ANALYSIS OF SUITABLE LANDS FOR AGGREGATE MINING IN ANURADHAPURA AND GAMPaha DISTRICTS

By
Thilakarathne Dahanayake

Thesis submitted to the Faculty of Graduate Studies, University of Sri Jayewardenepura for the Partial fulfillment of Masters of Science Degree in GIS and Remote Sensing on 2016
DECLARATION

I do hereby declare that the work reported in this project report was exclusively carried out by me under the supervision of Prof. Sunethra Thennakoon and Dr. Ranjith Premasiri a report on this has not been submitted in whole or in part to any University or any other institution for another degree.

Date: 2016/3/20

T. Dahanayake
ACKNOWLEDGMENTS

I wish to express my sincere gratitude to my supervisors, Prof. Sunethra Thennakoon and Dr. Ranjith Premasiri for the guidance and directions provided to me in conducting this study.

I would like to appreciate the monumental patience, the kind support, and most importantly encouragement extended to me by Prof. Sunethra and Dr. Ranjith Premasiri which stood by me like a pillar of strength enabling me to complete this research successfully.

I would also like to express my sincere gratitude to Prof. R.M.K. Rathnayake – Course coordinator for his kind instructions and correct guidance to success this research.

The Chairman, Board of Directors, The Director General, General Manager, Deputy Directors, and the members of the staff at Geological Survey Mines Bureau who supported me in conducting this study need to be mentioned with lot of gratitude.

Also I am very much grateful to all the Lecturers, Instructors of the MSc program in GIS and Remote Sensing and the staff of the Postgraduate Institute of Science, for the great support and guidance throughout the whole course.

Further, I wish to thank my wife, daughter and son for the support extended to me.
## CHAPTER STRUCTURE

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declaration</td>
<td>i</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>ii</td>
</tr>
<tr>
<td>Chapter Structure</td>
<td>iii</td>
</tr>
<tr>
<td>List of Tables</td>
<td>vi</td>
</tr>
<tr>
<td>List of Figures</td>
<td>vii</td>
</tr>
<tr>
<td>List of Annexure</td>
<td>viii</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>ix</td>
</tr>
<tr>
<td>Abstract</td>
<td>x</td>
</tr>
</tbody>
</table>

### CHAPTER ONE – INTRODUCTION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background of the Study</td>
<td>1</td>
</tr>
<tr>
<td>Research Problem</td>
<td>6</td>
</tr>
<tr>
<td>Significance of the Study</td>
<td>7</td>
</tr>
<tr>
<td>Objectives of Project</td>
<td>11</td>
</tr>
</tbody>
</table>
CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction 12
2.2 Minerals mining industry and its significance 13
2.3 Mineral Mining industry in Sri Lanka 14
2.4 Aggregate mining industry in Sri Lanka 18
2.5 Environmental and social issues related to mining industry 20
2.6 Legal and regulatory framework related to metal aggregate mining 26
2.7 Geographic Information Systems (GIS) for mining 29

CHAPTER THREE – METHODOLOGY

3.1 Study Area 31
3.2 Selection of the study area 31
3.3 Background details of the study area 32
3.4 Topography 33
3.5 Geology 34
3.5.1 Geology of Anuradhapura District 34
3.5.2 Geology of Gampaha District 37
3.6 Methodology used for the research 40
CHAPTER FOUR - RESULTS AND DISCUSSION 44 - 63

4.1 Introduction 44

4.2 The distance between mining locations and bulling surrounded by the site 47

4.3 The distance between mining locations and roads surrounded by the site 55

4.4 The distance between mining locations and water body/ streams Surrounded by the mines 55

4.5 Land use percentages surrounded by the mine sites 56

4.6 Analysis of the suitable locations for mining in the study area 57

CHAPTER FIVE - CONCLUSIONS AND RECOMMENDATIONS 64 - 66

5.1 Conclusions 64

5.2 Recommendations 65

References 67

Annexure
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Available Minerals in Sri Lanka</td>
<td>16</td>
</tr>
<tr>
<td>2.2</td>
<td>Years 2005 - 2014 issued mining licenses by the GSMB for aggregate mining</td>
<td>19</td>
</tr>
<tr>
<td>2.3</td>
<td>Mining License categories and its parameters</td>
<td>27</td>
</tr>
<tr>
<td>3.1</td>
<td>Data Used</td>
<td>40</td>
</tr>
<tr>
<td>4.1</td>
<td>Distances from the each mine location to buildings in the study area</td>
<td>47</td>
</tr>
<tr>
<td>4.2</td>
<td>Roads located around the mines</td>
<td>55</td>
</tr>
<tr>
<td>4.3</td>
<td>Water body located around the mines</td>
<td>56</td>
</tr>
<tr>
<td>4.4</td>
<td>Percentages of land use patterns of 300 meter surrounded from the mines</td>
<td>57</td>
</tr>
<tr>
<td>4.5</td>
<td>Availability of the surrounded land use of the mines for large scale mining</td>
<td>58</td>
</tr>
<tr>
<td>4.6</td>
<td>Availability of the surrounded land use of the mines for medium scale mining</td>
<td>59</td>
</tr>
</tbody>
</table>
List of Figures

<table>
<thead>
<tr>
<th>Table No</th>
<th>Caption</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Study area</td>
<td>33</td>
</tr>
<tr>
<td>3.2</td>
<td>Geology Map of Anuradhapura Districts</td>
<td>36</td>
</tr>
<tr>
<td>3.3</td>
<td>Geology Map of Gampaha Districts</td>
<td>39</td>
</tr>
<tr>
<td>4.1</td>
<td>Aggregate mines locations in Anuradhapura Districts</td>
<td>45</td>
</tr>
<tr>
<td>4.2</td>
<td>Aggregate mines locations in Gampaha Districts</td>
<td>46</td>
</tr>
<tr>
<td>4.3</td>
<td>Buildings and roads in 100m and 300m distance at mine A1 in Anuradhapura district</td>
<td>49</td>
</tr>
<tr>
<td>4.4</td>
<td>Buildings and roads in 100m and 300m distance at mine A2 in Anuradhapura district</td>
<td>50</td>
</tr>
<tr>
<td>4.5</td>
<td>Buildings and roads in 100m and 300m distance at mine A3 in Anuradhapura district</td>
<td>51</td>
</tr>
<tr>
<td>4.6</td>
<td>Buildings and roads in 100m and 300m distance at mine G1 in Gampaha district</td>
<td>52</td>
</tr>
<tr>
<td>4.7</td>
<td>Buildings and roads in 100m and 300m distance at mine G2 in Gampaha district</td>
<td>53</td>
</tr>
<tr>
<td>4.8</td>
<td>Buildings and roads in 100m and 300m distance at mine G3 in Gampaha district</td>
<td>54</td>
</tr>
<tr>
<td>4.9</td>
<td>Suitability Levels of Aggregate mines locations in Anuradhapura Districts</td>
<td>61</td>
</tr>
<tr>
<td>4.10</td>
<td>Suitability Levels of Aggregate mines locations in Gampaha Districts</td>
<td>62</td>
</tr>
</tbody>
</table>
List of Annexure

1. Aggregate mines location details (XY GPS Points)
# LIST OF ABREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>Artisanal Mining</td>
</tr>
<tr>
<td>DSD</td>
<td>Divisional Secretariat Divisions</td>
</tr>
<tr>
<td>CEA</td>
<td>Central Environmental Authority</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GND</td>
<td>Grama Niladari Divisions</td>
</tr>
<tr>
<td>GNP</td>
<td>Gross National Production</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GSMB</td>
<td>Geological Survey and Mines Bureau</td>
</tr>
<tr>
<td>IEER</td>
<td>Initial Environmental Examination Report</td>
</tr>
<tr>
<td>IML</td>
<td>Industrial Mining License</td>
</tr>
</tbody>
</table>
Aggregate mining industry in Sri Lanka increased during the last two three decades. After the civil war in the country, as a basic raw material for the construction industry, the demand for the aggregate rapidly increased. To fulfill this massive demand aggregate mining project are operating throughout the Island. Those mining activities have been created many social and environmental issues. Most of these projects are operating in inappropriate locations. Therefore, finding of economically viable, environmental friendly aggregate project is a prime requirement. This research was aimed to find suitable locations for the aggregate mining. For this research mainly data was collected from Geological survey and mines bureau. And also used land use maps from Survey Department. Anuradhapura and Gampaha districts were selected as study area. Accordingly available large scale aggregate mine sites selected as the sample. Mainly applied GIS tools for the research. By the research initially plotted all the aggregate mines. Then created buffers in several distance using proximity analysis GIS tool. The land use pattern surrounded by the mine sites was categorized. And calculated the percentages of each land use pattern within 300 x
meter range from the mines. It was decided to consider that some of the land use patterns are not suitable to operate the aggregate mines. Especially decided that home lands surrounded by the mines are not suitable. Further measured the distance to the buildings, roads and water body and water streams within 100 meters and 300 meter range from the mine sites. And categorized the suitability.

By the research, it was identify that the most of the mines locations are not in a suitable level. Only 16% mines were in suitable level. Nearly 50% mines were in not suitable level. Also nearly 33% mines were in moderate level. The main reason for the rejection of most of the mines was the nearby buildings. Therefore it is a rapid requirement to conduct the exploration and find suitable locations for further mining.

Keywords: rock outcrops, aggregates, GIS, Suitability
Chapter One

INTRODUCTION

1.1 Background of the study

Sri Lanka inherits a rich agrarian civilization. The remains of the ancient civilization provides ample testimonies to the world, the kind of well-developed and very well advanced construction industry of the historic Sri Lanka. The tacit knowledge base utilized, in building Sigiriya, Lowamahapaya, RuwanwelIStupa&YodhaEla, was few that depicts the unparalleled pride of a nation. With a rich cultural heritage further refined by the Buddhist philosophy enabled to bring construction work to an advanced plateau. The technologies used in building massive tanks were amazing even to the most modern technologies of the present. Thus, construction industry has a very proud history in Sri Lanka.

Though stones were utilized in the construction industry in Sri Lanka for times immemorial, quarry mining gained importance with the use of cement during the late 17th Century in Sri Lanka. When the foreign invaders began their conquest for superiority in Sri Lanka, they built fortresses all over the island especially in the costal belt and to build the massive structures and stone walls, they destroyed the ancient temples to get the stones. Also, there were evidences that Portuguese, Dutch and English invaders used quarry mines for their construction purposes.

Construction industry is being recognized as a key contributor to the Sri Lankan national economy. The post war era is characterized by tremendous increase in investments on infrastructure building from both private sector and public sector. Massive rehabilitation projects were undertaken to develop the infrastructure facilities in North & East and it
was observed foreign investment coming in to the country under BOT (Build Operate and Transfer) schemes. The contribution of the construction industry to the Gross National Product (GNP) is significant and during the period of 2002 to 2012 the contribution of the construction industry to the GNP varies from 6.2% to 8.2%. The growth rates started to pick after 2009 as major buildings and other infrastructure projects have taken place during this period. Especially in 2011 and 2012 there is a drastic increase in the contribution of the construction industry to the Gross National Product (GDP) of Sri Lanka. As per the Central Bank Annual Report, 2012 construction sector GDP stood at Rs. 247 b (US$ 1.9 b) in 2012 with a recorded growth of 21.6% in 2012 compared to the overall GDP growth of 6.4% and industrial sector growth was 10.3%.

As far as the growth of the construction is concerned, according to the central bank report, it can observe that during the year 2002 to 2012 there is a steady growth from 3% to 21.6%. Given the healthy and constant growth in years 2010, 2011 & 2012, the construction industry became one of the fastest growing segments in the national economy.

Due to the above circumstance building material based minerals industries were increased all over the Island legally or illegally to cater to the ever increasing demand of the economy. Geological Survey and Mines Bureau (GSMB) is the regulatory body for issuance of minerals mining licenses for any type of mineral base industries. The number of licenses issued increased dramatically during the last decade or so. According to the GSMB data the bureau has been issued 1272 mining licenses in year 1995 for all minerals and it has been increased up to 3593 in 2005. By the year 2014 this amount has been increased up to 4392.
During the period of 1995 to 2005 the number of mineral licenses issued increased by 2321 and it was a 182% increase when compared to 1995. During the period of 2005 to 2014 number of mineral licenses issued increased by 799 and it was an increase of 22% when compared to 2005. The increase of minerals mining was help to supply sufficient raw minerals for the construction industry. Mainly it was contributed to development of construction industry. When examine construction minerals sector especially for the cement industry limestone mineral was the major raw material. It was supplied by Aruwakkalu limestone mine in Puttalam. Also, after the civil war vast development projects could be seen in infrastructure development sector. Specially roads, highways, railways construction works rapidly increased. Not only that ports, airports, stadiums, grounds, mega building projects are also started to construct. At present also many mega development projects are going on. On the other hand population of the country is increasing day by day. As per the census department data Sri Lanka’s first population census was held in 1871. At the time of that census Sri Lanka’s population was two million. After 100 years of the first census, in 1971 it has increased up to 12.68 million. Within another 30 years this population has increased rapidly. In 2001 Sri Lanka population was 18.79 million. Year 2012 population census was the last census of the country. According to the 2012 census Sri Lanka’s population was 20.36 million. Also Sri Lanka’s annual population increase rate is 0.7%. Further census department statistics shows that the population density of the country is increasing rapidly. In 1981 Sri Lanka population density was 230 per square kilometer. It was 300 by 2001. Further this figure has increased. In 2012 Sri Lanka’s population density was 326 per square kilometer. When compare with some other large countries this is a higher density. When considered
countries like Australia its population density is 03 people per square kilometer. Sri Lanka comes to the 42 place among the highest population density countries. (World Bank Report 2014) To cater this increasing population it is required to commence many construction projects. This is happening by government projects or private projects. For all above constructions, it is main requirement is raw material. Among these sand, metal and quarry aggregate, cement is the major raw materials. For the supplying of these raw materials many mining projects were started. Most of these projects are still operating and those are supplying raw materials for current requirements. Also day by day new mining projects are starting to cater coming requirements.

When considering the metal quarry products it is a basic requirement for all construction industries. Therefore the demand for this raw material is also increased day by day. It can be identified increasing demand for this raw material by issuance of mining licenses for mining of quarry. As per the GSMB data it can be identified that the increasing rate of issuance of licenses for mining of metal quarries. As per the GSMB data the bureau has issued only 596 metal quarry mining licenses in 1995. After ten years it has been increased up to 2380. After another ten years it has been increased up to 2923. (GSMB Annual Report 2014)

The above figures clearly show how increased annually aggregate mining licenses in the country. Also it gives a massage increasing issuance of mining licenses; it would be create many social and environmental issues to the surrounding civilians and environment. aggregate mining weather it is mechanized or manual or it is legal or illegal, however its operating process impact to the surrounding human habitation and environment. However due to the increase of population and the density distribution of
the population, it is difficult to separate the aggregate mining areas from the residential areas as some other countries in the world like Australia, Canada, Soviet Russia and USA who have separate areas for mining activities. Therefore most of the mine sites are located close by residential areas. Also, additionally illegal, uncontrolled and irrational mining activities create many social and environmental issues.

It can be identified that the aggregate mining activities may cause following negative impacts to the surrounding people, property and environment.

a. The threat of lives and private and public property damage due to blasting

b. Aggregate mining results in noise pollution and affects the environment and nearby residents.

c. Environmental and health hazard due to dust generated in the mechanized aggregate mining.

d. Irrational and un systemized mining results in soil erosion, fly rock accidents and sometimes increase the threats of landslides.

e. Impact on the ground water levels.

f. Damage to the public roads by transporting vehicles.

g. Damage to the natural beauty of the area.

Although many negative impacts are created by the aggregate mining industry it cannot be stopped as it is a main raw material for the construction industry. Also it is a vital economic activity which directly linked to the construction industry, it cannot undermine due to the following advantages of aggregate mining.
a. The direct and indirect employment generation in aggregate mining sector.

b. Value addition to the construction industry.

c. Income generated from the direct and indirect employments in aggregate mining.

Therefore, it is very important requirement to implement a system to identify most suitable locations and methods for operating aggregate mining with minimum discomfort to the public and surrounding environment and maximum benefit to the country's development. Therefore, in this field research will be much benefited to the academic field.

1.2 Research problem

At Present most of the aggregate mining locations are situated in residential and sensitive areas. When mining activities carried out in these areas it may create numerous social and environmental issues. However when considering the requirement arising daily needs, this industry cannot be stopped. Therefore it is a requirement to find suitable mining deposit to mine without distributing to the surrounding people and environment. It will help to carry out mining activities with the concepts of the sustainable development. For this, it is essential to identify suitable locations for mining and also it is required to identify type of the mining such as large scale mining, medium scale mining and small scale mining. Because the surrounding environment of some mines is not suitable for operating large scale mining. But the location may suitable for medium scale mining as the impact by the medium scale mining lower than the large scale mining Therefore
Finding of suitable mining locations and identifying the suitable scale is very important. For this purpose, it can be applied modern scientific techniques such as GIS tools. Accordingly, using GIS techniques by this research it is expect to identify what are the suitable and not suitable mining locations for mining. Also it is expected to identify suitable mining scales to operate the mines. Further by this research, it is attempt to develop a basis for a systematic and a rational evaluation of the existing aggregate mines utilizing GIS methodologies. Accordingly, research tropic named as "Analysis of suitable lands for aggregate mining".

1.3 Significance of the study

Mineral resources are considered as natural resources. By the mining of mineral resources may create several social and environmental problems to the surrounding area. Therefore identify the unsuitable mining and control the expansion of these projects is an important to maintain a clam environment. By this research, can be identified the mining sites operating with social and environmental issues. This is one of the significant of this research. Also this research will help to identify the suitability of existing aggregate mines. It is difficult to find any surveys have been carried out about the suitability of the above rock deposits. By this research it is considering each mineral deposit and surrounding land use pattern and other infrastructure facilities around the aggregate mines. This is also a one significant of this research.

This research help to identify highly suitable, suitable, moderate and not suitable areas for metal quarry mining. Identification of the above will give the rational basis for the
regulatory body to evaluate the suitability of mining in the case of renewal of the licenses periodically. Regulate irrational and unsystematic metal quarry mining licensing. Address the environmental hazard where the pollution is heavy and also provide socio economic solutions.

When examine the significance academically, there are many research have been done by several organization internationally and locally regarding the impacts related to the mining activities. When considered international publications in mining industry and impacts by the mining, somewhat different than Sri Lanka. As an example it can shows Australia mining industry. By the study of "Impact of Mining and Resource Development: A Case Study for Eyre Peninsula Councils" (2013) explains South Australia’s mining industry and its some impacts. As per this survey shows that the Australia’s mining sector has expanded rapidly over the past decade. An expansion in foreign demand for Australian commodities particularly those used in steel and energy generation has been led by China and a number of periphery countries in Asia. South Australia’s mining output and mineral exploration expenditure has grown rapidly as new mineral deposits are discovered and developed to meet expected demand.

Consequently local councils on the Eyre Peninsula face increasing pressure to meet community demands and expectations for local infrastructure and services. To meet the challenges, Eyre Peninsula councils need to better understand how their region will be affected in terms of: population growth, housing demand and allotment of residential land as well as the impact on all other community infrastructure and services. It has identified
following general impacts of mining on regional communities. Impacts can be categorized economic, environmental or social in nature and can be both positive and negative.

**Economic** - Job creation: The mining industry has the potential to create additional jobs for local communities across a broad range of occupations.

Skills shortages: Mining companies face various challenges to find skilled labor for the construction of mines and operation. This leads to the recruitment of workers from local government agencies and the private sector in small regional communities creating acute shortages of skilled workers.

**Social** - Housing availability/affordability: Development of mines in regional areas can have a significant impact on the availability and affordability of accommodation.

Pressure on social and community infrastructure: Community infrastructure includes a wide range of built facilities, services and network of organizations which cater to the community’s needs. The influx of new mining workers increases demand for community infrastructure and services sometimes placing a strain on local councils.

**Environmental** - Land use conflict: Land use conflicts can arise between local communities and mining companies. Conflict is most likely to arise when resource-rich land in question lies close to urban areas and in cases where resources are located on prime agricultural land such as the lower Eyre Peninsula.
When examine locally published research related to the mineral industry by National Science Foundation (2004) published “Exploration of Sri Lankan industrial mineral resources” publication is an important publication. By this research examine about the existing problems faced by the mineral development industries. It is highlighted that the hurdles which is facing investors to take industries to the village. Mainly it is showing the institutional delays for the approvals and permission cause to fail the projects. Also this research shows that the majority of mineral industries in Sri Lanka are now operated by the private sector and the continuous use of local raw materials for such industries will, lead to accelerated depletion without knowing the reserve estimates. Therefore immediate action should be taken by the Government to formulate a comprehensive National Mineral Policy for Sri Lanka taking into consideration the concerns of the private sector. It is suggested that the Government consider studying the two legislative enactments related to mining of minerals and gemstones and assign functions so as to avoid duplication and even conflict of interests.

Also, by the research “Mineral Based Industrial Development & Sri Lanka’s Lethargic Syndrome” Ileperuma- (2015) is discussing the current situation of the minerals industry of the country. It is discussed and highlighted the lack of proper usage of the minerals in the country. Most of the Sri Lanka’s valuable minerals such as Graphite, Mineral sand, Vain Quartz are exporting as raw materials without any value addition. Further this author says that there are many possibilities to develop the minerals industry. Especially in mineral sand industry. At the moment the country exports mineral sands such as rutile and Ilmenite at dirt cheap prices to overseas companies. After value addition through
chemical industry, products manufactured using our own minerals are sold back to Sri Lanka at costs sometimes one thousand times the cost of the raw material. Illeperuma explain this situation, as a nation we are suffering from a lethargic syndrome, “can’t do”, “why bother if it can be bought from some other country”, “there is no market”, “it is too expensive to produce here”. These are the attitudes which kill us.

By all above researches have examine impacts created by the mining. Also they have tried to find solutions for the impact created by the mining. And also highlighted the importance of the value addition for the minerals. But this research somewhat different from the above research. By this research try to find suitable locations for mining of aggregates. Therefore this research is able to fill the gap in academic research field. Accordingly this research may significance for the academic field.

1.4 Objectives of the project

The main objective of the research is to ascertain and identify suitability of aggregate mining locations.

The specific objectives are:

- To identify the distribution of existing aggregate mining sites and measuring the distance to the buildings, roads and water bodies from the mines.
- To demarcate boundaries in different distance range for mining locations.
- To calculate the percentages of categorized land use patterns surrounding in each aggregate mining locations.
- To categorize the suitability of existing mines.
Chapter Two

LITERATURE REVIEW

2.1 Introduction

As a natural resources use of mineral resources have a long history. Since the beginning of civilization, people have used some minerals such as stone, ceramics and, later, metals found close to the Earth's surface. These were used to make early tools and weapons. The use of red pigments for ritual purpose is documented in Europe since the Paleolithic era. (Ortiz et.al, 2011). The oldest known mine on archaeological record is the "Lion Cave" in Swaziland, which radiocarbon dating shows to be about 43,000 years old.

According to the "Encyclopedia of Britannica" Mineral is a solid element or inorganic compound that has a definite chemical composition and, in nearly all cases, a regular internal crystal structure. When consider mining, extraction of valuable minerals or other geological materials from the earth from an ore body, lode, vein, seam, or reef, which forms the mineralized package of economic interest to the miner. Mining in a wider sense includes extraction of any non-renewable resource such as petroleum, natural gas, or even water.

The nature of mining processes creates a potential negative impact on the human and environment both during the mining operations and for years after the mine is closed. This impact has led most of the world's nations to adopt regulations designed to mitigate the negative effects of mining operations. Safety has long been a concern as well, and modern practices have improved safety in mines significantly. In this chapter, it is expected to discuss minerals mining industry, its regulatory background and issues related to the minerals mining industry.
2.2 Minerals mining industry and its significance

Minerals mining industry can be considered as one of the largest industries of the world. In the United States of America, the contribution to the GDP by the mineral sector in 2012 was $225$ USD billions. (The Economic Contributions of U.S. Mining -2014) When examine the nearest country, The Government of India, has targeted significantly higher share of GDP from mining. It aims to increase share of mining and quarrying in GDP from current $2\%$ of GDP to $5\%$ of GDP over the next 20 years. India ranked 4th amongst the mineral producer countries, behind China, United States and Russia, on the basis of volume of production. The Mineral Development and mining sector is a significant contributor to the India’s GDP growth; as there is a strong correlation between growth in same and the manufacturing sector; making it a catalyst for the growth of basic industries such as power, steel, cement etc. (Development of Indian Mining Industry - 2013) The world price of Australia’s mining exports has more than tripled over the past decade, while investment spending by the mining sector increased from $2\%$ of GDP to $8\%$ per cent. This ‘mining boom’ represents one of the largest shocks to hit the Australian economy in generations. It was finding that the mining boom has substantially increased Australian living standards. By 2013, it was estimated that it had raised real per capita household disposable income by $13\%$, raised real wages by $6\%$ and lowered the unemployment rate by about $1\frac{1}{4}$ percentage points. Gold, copper, coal, iron ore, mineral sands, nickel, uranium are some of the major minerals produced in Australia. (Downes. et. Al., 2014). Also, as a largest country of Asia the China has became a world leading producer of coal, gold, and most rare earth minerals. Not only that China accounted for about $57\%$ of the world’s pig iron production and $45\%$ of the world’s crude
steel production. (Asia School of Mines - 2012) The above figures show that the contribution and significance of the minerals mining industry of mineral rich countries.

Further examine the situation of mining industry at the global level; many countries have long history about the mining. One example is Great Britain. Mining was one of the most prosperous activities in Britain. Britain was rich in many minerals resources such as copper, gold, iron, lead, salt, silver etc. The UK is an important producer of a range of minerals that are consumed in many sectors of the economy. Some 195 million tones of minerals were extracted from the UK landmass for sale in 2013. These can be broken down into the following main categories with percentages of total production in brackets: (Minerals Year book - United Kingdom, 2013)

- 157 million tons (81%) of construction minerals
- 24.6 million tons (12.6%) of industrial minerals
- 12.8 million tons (6.6%) of coal
- 1.1 million tons (0.5%) of oil and gas (oil equivalent)

2.3 Mineral Mining Industry in Sri Lanka

When examine the Sri Lanka’s mining industry, this industry has a long history. The most famous example is the Sri Lanka’s Gem mining industry. From the ancient era, the country has earned considerable revenue by exports of gem. It is a significant evidence to identify the long history of the mining industry. In recent history, the country was become to pioneers among the Graphite producers. Especially during the first and second world war era Sri Lanka was the world’s one of the major Graphite supplier. (Herath, 1986)
By the publication of Minerals Based Industries (Herath, 1986) explains during-ancient time minerals in Sri Lanka had their place in the life of the people: Hard rocks have been extensively used for building and other purposes. Pottery (earthenware), brick and tile were produced from plastic clays. Iron ores have been smelted on a cottage industry scale at several points. Lime has been produced and the Island has long been renowned for its gems. In 1902 a State organization was set up to handle the mineral surveys of the Island. This institution then developed to what is known today as the Geological Survey Department of Sri Lanka. With the discovery over the years of a number of economic mineral deposits, by the Silvery, the State soon realized. (Herath, 1986) summarizes the major mineral based industries of Sri Lanka and in order to appreciate the occurrence, distribution and development of the mineral raw materials, mention is made of some aspects of mineral prospecting and exploration and the main economic minerals are listed. The geology of the country is described and the future of the mineral industry is discussed.

When considering Sri Lanka, it cannot be categorized as a major mineral producing country. The country's mining and quarrying sector contribution is 1.5% to the GDP. (Central Bank Report, 2014). Compare with other countries of the world, Sri Lanka is an island with limited minerals resources. But most of them high quality and valuable. Gem minerals, Sri Lankan Graphite, vein quartz, mineral sands are some of the examples. The country has identified more than twenty five minerals resources as available minerals. As per the mines and minerals act No 33 of 1992 some of the minerals are categorized as industrial minerals and some of the minerals are categorized as construction raw material minerals. Also the gem minerals are regulated by the Gem and jewelry Authority under
Gem and jewelry act. Also the hydrocarbon minerals administrated by the hydrocarbon act.

Accordingly, Sri Lanka’s minerals resources handled by three national acts. The Table 2.1 show the available minerals in Sri Lanka and their categories.

**Table 2.1: Available Minerals in Sri Lanka**

<table>
<thead>
<tr>
<th>MINERAL CATEGORY</th>
<th>MINERALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base and Other Minerals</td>
<td>Iron, Nickel, Chromium, Copper, Lead, Zinc and rare earth minerals</td>
</tr>
<tr>
<td>Building Materials</td>
<td>Brick, Tile, Cement clay, Sand, Gravel, Soil, Laterite, Limestone, Dolomite, Marble, Shale, Stone, Aggregate, and Dimension stone</td>
</tr>
<tr>
<td>Industrial Minerals</td>
<td>Ilmenite, Zircon, Rutile, Monazite, Coral, Shell beds, Graphite, Ball clay, Ceramic clay, Kaolin, Mica, Feldspar, Limestone, Salt, Gypsum, Ochre, Glass and Quartz, Garnet, Sillimanite, Calcite, Allanite, Fluorspar, Serpentinite, Apatite, Magnetite, Magnetic, Peat, Dolomite, and Wollatonite</td>
</tr>
<tr>
<td>Precious Metals</td>
<td>Gold, Silver and Platinum</td>
</tr>
</tbody>
</table>

When considering the last few decades, it can be observed that there are some minerals base industries have been developed. Before the civil war of the country, there was a mechanism to develop the minerals base industries. As example, can show the establishment of government organizations. Lanka Cement Corporation, Puttlam Cement Corporation, Lanka Minerals Sand Corporation, Eppawala Phosphate Limited, Lanka Salt Limited are some of the examples.

When consider major mines in Sri Lanka, Graphite mines are the largest mines of the country with export potential. Three big mines are at Bogala, Kahatagaha and Kolongaha operating now. Kahatagaha Graphite Lanka Ltd raised output from its underground mine. This mine had a capacity to produce 3,500 t/y of high-grade vein graphite. In the country, another famous Phosphate mineral deposit is available at Eppawala in Anuradhapura district. Substantial deposits of rock phosphate occur in the Eppawala area. As a fertilizer, phosphate deposit contributes to develop the agriculture sector. (Mineral year book, 2014)

The precious and semi-precious stones are found among the beds of older alluvium and river gravels of quaternary age in the valleys of Ratnapura district in the south-west of the island. A large variety of gems are extracting including sapphire, ruby, garnet, aquamarine, moonstone, topaz and, tourmaline. Throughout the history of the country gems were important minerals among the minerals.

Jaffna peninsula in Northern Province and Puttlam district in North Western province are rich for raw material use for the cement industry. Large deposit is situated it Aruwakkalu in Puttalam. Annual production is more than 1.3 million metric tons.
2.4 Aggregate mining industry in Sri Lanka

Minerals and minerals products are the backbone of most industries. In construction industry gets considerable contribution by building material minerals. During the last few decades the demand for the construction material minerals rapidly increased in Sri Lanka. Among these minerals; Sand, gravel and aggregate has a higher demand. The reason was for the higher demand of this is rapid development projects of the country. With the implementation of open economy in 1997, the doors opened to foreign investment. And under the Board of Investment (BOI) facilities many development projects have established. To cater these projects free trade zone were introduced. In Katunayaka, Biyagama, Koggala areas construction industry rapidly increased. Also based on the commercial city of Colombo and administrative capital of Sri Jayawerdenapura and suburb development was the main agenda of all the government became to the power.

On the other hand after the thirty years of civil war most of the areas of the country has commence many development projects under local or foreign investment. Specially Northern and Eastern provinces were mainly considered area. Also after the civil war the country was able to invest for mega development projects. Construction of highways, airports, ports, stadium, and development of road networks are among mega projects.

The above explained about the gradual increase of the construction sector during the last four decades. For these development activities one of the main requirements is construction raw materials. Among these raw materials cement, sand, gravel, aggregates are main raw materials. Therefore, to fulfill the increasing demand mining of these minerals has increased day by day. However until the end of 1980 decade supply of these raw materials was not a big problem. However from the beginning of 1990 decade there
were some shortages about the construction raw materials. In 1992 Sri Lanka Parliament passed the Mines and Minerals Act and established the Geological Survey and Mines Bureau for the functioning of the minerals regulatory works. After 1992 the bureau commenced to issue the licenses for mining. Among the issues licenses majority of the licenses were issued for aggregate mining licenses. The details of issued mining licenses for mining of aggregate are given in Table 2.2

**Table 2.2: Years 2005 - 2014 issued mining licenses by the GSMB for aggregate mining.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Large Scale</th>
<th>Medium Scale</th>
<th>Small Scale</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>17</td>
<td>131</td>
<td>1754</td>
<td>1754</td>
</tr>
<tr>
<td>2010</td>
<td>57</td>
<td>348</td>
<td>1398</td>
<td>1803</td>
</tr>
<tr>
<td>2012</td>
<td>72</td>
<td>752</td>
<td>1168</td>
<td>1992</td>
</tr>
<tr>
<td>2013</td>
<td>60</td>
<td>553</td>
<td>887</td>
<td>1500</td>
</tr>
<tr>
<td>2014</td>
<td>75</td>
<td>849</td>
<td>822</td>
<td>1746</td>
</tr>
</tbody>
</table>

Source: Mineral year book 2015 - GSMB

The Table 2.2 shows the increase of issuance of mining licenses for aggregate mining. This increasing rate caused to fulfill the rapid demand of the country. Also by this rapid increasing of issuance of licenses, the revenue of the government has increased.

As per the mineral year book published by the GSMB, year 2011 the bureau has earned 96 million rupees as royalty fees by issuing the licenses for mining. It was increased up to 140 million in 2013 and further increased up to 281 million rupees in 2014. Although
the increasing of licenses was contributed to development of construction industry and generation of income to the country, bureau has earned millions of for the construction industry development of the country this process was affected to the environment badly. Many social and environmental impacts has created by the aggregate mining. These impacts are discussing in details by the following chapter.

2.5 Environmental and social issues related to mining industry.

By the mining activities can be created many environmental impacts to the surrounding area. Vibration and noise pollution, creation of dusts, soil erosion, degradation of water level, deforestation, land slide threat, habitat lost are some of the negative impacts of the mining activities.

Some activities associated with aggregate extraction and processing may raise environmental concerns including the potential for increased dust, noise, and vibrations; physically altered landscapes and habitats; and impacts to surface and groundwater. These concerns can be monitored, controlled or mitigated by the aggregate mining industry with available technology and engineering. The following sections discuss some of these environmental concerns and the ways they are being addressed.

Noise and vibration:

Noise pollution associated with mining may include noise from vehicle engines, loading and unloading of rock into steel dumpers, power generation, and other sources. Cumulative impacts of shoveling, ripping, drilling, blasting, transport, crushing, grinding, and stock-piling can significantly affect wildlife and nearby residents. Vibrations may come from the processing plant and as a result of blasting. In blasting, explosives are
used to break the rock from its geological formation before it is further crushed. This creates both air and ground vibration. Vibrations are associated with many types of equipment used in mining operations. Vibration has affected the stability of infrastructures, buildings, and homes of people living near large-scale open-pit mining operations. According to a study commissioned by the European Union in 2000: “Shocks and vibrations as a result of blasting in connection with mining can lead to noise, dust and collapse of structures in surrounding inhabited areas. The animal life, on which the local population may depend, might also be disturbed.”

The impact of aggregate mining operation such as noise, dust, air quality, suspended particulate matter and gaseous emission poses serious environmental problem to both the inhabitant and the workers at the mines. (Ukpong, 2012) By the research of “Environmental impact of aggregate mining by crush rock industries in Akamkpa local Government area of Cross River State in Nigeria” Ukpong examined the environmental impact of aggregate mining activities of crushed rock industry Akamkpa local government area of Cross River state. By this research, it has been mainly considered dust and noise pollution by the aggregate mining. The results obtained were compared with allowable limit set by national and international regulatory agencies.

The research was revealed that the quarrying in Akamkpa Local Government of Cross River State has had significant adverse environmental impacts on the host communities. The aggregate mining in the area created much negative impact on the environment, objects, plants and human beings. From the result, workers are likely to have hearing loss impairment especially those working in crusher area, also the degree of suspended particulate matter levels are high compared to local and international standard. Hence,
workers and people living in the quarry vicinity are likely to suffer from silicosis if preventive measures are not considered. Ukpong further recommended that a carefully prepared and implemented dust control plan by Federal state, and local regulations and policies can help in reducing the amount of dust emission, if properly followed.

Impacts on water resources by discharge of contaminated water and mine waste:
A major environmental problem relating to mining in many parts of the world is uncontrolled discharge of contaminated water from mines. (Oelofse, 2008) by “Emerging Issues Paper: Mine Water Pollution” discussed discharge of contaminated water from the mine and its impacts to the environment. Some of the countries like South Africa have some experience about the discharge of harmful cadmium, cobalt, copper concentrations. This is not only associated with surface and groundwater pollution, but is also responsible for the degradation of soil quality, aquatic habitats etc.

For most mining projects, the potential of soil and sediment eroding into and degrading surface water quality is a serious problem. According to a study commissioned by the European Union: “Because of the large area of land disturbed by mining operations and the large quantities of earthen materials exposed at sites, erosion can be a major concern at hard rock mining sites. Consequently, erosion control must be considered from the beginning of operations through completion of reclamation. Erosion may cause significant loading of sediments to nearby water bodies, especially during severe storm events and high snow melt periods. “Sediment-laden surface runoff typically originates as sheet flow and collects in rills, natural channels or gullies, or artificial conveyances. The
ultimate deposition of the sediment may occur in surface waters or it may be deposited within the floodplains of a stream valley.

Sediments deposited in layers in flood plains or terrestrial ecosystems can produce many impacts associated with surface waters, ground water, and terrestrial ecosystems. Minerals associated with deposited sediments may depress the pH of surface runoff thereby mobilizing heavy metals that can infiltrate into the surrounding subsoil or can be carried away to nearby surface waters. The associated impacts could include substantial pH depression or metals loading to surface waters and/or persistent contamination of ground water sources. Contaminated sediments may also lower the pH of soils to the extent that vegetation and suitable habitat are lost. “Beyond the potential for pollutant impacts on human and aquatic life, there are potential physical impacts associated with the increased runoff velocities and volumes from new land disturbance activities. Increased velocities and volumes can lead to downstream flooding, scouring of stream channels, and structural damage to bridge footings and culvert entries. In areas where air emissions have deposited acidic particles and the native vegetation has been destroyed, runoff has the potential to increase the rate of erosion and lead to removal of soil from the affected area. This is particularly true where the landscape is characterized by steep and rocky slopes. Once the soils have been removed, it is difficult for the slope to be re-vegetated.

When examine the impacts by the mining on soil, water resources, vegetation cover and air quality, it is highly affected to the people surrounded by the Copper and nickel mines. (Asare and Darkoh, 2001) by the research of “Socio Economic and Environmental impact of mining in Botswana – a case study of the Selebiphikwe copper – nickel mine”
highlighted that the mining sector in Botswana is at present the backbone of the country’s economy. From 1990 up to the present, the contribution of mining has been within the range of 34 to 38 percent per annum. For example, in 1990/91, the GDP contribution from mining was 38.2 percent. However there are any social and environmental impacts are remaining by the research the authors’ addressed following questions:

1. What effects have the mining activities had on human migration, health, economic activities/investments, local employment and incomes?

2. How does the disposal of effluents and waste from the mining activities affect the surrounding environment?

3. To what extent are the environmental policies of the government complied with?

By the study it was identified followings as major negative impacts by the mining:

Destruction of vegetation

Soil contamination

Pollution of water resources

Water pollution

Dust emission

Squatters

High internal migration of labour

Pressure on social services

Social effects (commercial sex)

Alcoholism and conflicts among the youth,

Impacts of mining projects on social values:
The social impacts of large-scale mining projects are controversial and complex. Mineral development can create wealth, but it can also cause considerable disruption. Mining projects may create jobs, roads, schools, and increase the demands of goods and services in remote and impoverished areas, but the benefits and costs may be unevenly shared. If communities feel they are being unfairly treated or inadequately compensated, mining projects can lead to social tension and violent conflict. Environmental Impact Assessment (EIA) can underestimate or even ignore the impacts of mining projects on local people. Communities feel particularly vulnerable when linkages with authorities and other sectors of the economy are weak, or when environmental impacts of mining (soil, air, and water pollution) affect the subsistence and livelihood of local people. Power differentials can leave a sense of helplessness when communities confront the potential for change induced by large and powerful companies. The EIA process should enforce mechanisms that enable local communities to play effective roles in decision-making. Mineral activities must ensure that the basic rights of the individual and communities affected are upheld and not infringed upon. These must include the right to control and use land; the right to clean water, a safe environment, and livelihood; the right to be free from intimidation and violence; and the right to be fairly compensated for loss.

Impacts of migration:

According to the International Institute for Environment and Development: One of the most significant impacts of mining activity is the migration of people into a mine area, particularly in remote parts of developing countries where the mine represents the most important economic activity. For example, at the Grasberg mine in Indonesia the local
population increased from less than 1000 in 1973 to between 100,000 and 110,000 in 1999. Similarly, the population of the squatter settlements around Porgera in PNG, which opened in 1990, has grown from 4000 to over 18,000. This influx of newcomers can have a profound impact on the original inhabitants, and disputes may arise over land and the way benefits have been shared. (These were among the factors that led to violent uprisings at Grasberg in the 1970s and the 1990s.) “Sudden increases in population can also lead to pressures on land, water, and other human needs.

2.6 Legal and regulatory framework related to metal aggregate mining.

As per the Mines and Minerals act No.33 of 1992 aggregate has specified as a mineral. Accordingly, there is a requirement to get license for all the activities related to the aggregate mining. For the issuance of license, it has to follow the regulations prepared by the above act. According to the regulation there is a procedure for the issuance of licenses. Also the Geological Survey and Manes Bureau is the regulatory body for the issuance of licenses.

Accordingly the bureau is issuing two types of mining licenses for aggregate mining. There are

Artisanal mining and

Industrial mining licenses.

Artisanal mining is small scale mining and it is doing manually without using machineries. This license is again divided for two categories. Industrial mining is
mechanized type mining using machineries. Table 2.3 describes the details of the licenses issues by the bureau.

**Table 2.3: Mining License categories and its parameters.**

<table>
<thead>
<tr>
<th>Mining Category</th>
<th>License Category</th>
<th>Monthly Production (Cubes)</th>
<th>Bore Hole Depth</th>
<th>Machineries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Mining</td>
<td>A Large Scale</td>
<td>&gt; 525</td>
<td>Unlimited</td>
<td>Any Machineries</td>
</tr>
<tr>
<td>B Medium Scale</td>
<td>≤ 525</td>
<td>≤ 10 ft</td>
<td>Jack Hammers,</td>
<td></td>
</tr>
<tr>
<td>C Small Scale</td>
<td>≤ 210</td>
<td>≤ 5 ft</td>
<td>Rock Breakers,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Front end Loaders,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Excavators</td>
<td></td>
</tr>
<tr>
<td>Artisanal Mining</td>
<td>A Traditional Mining</td>
<td>≤ 210</td>
<td>≤ 5 ft</td>
<td>Only manual tools</td>
</tr>
<tr>
<td>B Traditional Mining</td>
<td>≤ 35</td>
<td>≤ 5 ft</td>
<td>Only manual tools</td>
<td></td>
</tr>
</tbody>
</table>
When consider the issuance procedure of the mining licenses, a license can be issued for a one year period. To issue a license following clearances has to be taken.

Archaeological clearance

Urban Development Authority clearance

Environmental clearance

If the land belongs to the government body, the consent of the relevant authority should be taken. Followings are the main government authorities which gives the clearances for mining activities.

Mahaweli Authority

Department of Forest

Land Reform Commission

License are issued for a period of one year by GSMB for an aggregate and the conditions under which the aggregate need to be operated and managed are clearly stated by GSMB at the time of issuance of the license. The licenses are subjected to annual renewal. Furthermore, after having obtained the GSMB license, Central Environmental Authority clearance need to be obtained and the explosives permit has to be obtained by the Ministry of Defense. If the aggregate mining is large scale, should be followed Environmental Impact Assessment and needs to be obtained environment clearance prior to issue the GSMB license.
2.7 Geographic Information Systems (GIS) for mining

Geographic Information Systems (GIS) are all systems that store, edit, and analyze, share and display geographic information. GIS applications can be described as tools allowing users to make interactive queries, analyze spatial information, edit data and maps, and present the outcome of these procedures. This chapter describes the most important environmental impacts of mining projects. Environmental management is inherently a spatial undertaking. Therefore using GIS in the field of environmental science has a long history. With the advent of powerful, affordable computers since the 1980s, GIS applications in environmental science grew rapidly.

The mining sector is characterized by complex environmental phenomena and processes which are highly variable in space and time and cover large areas. Environmental management is required for all phases of the mine site including exploration, exploitation and reclamation phases. For the management of environmental information related to a mine site as a part of environmental management GIS is an indispensable tool.

GIS in mining:
With the advent of Geographical Information System (GIS), many mining activities (from exploration to development of the mine, and production to mine rehabilitation) evolved from pure luck to science. Gone were the days when operations would rely on linen and paper maps and old surveys and drawings and superimposing transparencies to create layers and composite images.
GIS replaced old map-analysis processes, traditional drawing tools, and drafting and database technologies.

GIS can be used by mining companies to target mineral exploration, evaluate mining conditions, model mine construction, and display data such as geochemical or hydrological. GIS can also be employed in applying for mining permits, assessing environmental impact, and designing closure and reclamation plans. Although GIS is an
important tool for many industries, this review is mainly an overview of the different uses of GIS in the mining industry and a listing of sources of mining consultants and suppliers.
Chapter Three

METHODOLOGY

3.1 Study Area

For this research, it was selected Anuradhapura District and Gampaha Districts as the study area. The two Districts are discussed in detail below.

3.2 Selection of the study area

Aggregate mines are scattered all over the island distributed unevenly in all the districts. Compare to the some other districts Gampaha is one of the most developed district in Sri Lanka. Also Gampaha district is the nearest district to the Commercial Hub of Colombo and many development projects, foreign investment projects, private sector investments and government sector projects are going on. Gampaha is amongst the thickly populated areas based on the population density. Therefore it was revealed that there is a huge demand for the building materials for the housing and other construction. To fulfill the huge demand, all the locations available with rocks have turned out to be a quarry without concerning and without considering any parameters to be considered to operate a metal quarries.

Anuradhapura is a fast developing district and it can see lot of government investment took place as well as the Northern development projects. Lot of aggregate mining sites located to cater to those projects in North from where the demand was created. As a result of the irrational and unsystematic aggregate mining, many environment and social hazards were there in the district. Therefore it is an essential requirement to find suitable locations for mining to minimize the social and environmental issues. When consider to find suitable locations there may be some hurdles. Because Gampaha is a very highly populated district.
comparatively Anuradhapura district population density is lower than Gampaha district. Therefore, by this research it is expected to do a comparison. Considering the above factors the above districts have been selected as the study area.

3.3 Background details of the study area

Anuradhapura is the provincial capital of North central province. This is bounded by Mannar, Mulathiv and Vavunia districts by North, Kurunegala&Mathale districts by South, Puttalam from west and Polinnaruawa and Trincomalee districts from east. The main town of the district is Anuradhapura. This district has a long history. Anuradhapura was the first capital of the country. This capital city was first founded by King Pandukabhaya in 377 BC. Upon the Arrival of Buddhism with ArahathManindaThero. Anuradhapura became more established city in the country with many rich cultural & religious values.

As per the statistics the total population of the Anuradhapura district amounts to 860,575 while the total extent of the district is 717,900 Hectares. It is the largest district in Sri Lanka. The total forest cover amounts to 210,888 Hectares and the extent of inland reservoirs are 54,290 Hectares.

When consider Gampaha District, which located in the west of Sri Lanka and has an area of 1,387 square kilometers (536 sq mi) is one of the 25 districts of Sri Lanka. It is bounded by Kurunegala and Puttalam districts from north, Kegalle District from east, Colombo District from south and by the Indian Ocean from west. The borders of the district are the Maha River on the north, Kelani River on the south and 1,000 ft contour line on the east. The Capital of the district is town of Gampaha.
As per the statistics Gampaha District consists of 138670 Hectares and out of that 4600 Hectares are inland reservoirs while the forest cover the district is 2230 Hectares. Total population of the district is 2.3Mn. Figure 3.1 shows the location of the study area

Figure 3.1: Study Area

Source: Based on Survey department map created by author 2016

3.4 Topography

The topography of Sri Lanka is marked by great diversity caused by long years of faulting and erosion of the landscape. The central mountainous region with the highest elevations covered by virgin forests and grasslands rises up to about 2,500 m above mean sea level. The surrounding plains, which rise to about 50 to 100 m above sea
level, are largely used for agriculture and homesteads, but still have virgin scrubland where the population distribution is lower. This general topography of the country can be divided into three distinct geographical areas or well-marked peneplains featuring the coastal belt, the plains, and the central highlands.

3.5 Geology

3.5.1 Geology of Anuradhapura District

Ninety percent of the Island of Sri Lanka is underlain by Proterozoic high grade metamorphic rocks with Phanerozoic sediments being restricted to the coastal region. The Precambrian basement is divided into three major lithotectonic units, namely, Highland Complex (HC), Wanni Complex (WC) and Vijayan Complex (VC). Geologically, the areas covered by Anuradhapura District belong to both Highland and Wanni Complexes of Sri Lanka. Highland Complex rocks occupy in the eastern half of the District while Wanni Complex rocks occur in the western half of the District. In addition, minor alluvium covers of main river systems are identified in NW, NE and SW corners of the District.

The Highland Complex forms the backbone of the Precambrian rocks of Sri Lanka. Although the Highland Complex contains metasedimentary and minor metavolcanic lithologies of somewhat different composition, it appears to be part of one lithotectonic unit consisting of supracrustal and igneous rocks. Supracrustal rocks are abundant in the Highland Complex. But their proportion has been overestimated in the past as many of the quartzofeldspathic banded gneisses are of granitoid derivation and charnockitic gneisses (metamorphic transformation of granitoid gneisses into hypersthenic bearing rocks) also make up a significant proportion of these suites.
The Wanni Complex is characterized by thick sequences of ortho gneisses comprises of amphibolite grade, migmatitic, granitic and granodioritic gneisses in northwest and western sections of the country. Towards the northeast, granulite grade variants such as charnockitic rocks and minor granulite grade metasediments are common.

Highland series rocks identified within the District on regional scale are charnockites, charnockticbiotite gneiss, garnet biotite gneiss, garnet quartzofeldspathic gneiss, garnet sillimanitebiotite gneiss, quartzite, crystalline limestone and calc gneiss.

Wanni Complex rocks encountered within the District on regional scale are charnockites, charnockticbiotite gneiss, biotite gneiss, biotite hornblende gneiss, biotite hornblende migmatite, granitic gneiss and granitoid gneiss. These rock types granitic/granitoid rocks and hornblende biotite gneiss/migmatitic gneiss rocks are the predominant rocks occur mainly in western part of the District (in Wanni Complex). Generally, granitic / granitoid and hornblende biotite gneiss/migmatitic gneiss rocks are somewhat poor in strength. Hence, these rocks are not suitable for quarry operation, particularly for activities like road. Figure 3.2 displays the geology of Anuradhapura District.
3.5.2 Geology of Gampaha District

Ninety percent of the Island of Sri Lanka is underlain by Proterozoic high grade metamorphic rocks with Phanerozoic sediments being restricted to the coastal region. The Precambrian basement is divided into three major lithotectonic units, namely, Highland Complex (HC), Wanni Complex (WC) and Vijayan Complex (VC). Geologically the entire Gampaha District lies within the Wanni Complex of Sri Lanka. However, within the narrow western coastal strip of the District, Quaternary sediments cover which is resting on the Wanni Complex rocks is identified. Quaternary deposits of the project area consist of clastic sediments of beach plain. These clastic sediments spread for nearly 2-3km distance in western boundary zone of the District. In this somewhat thin coastal strip, unconsolidated and superficial Quaternary to Recent sediments are encountered. These include sandy, spits & beaches, sandy berms, sand dunes, blown sands, lagoonal and estuarine deposits with minor beach rock and coral formations from west to east direction.

In addition, alluvium cover of present and past river courses in the lowest peneplained region is also encountered throughout the District. The Wanni Complex is characterized by thick sequences of ortho gneisses comprises of amphibolite grade, migmatitic, granitic and granodioritic gneisses in northwest and western sections of the country. Towards the northeast, granulite grade variants such as charnockitic rocks and minor granulite grade metasediments are common. Wanni Complex rocks encountered within the District on regional scale are charnockites, charnockiticbiotite gneiss, biotite gneiss, biotite hornblende gneiss, biotite hornblende migmatite, granitic gneiss, granitoid gneiss and cordierite gneiss.
Of these rock types, granitic/granitoid rocks and hornblende biotite gneiss/migmatitic gneiss rocks are the predominant rocks occur mainly in central part of the District. Generally, granitic / granitoid and hornblende biotite gneiss/migmatitic gneiss rocks are somewhat poor in strength. Hence, these rocks are not suitable for quarry operation, particularly for activities like road construction. However, some granitic / granitoid rocks exhibits required strength and as a result, some of the granitic / granitoid rocks could be used for activities like road construction.

Within the eastern and southern part of the District, charnockite / charnockitic gneiss and cordierite gneiss rocks are identified. These charnockite / charnockitic gneiss and cordierite gneiss rocks are suitable for road construction activities.

Within the central and eastern parts of the District, Wanni Complex rocks represent series of synformal and antiformal structures. Several tenths of kilometers long and NNW-SSE directed significant shear zones are identified within the western part of the District. In addition, NW - SE and NW – SE trending and several tenths of kilometers long prominent lineaments could also be encountered within the District. Figure 3.3 displays the geology of Gampaha District.
Figure 3.3: Geology Map of Gampaha

Source: Geological Survey and Mines Bureau - 2010
3.6 Methodology used for the research

For this research following methodology was applied

Data Collection

For this research required data was collected from several sources as mentioned in below. It was integrated the relevant data as required by the study and in order to analyze the data and to arrive at conclusions

Table 3.1: Data used

<table>
<thead>
<tr>
<th>Data used and data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Land use data 1:50,000 and 1:10,000 - Survey Department</td>
</tr>
<tr>
<td>2. Registered Mining locations – GSMB</td>
</tr>
<tr>
<td>3. GPS points map - GSMB</td>
</tr>
<tr>
<td>4. Initial Environment Examination Reports(IEER) - GSMB</td>
</tr>
</tbody>
</table>

Source: Author created – 2016

The steps applied for the research mentioned below

Step 01

Selection of the sample:

For the research, it was selected six aggregate mining locations from both districts. Accordingly it was selected three mining sites from Anuradhapura district and other three mining sites from Gampaha district. These two districts were selected because they represent different land use and environment settings.
The mining location data was collected from unpublished report at GSMB. The selected locations are large scale mining locations. They were granted Industrial mining category “A” licenses. “A” category license is issued for large scale mining activities.

Step 2

All the mining locations were digitized and created a GIS shape file

Surrounding land use pattern was identified using Google image and land use maps. To identify the buildings and infrastructure facilities clearly GPS survey reports were used. These reports have been prepared as a requirement of Initial Environment Examination (IEE) procedure.

Step 3

It was demarcated buffers from each mining site as the next step. These buffers were created from 100 meter and 300 meter radius from the mining sites. Creating buffers proximity analysis tool was used in GIS platform.

Step 4

As the next step it was identified the hierarchy of the significance of the surrounding land use. Accordingly, the following land use categories were taken in to consideration. And mentioned below according to the given hierarchy.

Buildings - This includes houses, Religious places, schools, government or private institutions etc.

Road network – All the major and minor roads were included
Water body – Tanks and reservoirs were included

Water streams – Rivers and streams were included

Forest - All type of forests were considered

Agricultural and scrubs - Plantations, Chena and scrubs were included in this category

Out of above categories higher significance was given to buildings, road network and water bodies.

Step 5

The distance to each building, roads and water streams from the mine site were estimated. Also percentages of selected land use categories within the 300 meter buffer limit was calculated.

Step 6

Categorized the Mining sites as suitable, moderate and not suitable mines

The following parameters were considered to categorize the suitability levels.

Suitability for large scale mining

If the following parameters are fulfilled,

i) There are no any buildings, within 300 meter radius from the mine and;

ii) There is no any type of road or any water body /water streams within 100 meter radius from the mine.
iii) The surrounding area up to 300 meter distance from the site more than 75% covered by the scrubs, agricultural lands or forest land.

Suitability for Medium scale mining

i) There are no any building or road or water body or major water stream within 100 meter distance from the mine site, and

ii) If there are any building, road and water stream or water body beyond 101 meter and within 300 meter distance from the mine site with following conditions

   - Buildings density - should be less than 30 numbers.
   - Road category - should not be a major road
   - Size of the water body - should not be a major tank or river

iii) If the home land percentage of the land use within 300 meter range not exceeding more than 50%

Not suitable

If consists any of following factors,

i) If located any of building, main road or large water body or major water streams within 100 meter distance from the mine site.
Chapter Four

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter describe the relationship of the aggregate mining locations with sensitive factors such as buildings, water body, roads network, streams and surrounding land use in two districts. As describe in methodology chapter, two districts were selected for the research. From these two districts, it was selected six mining sites having Industrial Mining “A” category license issued by the Geological Survey and Mines Bureau for operating large scale mining. Accordingly, the distance to the buildings, water body, and roads from the mines were measured and analyzed. Also percentages of each land use pattern were calculated. Analyzing all the factors, it was categorized the mines as Suitable, moderate and not suitable mines. Also identified the scale of the mining such as large scale industrial mining, medium scale industrial mining.

For the easy reference, it was numbered three mines in Anuradhapura district as

Mine A 1,
Mine A 2 and
Mine A 3.

Also numbered mines of Gampaha district as

Mine G 1,
Mine G 2 and
Mine G 3.

The figure 4.1 shows the Anuradhapura district selected mines locations and figure 4.2 shows the Gampaha district selected mines locations.
Figure 4.1: Aggregate Mines Locations in Anuradhapura District

Source: Based on survey department map created by author 2016
Figure 4.2: Aggregate Mines Locations in Gampaha District

Source: Based on survey department map created by author 2016
4.2 The distance between mining locations and buildings surrounded by the sites

As the first step of the analysis measured the distance between the mines and each building. For this purpose it was mainly used GPS (Geographic Positioning System) survey reports and Google images. Table 4.1 shows that the distances to each building from each mine.

Table 4.1: Distances from the each mine location to buildings in the study area

<table>
<thead>
<tr>
<th>Mining site No</th>
<th>Total no. of buildings</th>
<th>Within 100 meter</th>
<th>Within 101 to 300 meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A1</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Mine A2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine A3</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Mine G1</td>
<td>66</td>
<td>5</td>
<td>61</td>
</tr>
<tr>
<td>Mine G2</td>
<td>21</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Mine G3</td>
<td>20</td>
<td>-</td>
<td>17</td>
</tr>
</tbody>
</table>

Source: Created by Author - 2016

According to the table 4.1 and figure 4.3, there are many buildings situated surrounded by the mine A1. There are 15 buildings located within 300 meter distance from the mine. Not only that, there are 5 buildings can be seen within 100 meter distance range. This type of mines cannot be considered as favorable mines for operating large scale mining.

The table 4.1 and the figure 4.4 show that the A 2 mine is located in the area away from the buildings. There are no any buildings within 300meter distance range. This mine is situated in a forest / scrub land. This location can be considered as suitable location.

Also figure 4.5 shows that, the mine A3. When considered this mine, it can be seen there are no any buildings within 100 meter distance range. The distance 101 meter to
300 meter distance also can see only one building. This building also situated at the
distance of 279 meter distance.

When considered G1 mine there are five buildings located within 100 meter radius. In
this site, it can be seen very serious situation. Because there are 61 buildings can be
seen within 101 meter and 300 meter distance range leading to not suitable category.
Figure 4.6 shows that the G1 mine and surrounded buildings. Operating a large scale
mining project under this type of background can be very harmful to the surrounding
people.

Also by the figure 4.7 shows that the mine G2. It is showing that in Mine G2 has 21
buildings within 101 meter to 300 meter radius. It does not have buildings within 100
meter distance. When considered Mine G3, this mine also has 17 buildings within
101 to 300 meter range and no any buildings within 100 meter distance range. The
figure 4.8 shows the distribution of the buildings of mine G3.
Figure 4.3: Buildings and Roads in 100m & 300m Distance at Mine A1 in Anuradhapura District

Source: Based on survey department map created by author 2016
Figure 4.4: Buildings and Roads in 100m & 300m Distance at Mine A2 in Anuradhapura District

Source: Based on survey department map created by author 2016
Figure 4.5: Buildings and Roads in 100m & 300m Distance at Mine A3 in Anuradhapura District

Source: Based on survey department map created by author 2016
Figure 4.6: Buildings and Roads in 100m & 300m Distance at Mine G1 in Gampaha District

Source: Based on survey department map created by author 2016
Figure 4.7: Buildings and Roads in 100m & 300m Distance at Mine G2 in Gampaha District

Legend
- Buildings
- Rock
- 100 Meter Buffer from the Mine
- 300 Meter Buffer from the Mine

Source: Based on survey department map created by author 2016
Figure 4.8: Buildings and Roads in 100m & 300m Distance at Mine G3 in Gampaha District

Legend
- Buildings
- Rock
- 100 Meter Buffer from the Mine
- 300 Meter Buffer from the Mine

Source: Based on survey department map created by author 2016
4.3 The distance between mining locations and roads surrounded by the sites

As the next step of the analysis, the distance between the mines and each road surrounded by the mines were measured. For this purpose, mainly used land use maps, GPS survey reports and Google images. For this measurement main roads and minor roads were considered. The table 4.2 show that the distances to each road from each mine.

Table 4.2: Roads located around the mines

<table>
<thead>
<tr>
<th>Mining site No.</th>
<th>Road category</th>
<th>Nos.</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A 1</td>
<td>Main road</td>
<td>1</td>
<td>175 meter</td>
</tr>
<tr>
<td>Mine A 2</td>
<td>None</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine A 3</td>
<td>None</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine G 1</td>
<td>None</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine G 2</td>
<td>Minor roads</td>
<td>3</td>
<td>Beyond 60 meter</td>
</tr>
<tr>
<td>Mine G 3</td>
<td>Minor road</td>
<td>1</td>
<td>Within 50 meter</td>
</tr>
</tbody>
</table>

Source: Created by Author - 2016

The table 4.2 shows that from the 6 mines there are three mines located nearby the roads. It shows that the mine A1 is located closed to the main road. Also there are no any roads can be seen around the mines A2, A3 and G1.

4.4 The distance between mining locations and water body / streams surrounded by the mines.

By the research it was examined the distance to the water body or water streams from the mines. For this purpose, it was used Google images and land use maps.
Table 4.3: Water body located around the mines

<table>
<thead>
<tr>
<th>Mining site No.</th>
<th>Water body/Stream and part of the tank</th>
<th>Nos.</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A 1</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine A 2</td>
<td>Small water stream</td>
<td>1</td>
<td>Within 100m</td>
</tr>
<tr>
<td>Mine A 3</td>
<td>Small water stream and part of the tank</td>
<td>2</td>
<td>Within 300m</td>
</tr>
<tr>
<td>Mine G 1</td>
<td>none</td>
<td></td>
<td>No water body</td>
</tr>
<tr>
<td>Mine G 2</td>
<td>none</td>
<td></td>
<td>No water body</td>
</tr>
<tr>
<td>Mine G 3</td>
<td>none</td>
<td></td>
<td>No water body</td>
</tr>
</tbody>
</table>

Source: Created by Author 2016

The table 4.3 shows the availability of water body or streams closed by the mines. According to the table it is cleared that there are two mining sites are situated near by the water stream or water tank. It was observed that mines A2 and A3 are located nearby the tank and streams. However these are small water stream and small water stream. When considered water body or water streams criteria, there is a favorable situation for operating large scale mines.

4.5 Land use percentages surrounded by the mines sites

As another step of the analysis was calculation of the percentages of surrounding land use pattern of each mine. For this purpose, it was used land use maps and further used Google images. Table 4.4 shows that the percentages of land use patterns within 300 meter surrounded by each mines.
Table 4.4: percentages of land use patterns of 300 meter surrounded from the mines

<table>
<thead>
<tr>
<th>Mining site No.</th>
<th>Home lands</th>
<th>Forest</th>
<th>Agricultural</th>
<th>Scrubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A1</td>
<td>15</td>
<td>00</td>
<td>00</td>
<td>85</td>
</tr>
<tr>
<td>Mine A2</td>
<td>00</td>
<td>10</td>
<td>00</td>
<td>90</td>
</tr>
<tr>
<td>Mine A3</td>
<td>00</td>
<td>15</td>
<td>00</td>
<td>85</td>
</tr>
<tr>
<td>Mine G1</td>
<td>20</td>
<td>00</td>
<td>80</td>
<td>00</td>
</tr>
<tr>
<td>Mine G2</td>
<td>15</td>
<td>00</td>
<td>85</td>
<td>00</td>
</tr>
<tr>
<td>Mine G3</td>
<td>30</td>
<td>00</td>
<td>70</td>
<td>00</td>
</tr>
</tbody>
</table>

Source: Author created - 2016

The table 4.4 shows that four out of six mines are located within the home lands in different percentages. Home land percentage of G 1 and G 3 mines are respectively 20% and 30%. Also it can be seen that in Anuradhapura district dominated land use is scrubs lands. A2 mine 90%. According to the table data, it can be observed that scrubs land can be seen in all the mines in Anuradhapura district. The A 2 mine area totally covered by the scrubs and forest lands. In Anuradhapura mines no any agricultural lands are situated.

4.6 Analysis of the suitable locations for mining in the study area

By this research, it was expected to find suitable locations for aggregate mining. To achieve this objective it was examined relationship of following factors which can be affected to the surrounding area by the mining activities.

- Buildings
- Roads
- Water body/ water streams
- Land use
The above factors were examined and identified the existing situation of all mining locations. For identifying the suitable locations it was analyzed each factor separately and details describe below.

**Distance between mines and building**

When examine the above factor it was identified most of the sites are located closed by the residential houses. By the table 4.1 shows the nature of the buildings situated around the mines.

According to the parameters decided to categorize the suitability, the following factor is one of the main factor.

For the large scale mining,

There should not be any buildings within 300 meter distance from the mines

| Table 4.5: Availability of the surrounded land use of the mines for large scale mining. |
|-----------------------------------------------|-----|-----|-----|-----|-----|-----|
| Parameter                                      | A1  | A2  | A3  | G1  | G2  | G3  |
| Building within 300m                          | yes | No  | yes | yes | yes | Yes |
| Main roads                                     | yes | No  | no  | no  | no  | No  |
| Minor roads                                    | no  | No  | no  | no  | yes | Yes |
| Large water body, water stream within 100m     | no  | No  | no  | no  | no  | no  |
| Surrounding area up to 300m more than 75% covered by scrubs, agricultural or forest land | yes | yes | yes | yes | yes | Yes |

Source: Author created - 2016

The table 4.5 has summarized the considered factors for large scale mining. From the six mines it shows that the requirement for operating large scale mines are fulfilled only one mine. It was in mine A2 it comes from Anuradhapura district. No any other mines can be selected for large scale mining. Because the main reason is all these mines are situated near by the buildings. When consider other factors it was given a
higher significance to the roads. It can see within 300m distance from the A1 mine it is running a main road. This type of situation is very unfavorable for operating a large scale mining without disturbing to the surrounded area.

After rejecting five out of six mines for operating large scale mining, it was examined the moderate level suitability of operating mines in medium level. Considered parameters and mines details are showing in table 4.6. As the mine A2 is suitable for the large scale mining it was considered all other mines except A2 mine.

Table 4.6: Availability of the surrounded land use of the mines for medium scale mining.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A1</th>
<th>A3</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building within 100 meter distance</td>
<td>Yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>No</td>
</tr>
<tr>
<td>No of buildings within 101 m - 300 m</td>
<td>10</td>
<td>01</td>
<td>61</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>Road category</td>
<td>Main</td>
<td>-</td>
<td>-</td>
<td>Minor</td>
<td>Minor</td>
</tr>
<tr>
<td>Size of the water body</td>
<td>-</td>
<td>Small water stream part of the tank</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Home land percentage within 300 meter</td>
<td>15</td>
<td>00</td>
<td>20</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: Author created - 2016

According to the table 4.5, it is showing the availability of surrounded land use of the mines. For the moderate level, it has been decided to 100 meter buffer zone without buildings for medium scale mining. The table shows that the building are located within 100 meter distance from the Mine A1 and mine G1. Accordingly, both of the mines are categorized as not suitable lands for the mining.
After rejecting mine A1 and G1, it was considered A3, G2 and G3 mines for the medium scale mining, as there are no any buildings within 100 meter distance from the mines. Accordingly, considered building density. For this criteria measured number of buildings within 101 to 300 meter distance range. It was examined that A3 mine has only one building. And G2 and G3 mines have 21 and 17 buildings respectively. As the methodology section explained, it has been decided to buildings density should be less than 30 for the moderate category. On this criteria the above three mines were suitable for medium scale mining, if the following parameters are fulfilled.

Accordingly it was examined the other three criteria. It was found out no any road is lying around the A3 mine and only minor roads are lying near by the G2 and G3 mines. Also there are no any water body or water streams nearby G2 and G3 mines. Only a small scale stream and part of the tank was observed nearby the A3 mine.

Also it was calculated the land use percentages of the above three mines. The all three mines home land percentage was less than 50% of the 300 meter range. Therefore A3 mine and G2, G3 mines were selected as moderate category. These locations can be operated medium scale mining projects. Figure 4.9 shows the suitability level of Anuradhapura district and figure 4.10 shows the suitability level of the Gampaha district.
Figure 4.9: Suitability Levels of Aggregate mines locations in Anuradhapura Districts

Source: Based on survey department map created by author 2016
Figure 4.10: Suitability Levels of Aggregate mines locations in Gampaha District.

Source: Based on survey department map created by author 2016
According to the analysis it was selected only one mine as the suitable location. It was A2 mine in Anuradhapura district. Also three mines were selected as moderate. These were A2 in Anuradhapura district and G2 and G3 in Gampaha district. Both mines from both districts were rejected. These are A1 in Anuradhapura district and G1 in Gampaha district.
Chapter Five
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of this research was to identify the suitable locations for the aggregate mining. The study areas were Gampaha District and Anuradhapura District. In order to do the analysis it was utilized the GSMB data available pertaining to aggregate mining sites and GPS reports data related to buildings. Also used 1:50,000 maps available in survey department. For the research used GIS tools and techniques. By the research, mainly considered buildings, roads, water body, and water streams as main significant features. Also considered home lands, agricultural lands and forest lands as significant land use pattern. It was examined the relationship between the above features and the mines. It was identified that the finding of suitable locations for large scale mining is a difficult task with the present environment which is highly populated areas. Because of operating of aggregate mines should be a lesser environmental and human impact.

The importance of the study can be viewed in the light of the growing environmental concern throughout the world. The world is moving towards a much green environment, less pollution, safer place for human habitation and by a large an environmentally responsible citizen and nation. In the light of that, environmental friendly industries are very important for an economy in a country. This applies to both developing nations as well as to developed nations.

By this research there are several factors were considered to find suitable locations for the mining. The highest significance was given to the buildings. Because of the human impacts are very significant when operating aggregate mining. Also it was considered other important factors such as Surrounding roads, water bodies, water streams, home lands and cultivations etc. It was successfully figured out the suitable and not suitable areas for aggregate mining and thus it was successful in achieving the main objective of the study.

For the study, it was selected two districts, because the existing environment conditions are different in these two districts. When compared two districts, Anuradhapura is a large
district than the Gampaha district. On the other hand, population density of Gampaha district is higher than the Anuradhapura district.

According to the research, it was identified that suitable level for the mines was very limited. From six mining sites, it was only one mining location selected as suitable location. As a percentage, this value was 16.6%. Also, it was examined the moderate percentage level. This is also very lower level. The moderate percentage was 33.3%. According to these figures, almost 50% of the sites are in not suitable level for operating large-scale mines. On the other hand, in Gampaha district, it was unable to find any mines for large-scale mining. The main reason to reject most of the selected location is the nearby buildings.

When compared suitability levels in two districts, in Anuradhapura district, 33% of mines are suitable for large-scale mining, and another 33% of the mines are suitable for medium-scale mining. Not suitable percentage is also 33%. In Gampaha district, it was not identified any location for suitable category for large-scale mining. It was identified that 66% of the mines are of moderate level. These locations are suitable for operating medium-scale mining. Also, 33% mines are rejected as not suitable mines. The selected locations for medium-scale mining also surrounded by many houses. Therefore, it is a prime requirement to insist to the project owners to carry out mining activities strictly following the safety conditions given by the authorities.

5.2 Recommendations

The mining industry remains the backbone of many economies in the world. For the development projects, one of the basic requirements is construction raw materials. As a basic construction raw material, aggregate mining industry has a major role in the society. Although the aggregate mining industry is very essential to the country’s economy, by the unsystematic mining may cause many negative impacts to the surrounding environment. Specially mining activities can be badly affected to the people who nearby the mines. Therefore, it is very important to find very suitable locations for the mining. However, in Sri Lanka, most of the mines are located near by the residential...
area. This situation has become a social issue. By this research, it was able to identify this circumstance. Also it was found out suitable, moderate and not suitable locations for the mining.

Therefore it is very important to introduce clear mechanism for mineral industries. In this process the main and basic requirement is finding a suitable location for the mining.

During the research it was identified that the most of the location were not in a suitable level for the mining due to the surrounding land use pattern. Most of the mines were not located in the best of the location to minimize the impact to human habitation, reduce the social impact. It was identified that the surrounding land use pattern has been neglected when conducting mining.

During the research it was identified that some mining sites are located within 100 meter distance range. This type of locations is unsuitable for the mining and it is very dangerous to the surrounding residences.

With the mega development projects it is very essential requirement to find aggregate as a basic raw material. Therefore the relevant authorities have a responsibility to do the proper exploration and find very suitable locations, especially in remote areas. Also to minimize the social and environmental impacts it has to be taken action to control the permission already given for the not suitable areas.

As identified the requirement of the aggregate as a raw material, it is a requirement to reserve the mining deposits area for the future usage. Therefore, the authorities can explore untouched aggregate rock outcrops in remote areas and demarcate suitable buffer zones. Also requirement to make regulatory framework to avoid construction within the reserved area.
REFERANCE


Exploration of Sri Lankan Industrial Minerals Resources - Research Committee on Geology & Mineral Resources of the National Science Foundation (NSF) 2004


Gazette Extraordinary of the Democratic Socialist Republic of Sri Lanka 1997.01.10 No.LDB 3/92/ii

Gazette Extraordinary of the Democratic Socialist Republic of Sri Lanka 2005.11.10 No.1418/27

Gazette Extraordinary of the Democratic Socialist Republic of Sri Lanka 2009.012.01 No.1582/36


Gunasekera, R., 2011, Lanka Mineral Sands ramps up and seeks partners: Industrial Minerals, no. 530, November, p. 21


Ileperuma O.A., 2015, Mineral Based Industrial Development & Sri Lanka’s Lethargic Syndrome- “Colombo Telegraph” Colombo

Impact of Mining and Resource Development: 2015 A Case Studies for Eyre Peninsula Councils- The South Australian Centre for Economic Studies- 2013


International Institute for Environment and Development 2002 "Breaking New Ground: Mining, Minerals and Sustainable Development: Chapter 9:


MINEO Consortium, 2000 “Review of potential environmental and social impact of mining” 26
http://www2.brgm.fr/ mineo/UserNeed/IMPACTS.pdf

Guidebook for Evaluating Mining Project EIAs


Parliament of Democratic Socialist Republic of Sri Lanka 1993 National Gem and Jewellery Authority Act No.50


http://cea.nsf.ac.uk/bitstream/handle/1/4143/06206.pdf?sequence=1&isAllowed=y accessed on 26/11/2015
Anexture i

Aggregate mines location GPS point (X, Y coordinates)

<table>
<thead>
<tr>
<th>Mine No</th>
<th>Name</th>
<th>District</th>
<th>Village</th>
<th>GPS Points X</th>
<th>GPS Points Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>IPC AGRO</td>
<td>GAMPAPA</td>
<td>DIVULAPITIYA</td>
<td>120544</td>
<td>225813</td>
</tr>
<tr>
<td>G2</td>
<td>B.C. DAREJU</td>
<td>GAMPAPA</td>
<td>DIVULAPITIYA</td>
<td>120781</td>
<td>227180</td>
</tr>
<tr>
<td>G3</td>
<td>SENOK</td>
<td>GAMPAPA</td>
<td>KOTADENIYAWA</td>
<td>124322</td>
<td>231075</td>
</tr>
<tr>
<td>A1</td>
<td>MAGA</td>
<td>ANURADHAPA</td>
<td>KEKIRAWA</td>
<td>183817</td>
<td>319083</td>
</tr>
<tr>
<td>A2</td>
<td>MAGA</td>
<td>MAGA</td>
<td>KEBITHIGOLLEWA</td>
<td>187728</td>
<td>373058</td>
</tr>
<tr>
<td>A3</td>
<td>MAGA</td>
<td>ANURADHAPA</td>
<td>NOCHCHIYAGAMA</td>
<td>143184</td>
<td>341087</td>
</tr>
</tbody>
</table>