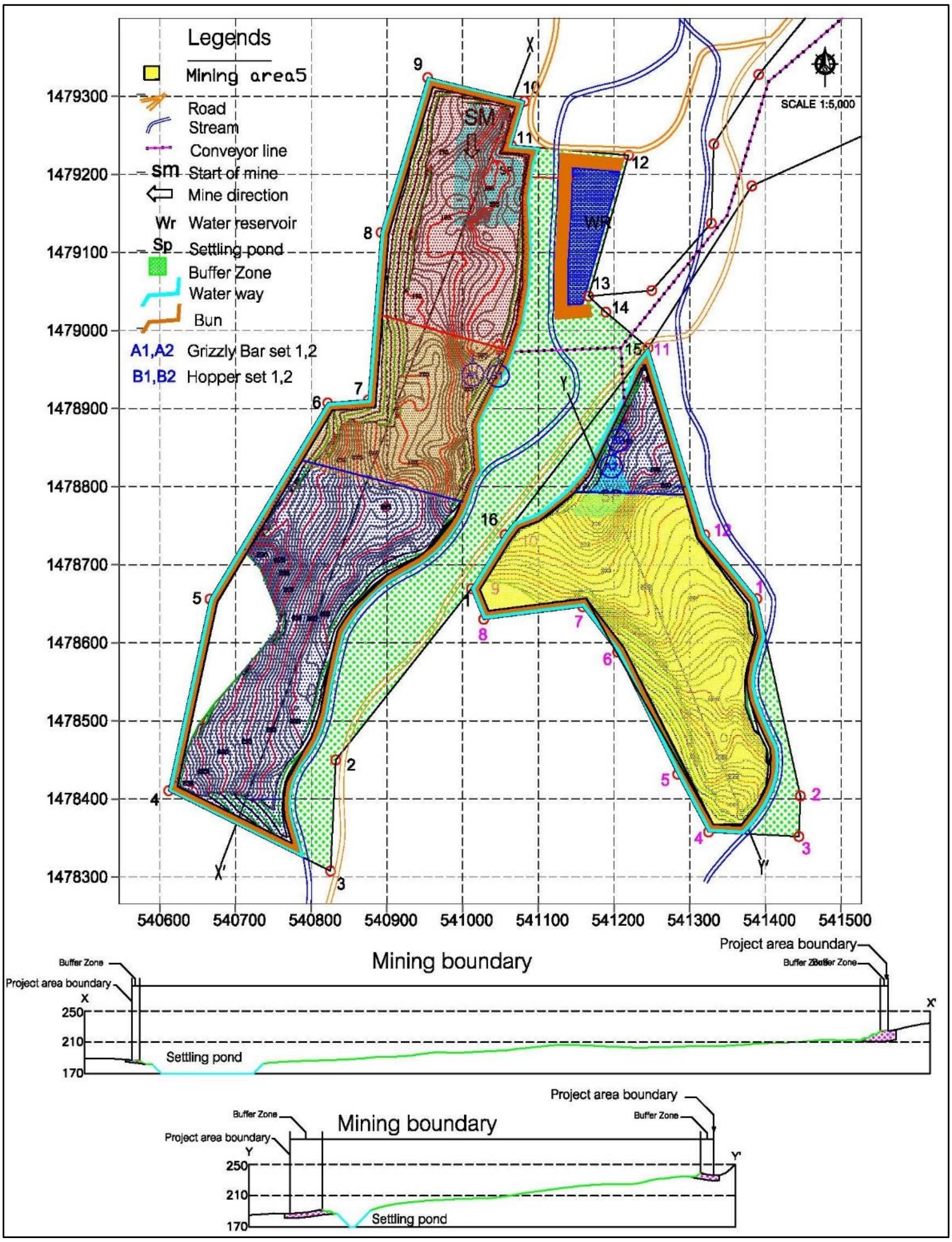


Figure 4. 12 Mine layout at the end of the fifth year

4.6. Loading and Transportation

Typically for the tin mining production. There are selecting the main equipment as belt conveyor, wheel loader, excavator, and trucks system are chosen to be a material transportation equipment because the flexibility and facilities. To make sure that the selected equipment meets production requirement, the decision of equipment selection has been conducted at the expected into the initial and maximum operation parameters of the facilities to working of each equipment.

In this study, a wheel loader (model Komatsu WA380z-6), excavator (model Komatsu PC 300LC-6 and Komatsu PC 200LC-8), a truck (model Hino FM2PNLD) and belt conveyor are used. The production capacity calculation of equipment is illustrated in the following sections.

According to the topography condition and operation cost, for this project belt conveyors were selected for the transport of the tin ore with sand from mine site to the processing plant. The production capacity is 100 tons per hours.

4.6.1. Loader production Calculation

The loader model Komatsu WA380z-6 with a capacity of 2.9 cubic meter is used in this calculation. From equation (3.6), the estimation of the production capacity per hour of the wheel loader is shown in Table 4.7 together with all input parameters.

Table 4. 4 Estimation of production per hour of the wheel loader

Parameters	Equation	Result
BC (bucket size)	2.9 m^3	3.79 CY
BF (bucket fill factor)	95 percent	0.95
D (density in place)	1.5 ton/m^3	1.15 t/CY
MA (mechanical availability)	85 percent	0.85
JF (job factor)	90 percent (assumption)	0.90
SF (swell factor)	67 percent (ore with sand)	0.67
CT (average cycle time)	40 sec	40
O (production)	$\frac{BC \times BF \times D \times MA \times JF \times 3{,}600\ sec}{(1+SF) \times CT}$	170 tons/hour

From the calculation of the wheel loader production capacity in the Table 4.7, the resulting production is 170 ton/hour. One wheel loader is required to feed tin ore with sand to hopper. The production is transported from the mine site to the production plant using belt conveyor with a capacity of 100 ton per hour.

4.6.2. Excavators Production Calculation

As mentioned above, the excavator models Komatsu PC 300LC-6 and PC 200LC-8 are used in mining operation with a capacity of 1.6 cubic meters. The details of the calculation are shown in Table 4.8, which are similar to the calculations for the wheel loader.

Table 4. 5 Production per hour of excavator calculation

Parameters	Equation	Result
BC (bucket size)	1.6 m^3	2.09 CY
BF (bucket fill factor)	100 percent	1
D (density in place)	1.5 ton/m^3	1.15 ton/CY
MA (mechanical availability)	95 percent	0.95
JF (job factor)	95 percent (assumption)	0.95
SF (swell factor)	67 percent (ore with sand)	0.67
CT (average cycle time)	15 sec	15
O (production)	$\frac{BC \times BF \times D \times MA \times JF \times 3{,}600\ sec}{(1+SF) \times CT}$	311 tons/hour

4.6.3. Truck Production Calculation

For tin mining operation, trucks are an important equipment for the transport of the tin ore with sand or waste material from mine site to Grizzly screen or stockpile. In the mining task, it is necessary to understand about amount and the type of the trucks to reduce the operation cost and enhance the productivity. In this project study, there are selected the type and the production capacity of the truck into the calculation number and the cycle time of the truck.

The main purpose of the truck production calculation there are 3 folds which are; the first is the estimate the loading time of wheel loader; the second to estimate the hauling time for truck from working bench to Grizzly screen, the third to estimate the return time of the truck from Grizzly screen to the working bench. The assumption have been made that the dumping time and the spotting time are 0.8 minutes and 0.8 minutes respectively base on the information of Caterpillar Handbook *(Cateriller Performance Handbook, 1979-2004)* The detail input information is provided is provided in Appendix B.

In this study, the calculations of the cycle time are based on a haul road connecting the center of the pit to the Grizzly screen. The distance of the hauling and returning is divided into segment based on the road condition (percent grade, working condition) as shown in Table 4.9 which illustrates the calculation of the truck average speed and time for hauling and returning segments. The result of the calculation show that, the total hauling time is 2.75 minutes, and the total returning time is 2.42 minutes. A wheel loader loading time is 1.56 minutes. The total cycle time of the trucks is 8.33 minutes. The summary of total truck's cycle time is provided in Table 4.10

Table 4. 6 Hauling and returning time.

Hauling segments	Length (m)	Grade (%)	Avg. Seed (km/h)	Time (min)
1	195		20	0.585
2	425	10	16	1.59
3	180	0	19	0.57
Total	800			2.75
Returning				
1	180	0	25	0.432
2	425	-10	17.5	1.46
3	195	0	22	0.53
Total	800			2.42

Table 4. 7 The total truck's cycle time

Load	1.56 minutes
Haul	2.75 minutes
Dump	0.8 minutes
Return	2.42 minutes
Spot	0.8 minutes
Total	8.33 minutes

4.6.4. The unit production of trucks

The main objective of the unit production calculation are defined the amount of the trucks used into tin mine operation. The unit production calculation considers from the truck payload, the truck cycle time, hour per shift of working, and operation efficiency. Table 4.11 illustrates the unit production calculation.

Table 4. 8 The unit operation calculation

Parameters	Equation/Assumptions	Result
Working time	52.5 min/hour (assumption)	52.5 min/hour
Operation efficiency	90 percent (assumption)	0.9
Productivity	Truck/cycle*1cycle time*work time*operation efficiency	85.05 ton/hour
N (number of the truck)	Cycle time/Loading time	6 trucks
To reach 622 ton/hour (backhoe 2 units)	(622 (ton/hr)/(productivity)	8 trucks

From the result of the unit production calculation 8 trucks are required to fulfill the 622 tons per hour of material handling.

To summarize the loading and transportation requirement of the tin mine operation which the total cycle time of the truck operation from mine site to Grizzly screen is approximately 8.33 minutes, and it requires 1 wheel loader, 2 excavators and 8 trucks to handle 622 tons per hour of tin ore with sand production.

4.7. Ore grade distribution

The data collected at each pitting consisted of data assay that was tin percent grade (Sn). The quality of tin was measured from taking the sample in each pits to analysis. Then, the result from chemical analysis of some pitting was different quality. Also, it need to consider about ore grade distribution in around the mine boundary. It is also provided sub-area of high quality and low quality for mine operation. When understanding or known ore grade distribution is facilitated to mine development. Table 4.12 show a part of the data preparation for input to Minescape software to build ore grade contour mapping.

Table 4. 9 Data preparation for input to Minescape software

Pitting	E	N	Average (%Sn)
1	540,648	1,478,418	0.081
2	541,216	1,478,651	0.105
3	540,936	1,478,611	0.065
4	540,941	1,478,765	0.115
5	540,926	1,478893	0.161
6	540,968	1,479,045	0.146
7	541,109	1,478,753	0.084
8	541,350	1,478,702	0.118
9	541,465	1,478,389	0.131
10	541,404	1,478,327	0.107
11	541,317	1,478,528	0.108
12	541,365	1,478,907	0.083
13	541,020	1,478,779	0.142
14	541,014	1,478,893	0.023
15	540,896	1,478,718	0.1106
16	540,780	1,478,582	0.094
17	541,009	1,479,109	0.058

4.7.1. The result of tin ore with sand estimate from grade contour lines

In this project study, they are using the data analysis from pitting, the corresponding coordinates as well as the average tin percent grade to build the grade contour lines. The percent grade in each pitting was different. The editing of the data files for a subsequent use in the mining software was done using excel.

The ore grade contour lines can be created by using MineScape Software. First, the corrected data analysis file in imported. After running, it displayed to distribution of the tin grade control lines over the entire mining area. Thus, it was exported and adjusted using AutoCAD. The estimation tin ore with sand from tin grade control lines was considered to build the grid (50 x 50 m), the thickness of sediment layers (estimates from electrical resistivity), specific gravity of sand, and distribution of the tin grade control lines. Figure 4.12 illustrates the tin ore grade contour lines mapping.

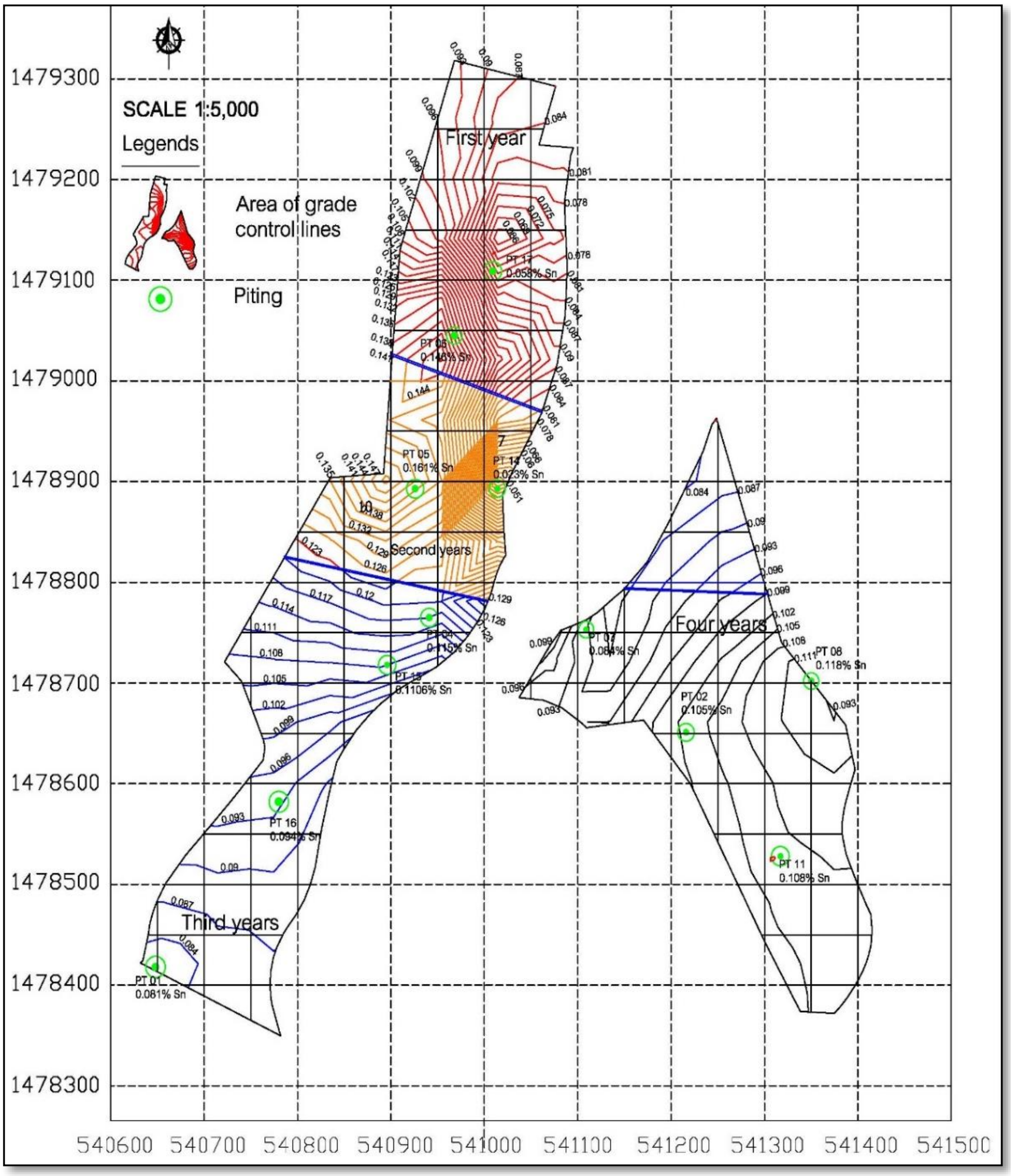


Figure 4. 13 Ore grade distribution

The ore grade contour lines might increase the understanding about the distribution of tin within the area. Thus, the ore grade distribution of tin related to the mining development to get the profit from mining business. Especially the blending of low-grade ore with high grade ore to increase the overall tin ore quality is exceeding important for economic value of the tin ore. From the result of tin ore with sand estimation from the grade contour lines.

4.8. Financial Analysis

The main objective of the financial study is about worthiness, material result by putting into financial schemes, which is expectation into achieving a profit from the project investment. The financial study involves the discount cash flow (DCF) analysis, the internal rate of return (IRR), and the net present value (NPV).

The project investment, some important parameters for considering the project to be feasible are the DCF, IRR and NPV. The DCF is used for calculate the cash inflow and cash outflow. The IRR is used for comparison with the interest rate of the project. NPV is also used to validate the feasibility of the projects investment.

4.8.1. Comparison of transportation method

The belt conveyor and dump trucks are compared of finance investment, there are cost estimated of expense into transportation tin ore with sand from mine site to the production plant. The distance of belt conveyor is approximately 2 kilometers. The parameters to calculate the operating cost of belt conveyor as the investment cost for make the foundation 2,000,000 baht, the price of belt conveyor lines is 20,777,250 baht and included install price, the electricity cost, and repair payment. The result of the estimated cost of a belt conveyor to transport the tin ore with sand is 15 baht per ton. The parameters to calculate the operating cost of dump trucks is 2,000,000 baht for the road construction, the dump trucks cost is 26,400,000 baht and other payment such as operators, fuel, repair payment, ware part and tire cost. The result of estimated cost of the dump trucks to transport the tin ore with sand is 29 baht per ton. Therefore, in this project study is selected the belt conveyor to transport the tin ore with sand, which is considered from operation estimate cost. The detail of calculation is provided in Appendix A.

4.8.2. Discount Cash Flow calculation (DCF)

This increasing confidence into investment of the project which the machine and equipment of the processing plant 72,000,000 baht was references from the processing plant design of tin ores at Sikhara Mining Co.,Ltd. Thailand.

The pre-feasibility estimate of the project investment, there are many steps to calculate the discount cash flow. In this step, there are assumption the main parameters need to determine the cash flow models as capital cost (Quanchai Leepowpanth, 2010), operating cost, depreciation cost, sale cost, the tax rate and royalty. The input parameters and calculation sheet are shown in Tables 4.2 and 4.3

Table 4. 10 The input parameters for financial analysis.

Investment	baht
Land	12,800,000
Construction	14,080,000
Machine and Equipment of the processing plant	72,000,000
Vehicles 3 Unit	3,000,000
Construction of mine site	2,000,000
Machine and Equipment of mine site	66,930,000
Total	170,810,000
Capital Expenditure (Capex)	baht
Installing (25% of Machine and Equipment in the processing plant)	18,000,000
Piping (25% of Machine and Equipment in the processing plant)	18,000,000
Electric (25% of Machine and Equipment in the processing plant)	18,000,000
Waste water treatment (25% of Machine and Equipment in the processing plant)	18,000,000
Public Utility (15% of Machine and Equipment in the processing plant)	10,800,000
Reserve (15% of Machine and Equipment in the processing plant)	10,800,000
Fee	10,000,000
Total	103,600,000
Total CAPEX	274,410,000
Working capital	10,000,000
Total	**284,410,000**

Table 4. 11 Production price, Royalty, and Tax

Input parameters	Values
Tin concentrate price	538,000 baht per ton
Sand price (baht/ton)	300 baht per ton
Aggregate price (baht/ton)	100 baht per ton
Royalty of Tin concentrate	38,825 baht per ton
Royalty of Sand	14 baht per ton
Royalty of Aggregate	14 baht per ton
Tax rate (baht/year)	30 percent
Discount rate @	13 percent
The housing development fund (baht/year)	500000 baht/year
Health Insurance Fund (baht/year)	200000 baht/year
Rehabilitation cost (34,000 baht/amount rai of rehabilitation in each year)	1,309,000 baht/year

Table 4. 12 Discount cash flow calculation sheet

Year	0	1	2	3	4
Capital expense (baht)	274,410,000	-	-	-	-
Working Capital (baht)	10,000,000	-	-	-	-
Total investment (baht)	284,410,000	-	-	-	-
Price of Tin (baht/ton)	538,000	-	-	-	-
Tin Production (ton/year)		630	630	630	620
Revenue from selling Tin (baht/y)		338,940,000	338,940,000	338,940,000	333,560,000
Price of Sand (b/t)	300	-	-	-	-
Sand Production (t/y)		475,230	475,230	475,230	472,918
Revenue from selling Sand (b/y)		142,569,000	142,569,000	142,569,000	141,875,400
Price of Aggregate (b/t)	100	-	-	-	-
Aggregate Production (t/y)		89,106	89,106	89,106	88,672
Revenue from selling Aggregate (b/y)		8,910,600	8,910,600	8,910,600	8,867,200
Gross Revenue (b/y)		490,419,600	490,419,600	490,419,600	507,102,600
Royalty of Tin (b/t)	38,825	-	-	-	-
Expense for Royalty of Tin (b/y)		24,459,750	24,459,750	24,459,750	24,071,500
Royalty of Sand (b/t)	14	-	-	-	-
Expense for Royalty of sand (b/y)		6,653,220	6,653,220	6,653,220	6,620,852
Royalty of Aggregate (b/t)	14	-	-	-	-
Expense for Royalty of Aggregate (b/y)		1,247,484	1,247,484	1,247,484	1,241,408
Sale and Marketing Expense 10% (b/y)		49,041,960	49,041,960	49,041,960	48,430,260
Total Expense of royalty and sale (b/y)		81,402,414	81,402,414	81,402,414	80,364,020
Total Revenue (b/y)		409,017,186	409,017,186	409,017,186	424,458,580
Operating expense (b/y)		187,602,690	88,374,285	91,103,530	96,560,656
Depreciation (b/y)		15,297,000	15,297,000	15,297,000	112,119,000
Income before Tax (b/y)		206,117,496	307,354,901	302,616,656	215,778,924
Tax @ 30% (b/y)		61,835,249	92,206,470	90,784,997	64,733,677
Income after tax (b/y)		144,282,247	215,148,431	211,831,659	151,045,247
Cash flow (b/y)	-284,410,000	263,179,247	230,445,431	227,128,659	263,164,247
	284,410,000	187,602,690	88,374,285	91,103,530	96,560,656

4.8.3. Internal Rate of Return (IRR)

The IRR is the internal rate that the cash inflow equal to the cash outflow or the sum of discounted of net cash flow equal zero. IRR is very important for the project investment and it uses to identify the payback period or when the project will get profit. If the result of IRR calculated equal to the interest rate. Thus, the net present value will be zero, and the project will not get any profit. Also, the project is feasible when IRR is higher than the interest rate. The IRR has to be approximated by trial or error method. However, the IRR can be conveniently tabulated in the Microsoft excel spread sheet. In this project study, IRR is calculated at 79 percent which is much more than the interest rate (13 percent). In this project's interest rate is defined from cash flow evaluations at the feasibility study of Canadian institute of Mining and Mineral Economic Society which is defined in each stage between the interest rate and the project stage.

4.8.4. Net Present Value (NPV)

The NPV is the sum of discount annual cash flow or the sum of present value. If calculation of NPV is positive that considers a feasible the project and if calculation of NPV is negative that considers a non-feasible the project. In this project study, NPV is positive which is equal to 447,779,678 baht. Therefore, in this tin mine project considers economics evaluation feasible. Table 4.4 illustrates the calculation sheet of NPV.

For the financial analysis of this project, it can be summarized that the interest rate defined at 13 percent with sources of funding are from the owner project. The IRR is estimated at 79 percent which is considerably much more than interest rate, NPV is 447,779,678 baht, and the payback period equal to 1.09 year. Also, taking these economics factors into account, the tin mine project is proven feasible.

Table 4. 13 The calculation sheet of NPV

Year	0	1	2	3	4
Capital expense (baht)	274,410,000	-	-	-	-
Working Capital (baht)	10,000,000	-	-	-	-
Total investment (baht)	284,410,000	-	-	-	-
Price of Tin (baht/ton)	538,000	-	-	-	-
Tin Production (ton/year)		630	630	630	620
Revenue from selling Tin (baht/y)		338,940,000	338,940,000	338,940,000	333,560,000
Price of Sand (b/t)	300	-	-	-	-
Sand Production (t/y)		475,230	475,230	475,230	472,918
Revenue from selling Sand (b/y)		142,569,000	142,569,000	142,569,000	141,875,400
Price of Aggregate (b/t)	100	-	-	-	-
Aggregate Production (t/y)		89,106	89,106	89,106	88,672
Revenue from selling Aggregate (b/y)		8,910,600	8,910,600	8,910,600	8,867,200
Gross Revenue (b/y)		490,419,600	490,419,600	490,419,600	507,102,600
Royalty of Tin (b/t)	38,825	-	-	-	-
Expense for Royalty of Tin (b/y)		24,459,750	24,459,750	24,459,750	24,071,500
Royalty of Sand (b/t)	14	-	-	-	-
Expense for Royalty of sand (b/y)		6,653,220	6,653,220	6,653,220	6,620,852
Royalty of Aggregate (b/t)	14	-	-	-	-
Expense for Royalty of Aggregate (b/y)		1,247,484	1,247,484	1,247,484	1,241,408
Sale and Marketing Expense 10% (b/y)		49,041,960	49,041,960	49,041,960	48,430,260
Sale Expense (b/y)		81,402,414	81,402,414	81,402,414	80,364,020
Total Revenue (b/y)		409,017,186	409,017,186	409,017,186	424,458,580
Operating expense (b/y)		187,602,690	88,374,285	91,103,530	96,560,656
Depreciation (b/y)		15,297,000	15,297,000	15,297,000	112,119,000
Income before Tax (b/y)		206,117,496	307,354,901	302,616,656	215,778,924
Tax @ 30% (b/y)		61,835,249	92,206,470	90,784,997	64,733,677
Income after tax (b/y)		144,282,247	215,148,431	211,831,659	151,045,247
Cash flow (b/y)	-284,410,000	263,179,247	230,445,431	227,128,659	263,164,247
	284,410,000	187,602,690	88,374,285	91,103,530	96,560,656
NPV = ∑ (present value) = 447,779,678 baht					
IRR = 79%					
Payback Period = 1.09 year					

CHAPTER V
ENVIRONMENT AND SOCIAL IMPACTS

5.1. Introduction

Mining operation is very useful in raw metal production for industrial consumption. It's the process of excavation for removing the soil and rocks (overburden), which has changed the physical and the biological resources. This has affected the air, water, and soil quality, biological, animal, scenery, and life. Thus, tin mining operation should be paralleled with mine designed and the control of environmental impact.

In tin mining operation, there are some problems which are related to the environment, such as noise, water, air and dust quality. These problems are generated by excavation and transportation during the operation.

Noise, due to mining, is a common source of community concern because operation noise emissions frequently occur on a continuous basic. It can interfere unreasonably with day to day activities of mining operation and result in an adverse impact on residential amenity.

Water pollution, that means contaminated surface and groundwater, occurs by the erosion of sediments, the water around open pit surface and waste water from sludge dewatering on the processing plant.

Air and dust, which came from loading and hauling can lead to community due to the damage of small particle of dust. This is a serious matter for the people.

5.2. Noise pollution control

Noise is one of the main problems in the tin mine operation. It's happened any time during the mine's started to operate. For instance, noise of machine, excavation, transportation, and other machine in the plant. There is mitigation of the impacts and reduce the noise during operation, which are measure from sources noise to estimates the impact communities and local people surrounded this project.

In this study, mitigation of the noise from the tin mine operation are recommended as following;

a) There are mitigation of the noise sources as identify the time in a range of the operation of equipment.
b) There is mitigation of the noise by planting fast growing trees in the surrounding of sources noise, especially, mining area and the processing plant.
c) Optimum placement of waste dumps, location of haul roads, and location of the plant, it can be used to shield fixed items of plant which generate noise.

5.3. Water pollution control

In mining operation, it's excavating for remove rocks and soil (overburden). As a result, the surface of the mining area is deeper than the surrounding terrain. Also, there is an impact on surface and groundwater. The mining development occurred erosion and weathering which is a cause of muddy water and the shallowness of river or stream, include to the erosion of waste mineral contaminate in the quality water.

The measuring of the water quality should be planed before mining operation and in the range of mining operation for mitigation of the impact to water. In the tin mine operation, there are recommendation for the mitigation of the impact on water quality;

a) When finished mine operation phase in a range of the second years that should be build a setting pond for contain muddy water and the sediment weathered in the raining season.
b) Build a water reservoir used for the mineral processing plant.
c) Build a setting ponds for container the waste water from sludge dewatering of the mineral processing plant. It could be treated by leaving waste water in the setting pound for some periods. When the sediment to bottom of setting pound, if there are a lot of the sediment on the setting pond that must to remove to other place and water is discharge to water reservoir for used into dewatering process again.
d) The water reservoir before discharge into a stream the water quality should be measured.

5.4. Air and dust pollution control

The primary air emission associated with quarry operations is dust. Dust can be a nuisance to neighbors and may be a safety hazard to tin mine employees. Dust from mining or tin mining operation, if allowed to enter the atmosphere creates an uncomfortable working environment, equipment working, reduces visibility and creasing the risk of accidents. Also, the mitigation of the air and dust pollution. There are the planting fast growing trees in the surrounding of the project area and a spray water around in around source dusts, and road. “Sprinklers” should be installed the end point of the belt conveyers before stockpile of material.

5.5. Communities liaison

In the mining development, there are many a problem can’t avoid such as the impacts on the environmental and the communities. Also, the main target of mining development is expected to usefulness of the natural resources without the environmental impact or at least a reduction of the impact to a minimum.

The liaison between the mining company and the community is important at every point, from the beginning of the exploration stage throughout the mine operation stage and rehabilitation period. The mining company should plan to establish a relationship with the community, directly contribute to economic and social development in the surroundings of the project area, and provide fund for developing rural areas such as create new road in around the project area to comfortable into traffic of people. In addition, the activity with the community like soccer, or field trips are recommended to add a link between the community and the company.

5.6. Mine rehabilitation

Rehabilitation should be considered into planning and mine design to closure phase, or considered through all stages of the mining development, which rehabilitation parallel with the project operation phase, which is important to the success of closure mine. In addition, the objective of reclamation is to return the land and adjust land after the mining operation is finished. It is involves a number of activities such as removing any hazardous materials, reshaping the land, restoring topsoil, and planting native grasses (trees, or ground cover). The reclamation or rehabilitation is the process of repairing any negative effects of mining activities on the environment.

It is suggested that, during the mine operation, there are some activities for mine rehabilitated, especially, and adjust along the slope. The planting the fast growing trees, to keep the site green around the mine area, and reduction erosion by planting native grass on the ground cover, adjusting the mine area to keep the stabilities and develop to agriculture area in the future. This project's location was connected with the national conserved forests and stream, it should be converted the mining area. Likewise, the national conserved forests and pit into a water reservoir, which include small ponds, and a large water reservoir. This reservoir will benefit local communities for agriculture and fish cultivation.

In this project, it is required to adjust 2 benches of 5 meters bench height and 5 meters bench width and overall slope 30 degree which is suitable for planting of the fast growing trees. Figure 5.1 and 5.2 illustrates the planting fastest growing trees on the 5 meters bench width. The distance between the planted trees is about 2 meters.

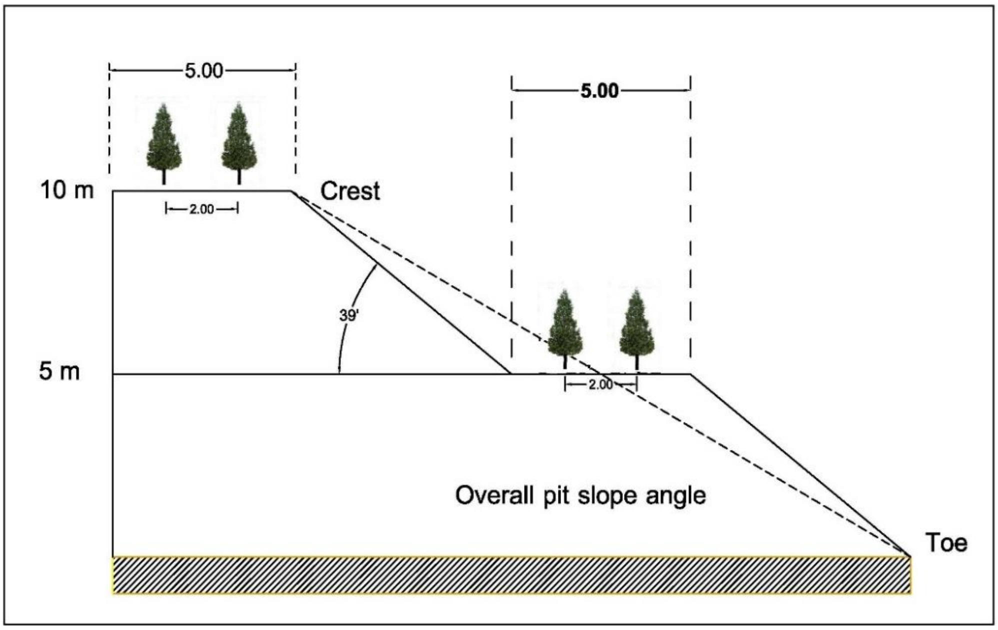


Figure 5. 1 Bench toe: tree: tree: bench crest

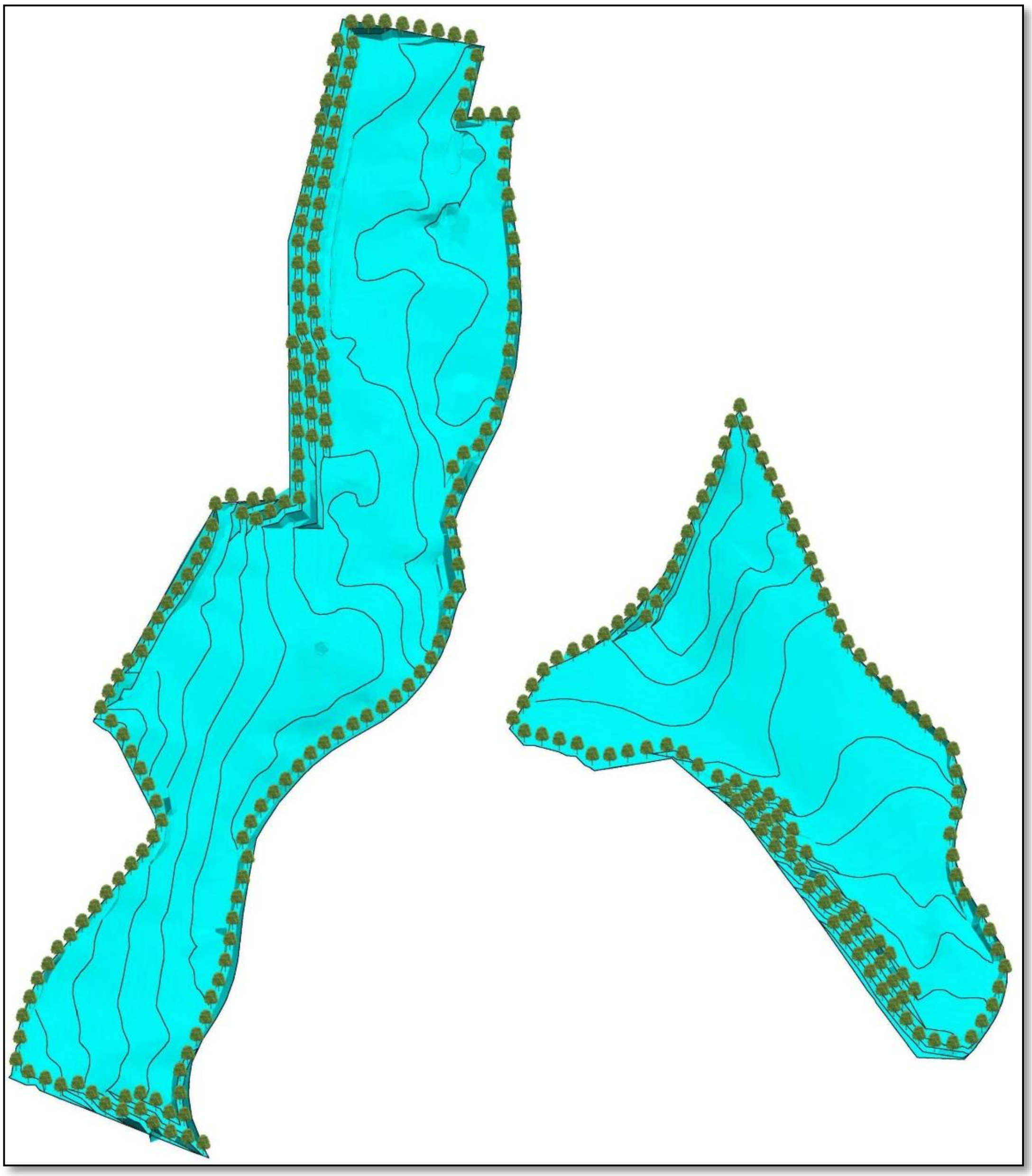


Figure 5. 2 Planting fast growing trees around the project area

CHAPTER VI
CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

From the results of this study, there are many important points which can be concluded in accordance with the results from each steps of work. These results are primarily used for a pre-feasibility study of tin mine: a case study of tin mine in Thailand. These point are:

1. Electrical resistivity are used to determine tin deposit layers and bedrocks, which can be interpreted from the section line 1 (L1) to line 7 (L7) and the distance approximately 1,890 meters. As the result, it has tin accumulation of tin in the sediment layers or eluvial deposits, they are the thickness about 15 meters and the average thickness is 5 meters and tin grade is 0.1 percent distributes of all the project area.
2. Prior to entering the data into the MineScape software, it was adjusted using AutoCAD. The main data was the minable limit, topographic and bedrock contour lines. This project selected study area covers approximately 242 Rai (387,200 square meters). According to the regulation of government for minable limit. Exclude for buffer zone (10 meters from road, stream and mining concession boundary), the minable limit of this project is remaining approximately 154 Rai (246,400 square meters).
3. The parameters used for reserve estimate such as specific gravity of t sand equal to 2.6, and the sediment layers is distributed all the area with the thickness approximately 5 meters and average tin (Sn) ore grade 0.1 percent. According to using the MineScape program for volume calculation can be calculated approximately 1,075,180 cubic meters multiply with specific gravity of sand equal to 2.6, the result of the tin ore reserve with sand approximate 2,795,468 metric tons.
4. Open pit optimization in order to achieve the optimal pit design. The total minable of the tin ore reserve with sand of ultimate pits is 2,795,468 metric

tons, the six years mine life and the production of 700,000 metric tons per year. The overall slope 30 degree and benches face angle is 39 degree.

5. In this study, mine planning and mine scheduling are planned for annual production six years.
   i. The first year is the mine development phase. The activities in this year are the preparation of the infrastructures, installation of the machines and the belt conveyor, preparation of the road, construction of the settling pond and water reservoir.
   ii. The second year to fifth year is the mine operation phase. The activities in this phase is excavation tin ore by using hydraulic excavator and transport tin ore with sand by using dump truck from mine site to the Grizzly screen. Then, the tin ore with sand is transported using the 1.6 kilometer long belt conveyor to processing plant with production capacity 100 tons/hour.

       According to the mine planning, the production plan for tin ore with sand is 700,000 metric tons per year to be sent to the processing plant and the finished production of tin is 630 metric tons per year.
   iii. In the fifth year, the mine production is 695,468 metric tons per year and the processing plant production of tin product is 620 metric tons per year. The total tin ore with sand mining production of the project is 2,795,468 metric tons and the total tin products from the processing plant is 2,510 metric tons.
   iv. In the sixth year, the project goes into the mine closure phase. The activities include landscape adjustment and mine rehabilitation by following the environmental regulation.
6. The loading and transportation requires 8.33 minutes for the total cycle time of truck operation from mine site to Grizzly screen. It requires 1 wheel loader, 2 excavators and 8 trucks to handle 622 tons per hour of tin ore with sand production.

7. The belt conveyor and truck are compared into finance investment that expense into transportation tin ore with sand, which transported using the belt conveyors is 15 baht per ton and dump truck is 29 baht per ton. The operation cost of tin mining in this project is 72 baht per ton.
8. Financial analysis, it can be summarized that the interest rate defined at 13 percent with sources of funding are from the owner project. IRR is estimated at 79 percent which is considerably much more than interest rate, NPV is 447,779,678 baht, and the payback period equal to 1.09 year. Also, taking these economics factors into account, the tin mine project is proven feasible.
9. After mine life, the mines are planted with local species and around the mine area to keep the site green and reduction erosion by planting native grass on the ground cover, adjusting the mine area to keep the stabilities and develop to agriculture area in the future. Pit should be converted into a water reservoir, which include small ponds, and a large water reservoir. This reservoir will benefit local communities for agriculture and fish cultivation.

6.2. Recommendations

This project is financially viable at this level. However, more data be collected to increase the level of confident of this study. There are some recommendations base on the data, the results of the research and the future work:

1. The data investigation in term of exploration should be undertaken into the drilling hole to increase the confidence of tin deposits, distribution of tin grade all of the area, and thickness of sediment layers or eluvail deposit.
2. The mining operation phase should be carried out to include the grade control which gives to the optimization process into processing plant.
3. The ore reserve estimation should be used more data and parameters, especially tin grade, thickness of mineral in each layers, and depth of deposits for more reliable ore reserve estimate.
4. The environment standards should take into accounted of the local specific condition.
5. For future study, the equipment can be alternated which depending on the task of mine development phase.

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APPENDIX

APPENDIX A

Financials Evaluation

INVESTMENT COST

No	Item	Price (baht)	Cost
1	**Land**		**12,800,000**
	Area (rai)		256
	Pricing (baht/rai)		50,000
2	**Construction**		**14,080,000**
	Area (sqm)		2,000
	Cost (baht/sqm)		7,040
3	**Machine and equipment**		**72,000,000**
4	**Construction of mine site**		**2,000,000**
5	**Machine and equipment of mine site**		**66,930,000**
	Back hoe Komatsu Pc 200 (1 unit)	4,500,000	4,500,000
	Back hoe Komatsu Pc 300 (1 unit)	7,200,000	7,200,000
	Dump truck Hino fm2pnld (8 units)	3,300,000	26,400,000
	Wheel loader Komatsu WA380Z-6 (1 unit)	6,900,000	6,900,000
	Fuel truck Hino FC9jeka (1 unit)	1,500,000	1,500,000
	Water truck Hino FC9jeka (1 unit)	1,500,000	1,500,000
	Survey equipment (1 unit)	760,000	760,000
	Belt conveyor equipment (1 unit)	22,770,000	22,770,000
	Grizzly screen and hopper (2 units)	1,000,000	2,000,000
6	**Vehicles 3 units (Pick up 4 x 4 WD)**	**1,000,000**	**3,000,000**
7	**Capital expenditure (Capex)**		**274,410,000**
	Installing (25% of Machine)		18,000,000
	Piping (25% of Machine)		18,000,000
	Electric (25% of Machine)		18,000,000
	Waste water treatment (25% of Machine)		18,000,000
	Reserve (15% of Machine)		10,800,000
	License Fee		10,000,000
8	**Working capital**		**10,000,000**
	Total		**284,410,000**

ASSUMPTION		
1. Investment	Baht	
Land	12,800,000	
Construction	14,080,000	
Machine and equipment	72,000,000	
Construction of mine site	2,000,000	
Machine and equipment of mine site	66,930,000	
Vehicles 3 units	3,000,000	
Capital expenditure (Capex)	274,410,000	
Working capital	10,000,000	
Total	**284,410,000**	
2. Operation		
Reserve of raw material (tin ore with sand)	2,795,468	Tons
Waste from big size	15%	
Net Run of Mine	2,376,148	Tons
Production Capacity	700,000	Tons/year
-M/C capacity	333	Tons/hour
-Working hour	7	hours/day
-Working day	25	days/month
Production of products		
1. Tin ore	0.1%	
2. Sand	80%	
3. Aggregate	15%	
4. Soil	4.9%	

Calculation amount of trucks		
Mining production	700,000	tons/year
production	2,333	tons/day
Production	333	tons/hr
Working	7	hours/day
Truck capacity	10 LCM	1 LCM = 1.5ton
Truck capacity	15 tons	
Truck cycle time	22 n	
Truck cycle time	0.36 hour	
Working		
Truck capacity	41	tons/hour
Amount trucks	8	units

Production	Year 1	Year 2	Year 3	Year 4	Total
Capacity (Tons)	700,000	700,000	700,000	695,468	2,795,468
Utilization	90%	90%	90%	90%	-
Working period (จำนวนกะ)	1	1	1	1	-
1. Tin ore (Tons/year)	630	630	630	620	2,510
2. Sand (Tons/year)	475,230	475,230	475,230	472,918	1,898,608
3. Aggregate (Tons/year)	89,106	89,106	89,106	88,672	355,990

3. Products Cost		
Selling Price		
1.Tin (metal)	538,000	baht/ton
2. Sand	300	baht/ton
3. Aggregate	100	baht/ton
Royalty of Tin (metal)	38,825	baht/ton
Royalty of Sand	14	baht/ton
Royalty of Aggregate	14	baht/ton
Maintenance cost	5%	of investment cost

R/M Prices		
Fuel	28	baht/liter
Transportation		
Transport cost (belt conveyers)	14	baht/ton
Transport cost (trucks)	22	baht/ton
Excavator		
Excavator Komatsu PC 300LC-6	3.6	baht/ton
Excavator Komatsu PC200LC-8	6	baht/ton
Mining equipment Cost		
Wheel Loader	11	baht/ton
Investment cost	6,900,000	baht
Fuel consumption	15	baht/hour
Excavator Komatsu PC200LC		
Investment cost	4,500,000	baht
Fuel consumption	23	Liters/hour
Operator	23,000	baht/month
Excavator Komatsu PC 300LC-6		
Investment cost	7,200,000	baht
Fuel consumption	30	Liters /hour
Operator	23,000	baht /month
Hino 10 wheels truck model FM2PNLD		
Investment cost	3,300,000	
Fuel consumption	17	Liters /hour
Operator	17,000	baht /month

1. Operation cost of mine equipment

Wheel Loader	year 1	year 2	year 3	year 4	year 5	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Investment cost (baht)	6,900,000					
Operation cost						
Operators		828,000	828,000	828,000	759,000	3,243,000
Fuel cost		3,024,000	3,024,000	3,024,000	2,772,000	11,844,000
Repair		1,490,400	1,490,400	1,490,400	1,366,200	5,837,400
Lube		604,800	604,800	604,800	554,400	2,368,800
Wear part		745,200	745,200	745,200	683,100	2,918,700
Depreciation		2,070,000	2,070,000	2,070,000	1,897,500	8,107,500
Total cost		8,417,400	8,417,400	8,417,400	7,859,700	33,111,900
Cost per ton (baht/ton)						12
Dump trucks (10 wheels)	year 1	year 2	year 3	year 4	year 5	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Investment cost (baht)	26,400,000					
Operation cost						
Operators		1,632,000	1,632,000	1,632,000	1,496,000	6,392,000
Fuel cost		7,996,800	7,996,800	7,996,800	7,330,400	31,320,800
Tire		1,587,600	1,587,600	1,587,600	1,455,300	6,218,100
Repair		712,800	712,800	712,800	653,400	2,791,800
Lube		1,599,360	1,599,360	1,599,360	1,466,080	6,264,160
Wear part		950,400	950,400	950,400	871,200	3,722,400
Depreciation		7,920,000	7,920,000	7,920,000	7,260,000	31,020,000
Total		22,398,960	22,398,960	22,398,960	20,532,380	87,729,260
Cost per ton (baht/ton)						30

Excavator Komatsu PC200LC-8		year 1	year 2	year 3	year 4	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Investment cost (baht)	4,500,000					
Operation cost						
Operator		276,000	276,000	276,000	253,000	1,081,000
Fuel cost		772,800	772,800	772,800	708,400	3,026,800
Repair		129,600	129,600	129,600	118,800	507,600
Lube		154,560	154,560	154,560	154,560	618,240
Wear part		80,798	80,798	80,798	80,798	323,190
Depreciation		1,127,820	1,127,820	1,127,820	1,127,820	4,511,278
Total cost		2,541,577	2,541,577	2,541,577	2,541,577	10,068,108
Cost per ton (baht/ton)						4
Excavator Komatsu PC 300LC-6						
Investment cost (baht)	7,200,000					
Operation cost						
Operators		276,000	276,000	276,000	253,000	1,081,000
fuel cost		1,764,000	1,764,000	1,764,000	1,617,000	6,909,000
Repairs		194,400	194,400	194,400	178,200	761,400
Lube		352,800	352,800	352,800	323,400	1,381,800
Wear part		129,600	129,600	129,600	118,800	507,600
Depreciation		1,804,511	1,804,511	1,804,511	1,804,511	7,218,045
Total cost		4,521,311	4,521,311	4,521,311	4,521,311	17,858,845
Cost per ton (baht/ton)						7

Hino 6 wheel trucks		year 1	year 2	year 3	year 4	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Wheel truck cost (2 units) (baht)	3,000,000					
Operation cost						
Operator (12,000 baht/month)		288,000	288,000	288,000	264,000	1,128,000
Fuel cost		1,764,000	1,764,000	1,764,000	1,617,000	6,909,000
Tire		22,680	22,680	22,680	20,790	88,830
Repair		108,000	108,000	108,000	99,000	423,000
Lube		352,800	352,800	352,800	323,400	1,381,800
Wear part		107,730	107,730	107,730	98,753	421,943
Depreciation		751,880	751,880	751,880	751,880	3,007,519
Total cost		3,395,090	3,395,090	3,395,090	3,174,822	13,360,091
Pick up 4 x 4 WD	1,000,000					
Operation cost						
Operator (10,000 baht/month)		120,000	120,000	120,000	110,000	470,000
Fuel cost		252,000	252,000	252,000	231,000	987,000
Tire		11,340	11,340	11,340	10,395	44,415
Repair		27,000	27,000	27,000	24,750	105,750
Lube		50,400	50,400	50,400	46,200	197,400
Wear part		18,000	18,000	18,000	16,500	70,500
Depreciation		250,627	250,627	250,627	250,627	1,002,506
Total cost		729,367	729,367	729,367	689,472	2,877,571

	0	1^{st}	2^{nd}	3^{rd}	4^{th}	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Belt conveyor cost (baht)	20,770,250					
Belt foundation	2,000,000					
Operation cost						
Electricity, 4 kw bath		3,974,400	3,974,400	3,974,400	3,643,200	15,566,400
Repair 5% of capital		346,171	346,171	346,171	317,323	1,355,836
Depreciation cost		6,231,075	6,231,075	6,231,075	5,711,819	24,405,044
Total cost		10,551,646	10,551,646	10,551,646	9,672,342	43,327,280
Cost per ton (baht/ton)						15
Road construction	2,000,000					
Dump truck cost	26,400,000					
Operation cost						
Operator		1,632,000	1,632,000	1,632,000	1,496,000	6,392,000
Fuel cost		7,996,800	7,996,800	7,996,800	7,330,400	31,320,800
Repair		1,330,560	1,330,560	1,330,560	1,219,680	5,211,360
Lube		1,599,360	1,599,360	1,599,360	1,466,080	6,264,160
Wear part		831,600	831,600	831,600	762,300	3,257,100
Tires		198,450	198,450	198,450	181,913	777,263
Depreciation		6,616,541	6,616,541	6,616,541	6,616,541	26,466,165
Total cost	2,000,000	20,205,311	20,205,311	20,205,311	19,072,914	81,688,848
Cost per ton (baht/ton)						**29**

SALES

Production in each year		year 1	year 2	year 3	year 4	Total
Tin ore with sand		700,000	700,000	700,000	695,468	2,795,468
1. Tin ore (tons)		630	630	630	620	2,510
2. Sand (tons)		475,230	475,230	475,230	475,230	472,918
3. Aggregate (tons)		89,106	89,106	89,106	89,106	88,672
Sales						
1. Tin metal 538,000 (baht/ton)		333,560,000	333,560,000	333,560,000	333,560,000	1,350,380,000
2. Sand 300 (baht/ton)		14,256,9000	14,256,9000	14,256,9000	14,256,9000	141,875,400
3. Aggregate 100 (baht/ton)		8,910,600	8,910,600	8,910,600	8,910,600	8,867,200
Operating Expense (baht)						
Operating Expense	215,159,400	16,788,000	18,466,800	20,145,600	21,992,280	77,392,680
Labour Cost (baht/year)	16,788,000	105	110	116	122	453
Inflation cost increase 5%/year	100	17,627,400	20,359,647	23,321,050	26,731,754	88,039,851
Labour cost and inflation		8,813,700	10,179,824	11,660,525	13,365,877	44,019,925
Welfare and management (50%)		1,762,740	2,035,965	2,332,105	2,673,175	8,803,985
Analyze cost (10%)		16,788,000	18,466,800	20,145,600	21,992,280	77,392,680
Total		81,993,690	86,365,285	91,103,530	96,560,656	356,023,162

Direct Labour (Mining plant)	No	baht	Total
Plant manager	1	80,000	80,000
Engineers	3	30,000	90,000
Accountants	2	20,000	40,000
Sales managers	2	18,000	36,000
Marketing Managers	2	18,000	36,000
Foreman	6	18,000	108,000
Workers	50	9,000	450,000
Securities	3	9,000	27,000
Housekeeper	1	9,000	9,000
Mine Manager	1	50,000	50,000
Foreman	1	30,000	30,000
Surveyor	1	20,000	20,000
Mechanic	1	20,000	20,000
Workers	5	10,000	50,000
Back hoe operators	2	23,000	46,000
Wheel loader operators	3	23,000	69,000
Dump truck operators	12	17,000	204,000
Driver	1	10,000	10,000
Water & fuel truck operators	2	12,000	24,000
Total (baht)			1,399,000
Production cost per unit	Tin ore with sand reserves	Operating expense	
Raw material	2,376,148	128,130,000	54 baht/ton
Electric	2,376,148	69,964,800	29 baht/ton
Maintenance (5% of Investment)		14,220,500	
Consumable (1% of Investment)		2,844,100	
Total		**215,159,400**	

OPEX		year 1	year 2	year 3	year 4	Total
Production		700,000	700,000	700,000	695,468	2,795,468
Mining Investment cost						
Back hoe Komatsu Pc 200	4,500,000					
Back hoe Komatsu Pc 300	7,200,000					
Dump truck Hino fm2pnld 8 units	19,800,000					
Wheel loader Komatsu WA380Z-6	6,900,000					
Fuel truck Kino FC9jeka	1,500,000					
Water truck Hino FC9jeka	1,500,000					
Pick up 4 x 4 WD	1,000,000					
Survey equipment	760,000					
Belt conveyor equipment	22,770,250					
Grizzly screen and hopper	2,000,000					
Workshop and tool	2,000,000					
Total investment	**69,930,250**					
Operation of mining cost						
Labour		4,860,000	4,860,000	4,860,000	4,575,000	19,155,000
Electricity		3,974,400	3,974,400	3,974,400	3,643,200	15,566,400
Fuel		15,573,600	15,573,600	15,573,600	14,275,800	60,996,600
Repair		2,662,200	2,662,200	2,662,200	2,440,350	10,426,950
Tire		1,621,620	1,621,620	1,621,620	1,486,485	6,351,345
Lube		3,114,720	3,114,720	3,114,720	2,868,040	12,212,200
Wear part		2,031,728	2,031,728	2,031,728	1,869,150	7,964,333
Depreciation		11,528,822	11,528,822	11,528,822	11,528,822	46,115,288
Total operation cost		45,367,090	45,367,090	45,367,090	42,686,847	178,788,116
Total cost (baht)	69,930,250	33,838,268	33,838,268	33,838,268	31,158,025	202,603,078
Cost per tin ore (baht/ton)		**65**	**65**	**65**	**61**	**72**
Depreciation	Value (baht)	D.Years	Year 1	Year 2	Year 3	Year 4
Construction	14,080,000	20	704,000	704,000	704,000	704,000
Machine and equipment	72,000,000	10	7,200,000	7,200,000	7,200,000	7,200,000
Construction of mine site	2,000,000	20	100,000	100,000	100,000	100,000
Machine and equipment of mine site	66,930,000	10	6,693,000	6,693,000	6,693,000	6,693,000
Vehicles 3 unit	3,000,000	5	600,000	600,000	600,000	600,000
Total	**284,410,000**		**15,297,000**	**15,297,000**	**15,297,000**	**15,297,000**

Cash flow		Year 1	Year 2	Year 3	Year 4
Capex (baht/ton)	**274,410,000**				
Working Capital	10,000,000				
Total investment	**284,410,000**				
Price of Tin (baht/ton)	538,000				
Tin Production (ton/year)		630	630	630	620
Revenue from selling Tin (baht/year)		338,940,000	338,940,000	338,940,000	333,560,000
Price of Sand (baht/ton)	300				
Sand Production (ton/year)		475,230	475,230	475,230	472,918
Revenue from selling Sand (baht/year)		142,569,000	142,569,000	142,569,000	141,875,400
Price of Aggregate (baht/ton)	100				
Aggregate Production (tons/year)		89,106	89,106	89,106	88,672
Revenue from selling Aggregate (baht/year)		8,910,600	8,910,600	8,910,600	8,867,200
Gross Revenue (baht/year)		490,419,600	490,419,600	490,419,600	507,102,600
Royalty of Tin (baht/ton)	38,825				
Expense for Royalty of Tin (baht/year)		24,459,750	24,459,750	24,459,750	24,071,500
Royalty of Sand and Aggregate (baht/ton)	14				
Expense for Royalty of sand (baht/year)		6,653,220	6,653,220	6,653,220	6,620,852
Expense for Royalty of Aggregate (baht/year)		1,247,484	1,247,484	1,247,484	1,241,408
Sale and Marketing Expense 10% (baht/year)		49,041,960	49,041,960	49,041,960	48,430,260
Sale Expense (baht/year)		81,402,414	81,402,414	81,402,414	80,364,020
Total Revenue (baht/year)		409,017,186	409,017,186	409,017,186	424,458,580
Opex (baht/year)		187,602,690	88,374,285	91,103,530	96,560,656
Depreciation (baht/year)		15,297,000	15,297,000	15,297,000	112,119,000
Income before Tax (baht/year)		206,117,496	307,354,901	302,616,656	215,778,924
Tax 30% (baht/year)		61,835,249	92,206,470	90,784,997	64,733,677
Income after tax (baht/year)		144,282,247	215,148,431	211,831,659	151,045,247
Cash flow (baht/year)	-284,410,000	263,179,247	230,445,431	227,128,659	263,164,247
	284,410,000	263,179,247	493,624,678	720,753,337	983,917,583
Interest	0.13 %				
NPV $\sum_{t=1}^{n} \frac{NCFt}{(1+IRR)t}$	**447,779,678 baht**				
IRR	**79 %**				
payback period	**1.09 year**				

APPENDIX B

Serial and Model of Machine Tin mine

SERIAL AND MODEL OF MACHINE TINMINE

	HINO 6 wheel truck model FC9JEKA (2 unit)		HINO 10 wheels truck model FM2PNLD(s) (8 unit)
No	DESCRIPTION	No	DESCRIPTION
1	Machine Type : 6 wheels truck	1	Machine Type : 10 wheel truck
2	Machine Brand : HINO	2	Machine brand : HINO
3	Machine Model : FC9JEKA	3	Machine Model : FM2PNLD(s)
4	Engines Model : HINO JO5E-TC	4	Engines Model : HINO P11C-UV
5	Engine power : 145 HP	5	Engine power : 145 HP
6	Max. output (EEC Net) : 107 KW:145PS at 2,500 rpm	6	Max. output (EEC Net) : 280 KW:380PS at 2,100 rpm
7	Max. torque (EEC Net) : 437 N.m (44.6kgf.m) at 1500 rpm	7	Max. torque (EEC Net) : 1,275 N.m (130kgf.m) at 1,500 rpm
8	**Machine serial number**	**8**	**Machine serial number**
9	Battery : 12 v.120 A.h at 20 hour	9	Battery : 12 v.120 A.h at 20 hour
10	Alternator : 24 v, 60 A	10	Alternator : 24 v, 50 A
11	Payload : 9.9 T	11	Payload : 25 T
12	Gear ratio : 18.6	12	GEAR ratio : 20.2
13	Tire size : 8.25-16-14 PR	13	Tire size : 11 R 22.5-16 PR
14	Fuel type : diesel	14	Fuel type : diesel
15	Fuel tank : 100 Liters	15	Fuel tank : 400 Liter

Wheel Loader Komatsu WA380z-6

No	DESCRIPTION	No	DESCRIPTION	Remark
1	Machine Type : Wheel Loader	1	Bucket capacity	2.7–4.0 m3
2	Machine brand : Komatsu	**2**	**Hydraulic cycle time**	
3	Machine Model : WA380z-6	3	Raise	5.9 sec
4	Engine Model : Komatsu SAA6D107E-1	4	Dump	1.8 Sec
5	Engine Power : 143 kW 192 HP @ 2100 rpm	5	Lower or Empty	3.3 Sec
6	Batteries : 136 Ah/2 x 12 V	6	Fuel type	diesel
7	Starting motor : 5.5 kW/24 V	7	Fuel tank diesel oil	300 Liter
8	Operating weight : 16610 kg	8	Fuel Consumption	23 Liter/hour
9	Tires : 23.5-25-16PR	9	Hydraulic system	139 Liter
10	Starting motor: 5.5 kW/24 V	10	Operating weight	17,200 kg

Excavator Komatsu PC 300LC-6

No	DESCRIPTION	No	DESCRIPTION	Remark
1	Machine type : Hydraulic excavator	1	Bucket capacity	0.52–2.30 m^3
2	Machine brand : Komatsu	2	Fuel Type	diesel
3	Machine model : Pc 300LC-6	3	Fuel tank diesel oil	605 Liter
4	Engine model : Komatsu SAA6D114E-3	4	Use water coolant	32 Liter
5	Engine power : 194 kW 260 HP @ 1950 rpm	5	Hydraulic tank	188 Liter
6	Number of cylinders : 6 cylinders	6	Fuel consumption	35 Liter/hour
7	**Machine serial number**	**7**	**Maximum travel speed**	
8	Battery of machine : 126 Ah/2 x 12 v	8	High speed	5.5 km/hour
9	Starting motor : 7.5 kW/24 Vx1	9	Medium speed	4.5 km/hour
10	Operation weight : 31600 – 34,400 kg	10	Low speed	3.2 km/hour
		11	Swing speed	9.5 rpm

Excavator Komatsu PC200LC-8

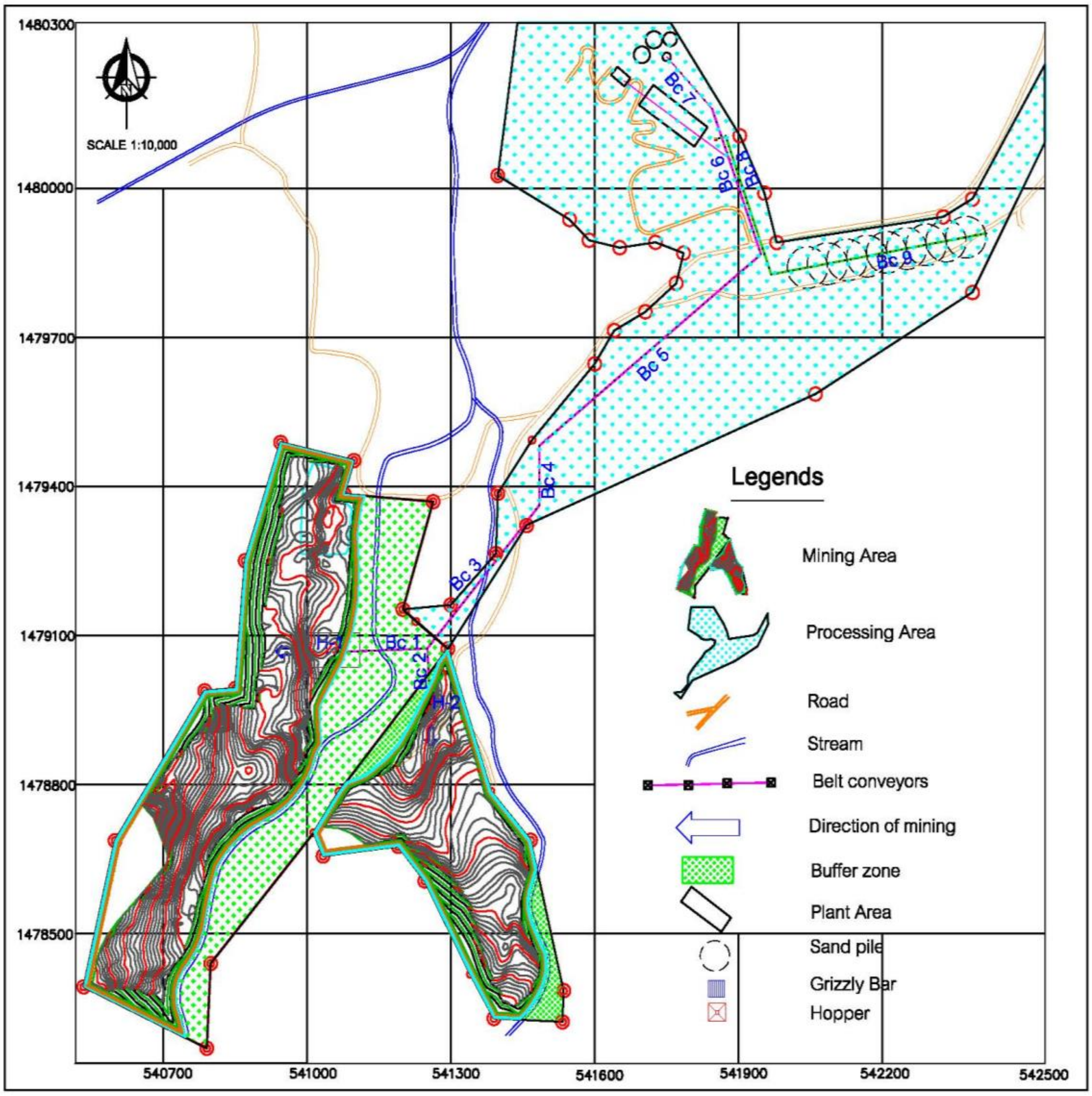
No	DESCRIPTION	No	DESCRIPTION	Remark
1	Machine Type : Hydraulic Excavator	1	Bucket capacity	1.4 m^3
2	Machine Brand : Komatsu	2	Fuel type	diesel
3	Machine Model : PC200LC-8	3	Fuel tank diesel oil	400 Liter
4	Engine Model : Komatsu SAA6D107E-1	4	Use water coolant	29.1 Liter
5	Engine power : 116 kW 155 HP @ 2000 rpm	5	Consumption	23.1 Liter
6	Number of cylinders : 6 cylinder	6	**Maximum travel speed**	
7	Batteries : large capacity	**7**	High speed	5.5 km/hour
8	Starting motor, 4.5 kW/24 V x 1	8	Medium speed	4.1 km/hour
9	Operating weight : 19400– 20010 kg	9	Low speed	3.0 km/hour
10	Alternator : 60 Ampere, 24 V	10	Swing speed	12.4 rpm

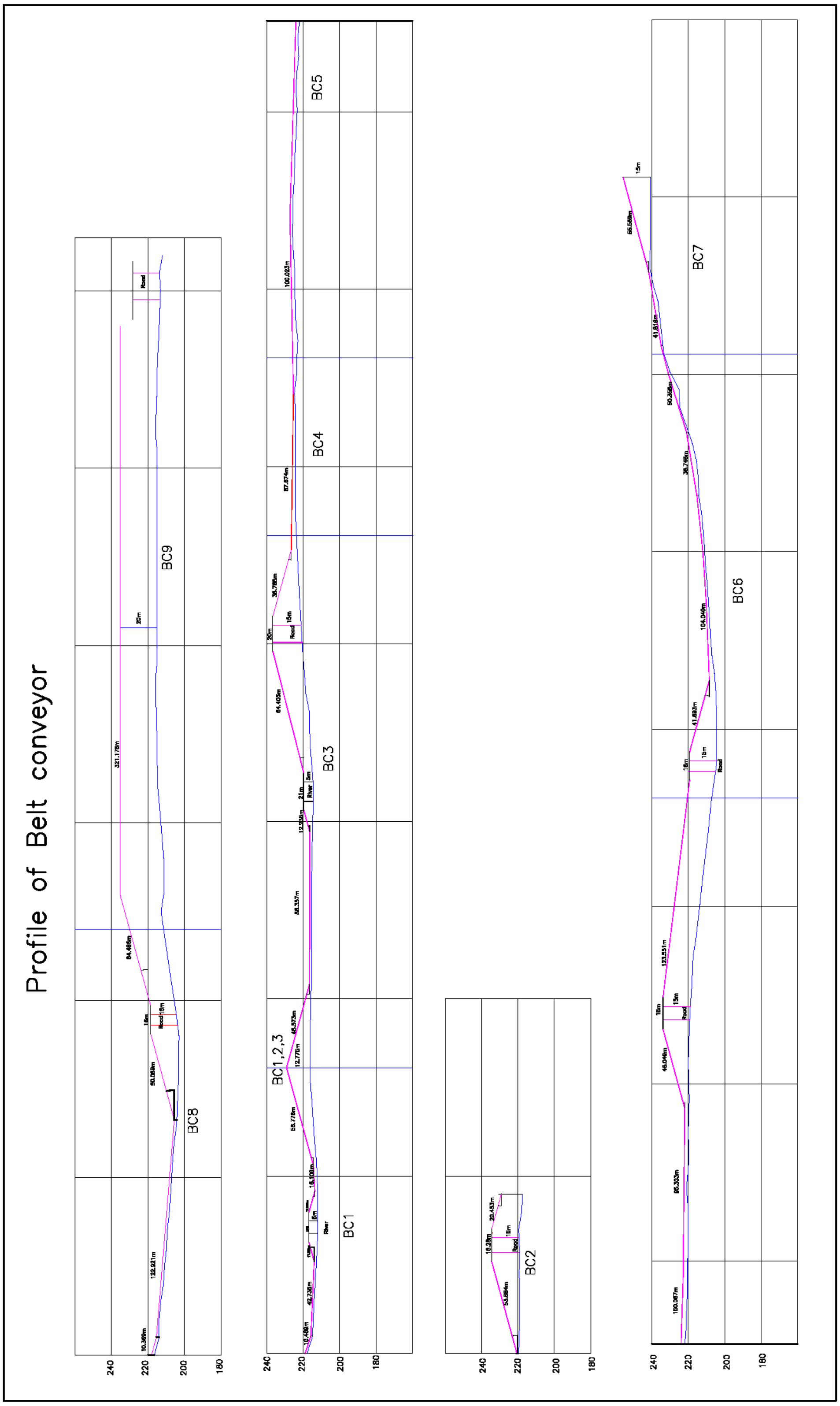
Equipment for processing plant and belt conveyors

No	List	Size (mm.)	power *(setting)*	working *(ton/hours)*	Units	price (THB)
1	Hopper	4000 x 4000 x 2500	-	100	1	300,000
2	Belt feeder	4000 x 600	7.5 kW	100	1	140,000
3	Belt Conveyor	30000 x 600	15 kW	100	1	600,000
4	Trommel (10mm. and 14#)	Ø 1800 x 6000	7.5 kW	50	2	1,372,000
5	Belt Conveyor	18000 x 600	7.5 kW	30	1	360,000
6	Trommel (30#)	Ø 1800 x 6000	7.5 kW	70	4	2,349,600
7	Sump	2400 x 2400 x 2500	-	-	1	300,000
8	Mineral Pump	3 inch x 2 inch	22 kW	20	1	140,000
9	Sump	2400 x 2400 x 2500	-	-	1	300,000
10	Mineral Pump	3 inch x 2 inch	22 kW	22	1	140,000
11	Hydrocyclone	Ø 375	-	20	1	190,000
12	Hydrocyclone	Ø 375	-	20	1	190,000
13	Spiral Concentrator	4 x 4 Spirals	-	48	2	1,600,000
14	Spiral Concentrator	4 x 4 Spirals	-	48	2	1,600,000
15	Distributor	2400 x 2400 x 2500	-	-	1	120,000
16	Distributor	2400 x 2400 x 2500	-	-	1	120,000
17	Shaking Table	1860 x 4500 x 1200	3 kW	0.5	12	786,240
18	Shaking Table	1860 x 4500 x 1200	3 kW	0.5	12	786,240
19	Spiral Classifier	12"x9'	3.7 kW	5	1	120,000
20	Belt Conveyor	6000 x 600	7.5 kW	10	1	180,000
21	Spiral Classifier	12"x9'	3.7 kW	5	1	120,000
22	Belt Conveyor	6000 x 600	7.5 kW	10	1	180,000
23	Spiral Classifier	12"x9'	3.7 kW	5	1	120,000
24	Belt Conveyor	80000 x 600	15 kW	10	1	180,000
25	Spiral Classifier	Ø 2000 x 8400	36 kW	40	1	952,067
26	Belt Conveyor	18000 x 600	15 kW	50	1	360,000
27	Jig	3600 × 2000 × 2600	7.5 kW	10	3	1,474,200
28	Ball Mill	Ø 2700 x 4500	245 kW	20	1	3,177,720
29	Spiral Classifier	Ø 1500 x 8300	15kW	20	1	752,400
30	Spiral Classifier	Ø 2000 x 8400	7.5 kW	40	1	2,230,800
31	Water Pump	8 inch x 6 inch	24 kW	300 m^3	1	115,000
32	Rotary Dryer	Ø 1200 x 8000	7.5 kW	1	1	2,800,000
33	Vibrating Screen	1600 x 4600 x 1100	5 kW	0.5	2	400,000
34	High Tension Separator, roll-type	Ø 120 x 1500	1 kW	0.2	1	660,000
35	High Tension Separator, Plate-type	Ø 320 x 1500	1 kW	0.2	1	830,000

No	List	Size (mm.)	power	working	Units	price (THB)
			(setting)	*(ton/hours)*		
37	Sump	2400 x 2400 x 2500	-	-	1	300,000
38	Pump	6 inch x 4 inch	45 kW	50	1	211,364
39	Hydrocyclone	Ø 375	-	20	1	190,000
40	Sump	2400 x 2400 x 2500	-	-	1	300,000
41	Mineral pump	3 inch x 2 inch	22 kW	20	1	140,000
42	Hydrocyclone	Ø 375	-	20	1	190,000
43	Tank Classifier	Ø 2500x 7000	-	-	2	467,400
44	Spiral Classifier	Ø 1000 x 6490	7.5 kW	40	1	752,400
45	Distributor	2400 x 2400 x 2500	-	-	1	120,000
46	Belt Conveyor	100000 x 600	15 kW	30	1	2,000,000
47	Belt Conveyor	50000 x 600	15 kW	50	1	1,000,000
48	Hopper	4000 x 4000 x 2500	-	100	1	300,000
G-1	Grizzly (G-1)	4000 x 9000	-	100	1	400,000
G-2	Grizzly (G-2)	4000 x 9000	-	100	1	400,000
H-1	Hopper (H-1)	4000 x 4000 x 2500	-	100	1	300,000
H-2	Hopper (H-2)	4000 x 4000 x 2500	-	100	1	300,000
BC-01	Belt feeder BC-01	4000 x 600	7.5 kW	100	1	140,000
BC-02	Belt conveyor BC-02	162000 x 600	15 kW	100	1	2,480,000
BC-03	Belt feeder BC-03	4000 x 600	7.5 kW	100	1	140,000
BC-04	Belt conveyor BC-04	95000 x 600	11 kW	100	1	1,470,000
BC-05	Belt conveyor BC-05	263000 x 600	22 kW	100	1	4,020,000
BC-06	Belt conveyor BC-06	151000 x 600	15 kW	100	1	2,325,000
BC-07	Belt conveyor BC-07	501000 x 600	30 kW	100	1	8,110,000
BC-08	Belt conveyor BC-08	224000 x 600	30 kW	100	1	4,400,000
BC-10	Belt conveyor BC-10	150000 x 600	15 kW	100	1	1,529,400
BC-11	Belt conveyor BC-11	4000 x 600	7.5 kW	100	1	140,000
BC-12	Belt conveyor BC-12	18000 x 600	4 kW	100	1	364,000
BC-13	Belt conveyor BC-13	237000 x 600	18.5 kW	100	1	4,400,000
BC-14	Belt conveyor BC-14	56000 x 600	15 kW	100	1	1,101,000
BC-15	Tripper Belt, BC-15	250000 x 600	15 kW	100	1	6,110,000
Total Cost (THB)						72,000,000

The layout of the belt conveyors

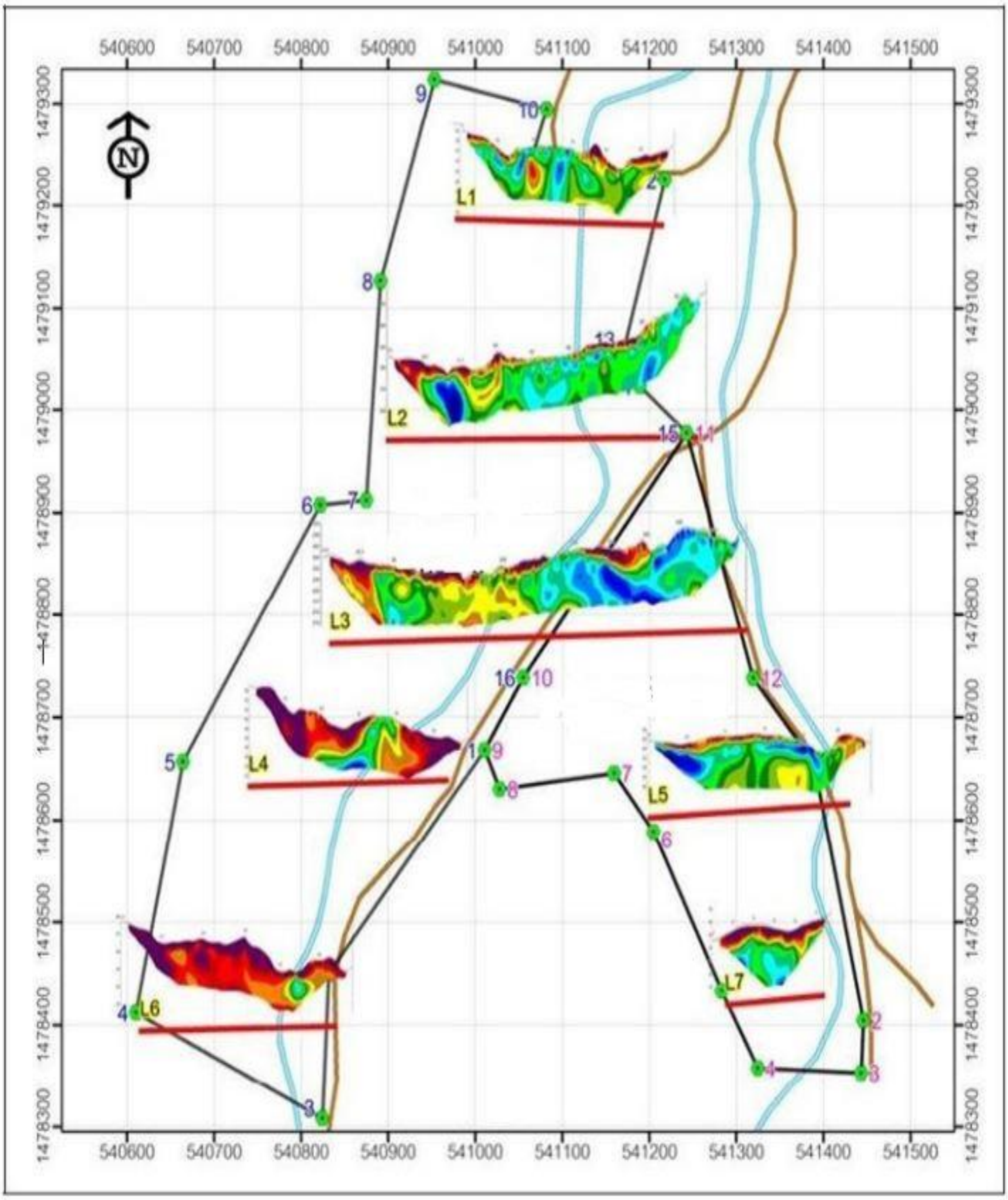




Profile of Belt conveyor
BC9
BC8
BC5
BC4
BC3
BC1,2,3
BC1
BC2
BC7
BC6

APPENDIX C

The Result of the Electrical Resistivity



540600
540700
540800
540900
541000
541100
541200
541300
541400
541500
1479300
1479200
1479100
1479000
1478900
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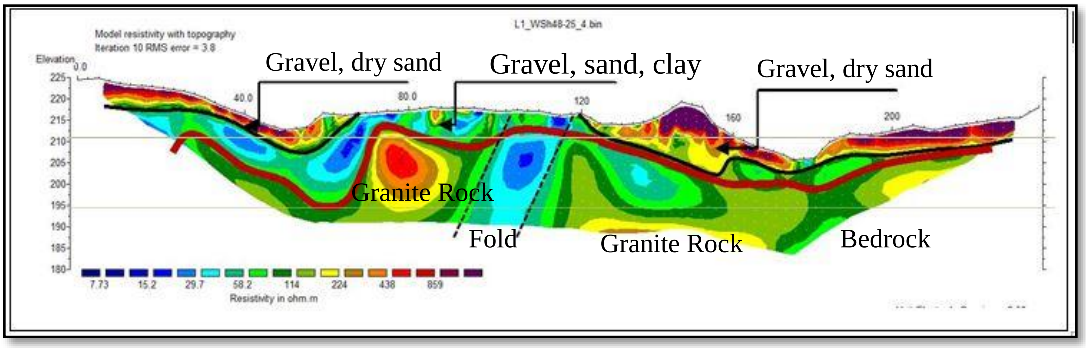
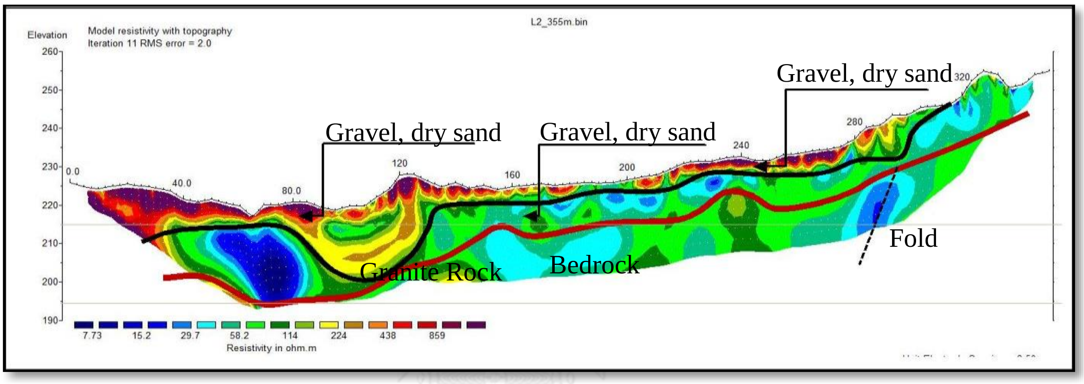
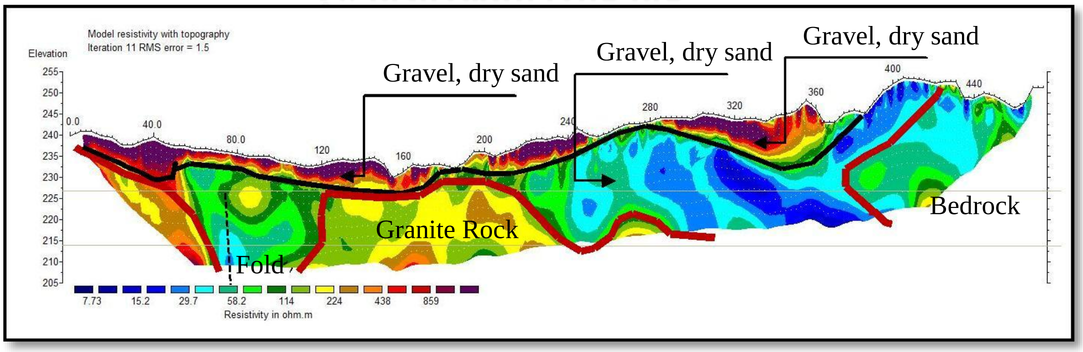
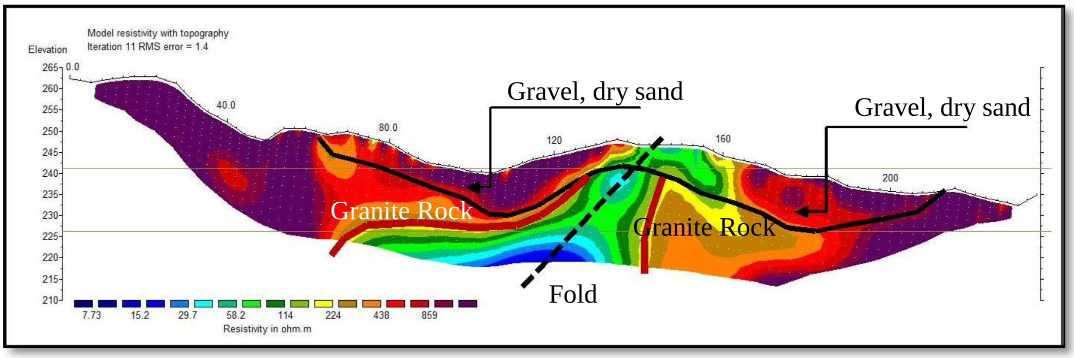
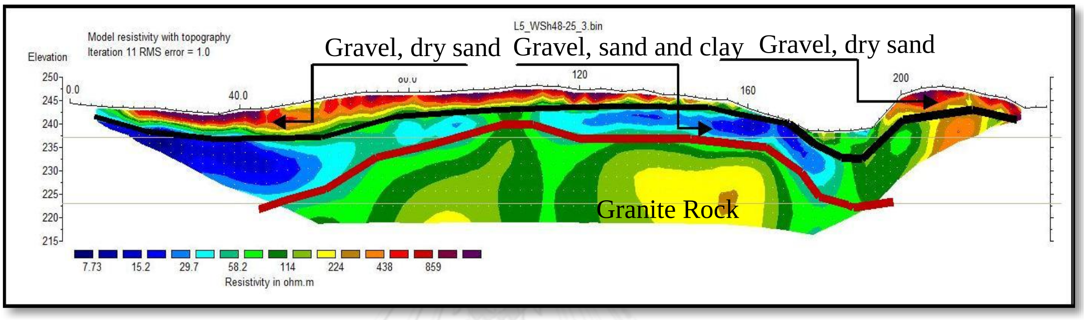
L3
L4
L5
L6
L7

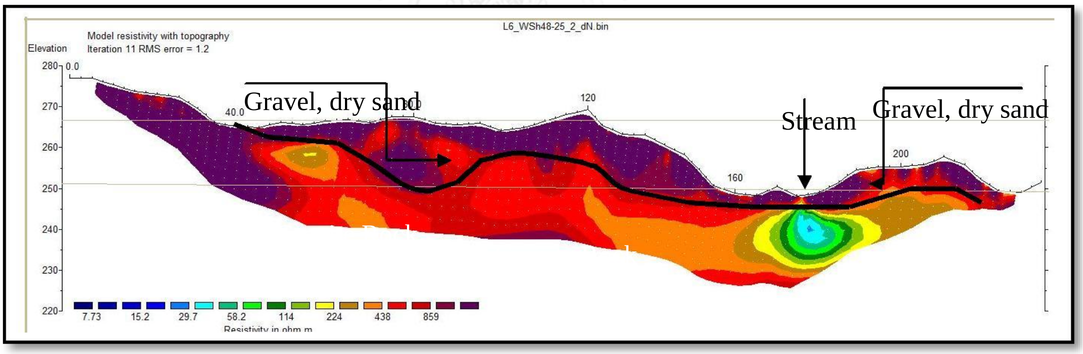

L1_WSh48-25_4.bin
Model resistivity with topography
Iteration 10 RMS error = 3.8
Elevation
Gravel, dry sand
Gravel, sand, clay
Gravel, dry sand
Granite Rock
Fold
Granite Rock
Bedrock
Resistivity in ohm.m

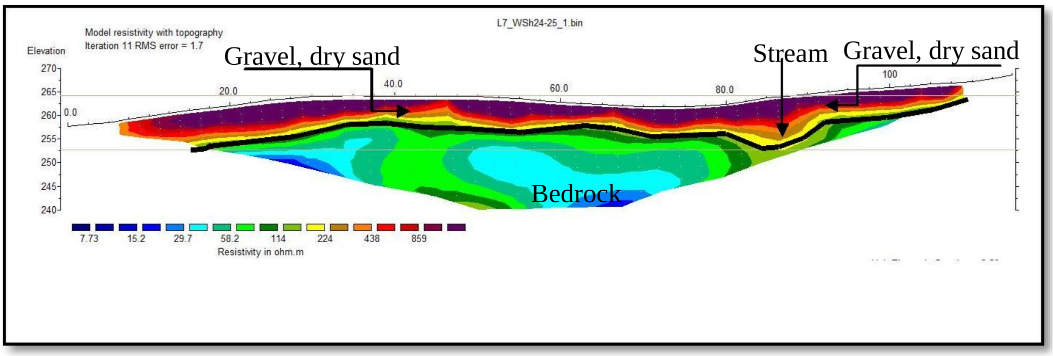

L2_355m.bin
Model resistivity with topography
Iteration 11 RMS error = 2.0
Elevation
Gravel, dry sand
Gravel, dry sand
Gravel, dry sand
Fold
Granite Rock
Bedrock
Resistivity in ohm.m


Model resistivity with topography
Iteration 11 RMS error = 1.5
Elevation
Gravel, dry sand
Gravel, dry sand
Gravel, dry sand
Bedrock
Granite Rock
Fold
Resistivity in ohm.m


Model resistivity with topography
Iteration 11 RMS error = 1.4
Elevation
Gravel, dry sand
Gravel, dry sand
Granite Rock
Granite Rock
Fold
7.73 15.2 29.7 58.2 114 224 438 859
Resistivity in ohm.m

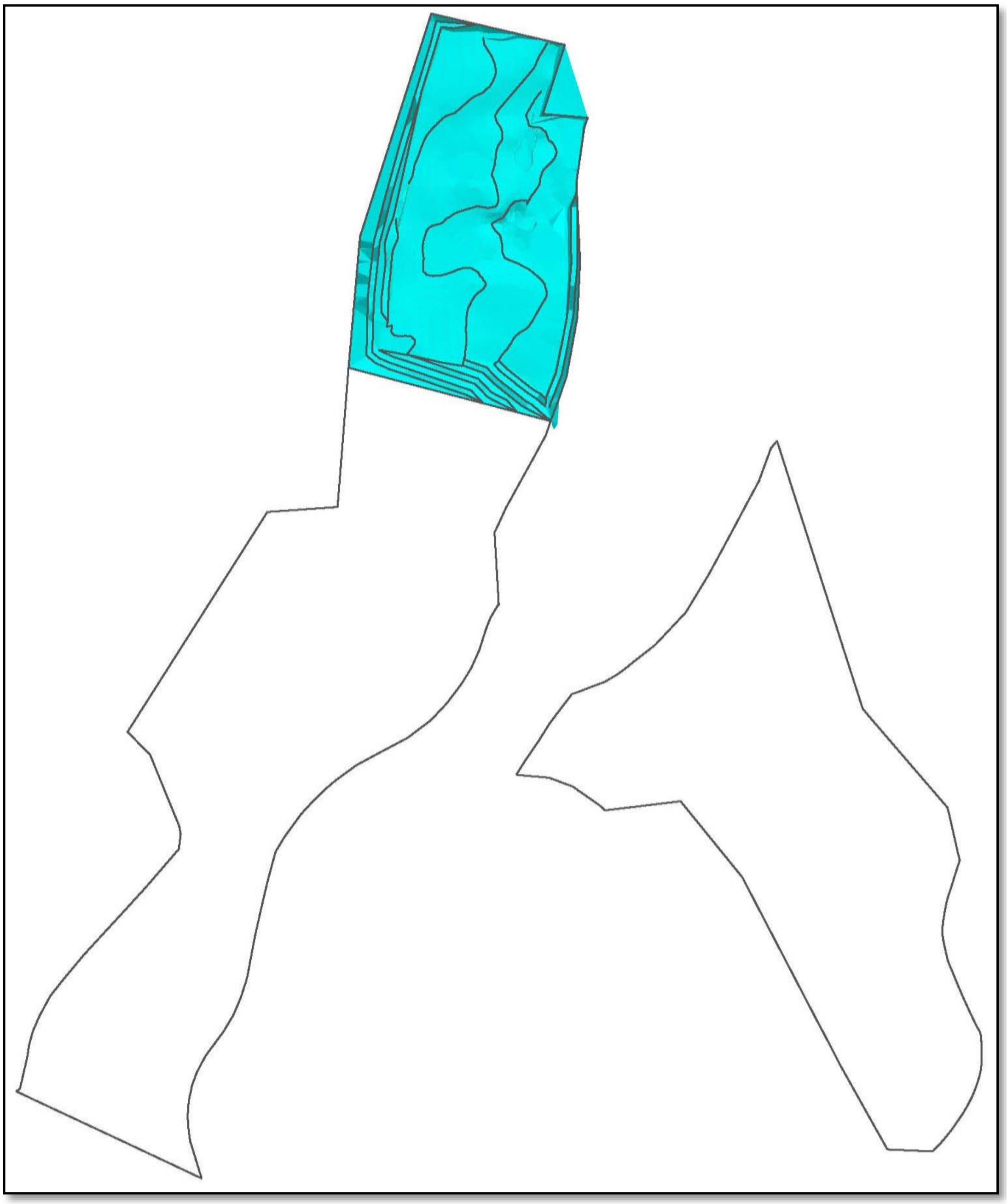

Model resistivity with topography
Iteration 11 RMS error = 1.0
L5_WSh48-25_3.bin
Elevation
Gravel, dry sand
Gravel, sand and clay
Gravel, dry sand
Granite Rock
7.73 15.2 29.7 58.2 114 224 438 859
Resistivity in ohm.m

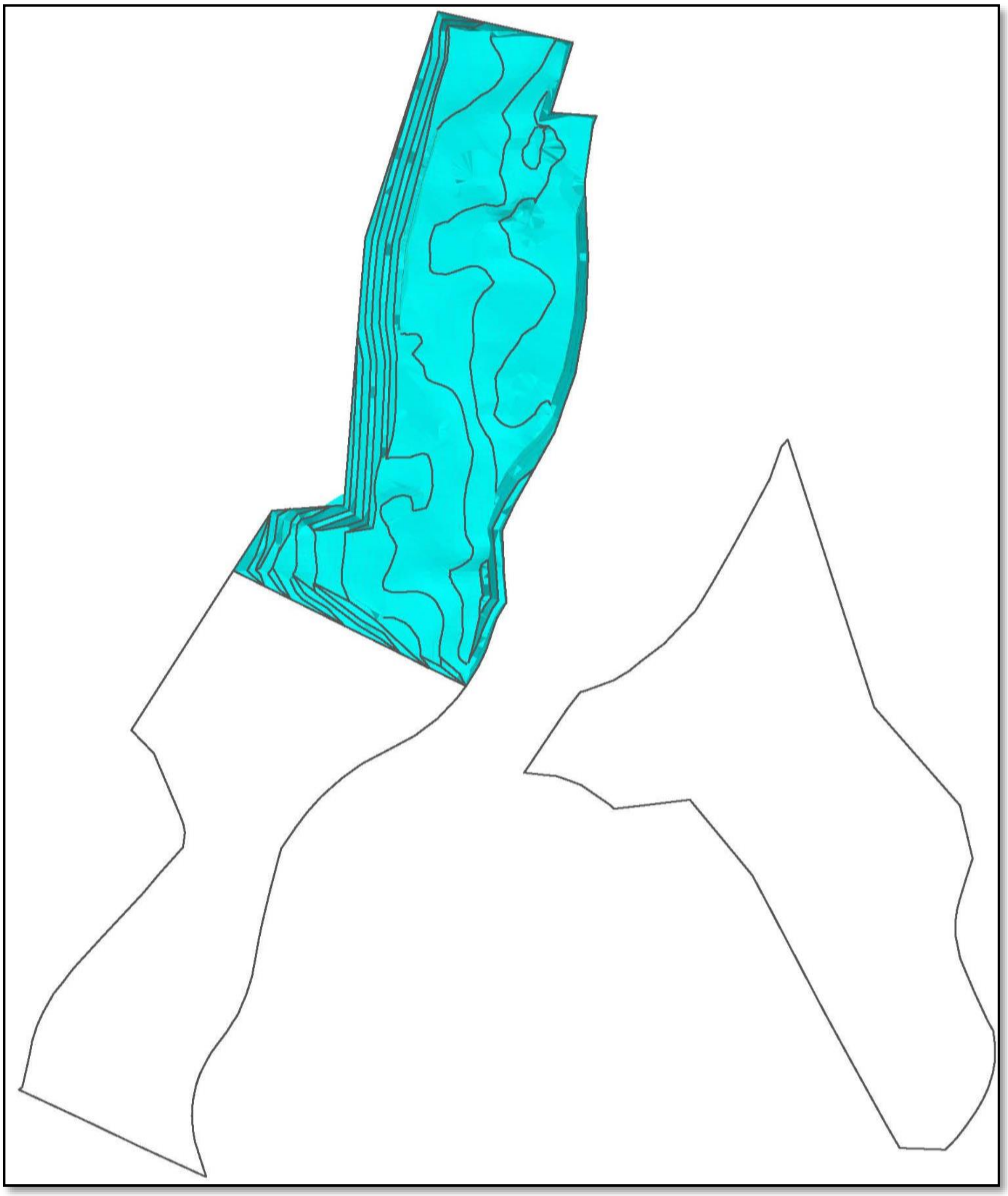

Model resistivity with topography
Iteration 11 RMS error = 1.2
L6_WSh48-25_2_dN.bin
Elevation
Gravel, dry sand
Stream
Gravel, dry sand
7.73 15.2 29.7 58.2 114 224 438 859

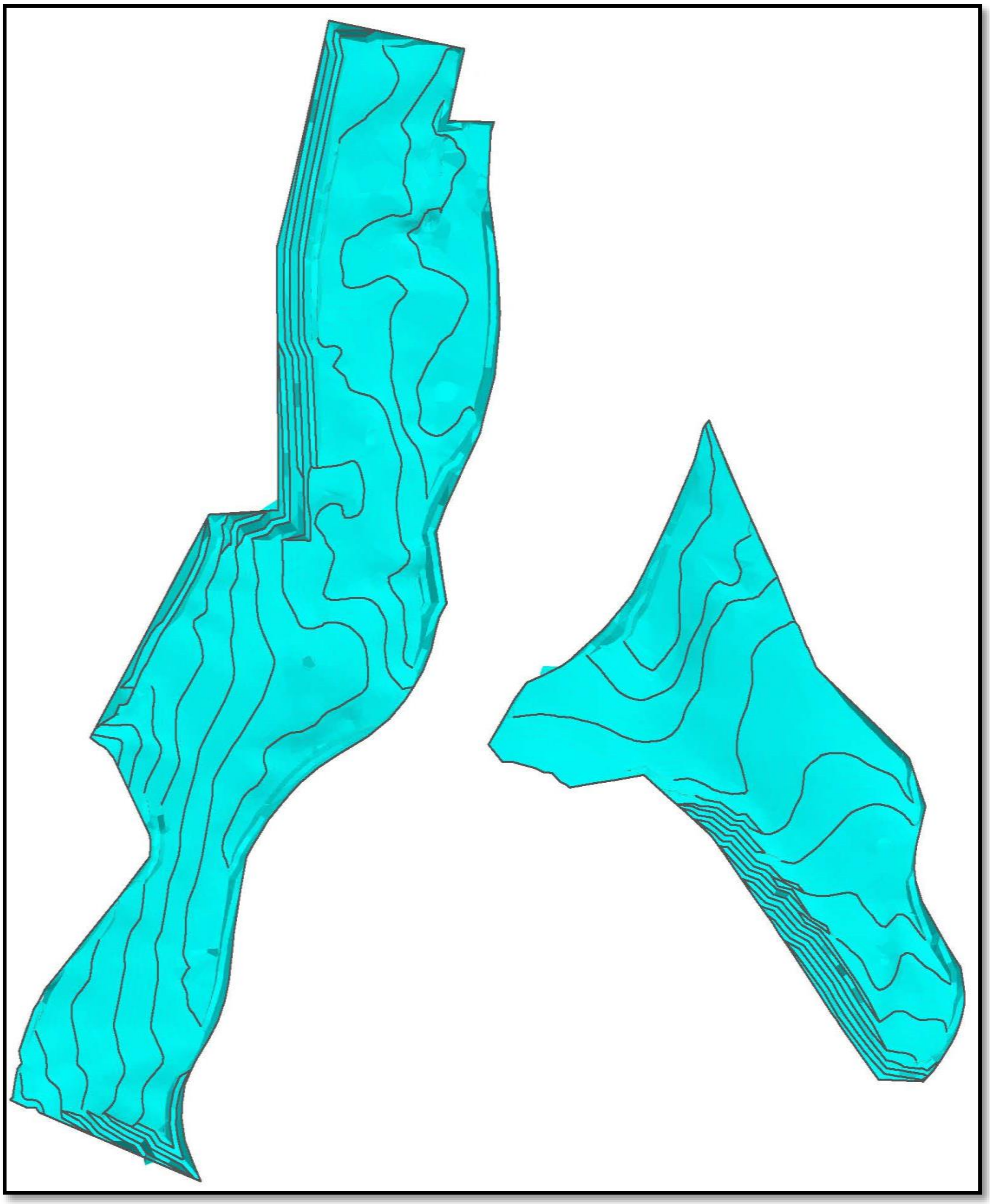

Model resistivity with topography
Iteration 11 RMS error = 1.7
L7_WSh24-25_1.bin
Elevation
Gravel, dry sand
Stream
Gravel, dry sand
Bedrock
7.73 15.2 29.7 58.2 114 224 438 859
Resistivity in ohm.m

APPENDIX D

3 D Model of mine design







VITA

Chanthaphone Milamith was born on September 19, 1990 in Sayaboury, Laos. He received him B.Eng. in Mining Engineering from the Faculty of Engineering, National University of Lao in 2014. In year 2015, he continued him study in Master of Georesources Engineering at Department of Mining and petroleum Engineering, Faculty of Engineering, Chulalongkorn University.