การออกแบบโรงแต่งแร่ดีบุก ที่บริษัท สิกขรา ไมนิ่ง จำกัด ประเทศไทย

นายมัวลาว ปาร์เบรีย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมทรัพยากรธรณี ภาควิชาวิศวกรรมเหมืองแร่และปิโตรเลียม
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

PROCESSING PLANT DESIGN OF TIN ORES AT SIKHARA MINING CO., LTD THAILAND

Mr. Moualao Parbrear

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Georesources Engineering
Department of Mining and Petroleum Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2015

Thesis Title	PROCESSING PLANT DESIGN OF TIN ORES AT SIKHARA MINING CO., LTD THAILAND
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มัวลาว ปาร์เบรีย : การออกแบบโรงแต่งแร่ดีบุก ที่บริษัท สิกขรา ไมนิ่ง จำกัด ประเทศไทย (PROCESSING PLANT DESIGN OF TIN ORES AT SIKHARA MINING CO., LTD THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: สมศักดิ์ สายสินธุ์ชัย, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ. ดร.สุรพล ภู่วิจิตร, 95 หน้า.

วัตถุประสงค์ของงานวิจัยในครั้งนี้ คือการศึกษาความเป็นไปได้เบื้องต้นของโรงแต่งแร่ดีบุกของบริษัทสิกขรา ไมนิ่ง จำกัด อำเภอบ้านคา จังหวัดราชบุรี ประเทศไทย โดยงานวิจัยครั้งนี้มุ่งเน้นที่การวิเคราะห์เปอร์เซ็นต์คุณภาพของแร่ดีบุกที่มีขนาดอนุภาคแตกต่างกัน จำนวน 20 ตัวอย่าง ใน 6 หลุม (น้ำหนักรวม 596 กิโลกรัม) โดยใช้วิธีการคัดแยกแร่ทางกายภาพ ตัวอย่างแร่ถูกวิเคราะห์โดยใช้เครื่องวิเคราะห์การเรืองแสงของรังสีเอกซ์ (XRF) ผลการวิเคราะห์จากตัวอย่างพบว่าแร่ตัวอย่างมีขนาดอนุภาค -0.265 นิ้ว ถึง +4 เมช มีองค์ประกอบทางเคมี ปริมาณธาตุดีบุก (Sn) 1.64% ปริมาณธาตุแทนทาลัม (Ta) 0.07% ปริมาณธาตุนีโอเบียม (Nb) 0.008% ขนาดอนุภาค -4 ถึง +14 เมช มีองค์ประกอบทางเคมี ปริมาณธาตุดีบุก (Sn) 2.10% ปริมาณธาตุแทนทาลัม (Ta) 0.07% ปริมาณธาตุนีโอเบียม (Nb) 0.01% ขนาดอนุภาค -14 ถึง +30 เมช มีองค์ประกอบทางเคมี ปริมาณธาตุดีบุก (Sn) 2.37% ปริมาณธาตุแทนทาลัม (Ta) 0.05 % ปริมาณธาตุนีโอเบียม (Nb) 0.008% ขนาดอนุภาค -30 เมช มีองค์ประกอบทางเคมี ปริมาณธาตุดีบุก (Sn) 2.43% ปริมาณธาตุแทนทาลัม (Ta) 0.07% และปริมาณธาตุนีโอเบียม (Nb) 0.009% ตามลำดับ จากผลการวิเคราะห์สามารถประยุกต์ใช้ในการกำหนดเครื่องจักรที่ใช้สำหรับในการตั้งโรงแต่งแร่ดีบุก เช่น ตะแกรงหมุน (Trommel) เครื่องแต่งแร่จิ๊ก (Jig) ไฮโดรไซโคลน (Hydrocyclone) เครื่องแยกแร่สไปรอล (Spiral Concentrator) โต๊ะแยกแร่ (Shaking Table) เครื่องบดบอลล์มิลล์ (Ball Mill) เครื่องแยกแร่สไปรัล (Spiral Classifier) ตะแกรงสั่น (Vibrating Screen) เครื่องแยกแร่แม่เหล็ก (Magnetic Separator) และ เครื่องแยกแร่ไฟฟ้าแรงสูง (High Tension Separator). ในการออกแบบโรงแต่งแร่ดีบุกจะใช้โปรแกรม “AutoCAD civil 3D” ซึ่งสินแร่ดีบุกสุดท้ายสามารถพัฒนาได้ถึง 74% และสามารถเก็บกลับคืนได้ที่ 90%

ด้านการเงินและการลงทุนประกอบไปด้วยการวิเคราะห์กระแสเงินสด ค่าปัจจุบันสุทธิ (NPV) และอัตราผลตอบแทนภายใน (IRR) เป็นจุดหลักในการพิจารณาทางเศรษฐศาสตร์ ซึ่งแสดง 79% ของอัตราผลตอบแทนที่คำนวณได้กับค่าปัจจุบันสุทธิของ 447,779,678 บาท และระยะเวลาในการคืนทุนอยู่ที่ 1.09 ปี

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

5770491021 : MAJOR GEORESOURCES ENGINEERING
KEYWORDS: CASSITERITE / MINERAL SEPARATION / PROCESSING PLANT DESIGN / FINANCIAL MODEL

MOUALAO PARBREAR: PROCESSING PLANT DESIGN OF TIN ORES AT SIKHARA MINING CO., LTD THAILAND. ADVISOR: ASSOC. PROF. SOMSAK SAISINCHAI, M.Eng, CO-ADVISOR: ASST. PROF. SURAPHOL PHUVICHIT, Ph.D., 95 pp.

The purpose of this research is to conduct a pre-feasibility study of a processing plant design at the Bankha district, Ratchaburi province. In this research will focus on the different particle-size at percent grade of tin from 20 samples of 6 pitting (total weight is 596 kgs), the study included mineral processing by using physical separation, mineral analysis of sample by using x-ray fluorescence (XRF). The chemical analyses of samples are as follows: the sample -3 +4 mesh: 1.64% Sn, 0.07% Ta and 0.008% Nb, the sample -4 +14 mesh: 2.10% Sn, 0.07% Ta and 0.01% Nb, the sample -14+30 mesh: 2.37% Sn, 0.05% Ta and 0.008% Nb and the sample -30 mesh: 2.43% Sn, 0.07% Ta and 0.009% Nb, respectively. These results can be applied to the definition of main machine for tin ore processing plant such as trommel, jig separator, hydrocyclone, spiral concentrator, shaking table, ball mill, spiral classifier, vibrating screen, magnetic separator and high tension separator, and designed by using the commercial software "AutoCAD civil 3D". The final tin concentrate can be upgraded to 74% Sn at a recovery of 90.0%.

Financial model, consisted of cash flow analysis, net present values (NPV), and the Internal Rate of Return (IRR) are the main point for economics consideration. In this point, 79% of internal rate of return was calculated with the net present values of 447,779,678 baht and the payback period was 1.09 years.

Department:	Mining and Petroleum Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Georesources Engineering	Co-Advisor's Signature	....
Academic Year:	2015		

ACKNOWLEDGEMENTS

First of all, I would like to express sincere thank to Prof. Dr. Boualinh Soysouvanh, dean of Faculty of Engineering, National University of Laos (NUOL), for his leadership and management of Faculty of Engineering.

I am deeply grateful to the AUN/SEED-Net for providing Friendship scholarship, and the Department of Mining and Petroleum Engineering of Chulalongkorn University (CU) that allowed me to have a great opportunity to study.

I am deeply indebted to all Department of Mining and Petroleum Engineering lecturers for their teaching, knowledge transfer, advice, support, generosity to students.

I would like to thank my thesis advisor, Assoc. Prof. Somsak Saisinchai, who shared me a lot of his expertise and research insight. I would also like to express my gratitude to my thesis co-advisor, Assist. Prof Dr. Suraphol Phuvichit, for kind suggestion and Dr. Apisit Numprasanthai, who gave me valuable advice and assistant during my thesis work.

I am indebted to Sikhara Mining Co., LTD (Thailand) for providing the samples. Special thanks are given to Mr. Amorn Plangklang, for his useful data in this study.

Sincere thanks are expressed to thesis committee members, Assoc. Prof. Dr. Dawan Wiwattanadate from the Department of Mining and Petroleum Engineering and Dr. Pornthip Parinayok from the PTT Energy Resources Co., Ltd, for their kind and applicable suggestions.

Also, I am thankful to my project partners for their assistance and support during my laboratory work.

I am forever grateful to my family, who always support, love, care and encourage me to do my best in all matters of life.

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CHAPTER I
INTRODUCTION

1.1. General Introduction

Thailand has been one of the world's leading tin producers for many decades. The major part of tin production is derived from the southern peninsula while a lesser amount is produced from the northern and central parts of the country. In Thailand, most of the tin is extracted by placer mining. Tin is the greatest economics importance. It is exceeded in export income only by rice, corn and contributes considerably toward the economics and social development of the country.

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

Most tin minerals found in Thailand are in the form of cassiterite (SnO_2). The occurrence of cassiterite is normally related to western granite formation extending from the north to the south of Thailand. There are two types of accumulation of cassiterite found in Thailand and they are in the form of primary and secondary types. The primary formation of tin is of hard-rock type without weathering from the source rock while the secondary one is of weathered rock type, either in situ or some are transported from the source rock by stream or river to form the alluvial deposit of tin and other associated heavy minerals (Aranyakanon, 1969).Tin deposit is commonly mined by gravel pump (or in some cases by hydraulic) mining as this method is cheaper to recover tin (MacDonald, 1983).

Thailand's tin industry has been playing a significant role towards the economics and social development of the country.

1.2. Problem Statement

Natural resources play a very important role in economic growth. It attracts foreign investments, creates jobs, and helps local people to earn more income. Thailand is a developing country with high usage demand of according to solve the insufficient tin supply problem, tin deposits in the country are considered to develop. Tin mining industry involves geological exploration, resource estimate, mine operation, processing plant design, financial analysis and effectively undertaken the tin processing plant.

1.3. Aims and Objectives

This research aimed to determine the pre-feasibility study of tin beneficiation plant practices. In order to achieve the aims of this research project, the following objectives were adopted.

1. To pre-feasibility study the processing plant design of tin ores.
2. To design the tin ore processing plant by using AutoCAD civil 3D.
3. To study a financial analysis involving cash flow model, Net Present Value (NPV), the Internal Rate of Return (IRR) and Payback Period.

1.4. The Schedule for Research Procedure

Schedule shows the timeline of the project, the project starts with study of the background and the literature review that experimental stage have to remove in the second stage study the equipment and machine for planning the tin ore processing plant. For the detail as shows in table 1.1 bellow.

Table 1.1 The schedule for research procedure by months

Step of thesis research (Mouth & Year, Starts at February 2015)	1	2	3	4	5	6	7	8	9	10	11
1. Study the background and literature review											
2. Experimental stage and mineral processing by using physical separations in the laboratory											
3. Study the equipment and machine for planning the Tin ore processing plant and design by using AutoCAD civil 3D											
4. Economics evaluation											
5. Conclusion and Recommendation											
6. Write thesis and technical paper											

1.5. Expected Benefits

This research were expected outcome benefits in many aspects involving

1. Improved understanding of the cassiterite mechanism behaviors for the application to processing plant design and mineral concentration.
2. Elucidation of the techniques for tin processing plant operation.
3. Determination of the possibility of investment, break even and the cost of a decision for the project.

1.6. Approach and Methodology

A number of experimental methods were undertaken to achieve the objectives. The experiment was started with pre-studies information. Physical separation techniques were employed in the laboratory scale. Then, the processing plant was design by using AutoCAD and civil 3D program. Finally, the possibility of investment was determined. The flow diagram of this project is shown in Figure 1.1.

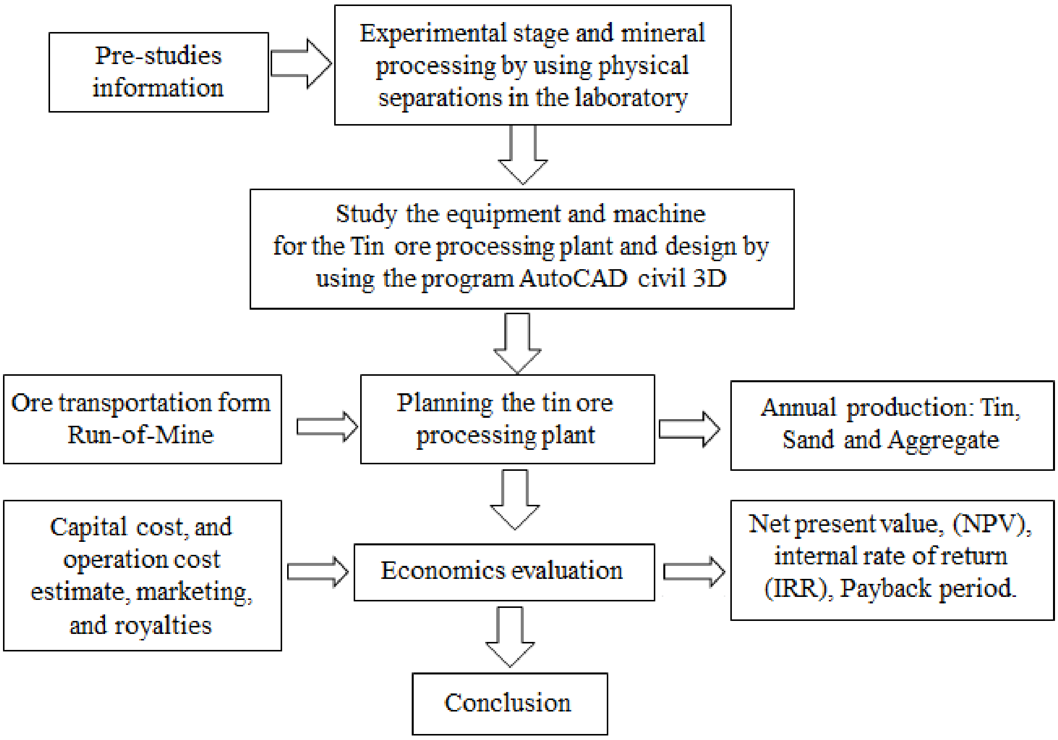


Figure 1.1 Procedure of this research

CHAPTER II
LITERATURE REVIEW

2.1. Background

This literature review firstly presented the tin minerals information and then the types of tin deposits in Thailand were exhibited with some relevant information. The mineral processing techniques and economics evaluation were also presented in this chapter.

2.1.1. Tin Mineral

Tin is preferentially concentrated during magmatic differentiation process and shows affinity for granitic rocks and their extrusive equivalence. Table below shows the list of tin minerals that occur in the earth crust, of these the only economic mineral is cassiterite (SnO_2).

The deposits of cassiterite are known in two types of geological occurrences - primary vein or hard-rock deposits and secondary placer deposits. The mineral assays about 0.4-1.5% Sn (occasionally 5-6%) in the hard-rock deposits and placer deposits are slightly poorer in grades. Pure cassiterite theoretically accounts 78% Sn. Typical concentrate grades vary between 65% and 78% Sn contents due to the presence of various mineral impurities containing the elements such as tantalum, niobium, titanium and others. Cassiterite occurring in the placer type deposits is often coarse grained and physically liberated state. World's major tin output is from placer deposits that are located in Brazil, Thailand, Indonesia and Malaysia. The hard-rock deposits are associated with granite rocks particularly greissenised granites. The cassiterite in load type deposits is highly disseminated and intimately associated with other minerals. Major tin producers from lode type deposits are China, Bolivia, Peru, Australia, South Africa, UK, Germany and Canada (Angadi, 2015).

2.1.2. Types of Tin Deposits in Thailand

There is no comprehensive descriptive work on the types or classification of tin deposits in Thailand. There is, however, a very extensive bibliography on individual tin deposits. The interested reader is referred to that review for a complete pre-1975 review and bibliography on the subject. This discussion is confined to specific information on types of tin deposits first reported and reviewed by (Aranyakanon, 1969).

The tin deposits are seven types in Thailand, such as hydrothermal lodes and greisen, disseminated cassiterite in altered granite, disseminated cassiterite in country rock, pegmatite, contact metasomatic, eluvial and placer deposits (Aranyakanon, 1969).

2.1.3. Use of Tin

Tin is a vital ingredient in a wide range of manufacturing sectors, including consumer goods, packaging, construction, vehicles and other forms of transport. The most important alloy compositions of tin are those required to support the ever growing electronics sector, providing a wide range of highly specialized solders of higher or lower melting temperature, and physical properties that allow all new product designs to be manufactured successfully. Solder is necessary for conductive joints in almost every electronic product, and the material also maintains its use for traditional industrial applications such as joining copper water pipes. The most important applications for inorganic tin chemicals are as catalysts for a wide range of industrial processes, glass coatings, and electroplating baths, fire-retardant, the ceramics and cement industries (see figure 2.1). Energy conservation has become a major technological driver and significant growth is expected in the use of tin catalysts for production of polyurethane foam thermal insulation and in tin oxide coatings for low emissivity ‘e-glass’, widely used in modern ‘green’ buildings (International Tin Research Institute (ITRI), 2012).

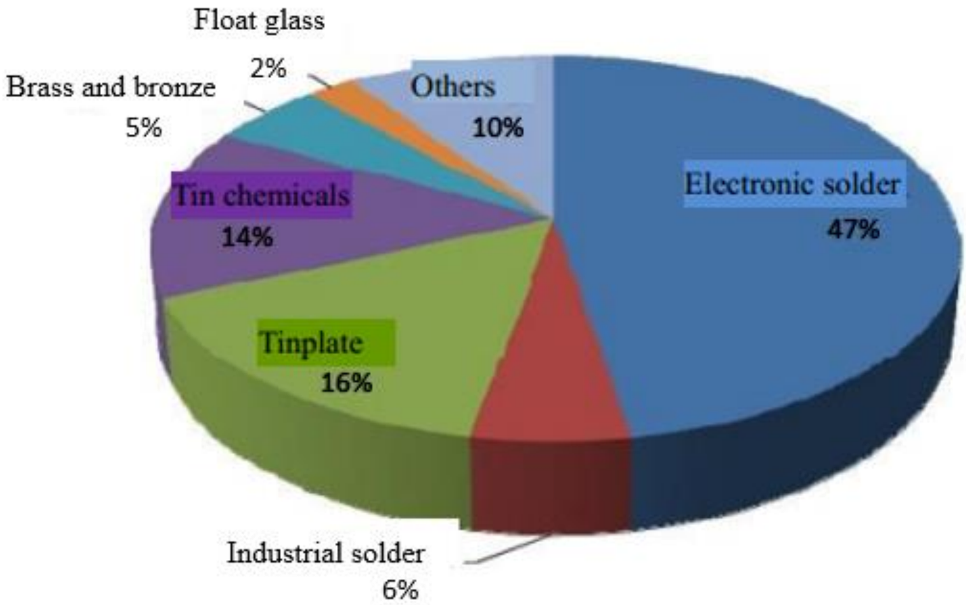


Figure 2.1 World Tin Consumption Distributions by Applications 2013

2.1.4. Project Location

The project area is located at the BanKha district, Ratchaburi province, western part of Thailand, which is far from Bangkok about 160 km. The project area can go from Bangkok to the Lam Buathong village, Bankha sub-district, and then continue to the road of department of Rural Road No: 5079 (Pu Khi Lex village road and the end of SubTery waterfall road) about 5 kilometers before arriving at the location. Figure 1 shows the location and topographic map of the study area. In this project, the selected study area covers an approximate area of 38.83 hectares (242.68 rai), the processing plant area is 40.8 hectares (255 rai), and the minable area of this project is about 24.64 hectares (154 rai) which appears on the topographic map by scale 1: 50,000 series L 7017 sheet 4835 I (see figure 2.2). The green boundary is the concession area and the pink one is processing area.

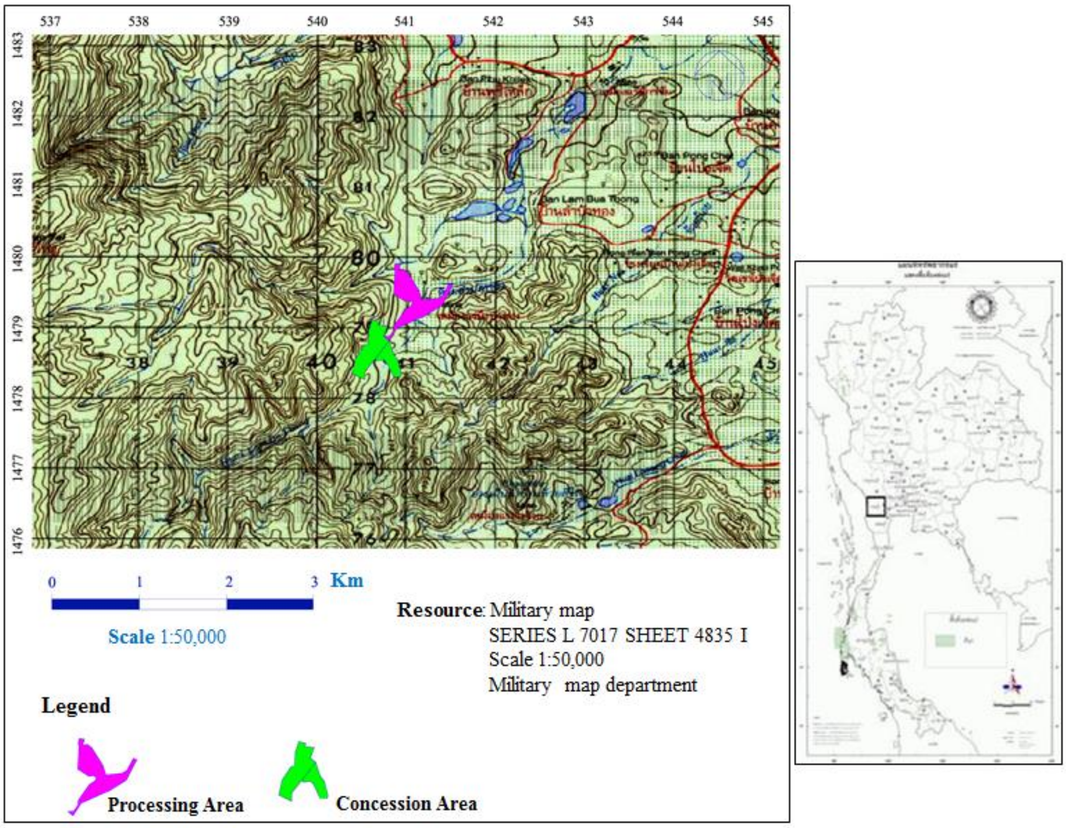


Figure 2.2 Shows the location and topographic map of the study area.

2.1.4.1. Geology of Project Area

From the geological map scale of 1: 250,000 between Honpathom province (ND 47-11) in 1985, Published by Geological Survey Division, Department of Mineral Resources, the characteristic geological of the study area contained by the Carboniferous Rocks and Cretaceous granite as detail following:

2.1.4.1.1. Igneous Rock

The formation Cretaceous granite that is granite, biotite-muscovite, and medium to coarse grained porphyritic tourmaline granite, pegmatite; aplite quartz veins and dikes. These formations appear on the west of this area.

2.1.4.1.2. Sedimentary Rock

The Carboniferous Rock that is formation KHAO PHRA the ground of KAENG KRACHAN contained by pebbly mudstone and sandstone, which is consisted of various size of quartz, grained quartzite, granite, feldspar, slate, phyllite and limestone clast, matrix are fine mud or clay, fine sand to medium sand, siliceous and calcareous cemented, generally massive, show slumping structure, slightly appearance of cross-bedding, turbidity flow, sand pipe, ripple marks and sole marking features in places, gray to dark gray, white to grayish brown on weathered surface; shale, gray to reddish gray; friable, conchoildal fracture and slaty cleavage; greywacke, brown; calcareous sandy shale, brown, usually found on top part of the formation contained brachiopods and bryozoan beds. These formations appear on the east of area.

2.1.4.1.3. Structural Geology

This structure composite by major fault, fracture/joint, the main structure appear show in formation Carboniferous rock by the fault Line and main joint were alignment in the northeast-northwest which can be found in the east of the concession area this request.

2.1.4.2. Geology of Tin Deposits in Study Area

Tin ore deposit in this area is a secondary deposit and placer deposit. Tin ores are accumulated in the Colluvial sediments. The evidence found indicates that the tin ores originates from two characteristics of primary deposit such as tin ores occurred with quartz - muscovite vein, and tin ores are occurred with Pegmatite vein.

2.2. Literature Reviews

(Somkiat, 1983) conducted a research to Trends in tin mining of on-land alluvial deposits in Thailand. This paper gave more detail on technological change made on traditional mining practice for on-land deposits in Thailand. The economic aspects were also discussed in some detail. The end of 1983, there were 1,154 activities operating in the country mines, and 737 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 a major made of tin mining over a long period of time and there were used gravel pump about 353 gravel pump mines. For economics aspect, there are comparison of cost per unit volume between gravel pump and dry striping method. As the result, if transporting distance is about 500 meters, total production cost by gravel pump is cheaper than the total production cost by dry stripping. However if transporting distance more than 500 meters, total production cost of dry striping is cheaper than total production cost by gravel pump. The same concept is also applied for the transporting cost. As shown in figure 2.3.

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.

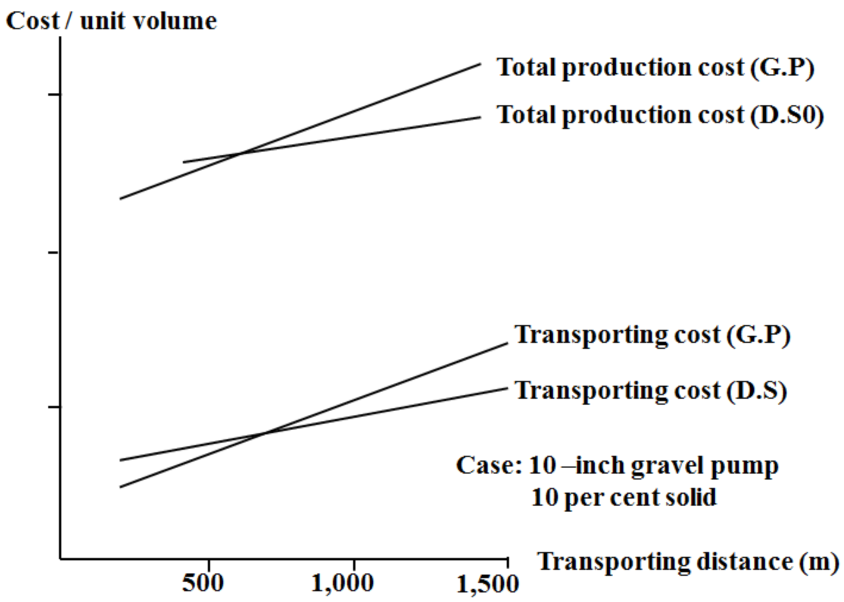


Figure 2.3 Comparison of cost per unit volume between gravel pump and dry stripping methods.

(Meechumna, 1985) most tin ores being mined in Thailand are of alluvial or eluvial type and tin is virtually all in the form of cassiterite, which is the heaviest of the alluvial minerals. It usually occurs as free and usually single-sized particles hence it can simply be separated from other semi-heavy and lighter minerals by gravity methods. Crushing and grinding are normally required only for lode ores to liberate valuable minerals from the gangue minerals before discharging into the primary concentration section. The typical flow sheet of tin-treatment is shown in Figure 2.4

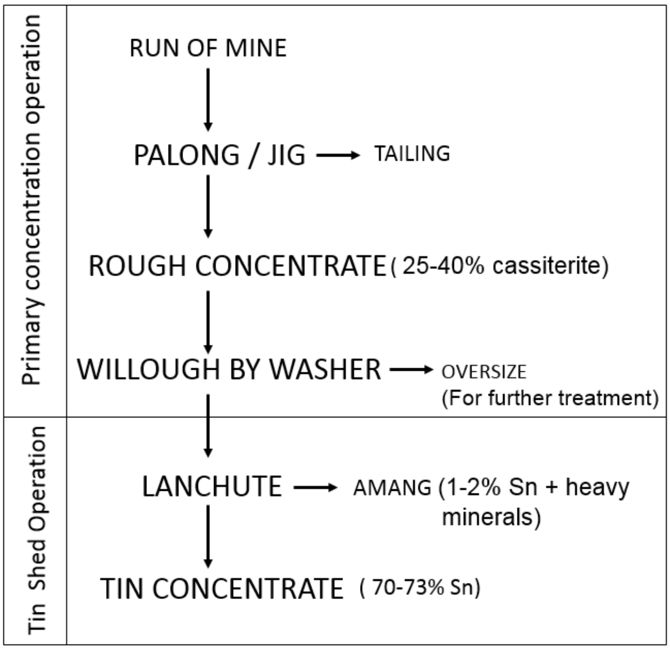


Figure 2.4 Typical flow sheet of tin treatment in Thailand.

- Primary concentration operations, the primary treatment of ore is mostly carried out by means of gravity concentration using palongs and jigs after rejecting barren rocks or pebbles with grizzlies or screens. Some mines use sets of shaking tables for primary concentration after the feed been classified.

- Tin-shed operations. After the preliminary concentration, the rough tin concentrates whether obtained from Palong or jig plant is sent to the tin shed for further treatment. Similar techniques are used regardless of secondary of mining and primary concentration. The process of secondary concentration is very simple but tedious and consists essentially of repetitive treatments of hydraulic classification and sluicing performed manually. Most tin concentrates obtained by this gravity concentration in the tin sheds are of marketable grade i.e. tin content not less than 72 per cent. Depending upon the skill of the tin-dressers and the grain size of the minerals, the percentage of cassiterite in lanchute tailings (amang) after repeated dressing ranges between 1 and 2 per cent. Apart from cassiterite, the amang usually contains the associated minerals of lower specific gravity such as ilmenite, zircon, monazite, xenotime, garnet, tourmaline etc (Meechumna, 1985).

(Smith, 1995) this is Discount Cash Flow Analysis Methodology and Discount Rate, the study of Canadian Institute of Mining-Mineral Economics Society (CIM-MES) about mining project give 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 who indicated the usage of the following rates for mining industry as base metals and Gold. By discussing with mining companies. The figure 3 showed the relation-ship between discount rate and production stage. There are 4 main production stage such as early exploration, pre-feasibility, feasibility study and mine operation. Each stage use different discount rate (see figure 2.5). In addition to this, mining investor also use this discount rate to make decision that involve capital investment and cash flow analysis model.

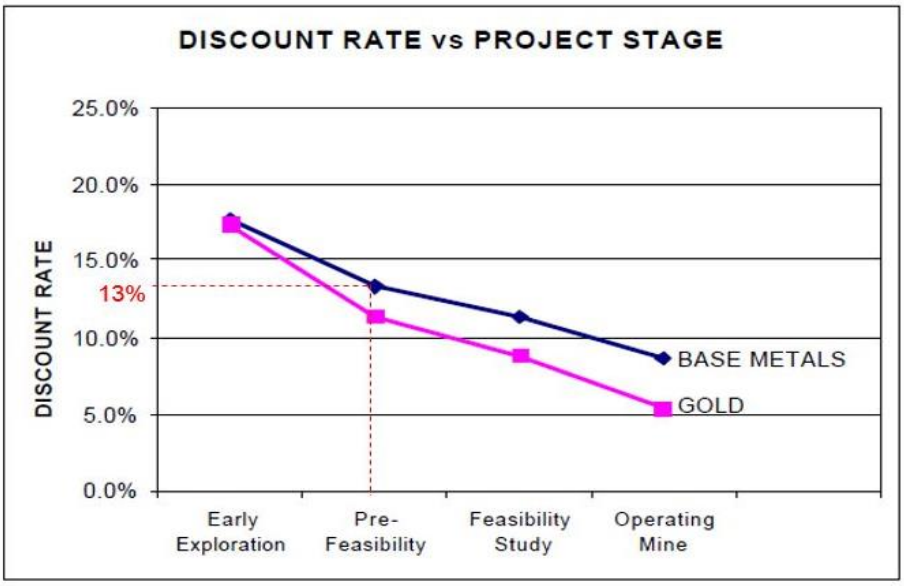


Figure 2.5 CIM MES Survey-Discount Rate and Project Stage.

(Sreenivas.T, 2000) and (Srinivas. T, 2004) reported the development of a processing scheme for the recovery of tungsten and tin values from the multi-mineral concentrate of wolframite, scheelite, and cassiterite collected from Kyrgyzstan (Central Asia). The primary gravity concentrate collected from the mine site assays about 18.05% WO_3 and 38.11% SnO_2. Both tungsten minerals wolframite and scheelite occurs in liberated state as well as fine distribution in each other. Cassiterite also found in liberated as well as intergrowth of columbite/tantalite and has fine dissemination of tungsten minerals within it. Because of this complex association of minerals an integrated process has been developed, which consists of physical beneficiation and chemical extraction techniques. The specific gravity, magnetic and electrical conductivity of wolframite, scheelite and cassiterite were explored in the separation. The concentrate thus generated was purified following the chemical route depicted in Figure 2.6. Tungsten extraction was carried out by a soda ash roast-aqueous leaching method. This method recovers about 90% tungsten values and 8–10% loss in residue. The residue contains 40% SnO_2 values that will be mixed with the cassiterite gravity concentrate to improve overall recovery values. The combined concentrate assays 67% SnO_2 that was further processed either by smelting-refining route or roasting-smelting refining route. The proposed integrated flowsheet would recover 80–90% tungsten and tin values.

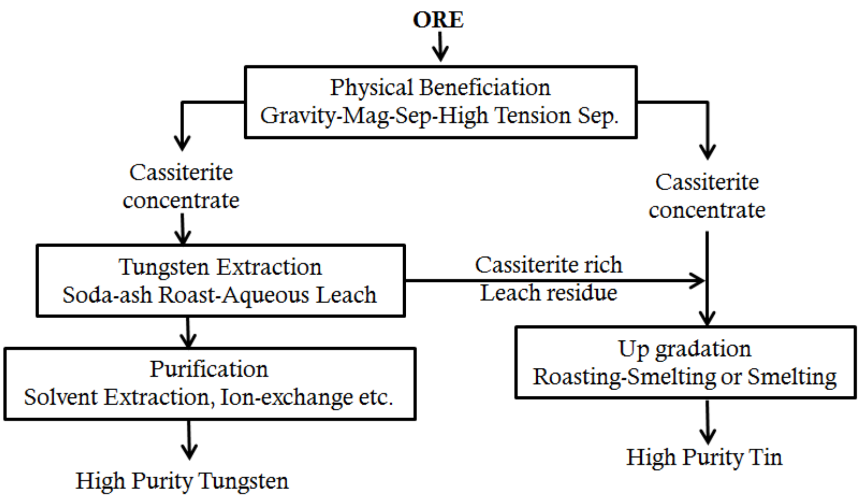


Figure 2.6 Separation of tungsten and tin values from wolframite-scheelite-cassiterite containing concentrate.

2.3. Mineral Processing Techniques

Cassiterite is the prime tin mineral present in the earth crust followed by stannite, kesterite, mawsonites, and other tin sulphides. The importance of mineralogy in the beneficiation of tin ores is reported by many researchers. These research articles outline the role of geological factors, mineralogy, texture, and mineral association in flow sheet development as well as in improving performance of the existing plants.

Carbonate-replacement (Skarn) tin deposits represent world's major exploration sites for primary tin ores. Cassiterite mineralisation in these replacement deposits occur in fine grained and closely associated with sulphides minerals such as pyrhotite, chalcopyrite, pyrite arsenopyrite, marcasite, sphalerite and galena in silicate-carbonate gangue. In many hard-rock deposits cassiterite and stannite are associated with complex polymetallic sulphide ores. Beneficiation of such ores is difficult since stannite behaves similar to pyrite and other sulphide minerals during various processing.

The disseminated nature of cassiterite occurrence in lode type deposits necessitates fine grinding to liberate mineral values from the host rock. The inherent brittle nature of cassiterite leads to the generation of undue fines not only during grinding but also during various other processing stages. The recovery of fine particles is a difficult process. It is a common practice in tin beneficiation to recover the mineral as coarse size as possible, which necessitates implementation of multi-stage processing routes. Many lode type tin mines use various pre-concentration units either before or after primary grinding stage. The pre-concentrate thus obtained is reground, classified and processed through appropriate gravity machines. Further cleaning of the concentrate can be achieved following similar techniques that are used in the placer tin processing. Generally, gravity concentrators (spirals and tables) are used to recover cassiterite particles >30 micrometer. However, recovery by gravity machines becomes gradually difficult as the particle size reduces to finer size. The performance data of many operating tin plants indicate a loss of about 30–40% cassiterite values in the gravity tails (Angadi, 2015).

2.3.1. Size Separation

Although the production of a final product having a specific size is sometimes the function of a sizing separator, the most important application is controlling the size of material fed to other equipment. This is because all equipment has an optimum size of material that it can handle most efficiently. There are two basic types of sizing separator; typically, screens are used for coarser separation, and classifiers for finer separations.

2.3.1.1. Sieve

Size analysis of the various products of a concentrator constitutes a fundamental part of laboratory testing procedure. It is of great importance in determining the quality of grinding and in establishing the degree of liberation of the values from the gangue at various particle sizes. In the separation stage, size analysis of the products is used to determine the optimum size of the feed to the process for maximum efficiency and to determine the size range at which any losses are occurring in the plant, so that they may be reduced. Sieve analysis is one of the oldest methods of size analysis and is accomplished by passing a known weight of sample material successively through finer sieves and weighing the amount collected on each sieve to determine the percentage weight in each size fraction. Sieving is carried out with wet or dry materials and the sieves are usually agitated to expose all the particles to the openings (shows in figure 2.7). Sieving, when applied to irregularly shaped particles, is complicated by the fact that a particle with a size near that of the nominal aperture of the test sieve may pass only when presented in a favorable position.

The process of sieving was divided into two stages: first, the elimination of particles considerably smaller than the screen apertures, which should occur fairly rapidly and, second, the separation of the so-called "near-size" particles, which is a gradual process rarely, reaching final completion. Both stages require the sieve to be manipulated in such a way that all particles have opportunities for passing the apertures, and so that any which blind an aperture may be removed from it. Ideally, each particle should be presented individually to an aperture, as is permitted for the largest aperture sizes, but for most sizes this is impractical. The effectiveness of a sieving test depends on the amount of material put on the sieve and the type of movement imparted to the sieve. A comprehensive account of sampling techniques for sieving is given in BS 1017-1. Basically, if the charge is too large, the bed of material will be too deep to allow each one a chance to meet an aperture in the most favorable position for sieving in a reasonable time. The charge, therefore, is limited by a requirement for the maximum amount of material retained at the end of sieving appropriate to the aperture size (Wills, 2006).

Figure 2.7 Nest: a. Lid, b. Sieve, c. Pan (Mining Laboratory at Chulalongkorn University, 2015)

2.3.2. Size Reduction

Size reduction, or comminution, is an important step in the processing of most minerals, in that it may be used to produce particles of the required size and shape. Also used to liberate valuable minerals from gangue so that they can be concentrated and increase the surface area available for chemical reaction.

A variety of equipment is available, but individually each is restricted in its application. In the minerals industry, most initial size reduction (crushing) is carried out by compression crushers, with tumbling mills used for subsequent fine size reductions (grinding). Over recent years, the most noticeable development has been the increasing size of equipment, as ore grades have decreased and mine sizes have increased. Indeed, it is now normal to find very large gyratory crushers treating run-of-mine ore, whereas in the past jaw crushers (Figure 2.8) had more than sufficient capacity (Errol, 1982).

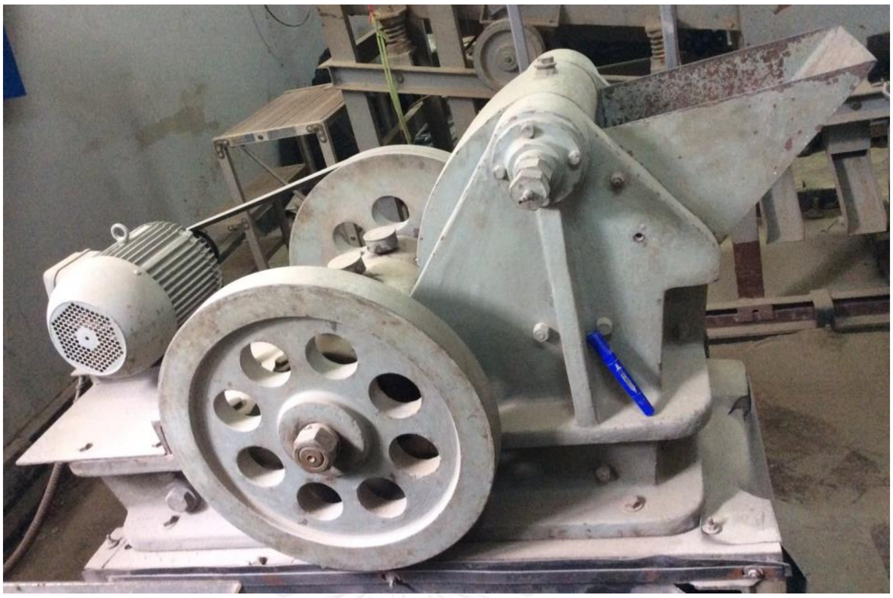


Figure 2.8 Jaw Crusher (Mining Laboratory at Chulalongkorn University, 2015)

2.3.3. Gravity Concentration

Gravity methods of separation are used to treat a great variety of materials, ranging from heavy metal sulphides such as galena (sp. gr. 7.5) to coal (sp. gr. 1.3), at particle sizes in some cases below 50μm. These methods declined in importance in the first half of the twentieth century due to the development of the froth-flotation process, which allows the selective treatment of low-grade complex ores. They remained, however, the main concentrating methods for iron and tungsten ores and are used extensively for treating tin ores, coal and many industrial minerals. In recent years, many companies have reevaluated gravity systems due to increasing costs of flotation reagents, the relative simplicity of gravity processes, and the fact that they produce comparatively little environmental pollution.

At present, gravity separation equipment are prime concentrating units in the beneficiation of coal, iron ore, heavy mineral sand, gold, barite, fluorspar, tin, tungsten, etc. Gravity concentration technique is inevitable for tin beneficiation, since heavy mineral cassiterite is associated with lighter gangue minerals. Use of pan, sluice box and pinched sluice for the beneficiation of placer tin old workings are reported by many researchers. Literature also reports various types of gravity separators such as jig, heavy media cyclone, spiral, shaking table, multi-gravity separator, Bertles Mozley separator, cross-belt separator, Falcon Ultra-Fine centrifugal concentrator, etc. in the concentration of tin ores. A lot of improvements have been achieved in the gravity concentration over the years. Many new types of equipment have been developed for the treatment of fine and ultra-fine particles (Angadi, 2015).

2.3.3.1. Jigs

Jigging is one of the oldest methods of gravity concentration; the basic principles are only now beginning to be understood showed in figure 2.9. The jig is normally used to concentrate relatively coarse material and, if the feed is fairly closed sized (e.g. 3-10mm), it is not difficult to achieve good separation of a fairly narrow specific gravity range in minerals in the feed (e.g. fluorite, sp. gr. 3.2, from quartz, sp. gr. 2.7). When the specific gravity difference is large, good concentration is possible with a wider size range. Many large jig circuits are still operated in the coal, cassiterite, tungsten, gold, barites, and iron-ore industries. They have a relatively high unit capacity on classified feed and can achieve good recovery of values down to 150μm and acceptable recoveries often down to 75μm. High proportions of fine sand and slime interfere with performance and the fines content should be controlled to provide optimum bed conditions.

In the jig the separation of minerals of different specific gravity is accomplished in a bed which is rendered fluid by a pulsating current of water so as to produce stratification. The aim is to dilate the bed of material being treated and to control the dilation so that the heavier, smaller particles penetrate the interstices of the bed and the larger high specific gravity particles fall under a condition probably similar to hindered settling (Wills, 2006).

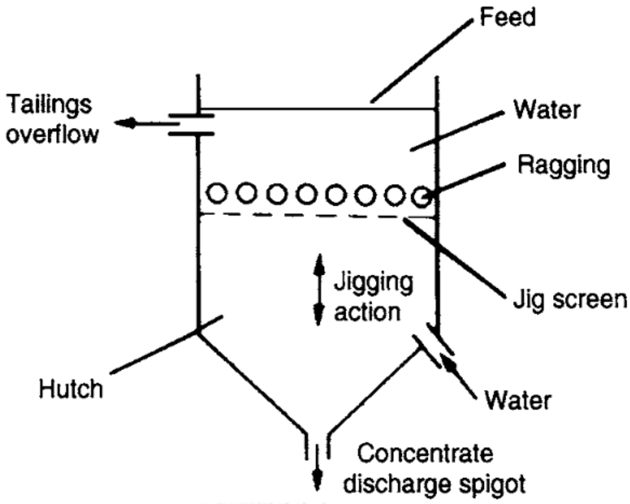


Figure 2.9 Basic Jig construction (Wills, 2006)

2.3.3.2. Shaking Tables

When a flowing film of water flows over a flat, inclined surface the water closest to the surface is retarded by the friction of the water adsorbed on the surface; the velocity increase towards the water surface; If mineral particles are introduced into the film, small particles will not move as rapidly as large particles, since they will be submerged in the slower-moving portion of the film. Particles of high specific gravity will move more slowly than lighter particles, and so a lateral displacement of the material will be produced. The flowing film effectively separates coarse light particles from small dense particles, and this mechanism is utilized to some extent in the shaking table concentrator (Figure 2.10), which is perhaps the most metallurgic ally efficient form of gravity concentrator, being used to treat the smaller, more difficult flow-streams, and to produce finished concentrates from the products of other forms of gravity system.

It consists of a slightly inclined deck, A, on to which feed, at about 25% solids by weight, is introduced at the feed box and is distributed along C; wash water is distributed along the balance of the feed side from launder D. the table is vibrated longitudinally, by the mechanism B, using a slow forward stroke and a rapid return, which causes the mineral particles to "crawl" along the deck parallel to the direction of motion. The minerals are thus subjected to two forces, that due to the table motion and that, at right angles to it, due to the flowing film of water. The net effect is that the particles move diagonally across the deck from the feed end and, since the effect of the flowing film depends on the size and density of the particles, they will fan out on the table, the smaller, denser particles riding highest towards the concentrate launder at the far end, while the larger lighter particles are washed into the tailings launder, which runs along the length of the table (Wills, 2006).

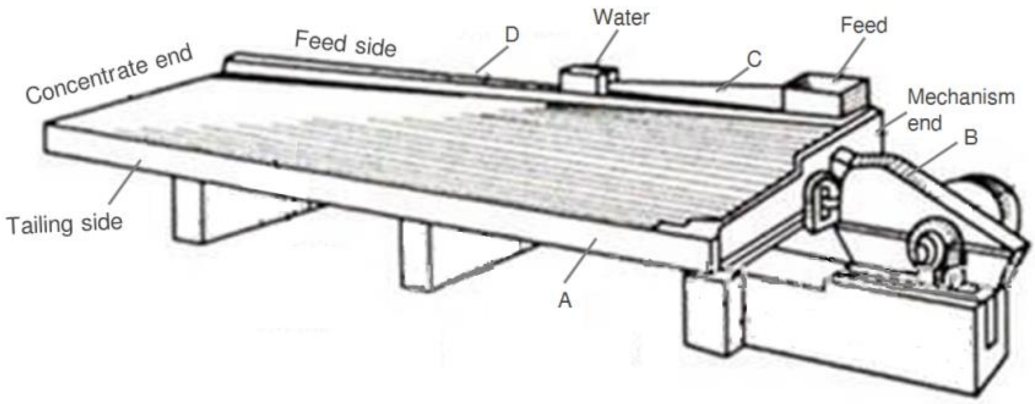


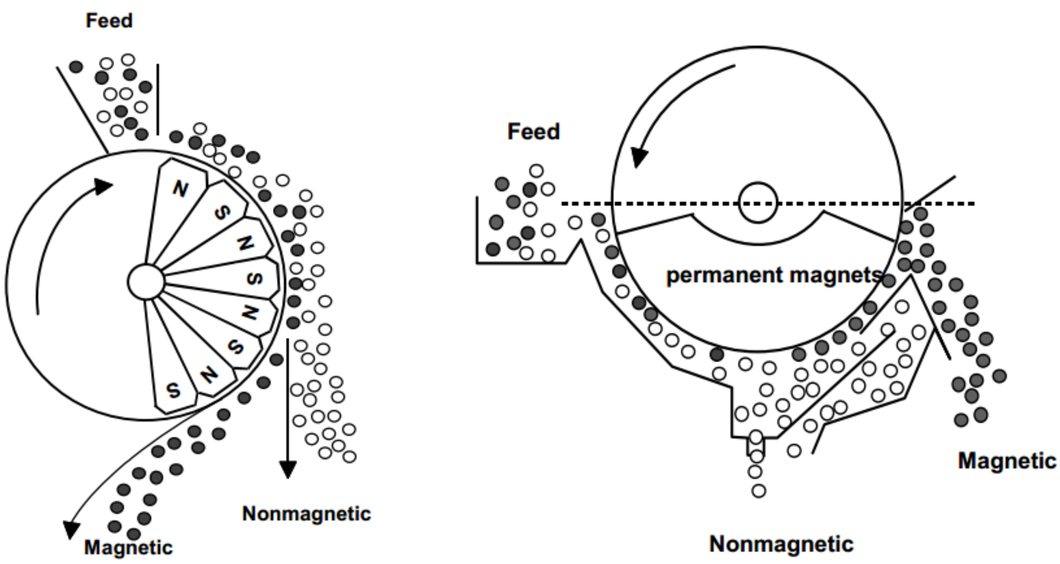
Figure 2.10 Shaking Table (Wills, 2006)

2.3.4. Magnetic Separation

A particle placed in a magnetic field interacts with this field. As a result, the particle moves in the field. This phenomenon is utilized in separation of particles of different materials and it is termed magnetic separation.

The principle of separation in low intensity magnetic field devices, operating both in air and water, are shown in Figure 2.11 and the properties of minerals in magnetic field shown in table 2.1. Among the wet separators there can be distinguished not only parallel current, but also counter–current, counter–rotary and other types of separators. Low intensity magnetic separators are applied for strongly magnetic particles.

A completely different type of magnetic separator is the Frantz isodynamic separator. It is built in such a way that the force acting on a particle is constant within the whole area of magnetic field. It is used in laboratories for determining magnetic properties of particles, including magnetic susceptibility and the potentials of separation. It represents analytical type of devices. Figure 2.12 shows the Frantz separator and forces affecting the particles and the types of mineral after separation shown in table 2.2.



a b

Figure 2.11 Operating principles of low intensity magnetic field separators: a – drum separator for dry separation, b – drum (parallel current type) for wet separation.

Table 2.1 The properties of minerals in magnetic field.

Ferromagnetic	Magnetic (Medium)	Magnetic (Low)	Non-Magnetic	
Magnetite	Ferberite	Wolframite	Gold	Barite
Ilmenite	Ilmenite	Columbite	Gypsum	Topaz
	Monazite	Tantalite	Copper	Kyanite
	Xenotime	Samarskite	Galena	Fluorite
	Garnet	Euxenite	Pyrite	Anhydrite
	Siderite	Hematite	Molybdenite	Mica
	Staurolite	Chromite	Rutite	Feldspar
		Epidote	Limonite	Calcite
		Olivine	Diamond	Quartz
		Apatite	Graphite	
		Hornblende	Scheelite	
		Tourmaline	Zircon	

Source: (Thongsongtum. T., 2015)

Figure 2.12 Frantz isodynamic separators (Mining Laboratory at Chulalongkorn University, 2015)

Table 2.2 Types of mineral separated by Frantz isodynamic separator

The magnetic field set at (Amperages)	Types of Mineral	Remark
0.4 A	Garnet, Ilmenite, Siderite	Frantz Separator set at: Forward slope of 15 degree, Side tilts of 25 degree.
0.7 A	Hydroilmenite, Columbite, Tantalite, Wolframite, Xenotime, Hematite, Siderite, Laterite, Tourmaline, Limonite.	
1.2 A	Hydroilmenite, Struverite, Tourmaline, Monazite, Muscovite, Biotite, Yttrotantalite, Samarskite, Leucoxene.	
Non-Magnetic	Cassiterite, Rutile, Zircon, Pyrite, Leucoxene, Thorite, Microlite, sand	

Source: (Thongsongtum. T., 2015)

2.3.5. "Electro-Dynamic" Electrostatic Separators

Drzymala (2007) electrostatic separators of the electro-dynamic type are all based on the original carpenter design. They are commonly called *high tension* separators. Figure 2. 13 show the major features of this separator. The feed is carried by the grounded rotor into the field of a charged ionizing electrode. The feed particles accept a charge by ion bombardment. The conductor particles lose their charge to the grounded rotor and are thrown from the rotor surface by centrifugal force; they them come under the influence of the electrostatic field of the nonionizing electrode and are further attracted from the rotor surface. The nonconductor particles are not able to dissipate their charge rapidly to the rotor, and so are held to the rotor surface by their own image forces. As the rotor carries the nonconductor particles on its surface, their charge is slowly lost and they drop from the rotor, middling particles losing their charge faster and dropping first. The residual nonconductors are removed from the rotor surface by a brush. In some high tension separators the removal of nonconductor particles from the rotor is assisted by high voltage "wiping"; this is carried out by means of additional electrode placed on the brush side of the rotor. Table 2.3 shows the properties of mineral that separation by electrostatic separator or high tension separator.

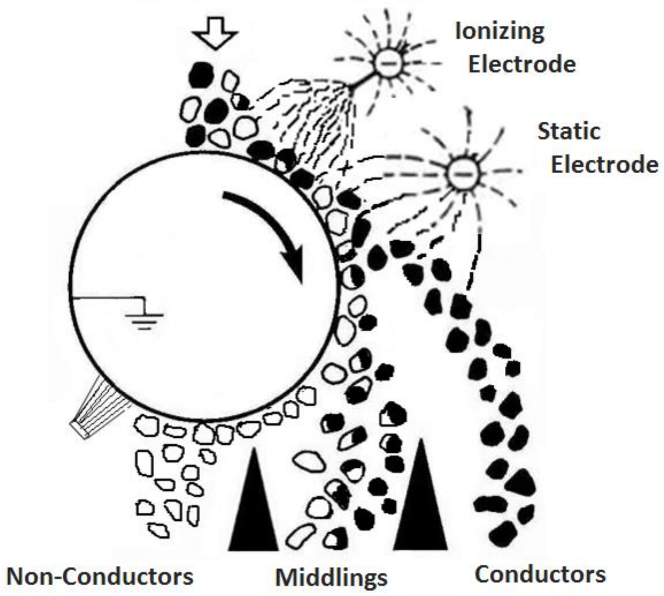


Figure 2.13 Operating principles of electro-dynamic or high tension separator

Table 2.3 The properties of mineral that separation by high tension separator

Conductor		Non-conductor	
Cassiterite	Copper,	Anhydrite	Apatite
Chromite	Columbite – Tantalite	Barite	Beryl
Chalcopyrite	Diamond	Corumdum	Calcite
Davidite	Euxenite	Epidote	Fluorite
Ferberite	Gold	Feldspar	Gypsum
Galena	Graphite	Granet	Hornblende
Hematite	Ilmenite	Kyanite	Mica
Molybdenite	Magnetite	Monazite	(Biotite,Muscovite)
Wolframite	etc.	Quartz	Olivine
		Sulphur	Silimanite
		Tourmaline	Siderite
		Xenotime	Topaz
			etc.

Source: (Thongsongtum. T., 2015)

2.4. Economics Evaluation

Economics is a social science that studies the allocation of scarce resources among competing ends. The principles, theories, or models of economics are used to explain and predict economic events. Policies are developed to correct economic problem. Financial analysis concerns the cash flow (CF) model, the Net present Value (NPV), and Internal Rate of Return (IRR).

2.4.1. Cash Flow Model

Cash flow (CF) model is a model that shows flow of cash of an investment over a defined period of time. CF typically shows (1) cash receipts at the end of each year generated by the investment, (2) cash disbursements of all costs (initial and subsequent costs) per year required for the operations, and (3) total time span of the investment in years. Cash flow diagram shows that a capital investment is an amount paid to receive expected net cash inflows over the economic life of the investment (Mian, 2011).

The cash flow is referred to net inflow or outflow of money that occurs during a specific time period.

Formula for calculate cash flow:

- Gross profit = gross revenue – operating expense – depreciation and depletion
- Net profit = gross profit (taxable income) – tax
- Cash flow = net profit + depreciation and depletion – capital cost

2.4.2. Net Present Value (NPV)

The net present value (NPV), also referred to as the present value of cash surplus or present worth, is obtained by subtracting the present value of periodic cash inflow. The present value is calculated using the weighted average cost of capital of the investor, also referred to the discount rate or minimum acceptable rate of return (Mian, 2011).When NPV of an 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 generates is equal to the positive present value. It also implies the rate of return on the investment is at least equal to the discount rate. The net present value method of evaluating the desirability of investments is mathematically represented by the following equation.

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

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

$$NPV = \sum_{t=1}^{n} \frac{NCF_t}{(1+id)^t} \qquad \text{(eq. 2.1)}$$

Where

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

I_o = the initial investment outlay at time zero

i_d = the discount rate

n = is the project's economic life in years.

Once the NPV of the investment alternative is calculated, the following decision rulers apply:

- If the NPV is positive, accept the project.
- If the NPV is negative, reject the project.

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 (assuming both alternatives have the same risk).

The NPV decision criterion follows directly from the assumption that the analyst is required to maximize the value of the project. This criterion results in optimal choice of projects.

2.4.3. Internal Rate of Return (IRR)

(Mian, 2011) Internal rate of return (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 NPV. IRR is the discount rate at which the net present value is exactly equal to zero, or the present value of cash inflow 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 value) and income (positive value) that occur at regular period. The equation for calculating IRR is:

$$\sum_{t=1}^{n} \frac{NCF_t}{(1+IRR)^t} = 0 \qquad \text{(eq. 2.2)}$$

The rule for making the investment decision when using IRR is:

- Accept the investment if its calculated IRR is greater than the return on the alternative use of funds or cost of capital.

- Reject the investment if its calculated IRR is less than the return on the alternative use of funds or cost of capital.

If the investment is financed 100% by borrowed capital, then the rate of return should at least exceed the interest rate being paid on the loan. A company could also set a minimum rate of return or hurdle rate.

If the calculated IRR is (1) greater than the required rate of return, the NPV is positive; (2) less than the required rate of return, the NPV is negative; and (3) equal to the required rate of return, the NPV is zero.

CHAPTER III
METHODOLOGY

3.1. The Equipment Used in this Research

3.1.1. Field Equipment

1). Global positioning system (GPS) / Geology hammer

2). Back hole / Shovel / Hoe / Bucket

3.1.2. Laboratory Equipment

1). Sieve

2). Shaking Table

3). Oven

4). Dry Magnetic Separator

5). Roll Crusher

6). Jig Separator

7). High Tension/Electric Separator

8). Frantz Isodynamic Separation

9). Microscope

10). Vibratory Cup Mill

11). Hydraulic Press

12). X-ray Fluorescence spectrometer (XRF)

13). X-ray Diffraction spectrometer (XRD)

3.2. Samples Preparation

Samples were obtained from pit number 2, 7, 8, 10, 12 and 13. The Samples from each depth in a pit were packed separately (see Figure 3.1), there were 20 samples of 6 pitting such as the pit number 2 there were 3 samples at a depth of 1 to 3 meters, the pit number 7 there were 4 samples at a depth of 1to 4 meters, the pit number 8 there were 3 samples at a depth of 1 to 3 meters, the pit number 10 there were 3 samples at a depth of 1 to 2.8 meters, the pit number 12 at a depth of 2.6 to 4.6 meters and the pit number 13 at a depth of 1 to 4.75 meters (total weight is 596 kgs).

Firstly, each sample was taken to wash for removing the dirt and fine particles, and then it was sieved to separate size.

Figure 3.1 Some pitting and sample in the concession area of this study

3.3. Experimental Methods

The experiments were designed to determine tin grade from the primary tin resource process. It was begun with wet sieving to remove the dirt. Then, roll crusher were employed for size reduction. Jig separator, shaking table, magnetic separation and high tension separator were also utilized. X-ray Fluorescence spectrometer (XRF) was used to identify the samples. After that, the samples were analyzed by using X-ray Diffraction spectrometer (XRD) for mineralogical study.

3.3.1. Wet Sieving

The purpose of washing of the sample is to remove organic dirt and clay. It was undertaken by hands with the sieve number 0.265 inch (3 mesh), 4 mesh, 14 mesh and 30 mesh respectively (see figure 3.2). During washing of the sample, the fined grained particles go down at the bottom of container, and coarse grained particles go up and flow with water when pouring water out. The fined grained particles remained at the bottom. Firstly, sample is sieved to separate to +3 mesh, and it is separated to find distribution and stock, it is not brought to any next process. Secondary, the sample passing +3 mesh (+3#) was sieved to separate to -3+4 mesh, -4+14 mesh, -14+30 mesh and -30 mesh, it is brought to next steps. Finally, the samples have been sieved to obtain 5 size fractions namely +3 mesh, -3 +4 mesh, -4 +14 mesh, -14 +30 mesh and -30 mesh fractions (see figure 3.3).

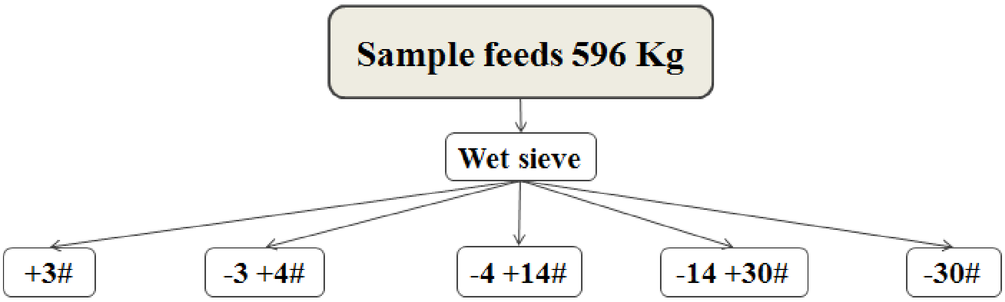


Figure 3.2 Flow sheet of size separation by wet sieving

Figure 3.3 Samples after sieve with wet sieving

3.3.2. Jig Separation and Crushing

The samples were separated by wet sieve and dried in the oven. The sample have size ranges of -4mesh+14mesh was brought directly to jig and the sample having size rank -3mesh +4mesh was crushed by roll crush to reduce of the size for jig concentration process (see figure 3.6 and flowsheet in figure 3.7). In this process has produced two products which were concentrate and tailing samples. The concentrate sample was used for magnetic separation to separate the magnetic and non-magnetic minerals. It should be remarked that this process water consuming (see figure 3.5).

Figure 3.4 Jig separation

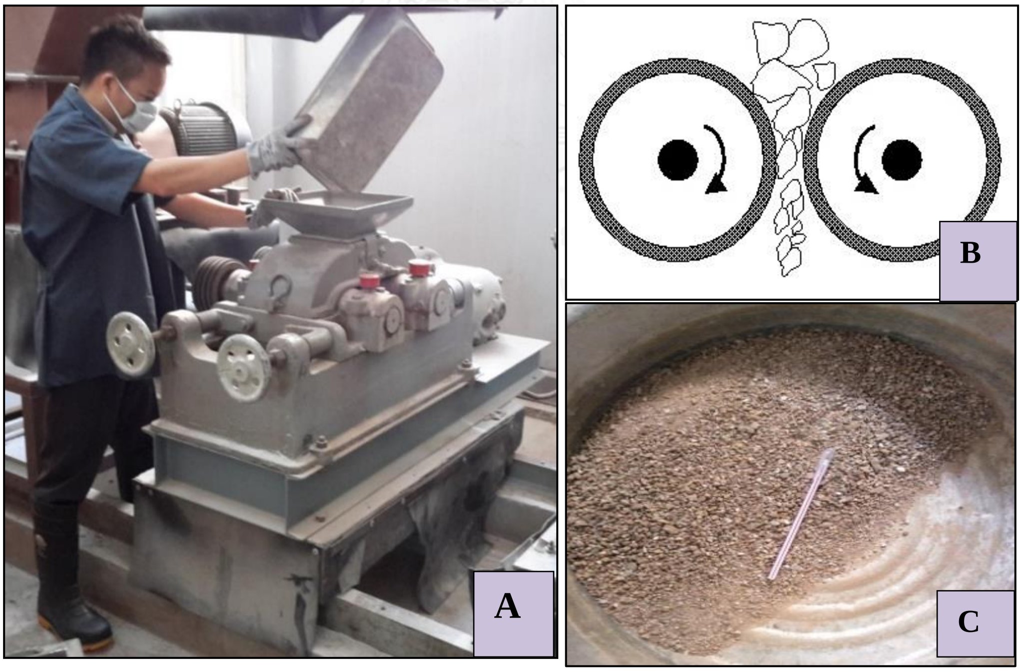


Figure 3.5 (A) Feeding sample to the roll crusher, (B) Basic elements of a roll crusher and (C) crushed sample

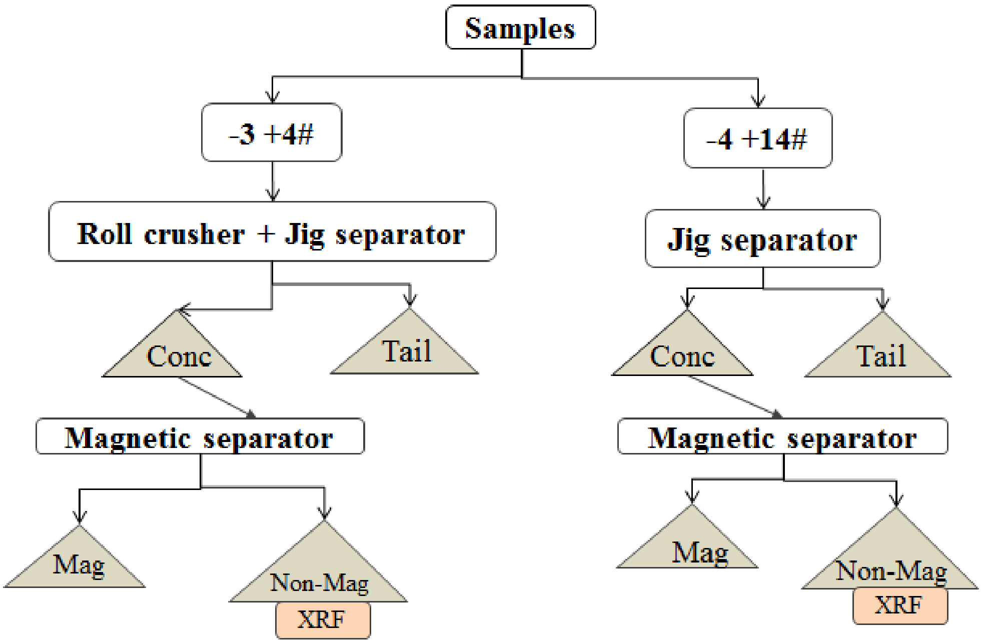


Figure 3.6 Flow sheet of crushing and jig separation

3.3.3. Shaking Table Separation

Feed slurry is distributed at the head of the table via a launder, together with washed water, and spread out across the inclined surface on the basis of particle specific gravity (SG), with high specific gravity grains moving along the top of the flowing film to discharge off the far end as concentrate, while low grains move down the inclined slope of the table with the majority of the water to discharge at the bottom as tailings.

Samples separated by wet sieve having size rank of -14 +30 mesh and -30 mesh were concentrated by shaking table, and put in the oven to dry for analysis by x-ray fluorescence (XRD). Shaking table separation is time and water consuming as we feed little and bring middling to feed again. By the end of this process, the product was obtained in concentrate and tailing showing in figure 3.8.

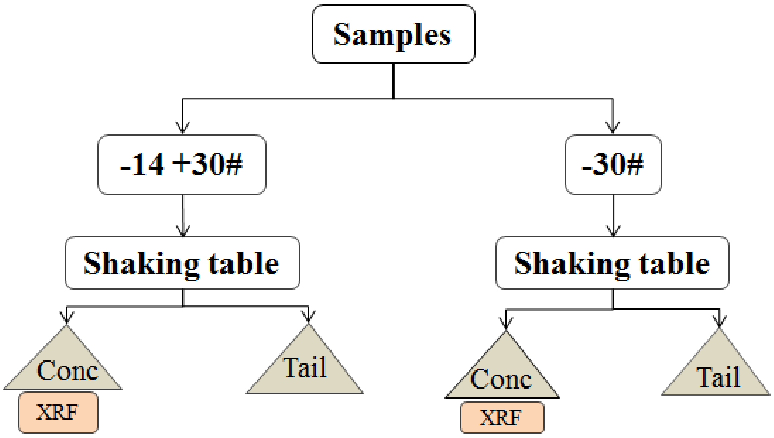


Figure 3.7 Flow sheet of shaking table

3.3.4. Grinding

Concentrate from jig and shaking table was sampled by Jone riffle obtain the weight of 100g or less than 100g depending on the samples and ground by cup mill to reduce size to smaller than 200 mesh for analyzing by X-ray fluorescence (XRF). Sample was ground for 5 minute and then prepared to put in the holder (see figure 3.9).

Figure 3.8 Vibratory cup mills

3.3.5. Mineralogical Study

After the experiments were undertaken by wet sieving and shaking table, some clean concentrate fraction from shaking table were collected for mineralogical study. Frantz isodynamic magnetic separator, x-ray diffraction spectrometer (XRD) and optical microscope were employed for the process as showing in figure 3.10.

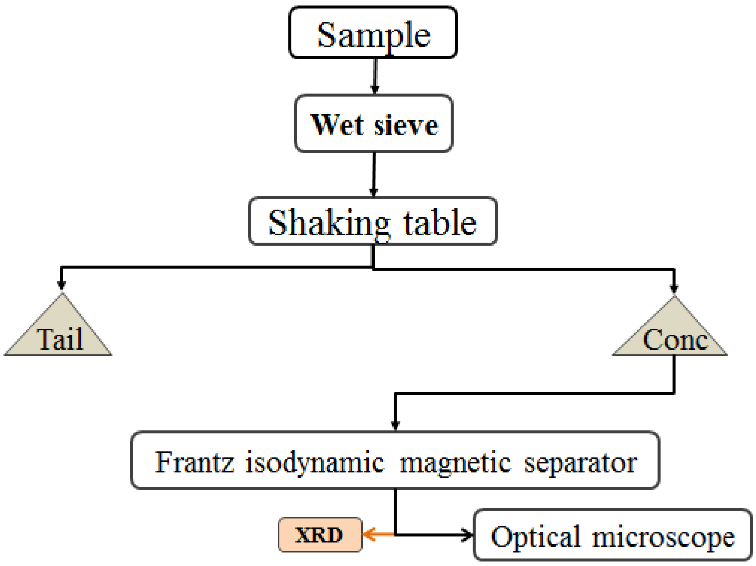


Figure 3.9 Flow sheet of mineralogical study

3.3.5.1. Frantz Isodynamic Magnetic Separator and Minerals Identification by Microscope

These are usually used in preliminary studies to provide a measure of specific susceptibility of individual mineral type to magnetic separation.

Before the samples were fed into the Frantz isodynamic magnetic separator, using the magnet to moves the ferromagnetic mineral. In this case the sample was passed through a Frantz separator set at a forward slope of 15 degree and a side tilts of 25 degree (see figure 3.12). The current of the separator was varied and the separated fractions at different amperages (A) were collected, so the current controlling magnetic field was set at 0 to 0.4A, 0.4 to 0.7 and 0.7 to 1.2A, respectively.

Figure 3.10 Frantz isodynamic magnetic separator

Table 3.1 The weight of samples from Frantz isodynamic separator

Feed	Magnetic at 0.0-0.4 A	Magnetic at 0.4-0.7 A	Magnetic at 0.7-1.2 A	Non Magnetic -1.2 A
20 g	2.48 g	4.23 g	3.14 g	9.34 g
100 %wt	12.40 %wt	21.15 %wt	15.70 %wt	46.70 %wt

The results showed that the types of magnetic from the samples were able to be separated. Microscope (Reflected optical microscope) was also use to identify mineral of each fractions. Microscopy is the technical field of using microscopes to view objects and areas of objects that cannot be seen with the naked eye (objects that are not within the resolution range of the normal eye) or seen not clear with. We use microscope to identify the mineral with grain size, grain sharp, crystal form and color such as in figure 3.13 to figure 3.15. It was taken the pictures by microscope and this sample was analyzed by x-ray diffraction (see figure 3.16).

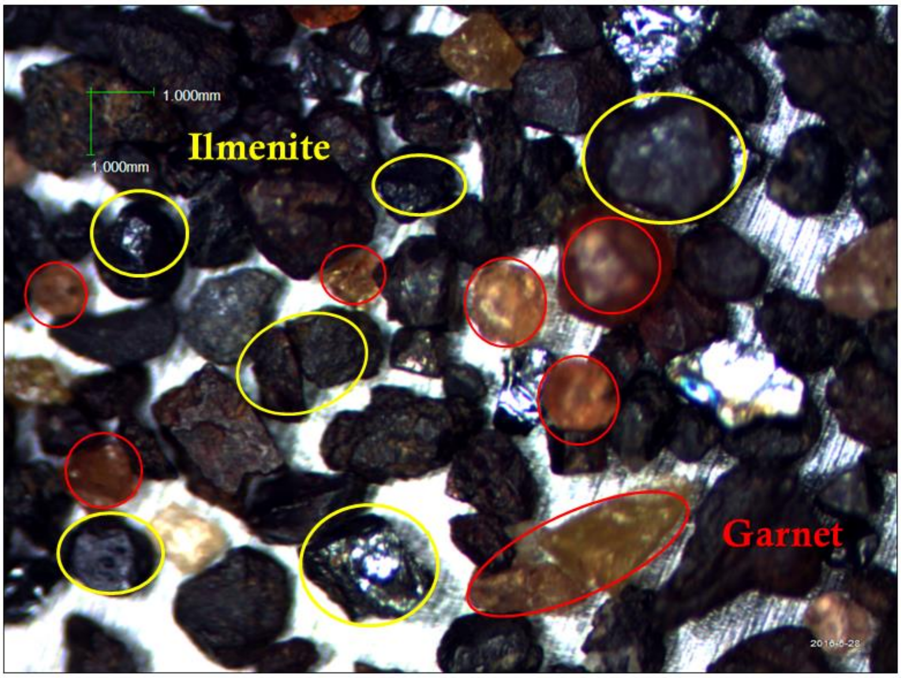


Figure 3.11 The result of magnetic at 0.0-0.4 A

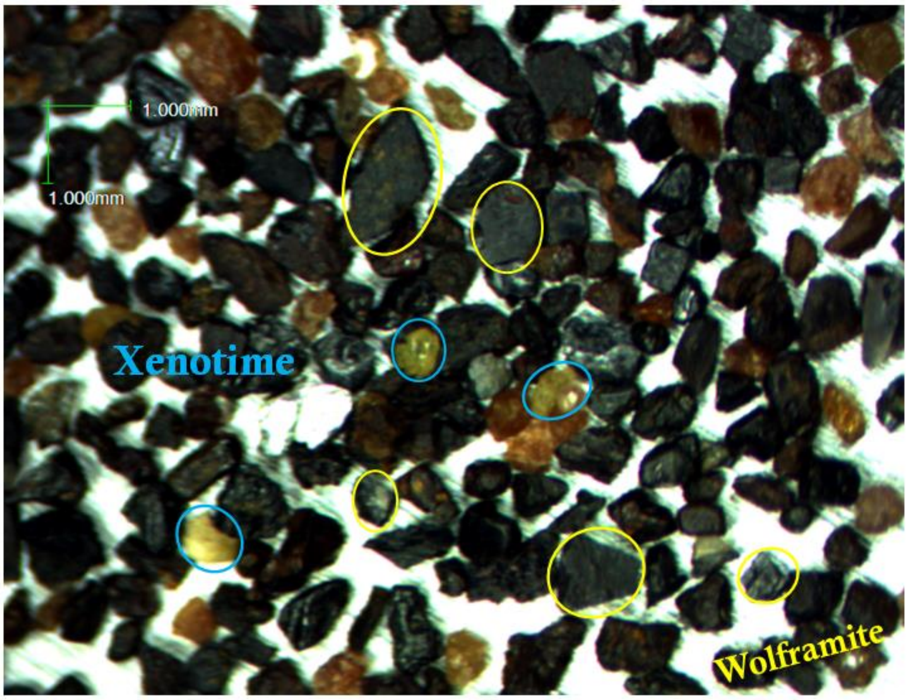


Figure 3.12 The result of magnetic at 0.4-0.7 A

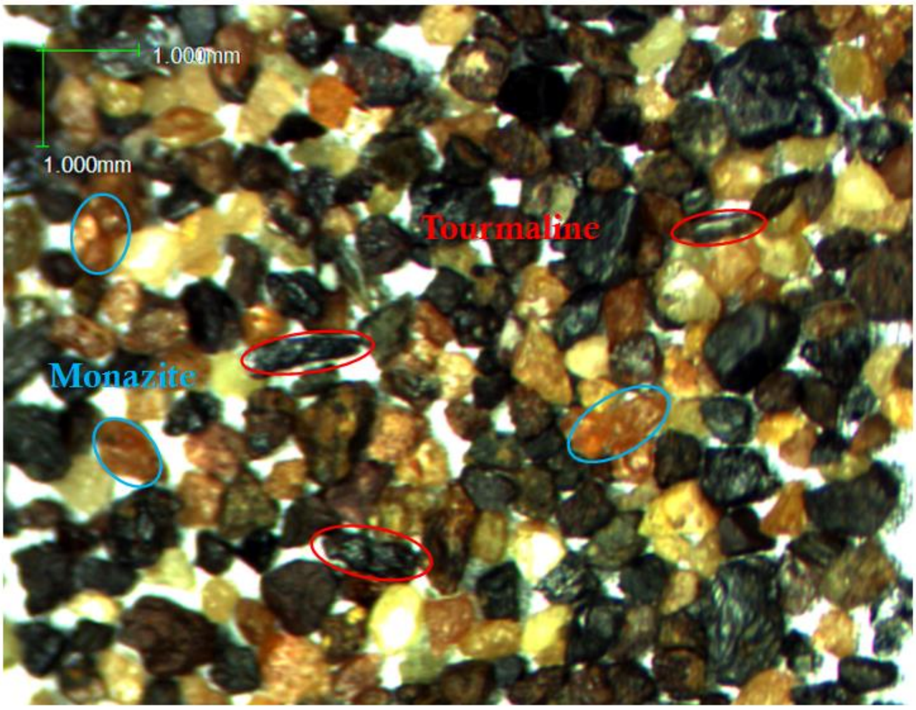


Figure 3.13 The result of magnetic at 0.7-1.2 A

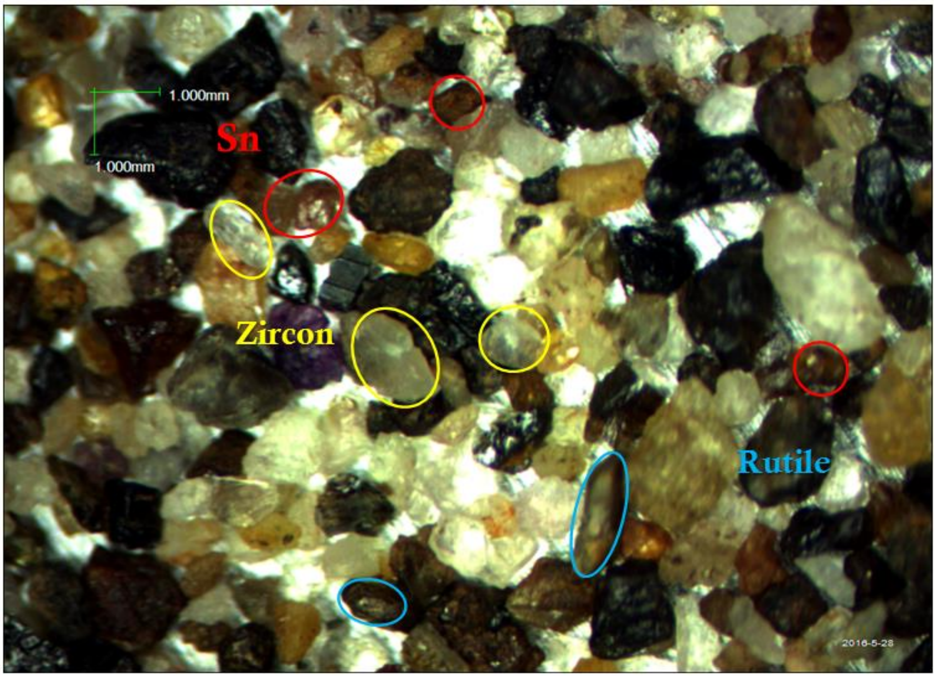


Figure 3.14 The result of non-magnetic at 1.2 A

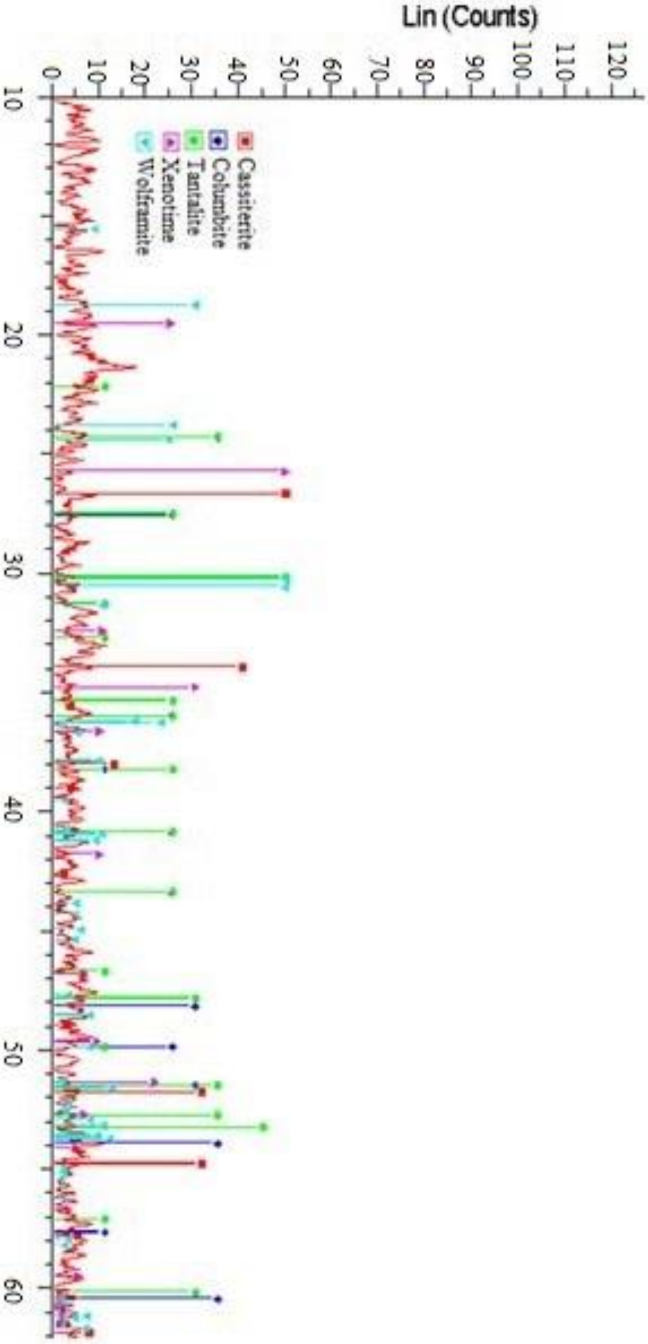


Figure 3.15 Identification of minerals in the samples from Frantz isodynamic magnetic separator by XRD

3.3.6. Upgrading Concentrates by Using Dry Process

After got the sample from shaking table of two size (-14+30 mesh and -30 mesh) as shown in figure 3.10 below and put in the oven to dry. And then take both sizes to run with dry magnetic separator (DMS), this machine separated the sample into three fractions such as magnetic, middling and non-magnetic fraction. After that, take only magnetic fraction to optical microscopy because it is the waste which contains mostly ilmenite and magnetite. The non-magnetic fraction contains mostly cassiterite and quartz, etc. It is brought to next process with electrostatic separator (High tension separator). Because of the sample are small amount after processed with DMS, that have to mix layer of the same size together (non-magnetic), and analysis by XRF. The high tension separator is separated the sample into three fractions as conductor, middling and non-conductor fraction but the middling fractions are feed again until doesn't have middling. The conductor fraction takes to analysis by XRF because it is major conduct mineral.

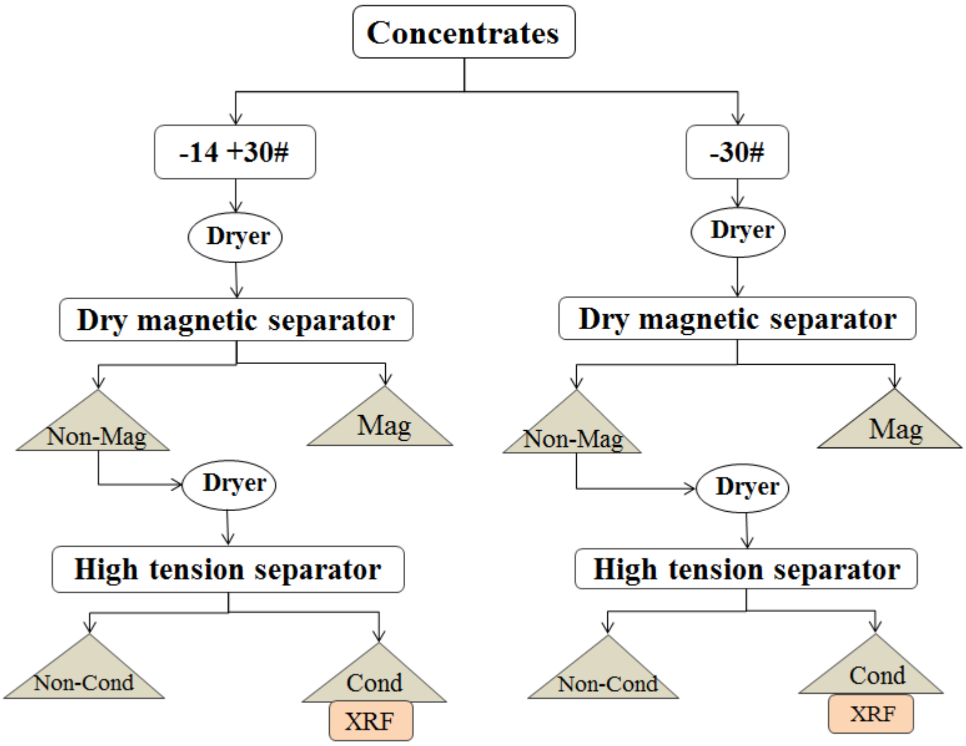


Figure 3.16 Flow sheet of upgrading by dry process

3.3.6.1. Processing by Dry Magnetic Separator (DMS)

Magnetic separators exploit the difference in magnetic properties between the ore mineral and are used to separate either valuable minerals from non-magnetic gangue. Magnetic separators are the physical method of mineral processing which separates the metals and waste which has different magnetic properties. Magnetic separations are classifying according to their magnetic field intensity into low intensity magnetic separators and high intensity magnetic separators.

Before testing with this machine, make sure that the machine run perfectly. The perfection of this machine is identified by testing of its capacity optimum started from 1A, 2A and 3A (Amperages). The result shown that 3A is the highest capacity that can provide with the most suitable recovery.

About how to run with this machine; firstly, turn on the button ON. Then, change the magnetic current to 3A (magnetic voltage 115v). Take all sample feed in the hopper regularly and slowly for getting the highest efficiency. And then, the sample will be separate into three fractions namely magnetic, middling and non-magnetic. In this case, it can separate magnetic mineral as ilmenite and almost magnetite. The end, take all samples to weight.

3.3.6.2. Processing by Electrostatic Separator (High Tension Separator)

This process can help remove valuable material from ores such as conductor and non-conductor mineral. It can separate quartz and muscovite from cassiterite for upgrading more. The first, we have to clean the equipment inside and outside of the high tension first. Start the machine ON, button of motor ON and button of feeder ON. Then, we have to calibrate of the button feeder control by setting on 2v/s (vibrate per second), DC high voltage 20 kV with AC high voltage 30 kV. And then, set the wire of static electrode at the angle maximum (105º). Each weighed sample was heated in the oven for five minutes to the temperature of about 100º C before feeding into the high tension separator. The samples were thus thoroughly dried and free from surface moisture. After we prepared and calibrated all properties of this machine already, we can start with the sample in the hopper (feeder). In this concept, our samples have been mix together with the same size as -14+30 mesh and -30 mesh. We mixed the sample together because some layer have only 6g or less after run with dry magnetic separator. When the sample flowed into the machine, the wire of electrode provided the electron to the surface of the mineral that can separate into three fractions. So we can separate the sample as conductor, middling and non-conductor mineral. We can separate quartz and muscovite from cassiterite as the conduct mineral.

3.4. Mineral Processing Operation Method of the Study

The processing of tin ores used the gravity concentration; it involves wet physical beneficiation and dry physical beneficiation. So the main machine can be applied to the processing plant such as trommel, jig separator, hydrocyclone, spiral concentrator, shaking table, ball mill, spiral classifier, vibrating screen, magnetic separator and high tension separator.

Firstly, the run-of-mine has fed to the primary mineral processing for separation size of larger than 2 inches gravel. In this point, it is discarded as waste by using Grizzly Bar, and the size less than 2 inches gravel feed to the next step mineral processing plant. The final process can be produced a commercial end products such as aggregate 15% wt, sand 80% wt and the main product is tin 0.12% wt (74% Sn) at a recovery of 90.0%. (See figure 3.21).

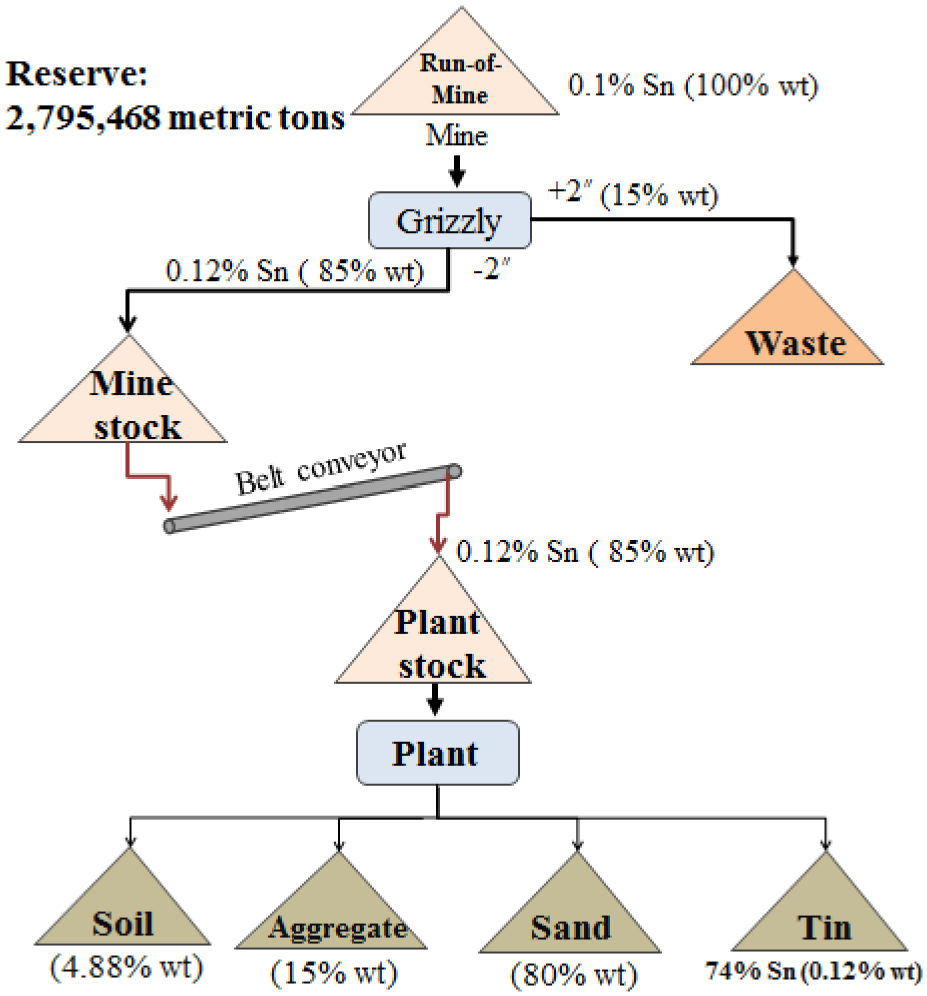


Figure 3.17 Typical flow sheet of mineral processing plant of the study

3.5. Economics Evaluation of the Study

The discounted cash flow methods are widely accepted and used in the industry for all types of investment, which it gives a confident to investor because of the investing need to spend a lot of money. It is necessary to calculate the Internal Rate of Return (IRR), the Net Present Value (NPV), Payback period, and discount rate (Hustrulid, and Kachta, 1995), which are the most important parameters for financial analysis. For the equation to calculation (Section 2.4 in the Chapter II)

CHAPTER IV
RESULTS AND DISCUSSION

This chapter showed the results the experiments undertaken in this research such as the results of wet sieve, jig separation, shaking table, XRF analysis, dry magnetic separation (DMS) and high tension separation. The results of mineral processing operation for the process of Tin ores. The designed by using the commercial software “AutoCAD civil 3D” and the result of economics evaluation.

4.1. Mass Distribution of Samples

Wet sieve is done in the separation size then weight the samples. In the next step is calculate percent distribution as shows in table 4.1 mass distribution and percent distribution of the sample pit number 2. According to the table, it can be observed that the percent of sample +3 mesh increases with the depth, but sample -3+4 mesh decreases with the depth such as in the sample pit number 2, sample +3 mesh increases from 10% to 32%. In contrast, the small in pit nmber 2 decreases; sample -4+14 mesh decreases from 26% to 9%; sample -14+30 mesh decreased from 16% to 3% and sample -30 mesh decrease from 40% to 5% (see figure 4.1). For the another samples not so much differently from this sample seen in figure 4.2. It should be remarked that knowing the distribution of sample size is crucially important because this information become one part of database in the plant design.

Table 4.1 Mass distribution of sample in the pit number 2

Depth (m)	Feed (g)	Size (Mesh)				
		+3	-3+4	-4+14	-14+30	-30
0-1	23,929	2,404	1,493	6,152	3,761	9,578
	100 %wt	10	6	26	16	40
1-2	34,172	4,763	1,771	1,887	4,508	10,753
	100 %wt	14	5	23	13	31
2-3	32,288	10,425	1,633	2,771	868	1,477
	100 %wt	32	5	9	3	5

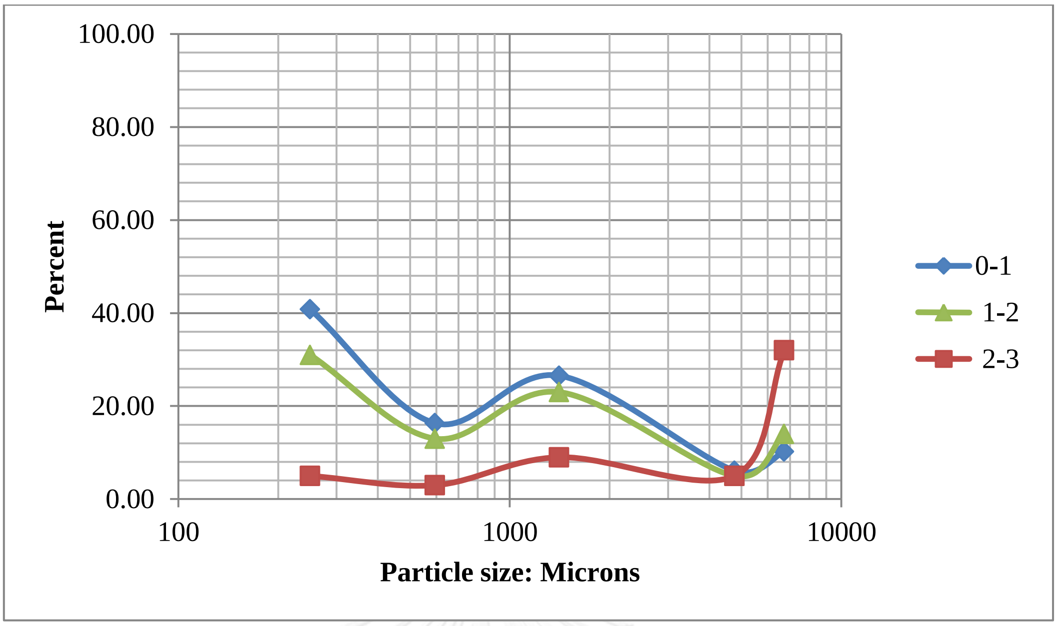


Figure 4.1 Showing the size distribution of pit number 2 at depth of 0-1m to 2-3m

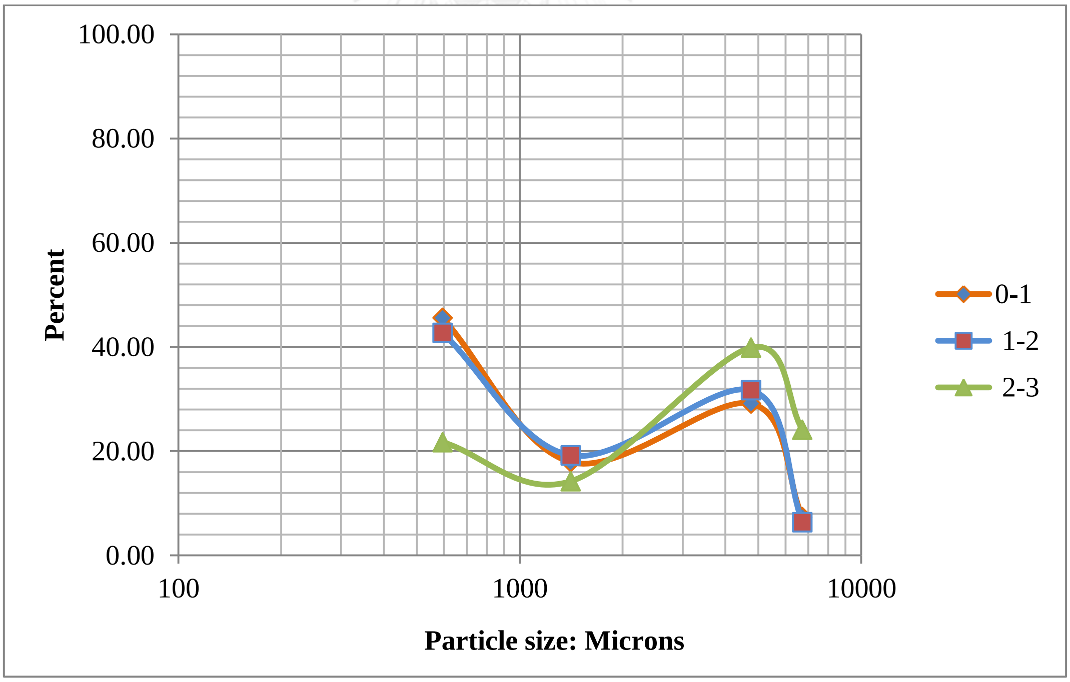


Figure 4. 2 Showing the percent distribution of Tin (Sn) for pit number 2 at depth of 0-1m to 2-3m

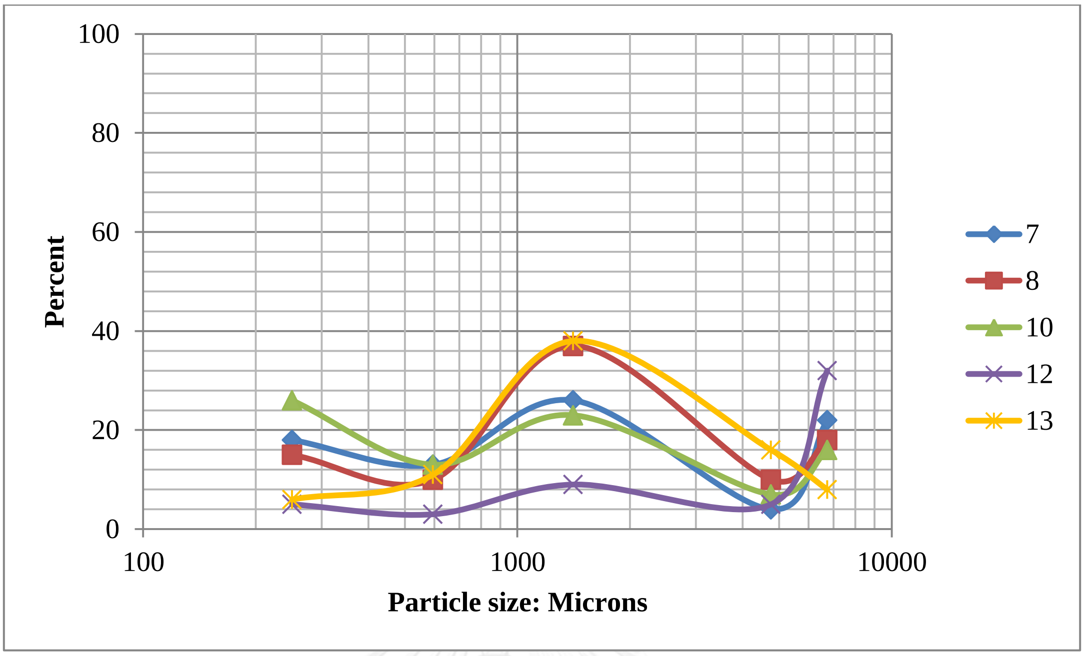


Figure 4. 3 Showing the size distribution of pit number 7 to 13

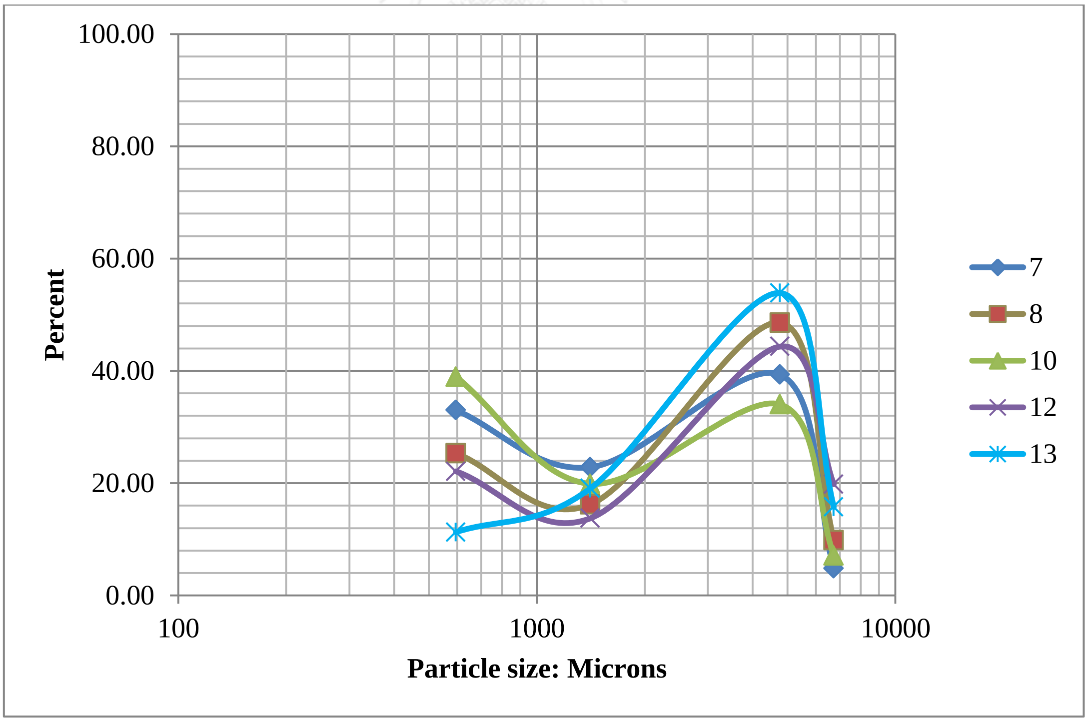


Figure 4. 4 Showing the percent distribution of Tin (Sn) for pit number 7 to 13

4.2. Mineral Concentration from Jig Separation

Sample -3+4 mesh and -4+14 mesh is concentrated by Jig to separate quartz and heavy minerals. The heavy mineral in our focus are cassiterite and columbite-tantalite. Sample -4+14 mesh is brought to Jig directly, but sample -3+14 mesh need to be reduced size to rank of -4+14 mesh before it is brought to be concentrated by Jig. Table 4.2 and 4.3 shows the result of mineral concentrating by Jig of pit number 2 and the average percent yield of all samples -3+4 is 41.21 % and the all samples -4+14 is 8.94%, this results show that this concentrating of sample -3+4 mesh produced high yield than the sample -4+14 mesh produced low yield. But it has no negative affect on our study since the result from XRF.

Table 4.2 The result of sample -3+4 mesh in the pit number 2 by Jig separator with magnetite ragging

Depth (m)	Feed (g)	Conc (g)	Tail (g)	% yield
0-1	1,406	602	804	46.45
1-2	1,572	667	905	48.19
2-3	1,219	618	601	58.41

Table 4.3 The result of sample -4+14 mesh in the pit number 2 by Jig separator with magnetite ragging

Depth (m)	Feed (g)	Conc (g)	Tail (g)	% yield
0-1	5,811	321	4,490	6.21
1-2	7,001	109	6,892	1.75
2-3	2,069	108	1,961	5.72

After doing this experiment, Jig separation can be separate mineral depend on the Specific Gravity of those minerals by using Jigs. The water flow rate is very important for Jig separation. High water flow rate, it not the good result of separation. For the good separation, it should use a suitable (low) water flow rate. Also, the particles would usually be of a similar size, often crushed and screened prior to being fed over the jig bed.

4.3. Mineral Concentration from Shaking Table

Sample -14+30 mesh and -30 mesh are concentrated by shaking table to separate quartz and heavy minerals. The shaking table slopes, feed water flow rate and the frequency set at 10 degree, 0.23 liter per second and 4.2 round per second respectively. Table 4.4 and 4.5 shows the result of mineral concentrating by shaking table of pit number 2. The all concentrates of samples -14+30 mesh and -30 mesh produced yield in average of 42.56% and 31.27% respectively. Since the result from XRF in tailings shown there is no tin, it can be surely claim that the recovery of shaking table is high. This good result can be achieved because the concentrating process of middling and tailings was done repeatedly.

According to the experiment by using jig separation and shaking table, the result and analysis by XRF presented in table 4.6. The calculation of tin (Sn) percent sample in each depth position showed in the table 4.7. The result in table 4.7 showed that average grade of tin (Sn) all pits vary from 0.13% Sn the lowest to 0.55% Sn the highest. Percent by mass of tin in total amount of sample in a depth of each pit is more than 0.1%.

Table 4.4 The result of sample -14+30 mesh in the pit number 2.

Depth (m)	Feed (g)	Conc (g)	Tail (g)	% Yield
0-1	3,761	885	2,876	31.86
1-2	4,508	1,535	2,973	38.27
2-3	868	218	650	43.60

Table 4.5 The result of sample -30 mesh in the pit number 2.

Depth (m)	Feed (g)	Conc (g)	Tail (g)	%Yield
0-1	9,578	1,330	8,248	20.27
1-2	10,753	1,465	9,288	21.12
2-3	1,477	119	1,358	14.82

Table 4.6 Percent by mass of tin from jig separation and shaking table

Sample (Pit number)	Depth (m)	Result of analysis by X-ray fluorescence (% by mass), %Sn			
		Size (Mesh)			
		-3+4	-4+14	-14+30	-30
2	0-1	1.95	1.78	1.78	1.81
	1-2	1.80	1.94	2.08	1.94
	2-3	2.32	2.13	2.28	2.09
7	0-1	1.59	2.22	2.09	2.34
	1-2	1.61	2.16	2.42	2.42
	2-3	1.59	1.77	2.20	2.37
	3-4	1.53	1.79	2.50	2.47
8	0-1	1.41	2.07	1.88	2.15
	1-2	1.82	1.95	2.42	2.40
	2-3	1.18	1.86	2.97	3.01
10	0-1	1.26	2.72	2.15	2.20
	1-2	1.72	2.67	2.71	2.32
	2-2.8	1.86	1.62	2.40	2.58
12	2.6-3.6	1.77	1.85	2.15	2.01
	3.6-4.6	1.70	2.46	1.85	1.84
13	0-1	1.12	2.20	2.46	3.05
	1-2	1.11	2.07	3.16	3.10
	2-3	1.76	2.41	2.63	2.70
	3-4	1.80	2.37	2.62	3.01
	4-4.75	1.84	1.94	2.57	2.76

Table 4.7 The grade and distribution of tin (Sn) in each samples and each pit

Sample (Pit number)	Depth (m)	%Sn	**Average**
			%Sn
2	0-1	0.32	**0.24**
	1-2	0.29	
	2-3	0.12	
7	0-1	0.06	**0.19**
	1-2	0.21	
	2-3	0.22	
	3-4	0.29	
8	0-1	0.32	**0.43**
	1-2	0.42	
	2-3	0.54	
10	0-1	0.69	**0.55**
	1-2	0.51	
	2-2.8	0.46	
12	2.6-3.6	0.18	**0.13**
	3.6-4.6	0.08	
13	0-1	0.43	**0.23**
	1-2	0.18	
	2-3	0.07	
	3-4	0.16	
	4-4.75	0.28	

4.4. The Result of the Dry Magnetic Separator (DMS)

After processed all samples with DMS, the samples were weighted and calculated to find the percentage Yield. In this processing, the middling wasn't gotten because it was taken to process five times. The result of both size shows in the table below:

Table 4.8 The result for calculation percent yield of sample -14+30 mesh

Sample (Pit number)	Depth (m)	Weight (g)			%Yield
		Feed	Non-Mag	Mag	Non-mag
2	0-1	212	210	1	99.06
	1-2	329	323	3	98.18
7	0-1	58	51	5	87.93
	1-2	146	142	4	97.26
	2-3	63	62	1	98.41
	3-4	223	195	25	87.44
8	0-1	278	273	2	98.20
	1-2	255	250	1	98.04
	2-3	37	36	1	97.30
10	0-1	661	655	5	99.09
	1-2	856	850	2	99.30
	2-2.8	375	368	2	98.13
12	2.6-3.6	45	40	1	88.89
13	0-1	71	42	28	59.15
	1-2	301	285	14	94.68
	2-3	128	112	13	87.50
	3-4	360	359	1	99.72
	4-4.7	195	171	19	87.69

Table 4.9 The result for calculation percent yield of sample -30 mesh

Sample (pit number)	Depth (m)	Weight (g)			%Yield
		Feed	Non-Mag	Mag	Non-mag
2	0-1	36	12	24	33.33
	1-2	26	12	12	46.15
7	0-1	47	18	28	38.30
	1-2	12	6	4	50.00
	2-3	46	19	26	41.30
	3-4	43	13	28	30.23
8	0-1	27	19	8	70.37
	1-2	12	9	2	75.00
	2-3	18	16	2	88.89
10	0-1	53	41	12	77.36
	1-2	65	29	36	44.62
	2-2.8	20	11	9	55.00
12	2.6-3.6	10	9	1	90.00
	3.6-4.7	8	6	1	75.00
13	0-1	16	6	9	37.50

The results showed that, the highest percentage yield of sample -14+30 mesh, in pit number 13, layers (3-4m) is 99.72%. In the non-magnetic fraction and sample -30 mesh, in the pit number 12, layer (2.6-3.6m) is 90%. This percentage yield is the percentage that the machine can separate minerals. So, the big size has the high percentage yield that can continue for the separation. But this separation also depend on the qualities minerals containing in the sample as magnetic minerals.

4.5. The Result of the Electrostatic Separator or High Tension Separator

After running with high tension separator, all outputs were weighted and the percentage yield was found from separation.

Table 4.10 The result for calculation percentage yield of high tension separator

Size (Mesh)	Weight (g)			% Yield
	Feed	Cond	Non-Cond	Cond
-14+30	4,424	1,421	2,996	32.12
-30	226	98	122	43.36

****Remark*:** Cond = Conductor fraction; Non-Cond = Non-conductor fraction

In this table show that, the percentage yield of size less than 30 mesh fractions is higher than the percentage yield of the sample -14+30 mesh fractions in concentrate (Conductor). It means that the small size can separate better then big size because the mineral contained the cassiterite; muscovite and quartz in the liberation.

4.5.1. The Result of Recovery from High Tension Separator

The recovery is the percentage of valuable mineral that obtained from the separation of ores. The recovery is the proportion or percentage of ore mined from the original seam or deposit.

Table 4. 11 The result of calculation recovery from high tension separator

Size (Mesh)	Weight (g)		% SnO_2		Recovery (%)
	(F)	C	(f)	c	
-14+30	4,424	1,421	0.55	1.7	29.82
-30	226	98	0.62	1.72	38.40

4.6. Mineral Processing Plant Design (Processing of tin ores)

According to the mine design or mine operation, the reserve is 2,795,468 metric tons, and this project area was located at rolling terrain, so the plant was designed as figure 4.5 to figure 4.14. For the geological in this area, tin ores deposit is a secondary deposit and placer deposit, so the processing of tin ores are suitable for the gravity concentration such as below:

4.6. 1. Wet Physical Beneficiation for Tin Ore

Figure 4.5 demonstrated the flowsheet of wet physical beneficiation for tin ore. The raw material feeds into the hopper (1) and by using belt conveyor (2, 3) to the 1st trommel (4) for size separation, the diameter of 1st trommel is 1.8m and a length of 6m. The 1st trommel has two screens; there are 10mm and 14 mesh. The +10mm fraction goes to the tailings dump by belt conveyor (5, 46). The -10 mm +14 mesh fraction feeds to the jig separator (27), the size of jig Chamber is 4.86m^2. The -14 mesh fraction feeds to the tank classifier (43), the tailings feed to the spiral classifier (30) to dewatering. The concentrates feed to the spiral classifier (44) to dewatering, then feeds to ball mill (28) to liberate, the diameter of ball mill is 2.7m and a length of 4.5m, after grinded feed to the spiral classifier (29), the fine particle feed to 2nd trommel (6) and the coarse particle feed to the ball mill to grind again. This 2nd trommel has only one screen, there is 30 mesh. After grinded the +30 mesh fractions feed to the sump (9) 8.6 cubic meters and by using pump (10) size 6"x 4" will be pumped to the hydrocyclone (12) to dewatering, the diameter of hydrocyclone is 375mm. The -30 mesh fractions also feeds to the sump (7) and by using pump (8) to the hydrocyclone (11) to dewatering. After that particles feed to the double spiral concentrators (13, 14) to separate the heavy minerals and light minerals. The concentrate materials flow to the tank distributor (15, 16) sizes 8.6 cubic meters to distribution, the middling flows to the sump (37) and by using pump (38) will be pumped to the hydrocyclone (39), and the tailings feed to the spiral classifier (25) to dewatering and by using belt conveyor (26, 47) feed to the tailings dump (Sand dump). After that the distributors distribute the particles, and feed to the shaking table (17, 18) by same flow rate. After shaking table, the middling flows to the sump (40), and by using pump (41) will be pumped to the hydrocyclone (42), after that feed to ball mill (28) to regrind, the tailings feed to the spiral classifier (23) to dewatering, and by using belt conveyor (24) feed to the tailings dump (Sand dump). The concentrates feed to the spiral classifiers (19, 21) and continue to the dry process (figure 4.4). The waste water from the process will be flow into the pond sludge and can be reuse in the process again after the sedimentation (figure 4.3).

4.6. 2. Dry Physical Beneficiation for Tin Ore

The particles from wet process feed to the rotary dryer (32). After that feed to the vibrating screens (33) two screens, 3-layer there are 60 mesh, 100 mesh and 150 mesh. It can get 4 products (+60 mesh, -60 +100 mesh, -100 +150 mesh and -50 mesh). The +60 mesh, -60 +100 mesh fractions feed to the roll-type high tension separator low-voltage (34), and the -100 +150 mesh, -150 mesh fractions feed to the roll-type high tension separator high-voltage (35). After that the concentrate of high tension separator feed to the magnetic separator (36). Finally, we got the 4 products of concentrate (figure 4.4).

4.6.3. The Area of the Tailings Dump (Sand Dump)

The sand dumps were designed to dump around the wet process (wet physical beneficiation for tin ore) in the west, east and south part of the processing plant. The area of sand dumps approximately 6,000 square meters, a height of 20 meters and can accommodate of approximately 300,000 tons.

4.6.4. The Water Used in the Process

This project is located nearly in the river, so it’s suitable to use the nature water and the water was stored from the mining area. For the waste water from the process can be reuse. After the sedimentation in the pond sludge and the water will be pumped to the recycling pond, the pond sludge, recycling pond with pond to store up was design as a below:

- Pond sludge (1) size of 1,600m^2 (40 × 40 m), a depth of 6m
- Pond sludge (2) size of 1,600m^2 (40 × 40 m), a depth of 6m
- Recycling pond (3) size of 1,600m^2 (40 × 40 m), a depth of 6m
- Recycling pond (4) size of 1,600m^2 (40 × 40 m), a depth of 6m

- Recycling pond (5) size of 1,600m^2 (40 × 40 m), a depth of 6m
- Recycling pond (6) size of 1,600m^2 (40 × 40 m), a depth of 6m
- Pond to store up (7) size of 4,000m^2 (80 × 50 m), a depth of 10m

The total amount of water for store up of 97,600m^3. The water used in the process not drains out of the process.

4.6.5. Dust Control of the Process

Even the process will be used the water by all the process and no more dust clouds. But may be the dust will cloud in the steps of transporting ores by belt conveyor to the process. So the moisture is added to the ores to prevent dust as it is transferred from the hopper, sprays are also used to capture airborne dust as the ores moves down the conveyor line.

These systems use spray nozzles to apply water such as the position nozzles at the beginning of the transfer point for dust prevention and the position nozzles to spray the air above the ores at the end of the transfer points or between changes point of belt conveyor to suppress airborne dust.

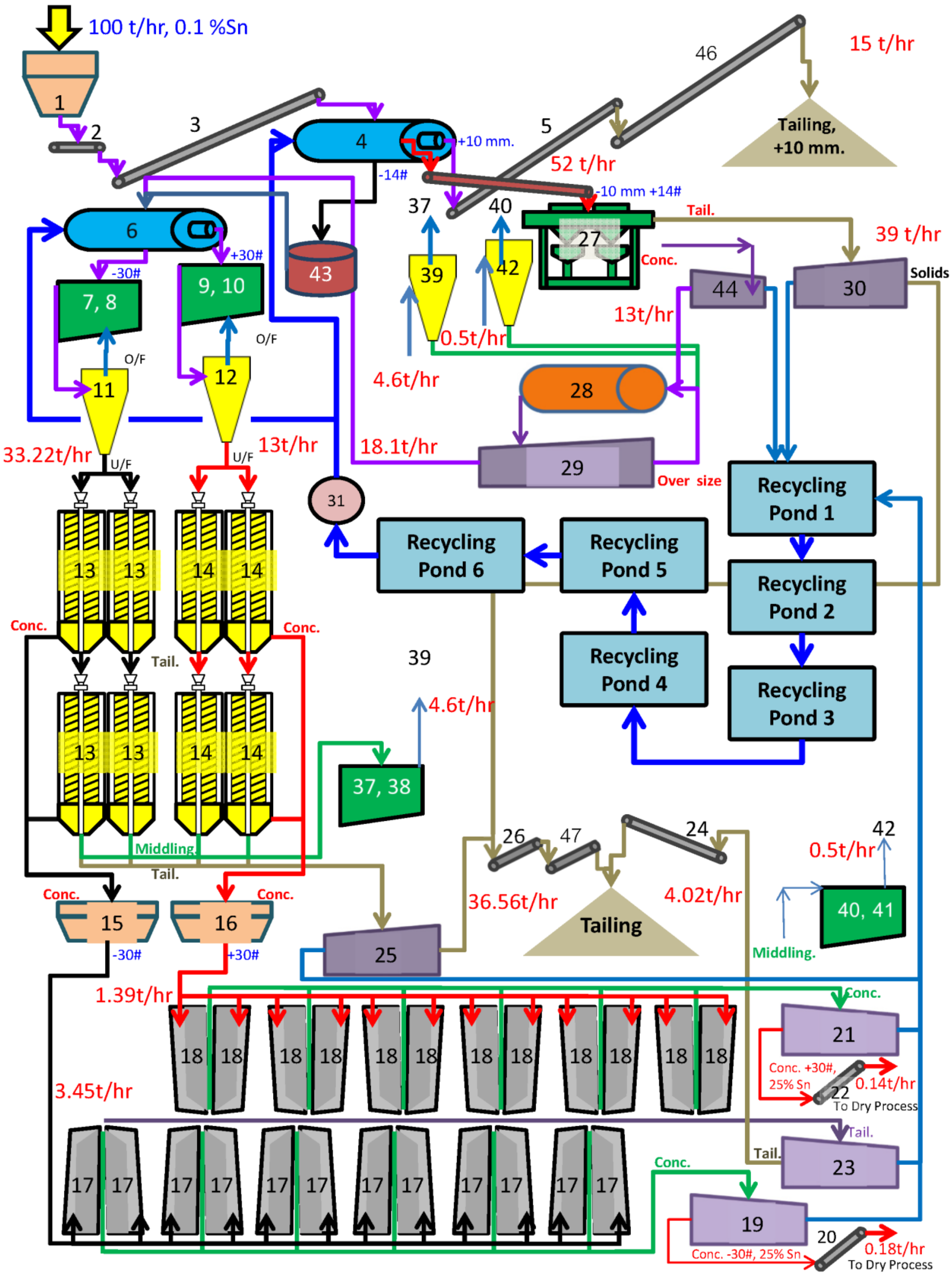


Figure 4.5 Wet physical beneficiation flowsheet for tin ore

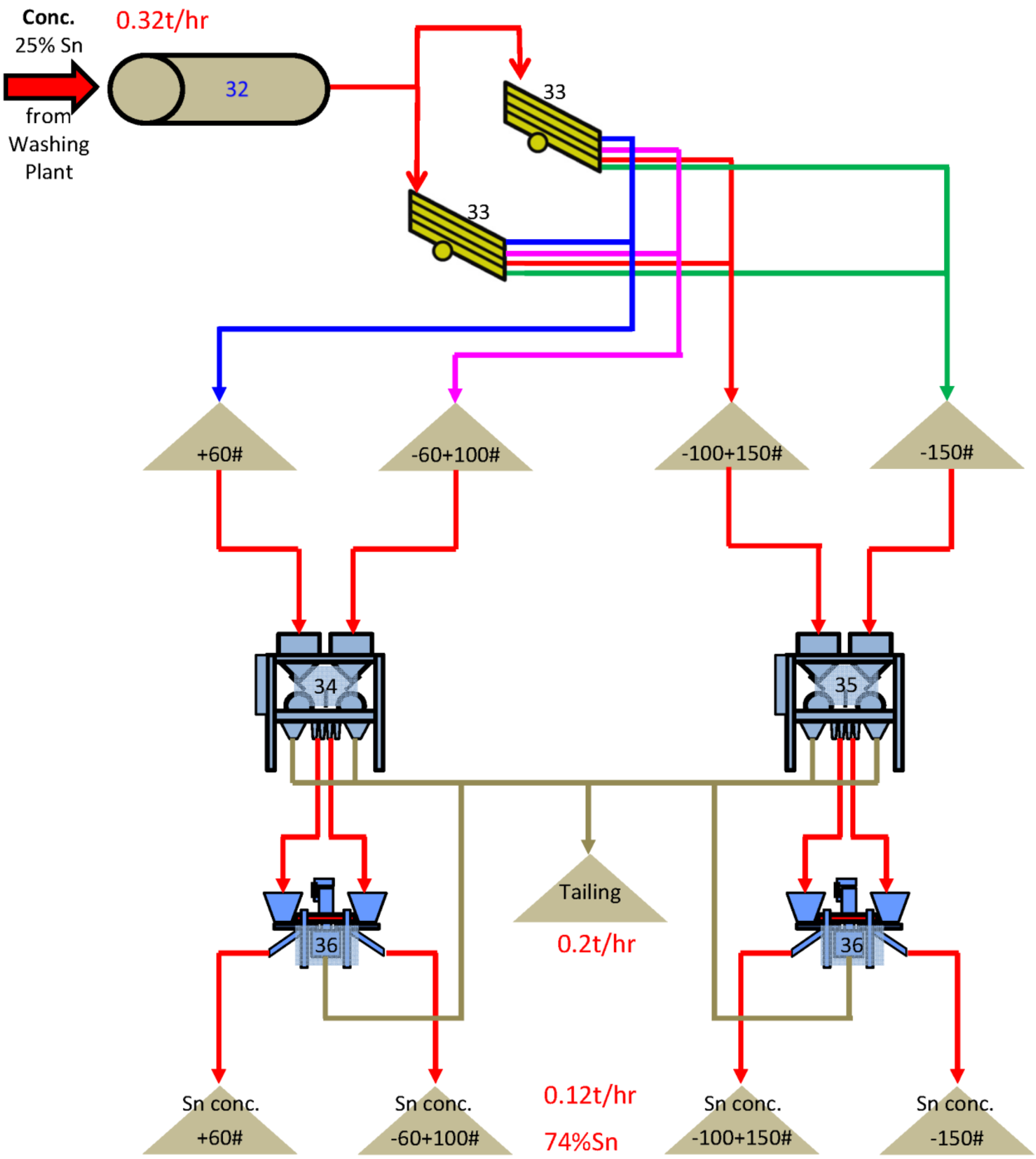


Figure 4.6 Dry physical beneficiation flowsheet for tin ore

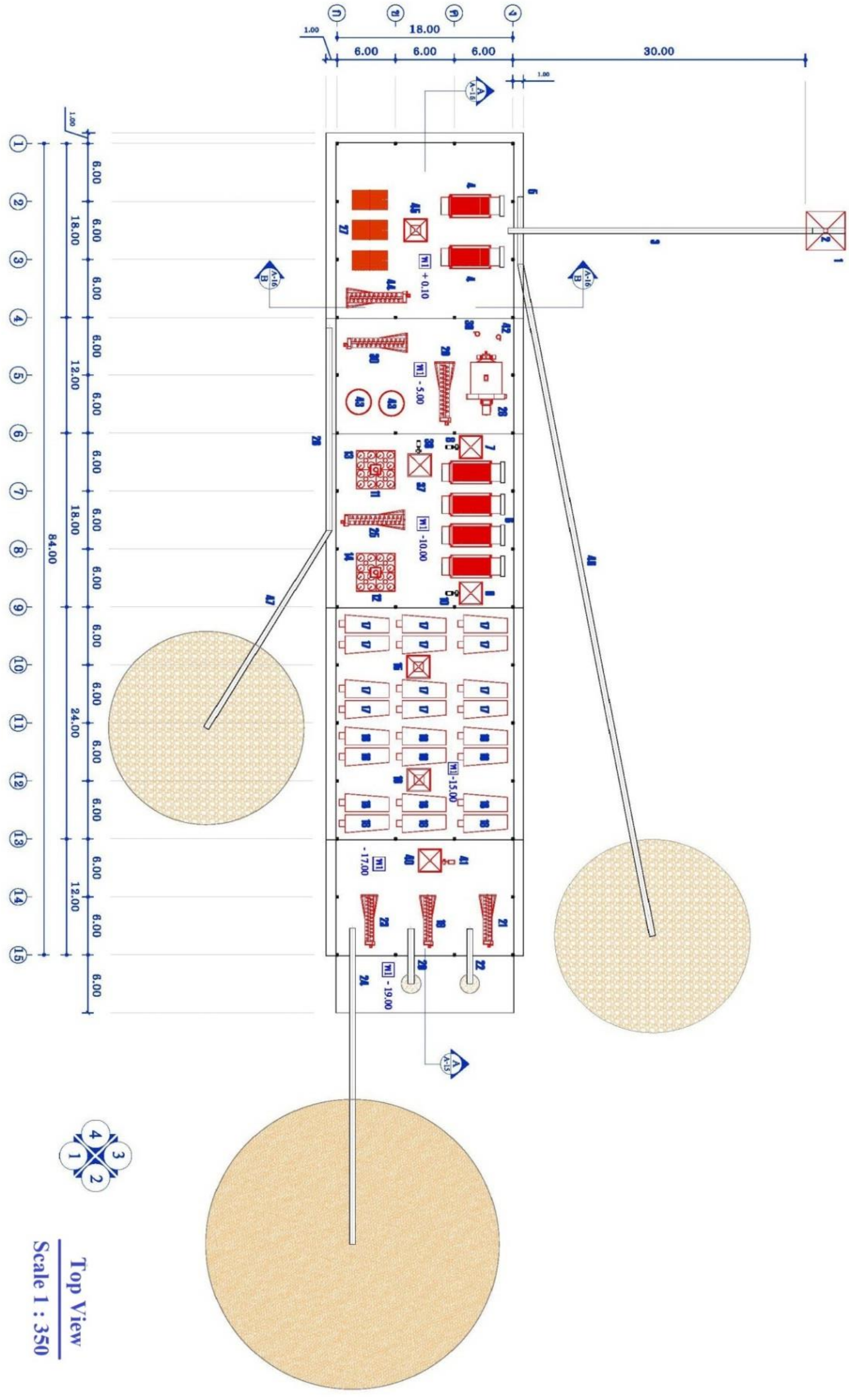


Figure 4.7 Top view designs of wet physical beneficiation for tin ore by AutoCAD civil 3D

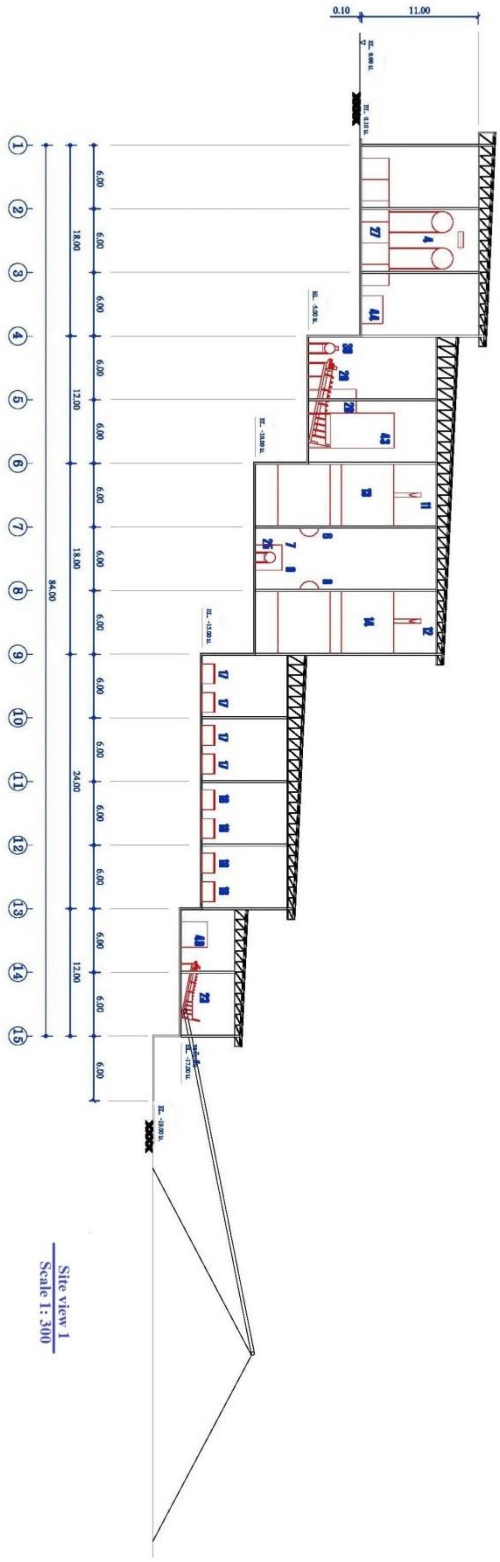


Figure 4.8 Site view 1 designs of wet physical beneficiation for tin ore by AutoCAD civil 3D

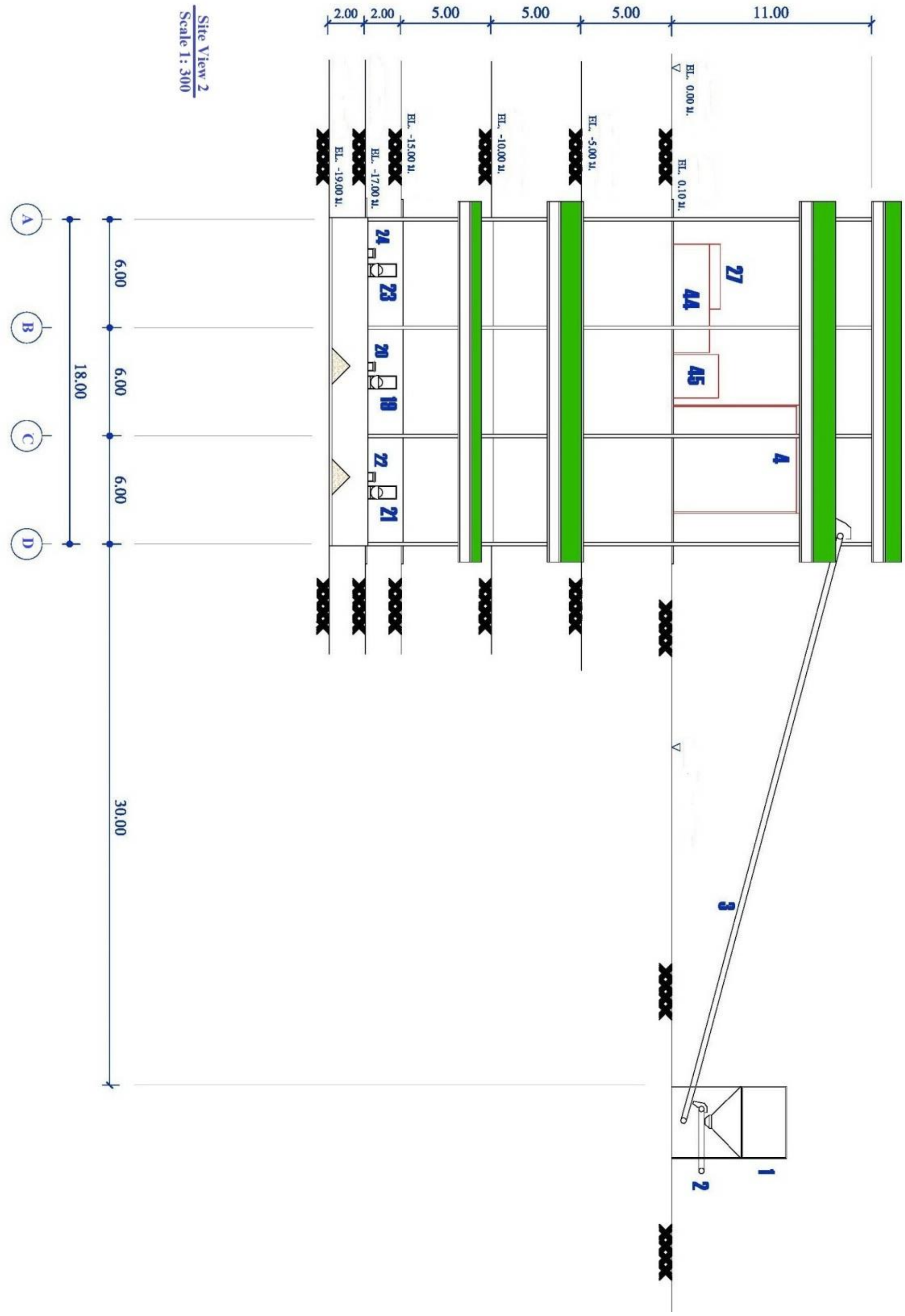


Figure 4.9 Site view 2 designs of wet physical beneficiation for tin ore by AutoCAD civil 3D

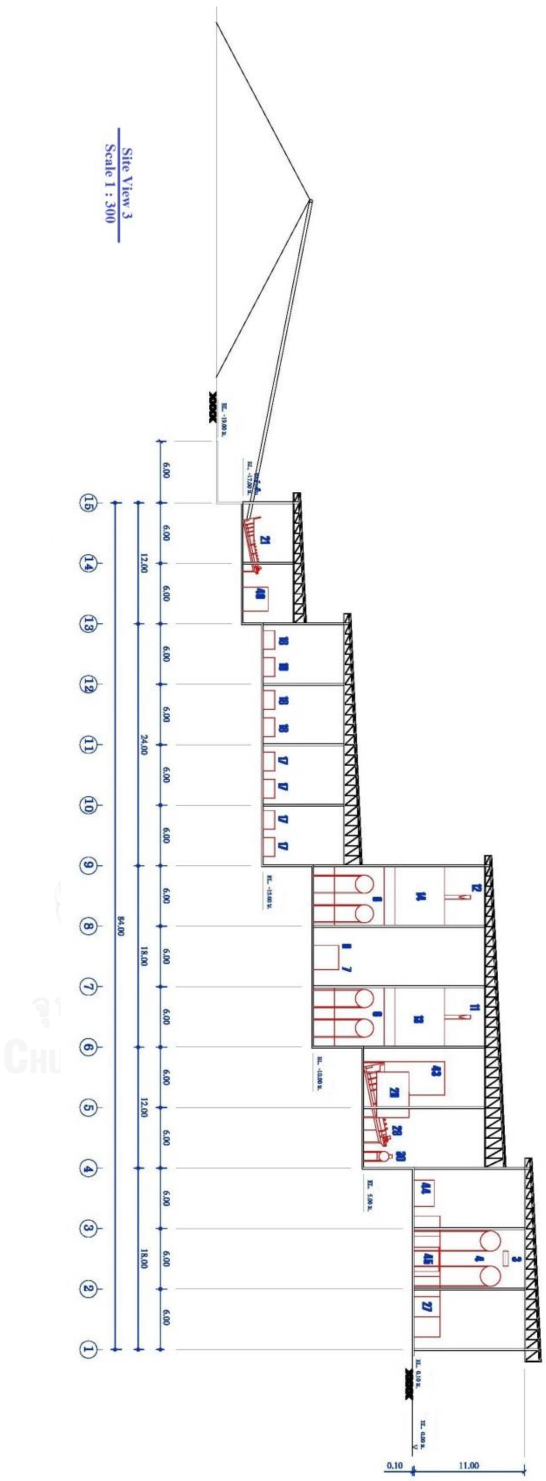


Figure 4.10 Site view 3 designs of wet physical beneficiation for tin ore by AutoCAD civil 3D

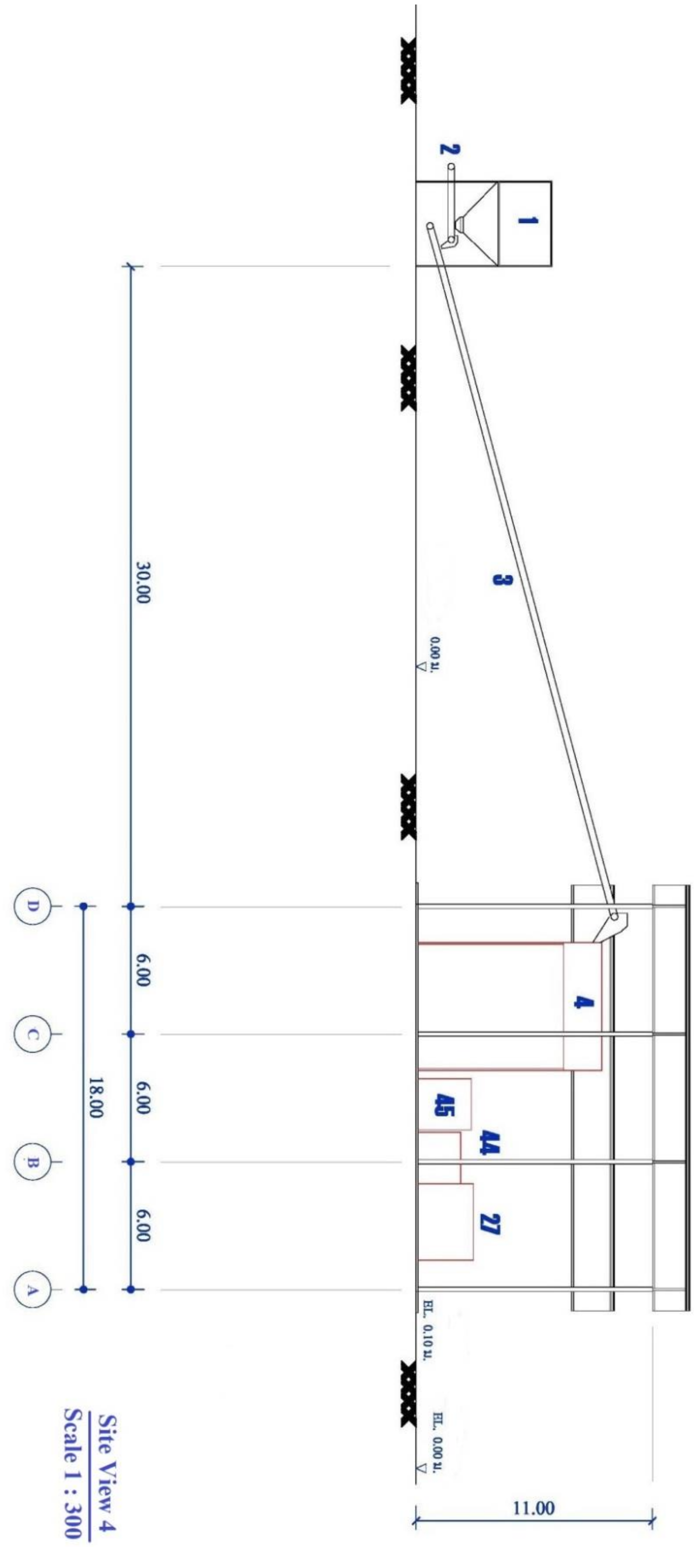


Figure 4.11 Site view 4 designs of wet physical beneficiation for tin ore by AutoCAD civil 3D

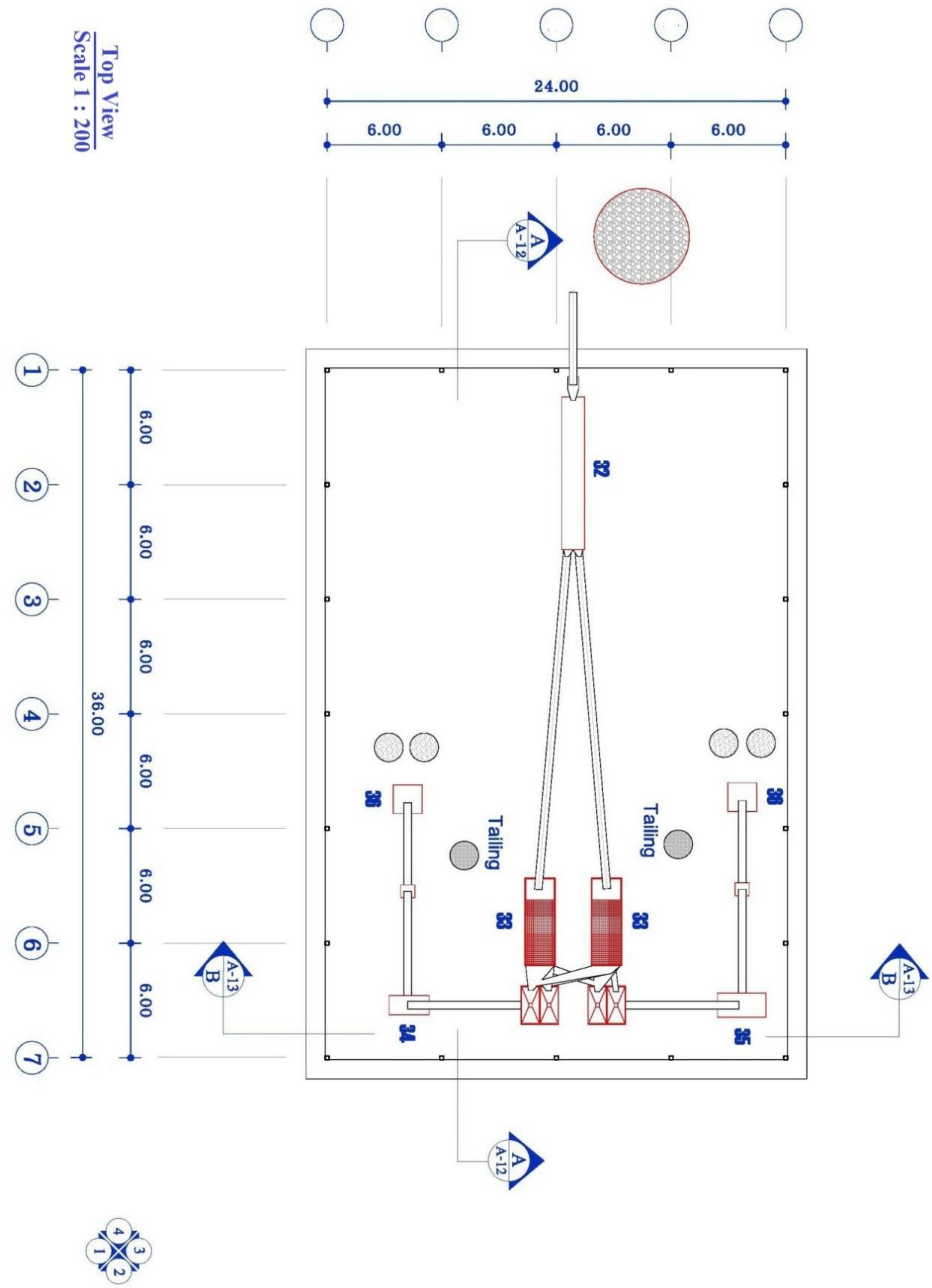


Figure 4.12 Top view designs of dry physical beneficiation for tin ore by AutoCAD civil 3D

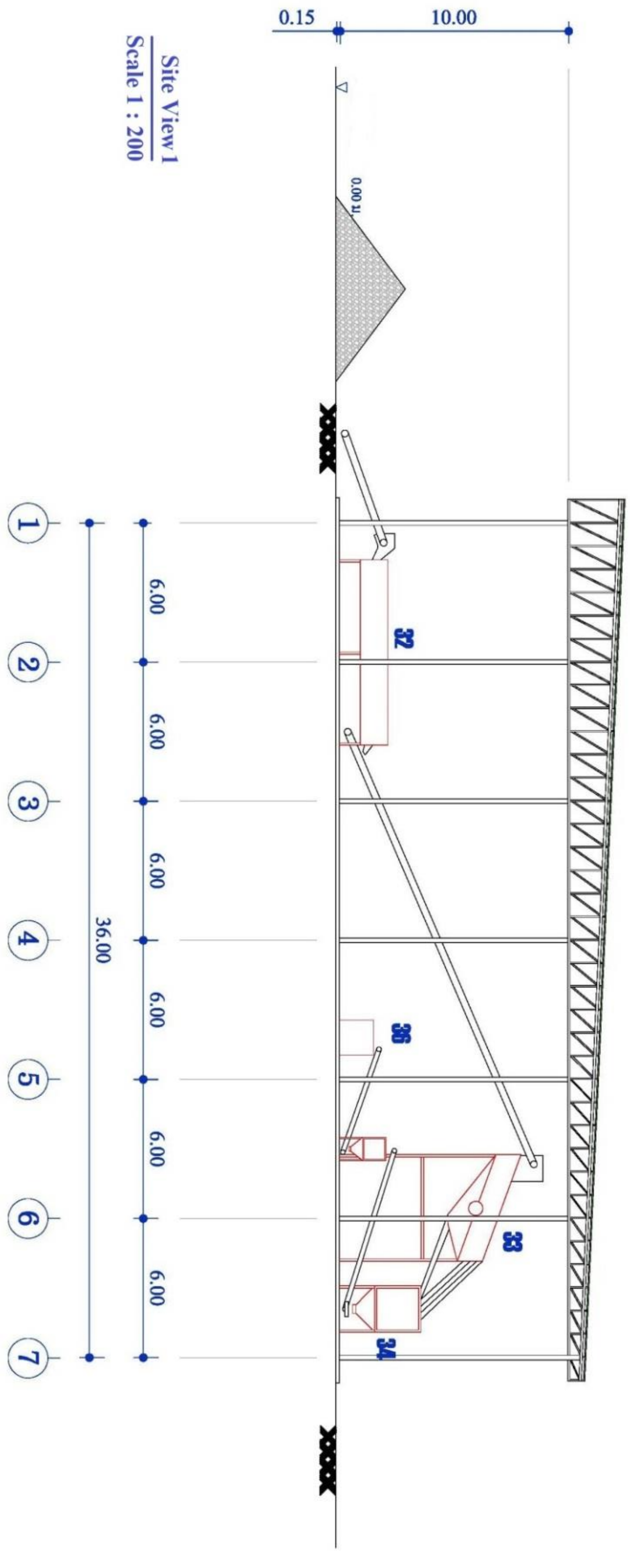


Figure 4. 13 Site view 1 designs of dry physical beneficiation for tin ore by AutoCAD civil 3D

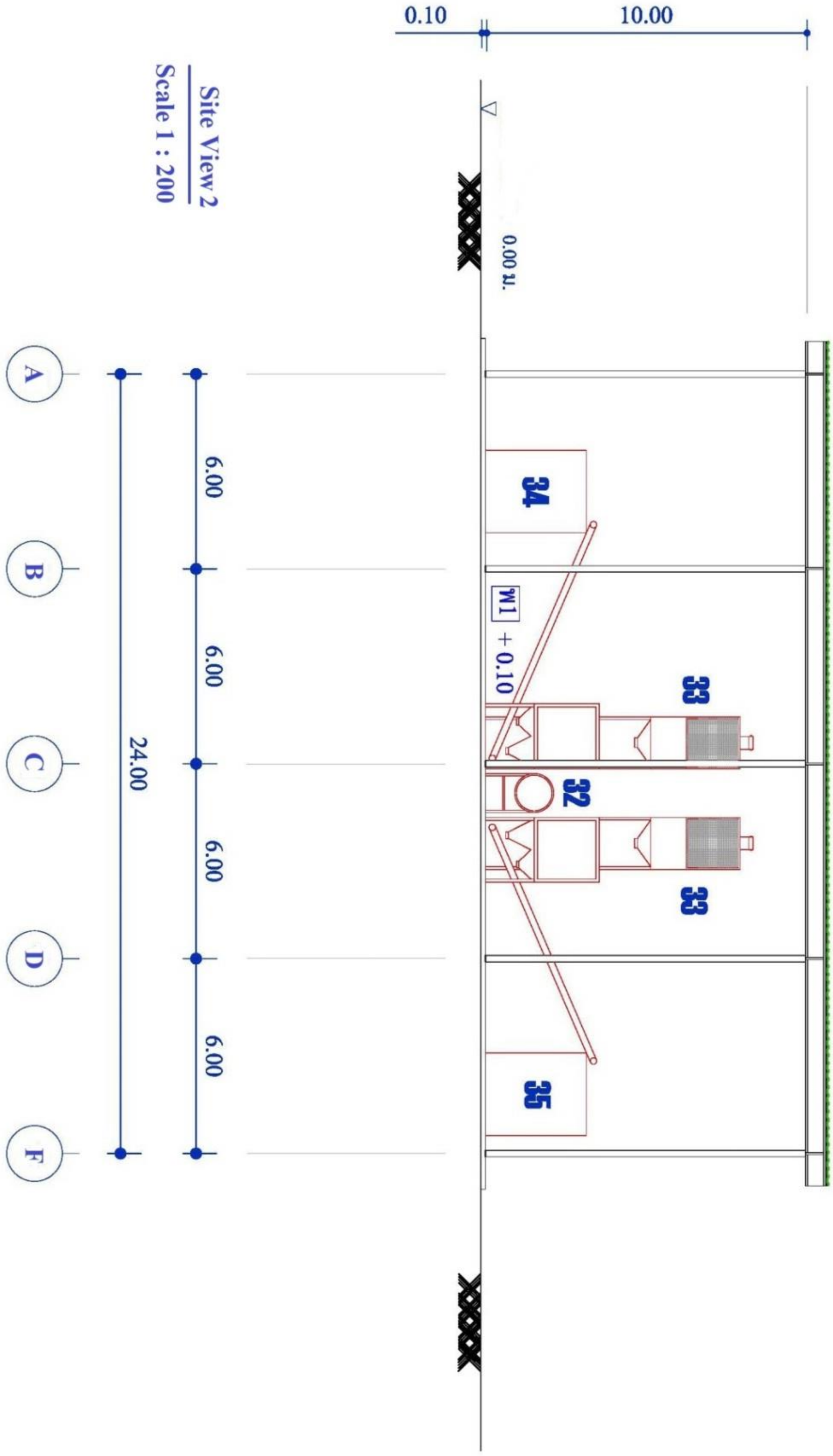


Figure 4.14 Site view 2 designs of dry physical beneficiation for tin ore by AutoCAD civil 3D

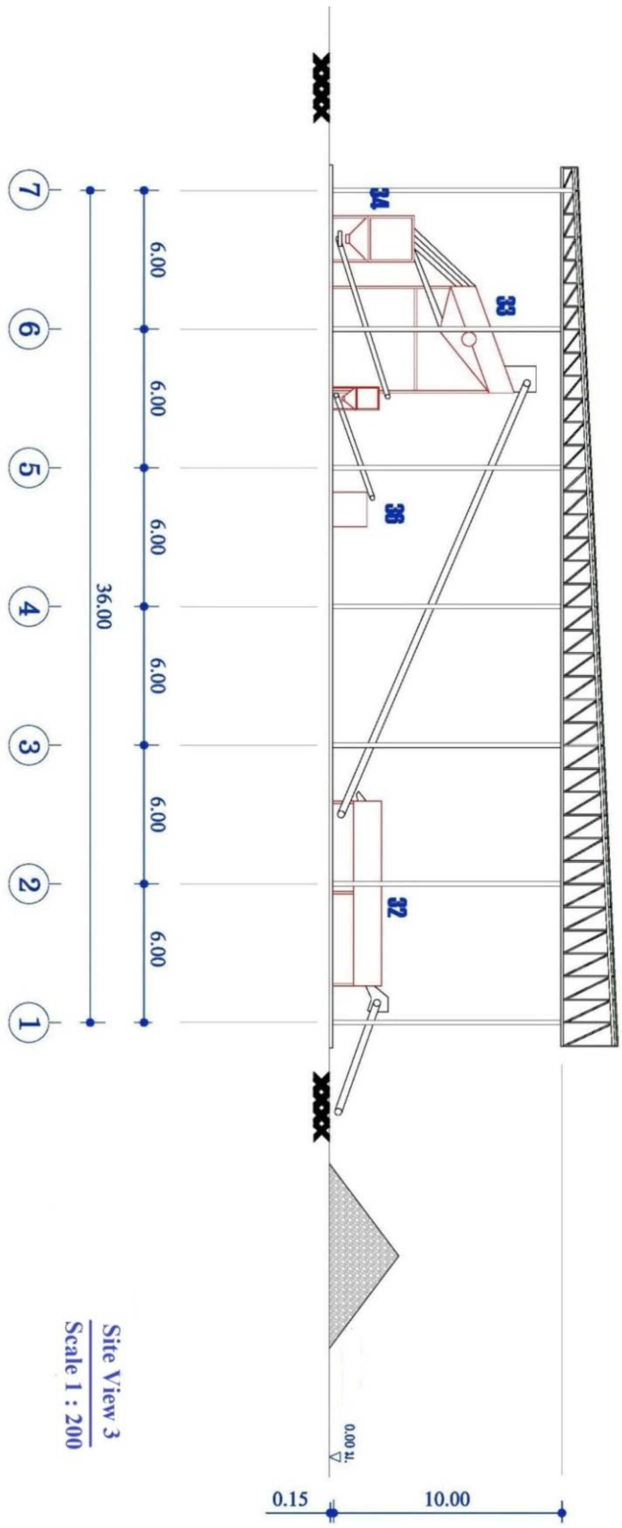


Figure 4.15 Site view 3 designs of dry physical beneficiation for tin ore by AutoCAD civil 3D

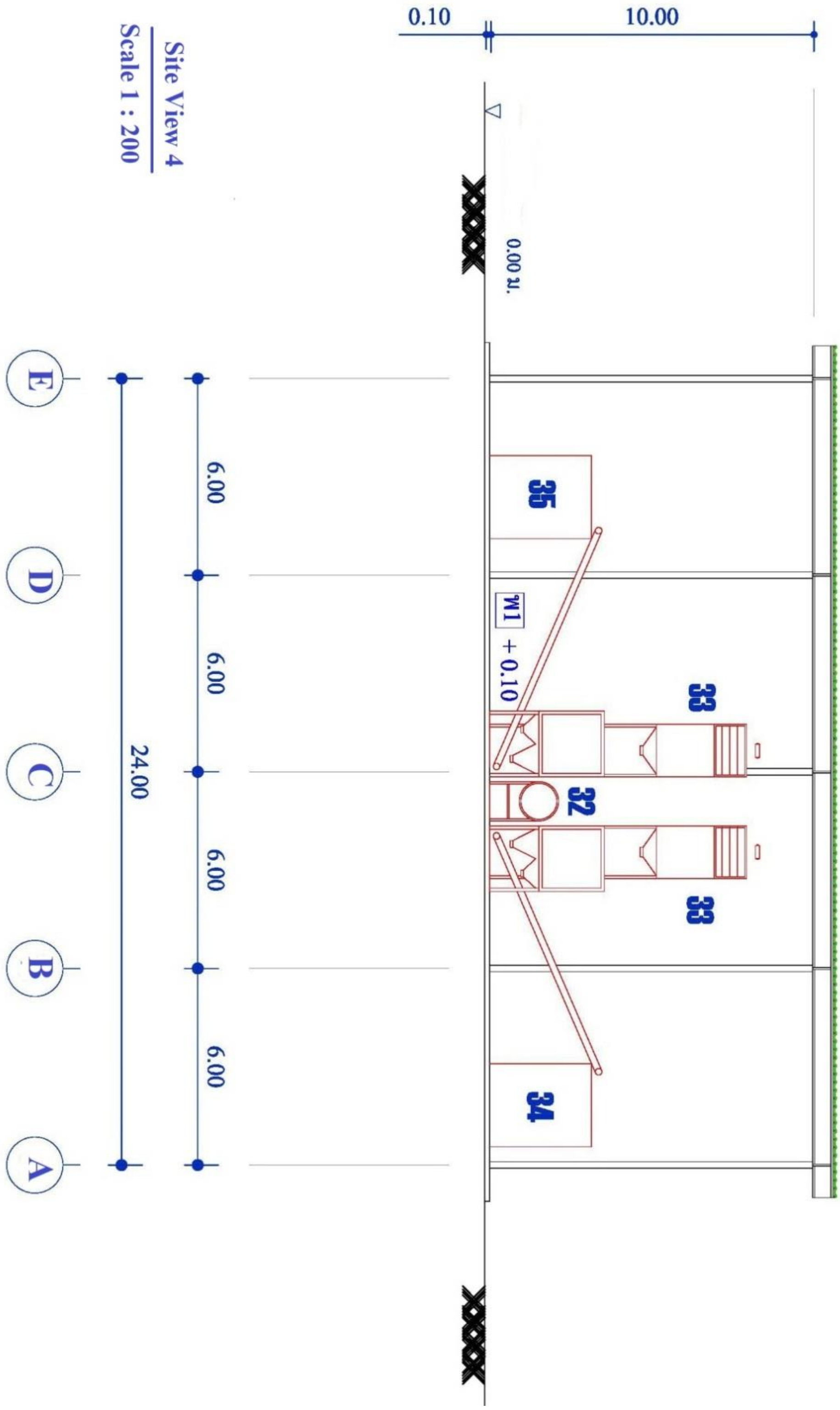


Figure 4.16 Site view 4 designs of dry physical beneficiation for tin ore by AutoCAD civil 3D

4.7. Economics Evaluation

The economic evaluation of the study, it involves the Discount Cash Flow (DCF) analysis, Net Present Value (NPV), and Internal Rate of Return (IRR).

For all the economic appraisal of investment project, some important parameters for considering the project to be feasible are the discount cash flow, net present value and internal rate of return. Discount cash flow is used to calculate the cash inflow and cash out flow. Net present value is used to validate the feasibility of the project. Internal rate of return is used to compare with the interest rate of the project.

For this economic evaluation, some data (mine operation) were gotten from the Pre-feasibility study of tin mine: a case study of tin mine in Thailand.

4.7.1. Discount Cash Flow Calculation (DCF)

The steps to calculate the discount cash flow, there are many steps to the calculation. So the parameters use to determine the cash flow models are capital cost, operation cost, sale cost (sale cost of Tin, sale cost of Sand and sale cost of Aggregate), depreciation, the tax rate and royalty (royalty of Tin, royalty of Sand and royalty of Aggregate) such as shown in table 4.12 and table 4.13 the input parameters and table 4.14 the discount cash flow calculation sheet.

Table 4. 12 The input parameters for discount cash flow

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. 13 Production price, Royalty, and Tax

Input parameters	Values
Tin concentrate price	538,000 baht per ton
Sand price	300 baht per ton
Aggregate price	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	30 percent
Discount rate	13 percent
Inflation rate	5 percent
The housing development fund	500,000 baht/year
Health Insurance Fund	200,000 baht/year
Rehabilitation cost, 154 rai (34,000 baht/rai)/year	1,309,000 baht/year

Table 4. 14 The 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	50,710,260
Total Expense of Royalty (b/y)		81,402,414	81,402,414	81,402,414	82,644,020
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)		60,657,149	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**	**263,179,347**	**230,445,431**	**227,128,659**	**263,164,247**
	284,410,000	**263,179,347**	**493,624,338**	**718,004,437**	**983,917,583**

b/y = baht/year

4.7.2. Net Present Value (NPV)

Net Present Value (NPV) is the sum of all project cash flows, discounted back to a common point in time. If the value of NPV is positive, it considers a feasible project and if the value of NPV is negative, it considers a non-feasible project. In the project, NPV is positive which is equal to **447,779,678 baht** (discount rate is 13 percent). Therefore, this tin ores project considers financially feasible. The calculation sheet of NPV is shown in table 4.16.

4.7.3. Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is the discount rate, which reduces the project net present value to zero. Internal rate of return is very important for the project investment and it uses to identify the payback period or when the project will get profit. In case when the internal rate of return equal to the interest rate, the net present value will be zero and the project will not get any profit. The project is feasible when the internal rate of return is higher than the interest rate. The internal rate of return has to be approximated by trial or error method. However, the internal rate of return can be conveniently tabulated in the Microsoft excel spread sheet. In this study, the internal rate of return is calculated at 79 percent which is much more than the interest rate (13 percent). In this project the 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 interest rate and project stage.

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. IRR is estimated at 79 percent which is considerably much more than interest rate, NPV is 447,779,678 baht, and the payback period also referred to as the breakeven point is defined as the expected number of years required for recovering the investment. In this project, the payback period equal to 1.09 years. Taking these economics factors into account, the tin ores project is proven feasible.

Table 4. 15 The calculation sheet of net present value (NPV)

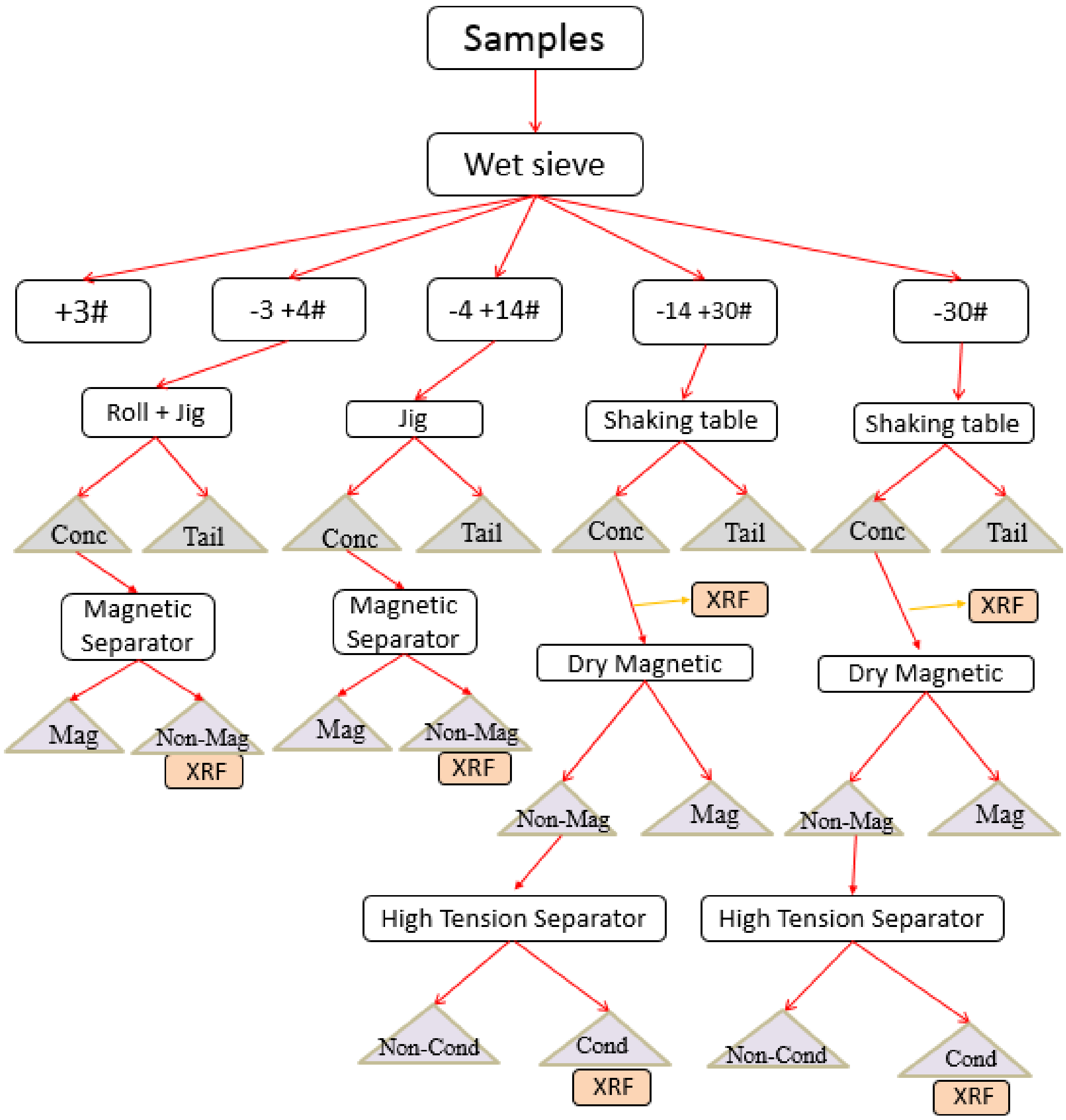
Year	0	1	2	3	4
Capital expense (baht)	274,410,000	-	-	-	-
Working Capital (baht)	10,000,000	-	-	-	-
Total investment (baht)	284,410,000	-	-	-	-
Price of Tin (baht/ton)	538,000	-	-	-	-
Tin Production (ton/year)		630	630	630	620
Revenue from selling Tin (baht/y)		338,940,000	338,940,000	338,940,000	333,560,000
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	50,710,260
Total 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)		61,358,249	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	**263,179,247**	**393,624,678**	**720,753,337**	**983,917,583**
NPV = ∑ (present value) = 447,779,678 baht					
IRR = 79%, Payback Period = 1.09 years					

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

1. The pre-feasibility was applied of physical separation methods for the experiment in this project such as removing dirt by washing, separating size by sieving, dewatering by oven, and reducing size by crushing and milling, concentrating by gravity separation, elemental analysis by x-ray fluorescence (XRF) and including grade calculation, average tin grade of each pit can be determined. The grade of samples are as follows: the sample of pit No. 02 at 0.2425% Sn, pit No. 07 at 0.2256%, pit No. 08 at 0.4299% Sn, pit No. 10 at 0.5534% Sn, pit No. 12 at 0.1731% Sn and pit No. 13 at 0.2531% Sn, respectively.
2. The gravity separation is more suitable for the separation of Tin ores in this project. As about 0.12% wt of Tin ores with 74% Sn at a recovery of 90%, and it is suitable for the removal of Aggregate and Sand. As about 15% wt of the aggregate, 80% wt of the Sand. The reserve is 2,795,468 metric tons, the total production is 700,000 metric tons per year, and the tin production is 630 metric tons per year.
3. 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. IRR is estimated at 79 percent which is considerably much more than interest rate, NPV is 447,779,678 baht, and the payback period also referred to as the breakeven point is defined as the expected number of years required for recovering the investment. In this project, the payback period equal to 1.09 years, and the mine life is 6 years. Taking these economics factors into account, the tin ores project is proven feasible.

All the process of experiment to identification the possible concentration of tin in raw materials, and mineral treatment processes to determine grade to tin, it can be summarized in the flowsheet below.



__Remark__ +3# = +3 Mesh; Roll = Roll Crusher; Jig = Jig Separator; Mag = Magnetic; Conc = Concentrates; Tail = Tailings; Cond = Conductor; XRF = X-ray Fluorescence.

Figure 5.1 The flowsheet of sieve size analysis, distribution of the valuable elements and separation of samples in this study.

5.2. Recommendations

The following recommendations are made for further study:

1. After the experiment with wet sieve, the sample was suggested to be processed by hydrocyclone before feeds to shaking table.
2. The project to recycle water is recommended as the process uses a lot of water.
3. Observing the exposure and outcrop in the concession area.
4. Doing more pitting so that the interpolation can be made to determine tin grade in whole concession area.
5. Study on the consumption of the new method to extract higher tin product with low percentage of mineral unnecessary.

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APPENDIX

Appendix A

The result of XRF analysis in this study

Table1. The result of the sample size (-0.265+4 # and – 4 + 14 #)

Faculty of ENGINEERING
CHULALONGKORN UNIVERSITY
Tel : 02-2186919
Fax : 02-2186920
Analytical Service
Department of Mining & Petroleum Engineering

Job No. J0050

Chemical Analysis Report

Customer name	SIKHARA Mining co.,ltd.
Sample name	H2,H7,H8,H10,H12,H13
Sample Description	Coarse grain sand ml8/2556 and ml9/2556
Date Received	March 1,2015
Date Report	March 5,2015

Analysis Method

Prepare sample	Grinding and Compression
Analysis method	XRF model MDX1000 OXFROD

Test Results

Name	Chemical Composition (% by weight)										
	Nb	Sn	Ta		Nb	Sn	Ta		Nb	Sn	Ta
H2D0-1-4	0.005	1.783	0.071	**H12D3.6-4.6-4**	0.008	2.457	0.071	**H8D2-3-0.265**	0.011	1.179	0.072
H2D1-2-4	0.003	1.939	0.072	**H13D0-1-4**	0.005	2.204	0.069	**H10D0-1-0.265**	0.002	1.258	0.071
H2D2-3-4	0.017	2.129	0.068	**H13D1-2-4**	0.005	2.071	0.081	**H10D1-2-0.265**	0.002	1.723	0.068
H7D0-1-4	0.011	2.216	0.071	**H13D2-3-4**	0.008	2.405	0.069	**H10D2-2.8-0.265**	0.005	1.863	0.071
H7D1-2-4	0.007	2.155	0.069	**H13D3-4-4**	0.011	2.365	0.067	**H12D2.6-3.6-0.265**	0.025	1.765	0.068
H7D2-3-4	0.012	1.773	0.069	**H13D4-4.75**	0.005	1.935	0.071	**H12D3.6-4.6-0.265**	0.025	1.696	0.071
H7D3-4-4	0.005	1.791	0.071	**H2D0-1-0.265**	0.005	1.949	0.069	**H13D1-2-0.265**	0.007	1.113	0.073
H8D0-1-4	0.023	2.065	0.068	**H2D1-2-0.265**	0.007	1.796	0.068	**H13D2-3-0.265**	0.005	1.755	0.069
H8D1-2-4	0.015	1.949	0.069	**H2D2-3-0.265**	0.006	2.317	0.067	**H13D3-4-0.265**	0.012	1.801	0.069
H8D2-3-4	0.041	1.864	0.067	**H7D1-2-0.265**	0.007	1.607	0.068	**H13D4-4.75-0.265**	0.007	1.836	0.071
H10D0-1-4	0.017	2.722	0.069	**H7D2-3-0.265**	0.006	1.586	0.069				
H10D1-2-4	0.012	2.673	0.066	**H7D3-4-0.265**	0.005	1.528	0.067				
H10D2-2.8-4	0.005	1.621	0.072	**H8D0-1-0.265**	0.008	1.411	0.071				
H12D2.6-3.6-4	0.021	1.849	0.085	**H8D1-2-0.265**	0.005	1.822	0.069				

Report By U. Thongklueng

Utit Thongklueng

Analyst

Approve By

Assoc.Prof Somsak Saisinchai

Head of Mineral Processing Laboratory

Remark:

1. This testing services are provided without warranty or liability. The Laboratory shall not be liable for any loss or damage of whatsoever resulting from the use of the results, or for any purpose.
2. Test result is true for the test sample at the laboratory only.
3. Retention samples are normally held for 30 days after reporting.
4. Test results are the strict confidentially of all work performed for clients. No reports or copies will be released to a third party only when written authorization is provided by the client.

Table2. The result of the sample size (-14 + 30 # and – 30 #)

Faculty of ENGINEERING
CHULALONGKORN UNIVERSITY
Tel : 02-2186919
Fax : 02-2186920
Analytical Service
Department of Mining & Petroleum Engineering

Job No. J0040

Chemical Analysis Report

Customer name	SIKHARA Mining co.,ltd.
Sample name	H2,H7,H12,H8,H10,H13
Sample Description	Fine grain sand ml8/2556 and ml9/2556
Date Received	February 5,2015
Date Report	February 10,2015

Analysis Method

Prepare sample	Grinding and Compression
Analysis method	XRF model MDX1000 OXFROD

Test Results

Name	Chemical Composition (% by weight)										
	Nb	Sn	Ta		Nb	Sn	Ta		Nb	Sn	Ta
H2D0-1-14	0.007	1.777	0.074	H12D2.6-3.6-14	0.012	2.154	0.008	H10D2-2.8-14	0.014	2.399	0.011
H2D0-1-30	0.012	1.813	0.073	H12D2.6-3.6-30	0.002	2.011	0.045	H10D2-2.8-30	0.009	2.581	0.026
H2D1-2-14	0.002	2.082	0.071	H12D3.6-4.6-14	0.005	1.854	0.064	H13D0-1-14	0.007	2.462	0.045
H2D1-2-30	0.002	1.937	0.072	H12D3.6-4.6-30	0.002	1.839	0.032	H13D0-1-30	0.012	3.048	0.071
H2D2-3-14	0.007	2.281	0.054	H8D0-1-14	0.012	1.875	0.033	H13D1-2-14	0.008	3.157	0.059
H2D2-3-30	0.012	2.094	0.041	H8D0-1-30	0.005	2.152	0.043	H13D1-2-30	0.007	3.101	0.055
H7D0-1-14	0.022	2.089	0.009	H8D1-2-14	0.011	2.424	0.055	H13D2-3-14	0.006	2.634	0.042
H7D0-1-30	0.009	2.343	0.016	H8D1-2-30	0.007	2.399	0.008	H13D2-3-30	0.019	2.699	0.073
H7D1-2-14	0.007	2.424	0.011	H8D2-3-14	0.002	2.966	0.006	H13D3-4-14	0.012	2.615	0.074
H7D1-2-30	0.006	2.418	0.006	H8D2-3-30	0.005	3.011	0.007	H13D3-4-30	0.019	3.006	0.044
H7D2-3-14	0.005	2.203	0.008	H10D0-1-14	0.006	2.151	0.077	H13D4-4.75-14	0.011	2.566	0.067
H7D2-3-30	0.012	2.369	0.004	H10D0-1-30	0.009	2.201	0.065	H13D4-4.75-30	0.012	2.757	0.720
H7D3-4-14	0.014	2.502	0.071	H10D1-2-14	0.007	2.709	0.061				
H7D3-4-30	0.014	2.474	0.023	H10D1-2-30	0.006	2.316	0.054				

Report By U. Thongklueng

Utit Thongklueng

Analyst

Approve By

Assoc.Prof Somsak Saisinchai

Head of Mineral Processing Laboratory

Remark:

1. This testing services are provided without warranty or liability. The Laboratory shall not be liable for any loss or damage of whatsoever resulting from the use of the results, or for any purpose.
2. Test result is true for the test sample at the laboratory only.
3. Retention samples are normally held for 30 days after reporting.
4. Test results are the strict confidentially of all work performed for clients. No reports or copies will be released to a third party only when written authorization is provided by the client.

Appendix B

Economics Evaluation

ASSUMPTIOM

Table1. Investment

	THB	Years
Land	12,800,000	
Construction	14,080,000	20
Machine and Equipment	72,000,000	10
Vehicles 3 Unit	3,000,000	5
Construction of mine site	2,000,000	20
Machine and Equipment of mine site	66,930,000	10
Total	170,810,000	

Table2. Capital Expenditure (Capex)

	THB
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
Public utility (15% of Machine)	10,800,000
Reserve (15% of Machine)	10,800,000
Fee	10,000,000
	103,600,000
Total CAPEX	274,410,000

Table3. Working capital

	THB
Working Capital	10,000,000

Table4. Source of investment fund

	THB
Owner	284,410,000
Total	284,410,000

Table5. Revenue

Input parameters	Values
Tin concentrate price	538,000 THB per ton
Sand price	300 THB per ton
Aggregate price	100 THB per ton
Royalty of Tin concentrate	38,825 THB per ton
Royalty of Sand	14 THB per ton
Royalty of Aggregate	14 THB per ton
Tax rate	30 percent
The housing development fund	500000 THB per year
Health Insurance Fund	200000 THB per year
Rehabilitation cost (34000 THB / rai/year)	1,309,000 THB per year

Table6. Operating expense (Opex)

Labour cost	Unit	THB per unit	Total
Plant manager	1	80,000	80,000
Engineer	3	30,000	90,000
account	2	20,000	40,000
Sales manager	2	18,000	36,000
Marketing Manager	2	18,000	36,000
Foreman	6	18,000	108,000
worker	50	9,000	450,000
Security	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
Worker	5	10,000	50,000
Back hoe operator	2	23,000	46,000
Wheel loader operator	3	23,000	69,000
dump truck operator	12	17,000	204,000
driver	1	10,000	10,000
water & fuel truck operator	2	12,000	24,000
Total			1,399,000
Raw Material	648,000	197.73	128,130,000
Electric	648,000	30	19,440,000
Maintenace (5% of Investment)	1	14,220,500	14,220,500
Consumable (1% Of Investment)	1	2,844,100	2,844,100
Total			164,634,600

Table 7. Detail of operating Expense for Tin Processing

Years	0	1	2	3	4
Processing cost	215,159,400	53,789,850	53,789,850	53,789,850	53,789,850
Labour Cost increase 10%/year	16,788,000	16,788,000	18,466,800	20,145,600	21,992,280
Inflation cost increase 5%/year	100	105	110	116	122
Labour cost and inflation		17,627,400	20,359,647	23,321,050	26,731,754
Welfare and management (50%)		8,813,700	10,179,824	11,660,525	13,365,877
Analyze cost (10%)		1,762,740	2,035,965	2,332,105	2,673,175
Total Opex		81,993,690	86,365,285	91,103,530	96,560,656

Table8. Depreciation

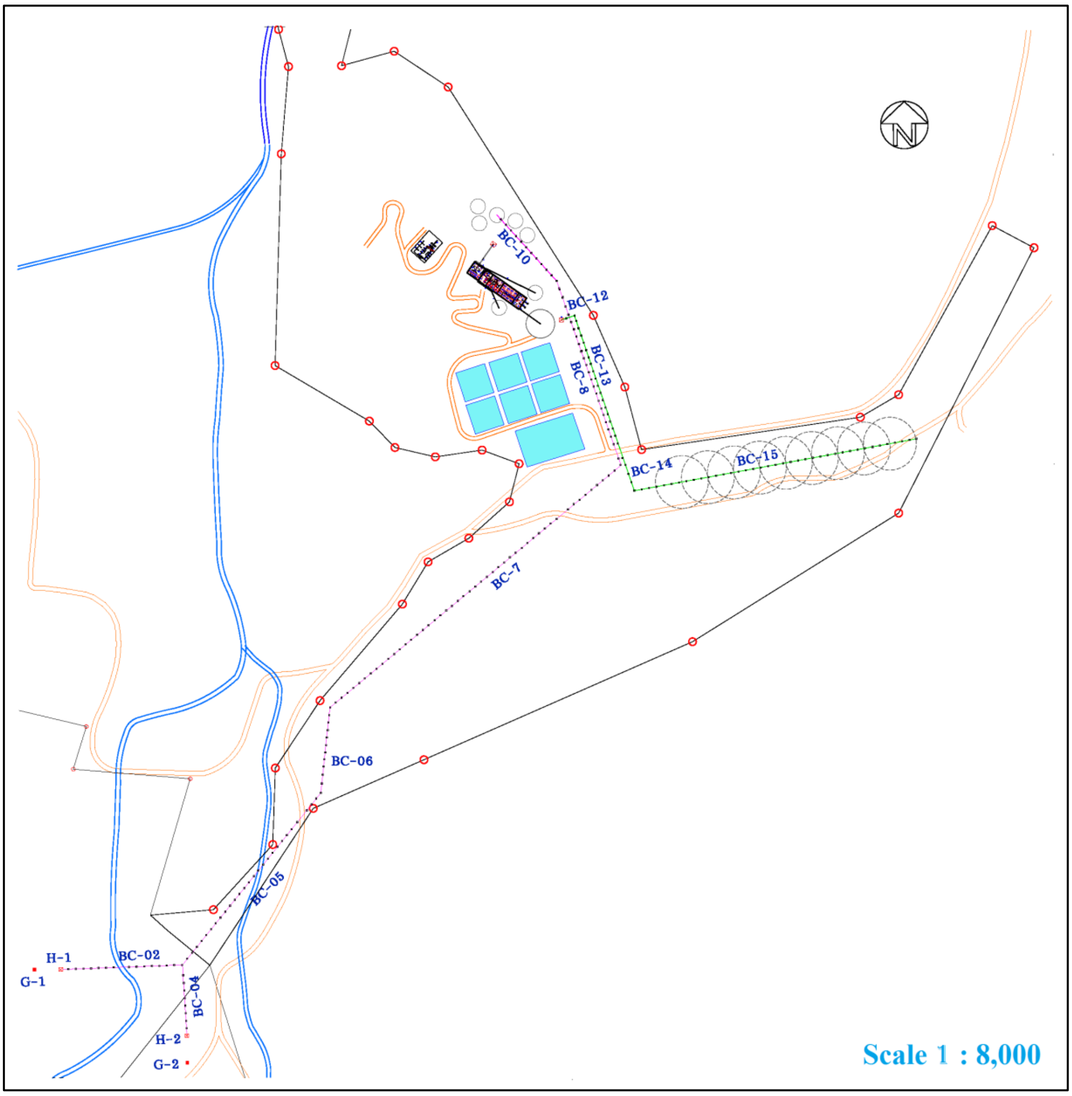
Year	0	1	2	3	4
Depreciation		15,297,000	15,297,000	15,297,000	112,119,000

Table 9. Cash flow of this study

Year	0	1	2	3	4
Capex (THB/ton)	274,410,000				
Working Capital	10,000,000				
Total investment (THB)	284,410,000				
Price of Tin (THB/ton)	538,000				
Tin Production (ton/year)		630	630	630	620
Revenue from selling Tin (THB/year)		338,940,000	338,940,000	338,940,000	333,560,000
Price of Sand (THB/ton)	300				
Sand Production (ton/year)		475,230	475,230	475,230	472,918
Revenue from selling Sand (THB/year)		142,569,000	142,569,000	142,569,000	141,875,400
Price of Aggregate (THB/ton)	100				
Aggregate Production (tons/year)		89,106	89,106	89,106	88,672
Revenue from selling Aggregate (THB/year)		8,910,600	8,910,600	8,910,600	8,867,200
Gross Revenue (THB/year)		490,419,600	490,419,600	490,419,600	507,102,600
Royalty of Tin (THB/ton)	38,825				
Expense for Royalty of Tin (THB/year)		24,459,750	24,459,750	24,459,750	24,071,500
Royalty of Sand (THB/ton)	14				
Expense for Royalty of sand (THB/year)		6,653,220	6,653,220	6,653,220	6,620,852
Royalty of Aggregate (THB/ton)	14				
Expense for Royalty of Aggregate (THB/year)		1,247,484	1,247,484	1,247,484	1,241,408
Sale and Marketing Expense 10% (THB/year)		49,041,960	49,041,960	49,041,960	48,430,260
Sale Expense (THB/year)		81,402,414	81,402,414	81,402,414	82,644,020
Total Revenue (THB/year)		409,017,186	409,017,186	409,017,186	424,458,580
Opex (THB/year)		187,602,690	88,374,285	91,103,530	96,560,656
Depreciation (THB/year)		15,297,000	15,297,000	15,297,000	112,119,000
Income before Tax (THB/year)		206,117,496	307,354,901	302,616,656	215,045,247
Tax 30% (THB/year)		61,835,249	92,206,470	90,784,997	64,733,677
Income after tax (THB/year)		144,282,247	215,148,431	211,831,659	151,045,247
Cash flow (THB/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	983,917,584
Interest	13%				
NPV (THB)	447,779,678				
IRR	79%				
payback period (year)	1.09				

Appendix C

Minerals Processing Design by AutoCAD civil 3D



*Remark: H-1, H-2 = Hopper; G- 1, G-2 = Grizzly Bar; BC - … = Belt conveyor

Figure1. Shows the top view design of this project

Appendix D

List of machine and equipment for processing plant design

Table 1.1 List of machine and equipment

No	List	Size (mm.)	power *(setting)*	working *(ton/hours)*	Unit	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

Table 1.1 List of machine and equipment (continue)

No	List	Size (mm.)	power	working	Unit	price
			(setting)	*(ton/hours)*		(THB)
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	20	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, roll-type	Ø 320 x 1500	1 kW	0.2	1	830,000
36	Magnitic Separator	2000x1000	5 kW	0.5	2	1,830,000

Table 1.1 List of machine and equipment (continue)

No	List	Size (mm.)	power (setting)	working (ton/hours)	Unit	price (THB)
37	Sump	2400 x 2400 x 2500	-	-	1	300,000
38	Mineral 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

Table 1.1 List of machine and equipment (continue)

No	List	Size (mm.)	power	working	Unit	price (THB)
			(setting)	*(ton/hours)*		
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
				Tatol		**71,976,831**

VITA

The author of this thesis was born on 10 October 1990, in Xieng khouang province, Laos. After receiving his bachelor's degree of Mining Engineering from the National University of Laos in 2014, he continuously started his geo-resources engineering master's study, which is presented in this thesis book in the Department of Mining and Petroleum Engineering, Faculty of Engineering, Chulalongkorn University. He was granted friendship scholarship to do this thesis during April 2015 – March 2016 from ASEAN University Network/ Southeast Asia Engineering Education Development Network (AUN/SEED-Net).