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Environmental Impact Assessment of Quarrying Activities on the downstream section of the Big Akaki Catchment. Addis Ababa, Ethiopia

A thesis submitted to Addis Ababa University School of Earth Sciences Graduate Studies as Partial Fulfillment of Master of Science in Geological Engineering (Environmental Geology and Geohazards) Stream.

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This is to certify that thesis prepared by Samrawit Yimame, entitled as Environmental Impact Assessment of Quarrying Activities on the Downstream Section of Big Akaki Catchment submitted in partial fulfillment of the requirements for degree of Master of Science in Environmental Geology and Geohazards fulfill the regulations of the university and meets the expected standards with respect to the originality and quality.

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Author declaration

I declared and confirm by my signature below this thesis is my work. I followed all ethical and technical principles of research in the preparations, data collection, data analysis, and compilation of this thesis. Any scholarly article which is included in this thesis has been acknowledged through the reference.

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Abstract

This study focused on the assessment of the impact of quarrying on the natural environment (water resources and land use land cover), and the vulnerability of the community downstream of the quarry sites within the Big Akaki River catchment, using an integrated geological, hydrogeochemical, land use/land cover and social impact assessment methods. Initial reconnaissance survey to select water sampling areas and assessment of overall operations of quarrying in the area was followed by surface water sampling at the quarry sites and upstream and downstream of the quarry sites, along three major rivers in the catchment. These water samples were analyzed for major physical and hydrogeochemical parameters. The results show that the turbidity, TDS, Temperature of the river waters and most of the ions increased their concentration from upstream to downstream of the quarry sites considered, indicating the clear impact of the quarrying activity on the rivers and directly affecting the community using these river waters for domestic and other related activities. However, it should be noted that this might not suggest chemical pollution only because of quarrying.

The land use/land cover change assessment was done by using spatiotemporal data of the area between 2000 and 2020, which enabled to assess~20 years of quarry expansion rate, calculated from the classified image by using standard remote sensing and GIS methods and tools. Landsat_7 ETM+, SPOT-5, SPOT-7 and Quickbird raster data for the years 2000, 2006, 2016 and 2020 have been used land use land cover maps for the years considered, and the net change between 2000 and 2020 have been produced and the change has been analyzed. The results indicate that quarrying sites have been expanded by about **692.68 ha,** mainly at the expense of the cultivated (agricultural area) which has decreased by **3941.19 ha** during the same period.

The social impact assessment conducted by a systematic, structured open and closed-ended questionnaire survey of the quarry workers and residents within the immediate vicinity of the quarry sites indicate multiple problems including dust, noise, vibration, and accumulated water in the abandoned quarry sites caused problem on residents and quarry workers. The study indicates that unless properly mitigated by all responsible bodies, the quarrying activity in the area will continue to cause serious damages to the natural environment and the community.

Key words: Environmental impact assessment, River Water, Quarrying, LULC, Upstream, Downstream, Quarry workers, Resident, Questionnaire, Physiochemical, Parameter.

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Table of contents **Page**

Table of figure **Page**

Acronyms (Abbreviations)

AA	Addis Ababa
C°	Degree Celsius
Cm	Centimeter
DEM	Digital Elevation Model
EC	Electrical Conductivity
EMA	Ethiopia Mapping Agency
ETM+	Enhanced Thematic Mapper Plus
GIS	Geographical Information System
GPS	Global Positioning System
GSE	Geological Survey of Ethiopia
Ha	Hectare
LULC	Land Use Land Cover
m.a.s.l	Meter above sea level
Mg/L	Milligram per Liter
MS	Milli Simin
T°	Temperature
TDS	Total Dissolved Solid
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WHO	World Health Organization

Chapter One

Introduction

1.1 General background

The rapid growth of construction activity, to meet the modern-day requirements of increasing population and housing and infrastructure development needs of the society has immensely boosted the demand for building materials. Rock quarrying continues to play a major role in this process. However, the activity has caused serious environmental degradation and socio-economic conflicts (Lad and Samanta, 2014). Quarrying is the process of obtaining natural resources, mostly rocks, found on the surface or below the ground. According to Vincent et al., (2012) the difference between mining and quarrying is that quarrying extracts nonmetallic rocks and aggregates while mining excavates the site for metallic mineral deposits. Some of the stones extracted are sandstone, limestone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock. The suitability of the stone for quarrying depends on its quality, the possibility of cheap and ready conveyance to a large market; and its inclination and depth below the surface. Quarrying activity exerts tremendous Pressure on limited soil and water resources, thus increasing the rate of erosion process and subsequent damage of existing arable lands. Quarrying operations can intensively modify preexisting ecosystem and disturb hydrogeological regimes. They can strongly modify the sub-stream, transform landscape patterns and integrity, destruct natural succession, as well as change genetic resources. In addition, mineral extraction can aggravate dust emission, noise pollution and disturbance due to increased traffic (Stehouwer et al., 2006). Quarries produce a lot of dust and noise and this affects the quarry workers and people living close to them (Eshiwani, 2014).

Quarrying activities played a great role in economic growth but; it leads to negative effects on the environment, such as land degradation, surface water pollution and groundwater depletion. Most of the time quarry sites mainly were agricultural and grazing land before the location of the quarries, and when the quarrying companies were established a lot of vegetation has been lost. Both the operations of quarrying and crushing being a hazard to the environment as well as to human beings, they require continuous monitoring of the workplace as well as the workers. Mining operations cause deforestation, loss of vegetation, soil erosion, groundwater level changes and pollution, which can lead to ecological imbalance. There is still potential for damage to the environment, particularly with water contamination. The activity discharges dust that settles not only on land, plants and trees but also on surface waters used for drinking and other domestic use (Eshiwani, 2014). Dumping of waste rock from the quarry in open areas disrupts drainage and causes diversion of rivers and streams into farming areas and results into flooding of crop fields (Stehouwer et al., 2006).

According to Ayodele & Lameed (2010) quarrying projects are usually sited for and embarked upon to satisfy the social and economic needs of the company without the need and aspiration of the people that are directly concerned at the nearest neighboring communities as well as the impact on the primary environment. In open-cast mining and quarrying environment, vast areas of land usually exist, leaving behind stagnant ponds or open pits. quarrying may have also a lasting effect on the environment in that most of the quarries leave a scar on the Earth’s surface and some of the quarries have been unable to reclaim the land to make it productive again as it was before. This destroys the beauty of the land permanently making it uneconomical (Eshiwani, 2014).

The extraction of construction material in Addis Ababa has been a source of public conflict for many years, especially in terms of the quarry operation, displacement of people, rehabilitation of quarry sites, and land after-use. One of the main reasons for the conflict has been the extraction sector's inability to adjust to the existing laws (Hailu Worku, 2018). According to Dejene Worku (2016) quarry operation have created problems related to change of landscapes, expansion of erosion, destruction of crops, stunted growth and reduction of agricultural yields which mainly happened due to contamination of soil, coating of vegetation, soiling of property, water pollution, loss of aesthetic values and loss of biodiversity.

The dramatic expansion in urbanization led to more demand of construction materials leading to an unprecedented expansion of quarrying activities in easily accessible areas like eastern Addis Ababa with an appropriate geologic setting (ignimbrites and basalts), in turn leading to massive land degradation and loss of fertile land due to forced expansion of urban centers (Yayesh Mihritie, 2017).

The quality of groundwater in the Akaki well field depends on the depth as well as the pumping rate of wells. In the area, where large-scale industries have been expanding, pollution due to the disposal of untreated industrial waste seems to be forthcoming. In addition, quarrying and agricultural activities that increase the influxes of solutes to water are widespread and locally increasing concentrations from harmless to toxic levels. The groundwater movement is sub-parallel to the surface water flow direction and more or less controlled by the topography of the area. The flow lines, sketched perpendicular to the contour lines, show the direction of groundwater flow. Land use pattern of the area is diverse but broadly classified into urban, agricultural and open areas with rock exposures (grazing sites). Scattered settlements are also found. Quarries are common near Tulu Dimtu. Prospecting for new quarry sites and expansion of existing ones is going on (Leta Gudissa, 2010). However, previous studies address the negative impact of different industries on the water quality of the Akaki well field, but detailed analysis of quarrying impact on surface water is needed because it has a major influence to the groundwater quality indirectly.

Generally, this study was try to address most of the problems stated above, environmental and social impact of quarrying activities such like; surface water impact due to quarrying activity, this was studied within collected surface water samples from three adjacent rivers and by analysis their physicochemical result before, within and after crossing quarrying sites and. Land use land cover change detection for twenty years back this also completed by using special and temporal data of the area like high-resolution images from 2000-2020to indicate quarry expansion its impact on land degradation. Additionally, this study was assessed the overall impact of a quarry operation on the quarry workers and nearby community, this objective was completed by conducting open and closed-ended questionnaires to respondents from five selected quarry sites.

1.2 Statement of the problem

Urban development in the capital city Addis Ababa due to rising in population and economic growth is rapidly growing; it increases significant demand of geological resources like construction materials and hence leading to an unprecedented expansion of construction material extraction within and in the suburbs of the city. Now a time; huge infrastructure projects are undertaken in Addis Ababa, most of which need the supply of quarry materials. Quarries are among the most potential supplier of various construction materials (Yayesh Mihiretie, 2017). According to Semere Mulat (2013) the environmental focus given by the producers is very small. Although it is not an easy task to evaluate the monetary value of environmental protection activities performed on quarry sites it can be considered as very negligible. Measurements should be always taken to investigate the impact that the operation in the quarry plant has on the surrounding environment and inhabitants.

Some studies have been conducted to investigate the environmental impact of quarrying activities in Addis Ababa and its surrounding (e.g., Yayesh Mihiretie, 2017; Enatfenta Melaku 2007; Semere Mulat, 2013; Zelalem Abate, 2016 and Hailu Worku, 2018). Previously most of the studies have attempted to address land degradation (land use land/cover change) and socio-economic impact of quarrying activity. As stated in Yayesh Mihiretie, (2017) the ground level change due to quarrying activities, urbanization and quarry expansion impact on land use/land cover change in eastern Addis Ababa. The current study was trying to analyze surface water impact due to quarrying activities on the lower catchment of 'Telku Akaki' and analyze land / use land cover change due to quarry expansion in the study area by using high-resolution satellite image. The area has been investigated very well to indicate water impact by different sources of pollutants (such as industrial, domestic, agricultural etc.). But quarrying activity impact the streams and rivers as well as groundwater has been generally overlooked. For this reason the current study investigates surface water impact due to quarrying activity by analyzing physiochemical parameter of the water before and crossing the drainage areas of the quarry sites to assess quarrying impact on the surface water parameter change.

Also this study assessed the impact of quarrying activity on the nearby communities through structured open and close-ended questioners. These have been done to assess noise, dust and vibration impact of the quarry activities; also it was trying to assess the impact of accumulated water on the abandoned and active quarry sites on the community. Most of the time abandoned quarry sites are very hazardous to nearby communities. For instance, accumulated water on abandoned quarry has been caused children's death when they try to swim in the ponds in summer season.

1.3 Location of the study area

The proposed study area is located in central Ethiopia in the south of Addis Ababa, specifically in the Akaki Kality sub-city, which is downstream of Big-Akaki catchment. The area is geographically bounded by UTM coordinates of 974000N-989000N and 474000E-489000E as showed in fig 1.1, the elevation of the area ranges from 2020 to 2355 m.a.s.l also the total study area cover about 11511ha.

1.4 Objective

1.4.1 Main objective

The main objective of this study is to assess the major impact of quarrying activity in the natural environment especially on surface water and to recommend the best mitigation measures in order to minimize any negative impacts of quarry activity.

1.4.2 Specific objective

- To analyze adjacent river water impact resulted from quarrying activities;
- To assess land-use/ land cover-change between 2000 and 2020 specifically to detect quarrying expansion;

– To assess the impact of quarrying activities on the quarry worker and communities in the near vicinity of quarry site.

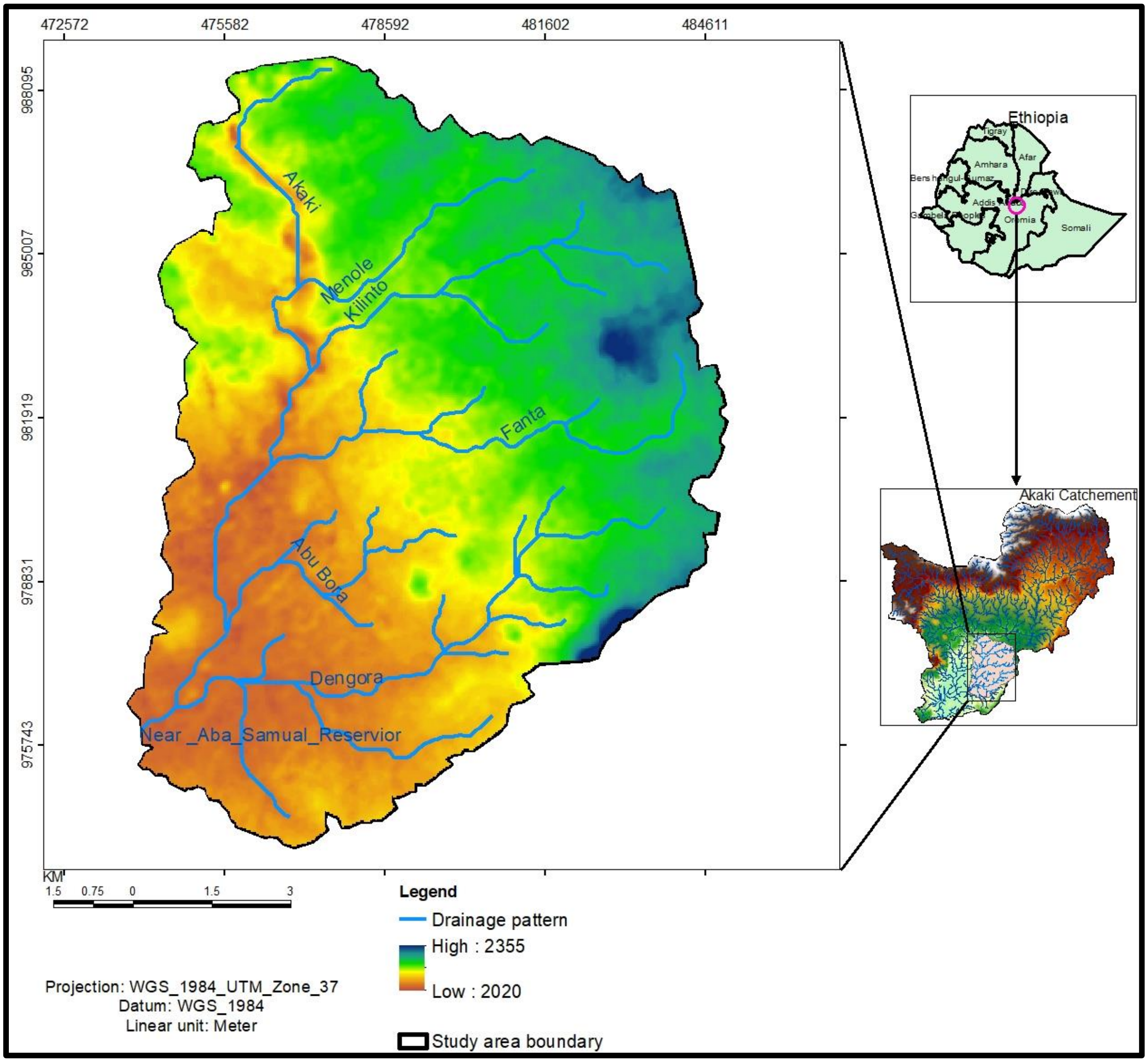

Figure 1.1. Location map of the study area.

1.5 Research questions

1. What are the impacts of the quarry on adjacent rivers?
2. What are the negative impacts of quarrying activity on the nearby community and workers?

3. What is the cause for land use/land cover change in the study area and which natural environment can affect by quarry expansion?

1.6 Significances of the study

This study is significant to control environmental and social impact of quarrying activity in the study area. It is useful for Addis Ababa Green Development and Environmental Protection Commission which issue license to the quarry owners according to this study result the organization can take measurements on those quarry sites which are exerting an impact on the natural environment and on the surrounding inhabitants. This research also helps them to manage quarry expansion in order to mitigate land degradation and to improve sustainable resource utilizations as well as exploitation. Additionally, this research will provide information to those future researchers and experts who give attention to environmental impact assessment of quarrying activity which is prospected and expanding all over the country parallel to construction development.

1.7 Limitation of the study

The major limitation of this study is the required high-resolution satellite image shortage with specified years doesn’t get from any organization. Another major challenge was laboratory and field water chemistry measurement instrument such as pH meter, turbidity meter and EC meter were not available in the department especially turbidity meter the most and major important tools for the current study was not available. Additionally, coronavirus was the most constraints during this study because all activities including laboratory work were overlooked, also it was very difficult to conduct questionnaires because of social distancing so that from the all quarry sites 5 quarry site and 100 total respondents were contacted, 10 community and 10 quarry worker respondents were contacted from each quarry sites.

1.8 Hypothesis of the research

- The quarrying operation has the power to damage the environment and it has a negative impact on the communities.
- Quarry expansion can affect the surrounding land use.
- Water resources can impact by quarry activity.

Chapter Two

Literature Review

This chapter aims to discuss the historical process of quarrying activities, advantages and disadvantage and detail discussion of the past environmental and social impact of quarry operation summarized from different sources.

Mining is the technique by which we extract economically useful resources from the Earth. Depending on the type of location and nature of the resource, there are different types of mining. These can be generally divided into surface and underground mining. The choice of surface or underground mining method depends on different factors like economic, geologic, engineering and other factors. Currently, environmental factors are also involved in the selection process (Enatfenta Melaku, 2007). One of the most widely used mineral/rock resources is construction material from the surface mining operation and it is extracted by quarrying method. According to Setegn Berie (2013) Mining and quarrying are extractive enterprises and involve the complete destruction of the habitat of an area where they take place.

2.1 Quarry operation

The quarry is a type of open-pit surface mining from which rock or minerals are extracted. Quarries are generally used for extracting construction materials such as dimension stone, ornamental stones, road building and industrial raw materials. The demand for these quarry materials is increasing at an alarming rate with increasing urbanization and urban population. Since all the activities in the urban center depend on materials from the Earth, especially quarry operations frequently are located near population centers and market areas (Enatfenta Melaku, 2007). According to Oguntoke et al. (2009) Quarrying of sand, gravel and building stones is widespread because it is less capital intensive compared to mineral extraction. As cited in Oguntoke et al. (2009) Quarrying operations generally involve the removal of overburden, drilling, blasting and crushing of rock materials. The various impacts produced by these operations are both size and locations dependent, specific impacts are on the air, water, soil, earth surface, flora, fauna and human beings (Areola, 1991; Enger and Smith, 2002). Once the mineral has been extracted and removed from the working area, there will normally be some processing carried out on site. Some materials may need to be crushed to reduce the size of individual pieces to a manageable size. Crushing plants can be noisy, and for hard rock, there is sometimes a need to use a pecker on the largest rocks before loading onto the dump truck, or a hydraulic breaker at the crushed feed (Nanor, 2011).

Quarrying can cause significant impact to the environment, with the right planning and management, many of the negative effects can be minimized or controlled and in many cases, there is great opportunity to protect and enhance the environment, such as with the translocation of existing habitats or the creation of new ones. Therefore to achieve the equilibrium between natural ecosystems, project planning, formulation and implementation are needed (Lameed and Ayodele, 2010).

2.2 Advantage and Disadvantage of quarry operation

Quarry operation has its own advantage from this it plays a great role for the development of the specific country in order to feed construction materials for huge projects such like road, bridge, dam and building, also it provides job opportunities for many young nations within the country. For the economic development of the country, quarrying put its own activity.

According to Eshiwani (2014) quarrying like most human activities has both negative and positive effects to the environment and the people living closer to the quarry as a source of income to the traders nearby, employment to the quarry workers and production of materials that are used in the construction industry are some of the positive effects of quarrying activities. Besides this, there can be a disadvantage of quarrying activity, during the operation or after the closure of the quarry. This can be from the poor training of workers; quarry and cutting shops owners have paid little attention to the environmental impact of their respective operations

(Peiter et al., 2000). Several serious environmental impacts related to quarrying activities on and near the river, such as vibrations, land degradation, land subsidence and landslides, water pollution, occupational noise pollution, and air pollution, will lead to health-related problems on the community and loss of biodiversity (Orkan et al., 2012). Also, the communities who work in and live near to the quarry are vulnerable to quarry impact.

According to Peiter et al. (2000) the quarry workers are more affected regarding health and safety problems associated with the quarry operation and due to the cutting shops, even the use of inexpensive safety equipment’s is not common, as most workers do not understand that long-term exposure can lead to illnesses such as silicosis, which results from inhaling dust while working in the quarries, or to deafness from excessive noise levels in the cutting shops. More immediate dangers include injuries to or the loss of eyes and limbs during the splitting of the dimension stone. There is below detailed presentation about the environmental and social impact of quarrying activities assembled from different journals and articles.

2.3 Environmental impact of quarrying activities

The environmental impact of quarrying can range from significant to highly significant and from short term to long term. The major impact of quarrying activities on the natural environment are land degradation, surface water pollution, groundwater contamination and depletion, deforestation, biodiversity degradation, migration of endemic animals due to noise and deforestation (disturbance of their habitat) visual impact (loss of natural beauty on the land cover) in the surrounding area of the quarry activities are going on.

According to Orkan (2012) quarrying operations can adversely alter pre-existing ecosystems, and change hydrogeological and hydrological regimes. This adverse influence of stone and sand quarrying induces damage in the property, depletion of ground water, loss of fertile topsoil, degradation of forests, deterioration in aquatic biodiversity and public health. On the other hand, haphazard quarrying of sand from riverbeds may cause a rapid change in bed configuration in response to the changes inflow. Blast-induced ground vibration is one of the most important environmental impacts of blasting operations because it may cause severe damage to structures and plants in the nearby environment (Abdullah et al., 2010).

The severity of the environmental problem depends on the characteristics of the mineral being extracted, the methods of mining, waste materials generated and the site characteristics. The effect is manifest in air, land, plants and water associated with the mining process. Environmental degradation accompanies mining operations and remains after they cease, with air pollution, scars on the landscape and threatened surface and underground waters (Ukpong, 2012). According to Adie et al. (2012) Quarrying is a form of surface mining that involves the use of dynamite to blast the rock and later, the broken rocks are drilled to get different shapes and sizes of aggregates and boulders. This process has its environmental hazards such as noise, vibration and fly chips of rocks that result from the blasting effects of the dynamites.

2.3.1 Major impact of quarrying activities on the natural environment

A. Impacts on water resources

The most abundant natural resources exploited from the subsurface are rock /mineral/, groundwater and petroleum they are the most resources exploited around the globe, obviously rock extraction is common in the most countries from the above-mentioned resources because of the need for construction materials is accustomed. According to Awoke Endalew et al. (2019) all over the world, there is a realization that quarrying activities have evolved over time to the mining industry. Due to these pollutants discharged from the quarrying area to the limited water resources, recently natural resources exploitation and utilization tremendously affect the surface and groundwater; exert pressures on the quality and quantity of water resources. The stone quarrying activity has disturbed the aquifers, resulting in a reduction in the groundwater level (Lad and Samanta, 2014). According to Semere Mulat (2013) solid and liquid waste discharged such as, scraps of metal, machinery parts discharges of fuel, lubricant or oil from heavy-duty machines, vehicles during maintenance are the main source of water and soil pollution from the quarry sites. Also dumping of waste rock in open areas disrupts drainage and causes diversion of rivers and streams Silt runoff from mines may be deposited in nearby streams outside the mining area. Discharge of domestic effluent may contaminate the surface water stream (Rassim et al., 2019).

If the groundwater availability is generally good in the quarry operation yard there will be amounts of water seeping in from zone extending throughout the full face of the quarry wall. Seeping of the side is resulting in a flow. Seeps come from groundwater migration through natural and blasting induced fractures in the rock. The fractures can be continuous or capable of providing a pathway for significance water leakage in to or out of the quarry. In light of the above condition extending quarry operation near the groundwater discharge area is expected to cause notable adverse ground water impact (Enatfenta Melaku, 2017). The main impacts of quarrying are the effects of blasting. Poorly designed or poorly controlled blasts may cause rocks to be projected long distances from the blast site (fly rock), which is a serious hazard. Poorly designed or poorly controlled blasting can fracture the surrounding rock, thus altering the ground-water flow paths (Langer and Arbogast, 2001).

According to the national council of Buhatan report on impact assessment of quarrying and mining activities, indicates that the impact of the mining/quarrying activities on the water was determined by physical observation and turbidity tests. The test revealed increased turbidity in downstream areas as compared to the upstream results. There is also a high probability of runoff from the mines and quarries into the nearby water source. Generally, groundwater quality is commonly affected by quarrying through increased fine sediment concentrations and accidental spillages. Removal of any soil cover allows direct access for pollutants into the aquifer (Hobbs and Gunnu, 2016).

B. Visual impact/land degradation due to quarrying/

Surface mining and quarrying typically generate a considerable number of environmental impacts among which landscape alteration remains one of the most significant impacts. Although landscape alteration does not directly affect public health, it may produce an adverse reaction among potential observers and compromise the use and potential growth of the surrounding territory. Landscape alteration might be perceived very negatively by observers who do not live in the mining or post-mining area and therefore, are not prepared to accept incongruities in the natural landscape; this represents a major issue within sites of high scenic value or where the tourist industry has a potential for growth (Valentina and Giorgio, 2013). The obvious environmental impact of aggregate mining is the conversion of land use, most likely from undeveloped or agricultural land use to a (temporary) hole in the ground (Langer and Arbogast, 2001).

According to Vector (2001) one of the most important environmental impacts resulting from opencast mining and specially quarrying is visual impact. The potential impacts generated over the landscape or visual resources by the extraction activity or its results are:

1. Creation of deforested fringes or areas with the possibility of bare rock
2. Disturbance of natural shape of the land
3. Changes in vegetation patterns
4. Introduction of linear morphologies
5. Creation of chromatic contrasts
6. Breaking of the landscape's visual continuity due to the changes in relation to the neighboring landscape elements.

C. Impacts on biodiversity

Quarrying activities are extractive and exploitive industries which inevitably depletes natural resources that are non-replaceable. Biological resource impacts of the quarry operation related primarily to the loss of habitat on vegetated lands, area of wetland, wooded habitat, and mixed habitat associated with preparation and construction of the new road. The forested habitat can be covered with pine and some hardwood trees (oak, poplar, ash, hickory, and sweet gum predominate). Various small mammals and resident and migratory birds can use the habitat. When the habitats are fragmented the useful wildlife will be lost (Enatfenta Melaku, 2017). Plants and vegetation around the local environment were seen covered with whitish dust emanating from the quarrying sites, and this may eventually affect/disturb the processes of photosynthesis leading to low plant production or eventual death of this vegetation (Oyinloye and Olofinyo, 2017).

2.3 Social impact of quarrying activities

According to Enatfenta Melaku (2017) if the quarry is in an urban center or near where surrounded by residential and recreational land of high scenic values, quarry operation will negatively impact on these values. The quarry would be visible to homes, parks and open space. The quarry operations will produce fugitive dust from blasting, vehicular emissions and other mining operation which would deterioration of air quality. The dust will affect negatively the health and the wellbeing of residents. favorable conditions for infections due to dust emission, noise, floods and other quarrying impacts are responsible for the persistence of the diseases in the communities, This is so because people in the quarrying area live at the risk of the diverse infections in performing their daily activities which include farming, quarrying, trading and performing of domestic chores (Vincent et al., 2012). Generally, the effects of dust emission from quarries have both micro and regional dimensions. Air pollution and ground vibration arising from blasting, crushing and emission of noxious gases have negative impacts on human health and well-being (Oguntoke et al., 2009).

The impact of aggregate mining operations such as noise, dust, air quality, suspended particulate matter and gaseous emission poses a serious environmental problem to both the inhabitant and the workers at Crush Rock Industries (Ukpong, 2012). According to Hailu Worku (2018) the assessment result showed that quarrying activities in the vicinity of Addis Ababa is the cause for many social conflicts and also creates significant livelihood challenges and many other impacts on indigenous local communities. The adverse socioeconomic impacts of mining include displacement of local people from ancestral lands and marginalization and other socioeconomic and sociocultural impacts.

2.4 Environmental Laws and Proclamations of the Federal Democratic Republic of Ethiopia

The federal Democratic Republic of Ethiopia has different laws policies and legislation in the constitution of the country related to any projects which can affect the environment (for instance extraction of natural resources including construction material). This is in order to protect the environment from anthropogenic damage and to control different negative impacts of mining activity which exerts many problems into the community. Generally, those proclamations are aimed to address the utilization of resources that can be without any impact and to implement sustainable development; some of them are justified below.

2.4.1 Proclamation No. 299/2002 Environmental Impact Assessment Proclamation

The Council of Ministers may issue regulations necessary for the effective implementation of this Proclamation. This legislation comprised so many articles including Environmental Impact Assessment of public Instrument; Jurisdiction of the proclamation; participation of the public about the project; Power to issues the regulation; cooperative duties; effective date of the regulation; Implementation Monitoring; Review of Environmental Impact Study Report; Duties of a Proponent. Those regulations are implemented by Federal and regional environmental protection authorities.

Proclamation no. 299/2002 indicated that every project should prepare an environmental impact assessment. A proponent shall undertake an environmental impact assessment, identify the likely adverse impacts of his project, incorporating the means of their prevention or containment, and submit to the Authority or the relevant regional environmental agency the environmental impact study report together with the documents determined as necessary by the Authority or the relevant regional environmental agency. Now a time Addis Ababa city environmental protection and green development commission which issues the license to quarry owners the proponent should submit environmental impact assessment before asking the commission to issue the license resource extraction (quarrying). An environmental impact assessment report is required to take measurements on the project if it harms the surrounding environment, historical heritage and on the community before permit the license.

2.4.2 Proclamation No. 52/1993 mining proclamation

All mineral resources are public property that have a significant contribution to the economic development of the country and that the state shall ensure the conservation and development of the resources for the benefit of the people. The Government may, designate any area of mineral as reserved or excluded for particular mining operations and exclude any area from mining operations particularly as regards sites of historical, cultural or religious interest and public buildings, infrastructure and other installations.

This legislation stated about Prospecting, exploration and exploitation of mineral resources should be carried out under appropriate technology and sound principles of resource conservation and develops national expertise in the mining industry; Give employees the training and education necessary for mining operations and comply with appropriate training programs.

2.4.3 Proclamation No. 300/2002 Environmental Pollution Control

According to this proclamation any pollutants discharged from different developmental activities can be controlled by the governmental organization and also the owner of the project could be take responsibilities and it must avoid any pollutants which can be hazardous to surrounding life and environment because the protection of the environment and safeguarding of human health and well beings as well as the maintaining of biota, is responsibility of all. This article aims to improve environmental quality; manage pollutants discharged into water, air and land, to mitigate harmful chemicals and radioactive element emissions. Generally that above-listed legislation plays a great role to protect the environment from various impacts according to the strength and weaknesses of an executive’s organization.

Chapter Three

General descriptions of the study area

3.1 Regional Geology

Historically Ethiopian geology records approximately 1 billion years. The development of basement of Ethiopia ranging in age from 880 to 550 Ma, the beginning of this event was the closure of the Mozambique Ocean between the east and west Gondwana. This deformed Proterozoic the basement rock underwent high erosion for lasted one hundred million years and destroyed Precambrian orogeny (Abbate et al., 2015). In Ethiopia the major rock types are Precambrian metamorphic rock associated with intrusions of post and syn-tectonic which are form the basement complex; The Late-Paleozoic to Mesozoic marine and continental sediments; the Cenozoic volcanic rock and the volcano-sedimentary volcano-clastic rock including Paleogene, Neogene and Quaternary sediments (Solomon Tadesse et al., 2003).

According to Abbate et al. (2015) the beginning of the breakup of Gondwana gave rise to the Jurassic flooding of the Horn of Africa with a marine transgression from the Paleo-Tethys and the Indian/Madagascar nascent ocean. After this Jurassic transgression and deposition of Cretaceous continental deposits, the Ethiopian region was an exposed land for a period of about seventy million years during which a new important Peneplanation surface developed. Concomitant with the first phase of the rifting of the Afro/Arabian plate, a prolific outpouring of the trap flood basalts took place predominantly during the Oligocene, over a Peneplained land surface of modest elevation. In the northern Ethiopian plateau, huge Miocene shield volcanoes were superimposed on the flood basalts. Following the end of the Oligocene the volcanism shifted toward the Afar depression which was experiencing a progressive stretching and successively moved between the southern Ethiopian plateau and the Somali plateau in correspondence with the formation of the Main Ethiopian Rift (MER).

The Main Ethiopian Rift (MER) has a complex structural pattern composed of southern, central and northern segments. Ages of onset of faulting and volcanism indicate a heterogeneous time space evolution of the segments, generally referred to as a northward progression of the rifting process (Marco et al., 2005). Ethiopian geology greatly shaped by the assembly and breakup of Gondwana and the present rifting events. The gangplank zone between the northern and central Great Ethiopian Rift is present in the regions of Addis Ababa and Nazeret (Tadiwos Chernet et al., 1998).

From Ethiopian complex geological setting represented by three major terrains such as Late Paleozoic, Mesozoic and Cenozoic continental marine sediments and Cenozoic volcanic and sedimentary rocks occur mainly in the eastern part of Ethiopia (Mengesha Tefera et al., 1996).

The main rock types which record the geology of Akaki-Beseka map sheet are Precambrian gneiss, Mesozoic sediments, Paleogene (Late Eocene-Late Oligocene) fissured flood basalts with minor rhyolite, trachyte and pyroclastic flow, Neogene (Miocene-Pliocene) pyroclastic, rhyolitic and trachytic flows and Pleistocene-Holocene basic to felsic volcanic and Phreatomagmatic deposits intercalated with lacustrine and alluvial deposits (Efrem Beshawered, 2010).

3.2 Geology of the study area

The study area is located in between Ethiopian western plateau and central Great Ethiopian Rift, particularly at the margin of the **MER**. The northern part of the study area is covered with Wechcha Trachyte this lithology cover the smallest part and the alluvium deposit has large coverage within the study area, in addition to this, the rest of area is covered with Addis Ababa basalt, Akaki basalt and welded pyroclastic flow and with Quaternary alluvium deposit. Descriptions of those lithological units are discussed here;

3.2.1 Addis Ababa Basalt (Eaa)

Addis Ababa basalt exposed at the northern and extends to the central part of the study area. It is is dark color fine-grained rock mainly composed of plagioclase, pyroxene and Opaque's. This rock unit is a fresh, compact fine-grained rock, but in places, it shows vesicular cavity filled with or without secondary minerals (Efrem Beshawered, 2010).

3.2.2 Welded pyroclastic flow (Nwp)

Welded pyroclastic flow covers the central to the northern part of the study area and categorized under the sin-rift unit. According to Efrem Beshawered (2010) this unit is light to dark-grey in fresh samples and reddish to yellow to pink in weathered ones. It is fine-grained, densely welded rock containing Vitrophyric Fiamme and lithic fragments with associated rhyolite lava flows interleaved with ash and un-welded tuffs.

Figure 3.1. Ignimbrite exposure in the northern part of the study area.

3.2.3 Wechcha Trachyte (Nwt (a))

According to Efrem Beshawered (2010) this unit is found in the main rift unit and it is composed of trachyte and Dendi-Wenchi pyroclastic material. However, in the current study area only Wechacha trachyte unites is exposed. In outcrop, Wechacha trachyte is coarse-grained, light gray, brown-grey to dark-grey in fresh samples to pinkish yellow to reddish-brown in weathered ones. The main rock-forming minerals are quartz, feldspars, and mica in this unit.

3.2.4 Scoria Fallouts (Qts)

Exposure of the Scoria unit is found in the eastern and southeastern portion of the current study area. This unit usually forms unevenly distributed cinder cones and sometimes broad-based gentle-sloping circular to elliptical hills. It is dark brown, reddish grey color, vesicular coarse-grained rock; generally Akaki basalt this includes pyric basaltic flows and scoria fallout are exposed on the western rift shoulder south of Addis Ababa (Efrem Beshawered, 2010).

Figure 3.2. Scoria exposure in the southern part of the study area.

3.2.5 Aphyiric Basaltic Flows (Qtp)

This rock unit distributed in a different parts of the study area. It is a dark color, fine-grained rock mainly composed of plagioclase, pyroxene and Opaque's. Generally, it is a fresh, compact fine-grained rock, but in places, it shows vesicular cavity filled with or without secondary minerals.

3.2.6 Alluvium (Qus)

This unit is found in the Quaternary surficial deposit. This unit covers a larger part from the present study area. Efrem Beshawered (2010) has been reported this lithological unit forms flat-lying topography and marshy areas. It consists of loose, brown to grey color sand, silt and clay-bearing clasts. These clasts include boulders of basalt, rhyolite and scoria. Besides, thick black, brown and reddish-brown soils are common. Lacustrine deposit was observed with alluvium unit in the southern part of the study area, it forms sheet like structure with light gray color at the exposure. However, its extent might be small and not map-able, in case not included with geological map.

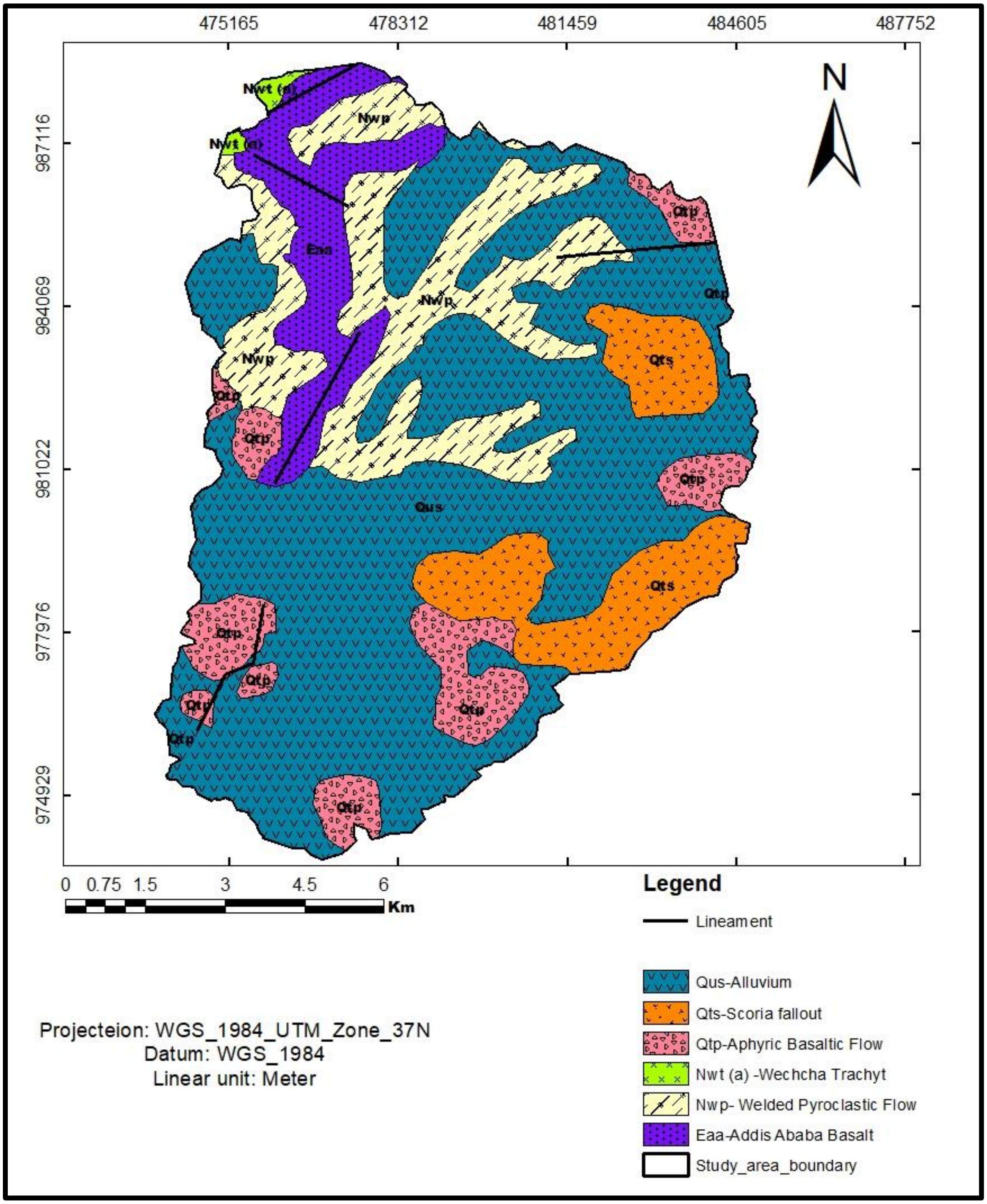

Figure 3.3. Geological map of the study area simplified from Efrem Beshawered, 2010 (GSE).

3.3 Hydrogeology

The availability of groundwater is controlled by the type of geological materials, degree of weathering and extent of fracturing the medium which it passes through, geomorphological setup, drainage density, land use land cover, climatic conditions, grain size, sorting and type of cementing material of unconsolidated sediments and type and thickness of soil development. The main permeability that is responsible for groundwater transmission and storage are porous and fractured permeability (Bereket Fenatw and Mihret Manaye, 2011). According to Solomon Waltenigus (2007) Addis Ababa area is underlain by complex system of aquifers of various sizes and hydraulic properties, which are mostly hydraulically connected. Aquifers can be made up of weathered and fractured volcanic rocks and pyroclastic deposits such as ignimbrites, scoria, tuffs and ashes. Intervocalic alluvial deposits and soils also exist as a result of time gaps between successive volcanic eruptions. A big variation among wells yields can, therefore, is attributed to this heterogeneity in the transmissivity of the water-bearing geological formations. The aquifer to the north of the Akaki well field mainly covering the Addis Ababa city and in the mountain area consists of weathered and fractured volcanic rock with minor sediments deposited between different series of lava flows. Some superficial deposits along the major river courses make shallow aquifers the vesicular and coriaceous basalts and also scoria are the main aquifers in Akaki and Dukem well fields (Bereket Fenatw and Mihret Manaye, 2011).

3.4 Hydrogeology of the study area

The total study area covered by volcanic rocks such as Addis Ababa basalt, welded pyroclastic flow of Nazret group (Ignimbrite), Akaki basalt (Scoria fallout and Pyric basaltic lava flow), Wechecha Trachyte and Alluvium deposit overlain on Scoraceous basalts of the trap serious volcanic group, this material is good for groundwater infiltrations within the study area. Based on this, the aquifer type and transmissivity of the medium and discharge amount is depending on those geological materials, primary and secondary structures (discontinuity and porosity) and weathering degrees. Bereket Fenatw and Mihret Manaye (2011) classified the permeability of the study area into three categories the first one is hydrogeological unites with fissured permeability, in this character the groundwater is stored in and flow through the fractured and weathered parts of volcanic rocks. Most of the Tertiary Volcanics of the area exhibit such permeability; the second one is hydrogeological unites with porous permeability those unit in the study area are Quaternary alluvium and unwelded pyroclastic flow it is the most dominant porous material in the current study area and the third one is hydrogeological unites with no permeability this is due to the geological material is more massive and has limited fracture with shallow depth, for instance in the study area Wechcha trachytic lava domes give in very low permeability and limited groundwater occurrence.

According to Bereket Fenatw and Mihret Manaye (2011) the hydrogeological system of the area is classified in the different aquifer-aquitard system. However from the total seven aquifers-aquitared systems only four types of aquifer system falls on the present study area. Based on the hydrogeological report acquired from GSE hydrogeological system of the study area is summarized below;

3.4.1 Extensive and high productive fissured aquifer immediately underlining the alluvial soil

This aquifer covers a larger part of the study area about 69.5 km² extended from northeast to southwest with alluvium soil. Aquifer transmissivity ranges from 100-500 m²/d with well discharge 4-20 l/s. The geological formation in this unit is trap serious volcanic group of scoriaceous basalt. Bereket Fenatw and Mihret Manaye (2011), tried to measure the water level of the wells. So that the high yield wells are inventoried in the scoriaceous basalt reaching up to 81 l/s with depth more than 200 meters. Boreholes drilled into the lacustrine sediment have depth in the range of 50-65 meters with an average yield not more than 0.5l/s. In general, as the depth of wells increases their discharge also increases hence penetrating the lower scoriaceous basalt.

3.4.1 Extensive and high productive aquifers

These hydrogeological units found in north, northwest, northeast, southern, southeastern and southwestern part of the study area with total areal coverage of 33.9 km². The transmissivity ranges from 100-500 km² with 5-25 l/s spring and well discharge. The geological formations of these aquifers are Akaki basalt which is scoria fallout and pyric basaltic flow, the trap serious basalts (Addis Ababa basalt). They form flat, hill and undulating terrain also in some area covered with alluvium soil.

Addis Ababa basalt

This unit is located in the northern and northwest parts of the present study area. It is the major groundwater source of Addis Ababa city next to the Akaki well field basalt. The texture of this lava flow is mainly of porphyritic to Aphanitic. Unfortunately, high water storage, transmissivity and permeability of this aquifer is concentrated to joints caused by cooling, lava tubes, vesicles that are interconnected, voids left between lava flows. The pump test result data indicates 295.6 m²/d transmissivity and 7.7 l/s safe yield from this lithology. The hydraulic property of this aquifer is not uniform through the entire area depending on the degree of weathering and fracturing. The presence of secondary infilling materials, minor fractures, less weathering horizons within this aquifer in different places create a variation in the productivity of the rock. Mostly the highest permeability is found in the partly decomposed weathered and fractured zones. In most parts of Addis Ababa city, this unit is overlain by fresh and massive ignimbrite so that most boreholes should penetrate the overlain ignimbrite to get good aquifer which is confined. Generally, the average yield, transmissivity and permeability from wells and hydrogeological characteristics of the rock make it to be classified as high productive with big groundwater level variation between 0-120 meters (Bereket Fenatw and Mihret Manaye, 2011).

Akaki younger scoria and pyric basaltic flow

This geological unit exposed mainly in the south, south eastern and northeastern part of the study area. It forms flat terrain to small weathered scoria cones at places. According to Bereket Fentaw and Mihret Manaye, 2011 a characteristic of this aquifer is highly dependent on the secondary permeability which is the result of fracturing and weathering activities. The interconnections of the vesicles which are abundant in Akaki basalt are poor or may be filled by secondary infilling materials. Thus the vesicles have little importance in permeability of the rock. However in some places the vesicles are affected by fractures resulted in the interconnection between them and hence increased the permeability. But the high permeability of scoria fallouts of the Akaki group is highly dependent on the vesicles and pours spaces. The recharge of this aquifer is mainly from the northern part of Addis Ababa city (Intoto and surrounding area) and from local streams. The aquifer is also recharged from direct precipitation of the area. It is the main groundwater source for the Addis Ababa city municipality water supply. The hydraulic property of the aquifer form representative boreholes indicates a high value; for instance, the yield and transmissivity from Akaki well number 16 (BH-104) is 87.5 l/s and 1523.5m²/d respectively. Generally in the Akaki well field it is observed higher transmissivity, yield and shallow groundwater level rather than in other outcrops of the same aquifer. In this field, the Akaki basalt is overlain by residual clay-silt and sandy soil materials ranging from 5 to 12 m thickness.

3.4.2 Extensive and moderate productive fissured aquifers

This aquifer localized in the northern and central part with the total coverage of 17.9 km² from the study area. The transmissivity ranges from 50-100 m²/d with average spring and well discharge 2-5 l/s. Geological formation exposed in the study area is welded pyroclastic flow of Nazret group (Ignimbrite) rock it occurs by forming plateau and flat undulating surface of the margin and escarpment of the western margin of Ethiopian Main Rift.

Welded Pyroclastic Flow of the Nazret group

Ignimbrites and pyroclastic flow of the rift floor, rift margin and escarpment are well jointed and fractured but in some cases it is massive and pumiceous. The permeability of the formation is exhibit good at the places where there are well-developed fractures and joints this is the major water-bearing horizon in the area. The primary structures of volcanic flows are also significant if it is affected by secondary weathering and tectonic activities. Especially on the rift escarpment this unit is highly affected by faulting and weathering and hence good permeability. Whereas in some places it is slightly weathered and fractures are small or absent thus very low permeability with slight secondary process produce only in a small increase in overall water circulation and storage capacity. The permeability and productivity of this aquifer are very variable with special variation, for instance in the plateau this unit acts as a confining layer for the underlying basaltic aquifer especially around Addis Ababa (Bereket Fenatw and Mihret Manaye, 2011).

3.4.3 Extensive and Low Productive fissured and/or porous aquifer

This hydrogeological unit exposed in the north part of the study area around the junction of Bulbula and Akaki River with small coverage of 0.1 km^2. The transmissivity of the unit ranged from 1-1m^2 with spring and well discharge 0, 0.5-0, 5 l/s. The geological formation presented on this aquifer is Wechcha trachyte it forms trachytic lava flow. This unit has varying structures and weathering conditions.

Wechecha Trachyte

Wechecha trachyte has different weathering conditions and varying structures. The water that precipitates on this dome lost as a runoff instead of vertical infiltration. This is due to that the trachytic lava domes have steeper slopes, massive and slightly weathered surfaces. In addition, the absence of thick soil development facilitates runoff to be higher. On the Wechecha trachytic dome, there are very often occurrences of major tectonic displacement and deep weathering zones, which have a strong effect on the hydraulic property of the rock. Moreover, the development of minor fractures has local permeability effect and also water-holding properties. In this unit, the amount of discharge of the springs ranges from 0.01-2 l/s (Bereket Fenatw and Mihret Manaye, 2011).

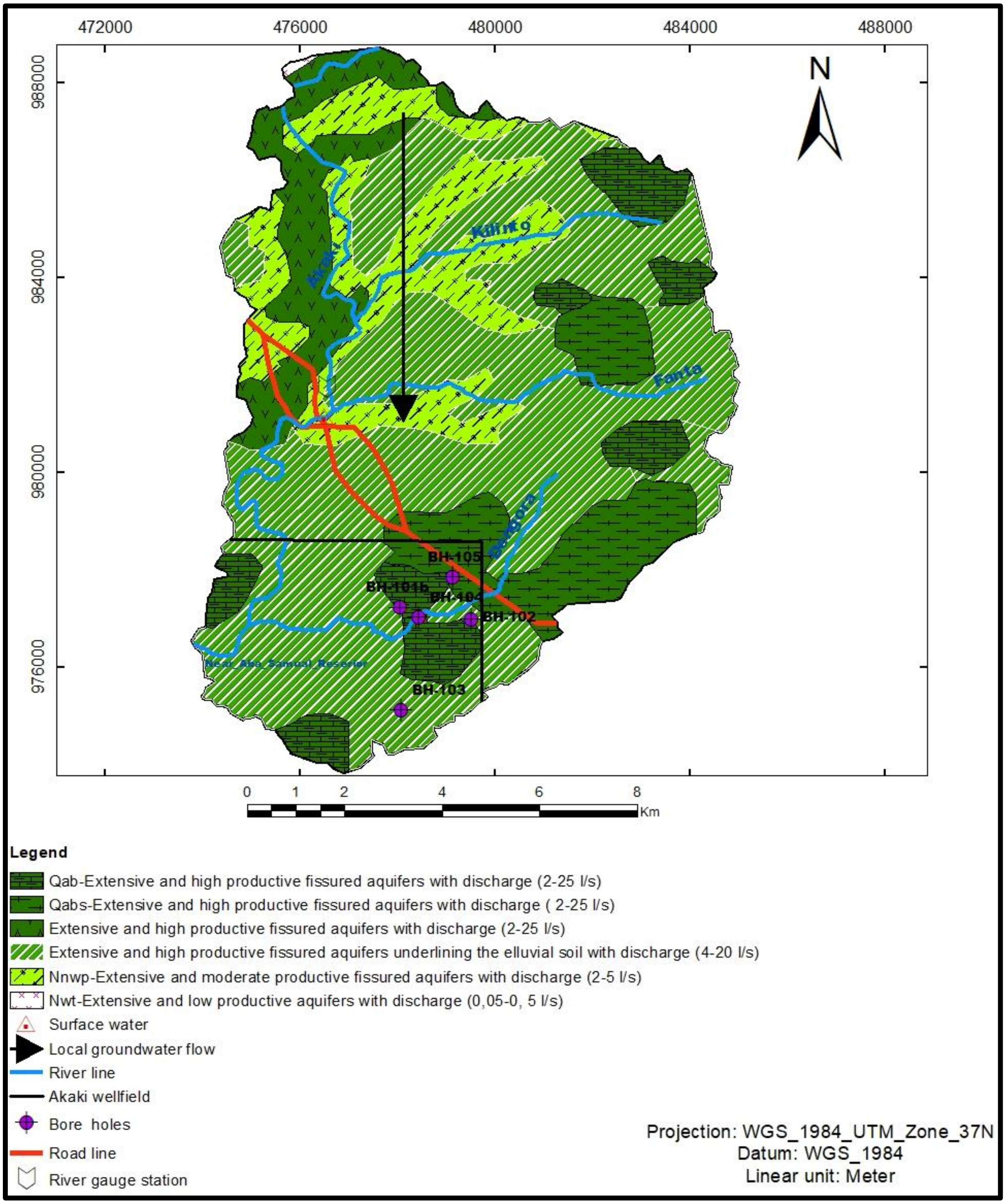

Figure 3.4. Hydrogeological map of the study area, simplified from Bereket Fentaw and Mihret Manaye, 2011 (GSE).

3.4 Engineering Geology

The present study area covered with expansive soil especially black cotton soil which is from the parental volcanic rock this is according to quantitative field investigation obviously well-known characteristics of Addis Ababa soil and the present study area is located in the southeastern part of Addis Ababa. As indicated in different systematic reports and articles this type of soil put difficulties for engineering structures. Expansive soils put the major geotechnical problems that can pose severe limitations on performance and lifetime of lightweight engineering infrastructure. Wide range of problems and hazards that are experienced in pavement engineering have to be challenging reminders of the requirement of careful consideration of expansive soils especially at the feasibility and design stages of road projects because such soils are particularly susceptible to large volume changes in response to moisture content fluctuations following seasonal climatic variations so this can lead to deformation of structures built upon them (Fekerte Arega et al., 2009).

On the other way, this type of soil can amplify seismic hazard (ground motion) as a result of the city designers and planners for heavy and huge engineering structures they must include seriously into consideration during a geotechnical investigation. According to Tilahun Mammo (2005) Addis Ababa city situated on Ethiopian Rift Margin which is seismically active zone it has more than three million inhabitants (this study was conducted before 5 years may the population increase by twofold). Several destructive earthquakes were occurred in the region (at the rift margin). These earthquakes were sometimes accompanied by light damages to some of the engineering structures in the city. In order to reduce the loss of life due to seismic hazard in the city, it is required detailed study of seismic hazard zone of the area and planned engineering structures carefully. Dramatically expansion of urbanization especially condominium house planning should be considered this problem to protect peoples from catastrophic hazards.

Figure 3.5. Fractured and weathered basaltic rock exposure in the northern part of the study area.

The Geology of the area was covered with volcanic rocks contains different strengths. According to quantitative data on the field, rock strengths were measured at the ground by its weathering degree nature of formation and based on primary and secondary structures such as Joint and faults. Based on the field observation the study area covered with scoria, Ignimbrite and basaltic rock. Alluvium soil underlay most of the exposed rock and it has low strength than underlain rock, basaltic rock exposure in the area shows more fracture with medium weathering degree. Lacustrine deposit in the present study area exposed at the south part around Tulu-Dimtu with small exposure naturally it has less strength than other geological material in the study area.

Figure 3.6. Lacustrine deposit in the southern part of the study area.

3.5 Climate

The climatic condition of Ethiopia is controlled by morphology, altitude vegetation cover and other factors. The climate of the study area is categorized under the climate of Addis Ababa it is a humid subtropical expediential summer climate that is mild with dry, winters expedient rainy summer and moderate seasonality. The dry and rainy months subdivided into three seasons the major rainy season start from late May to late September combined total five months, and one minor rainy season start from half of March to half of April and one dry season starts from October to February. Total average annual rainfall data of the study area acquired from four stations (Intoto, Addis Ababa Bole, Akaki, Addis Ababa Observatory) for the year 1981-2014 is 1126.0 mm. The average annual maximum temperature of the area is raised up to 21.8 C° and the average annual minimum temperature fall to 9.8 **C**°, according to the mean monthly temperature distribution of the study area November to December is the coldest and April to May is the warmest months in the study area.

3.6 Rainfall

The long term total means monthly rainfall data acquired from the nearby three (Addis Ababa observatory, Addis Ababa Bole and Akaki) meteorological stations for the total year of 31 from 1981-2016 demonstrate that rainfall amount of the area highest in July and August; there is a moderate amount of rainfall in September and June. Additionally, there is no rainfall in a month such as December, January and February generally those months are dry. The study area has got a minimum amount of rainfall at months of March, April and May which is called Bulge rainfall as shown in fig. 3.7.

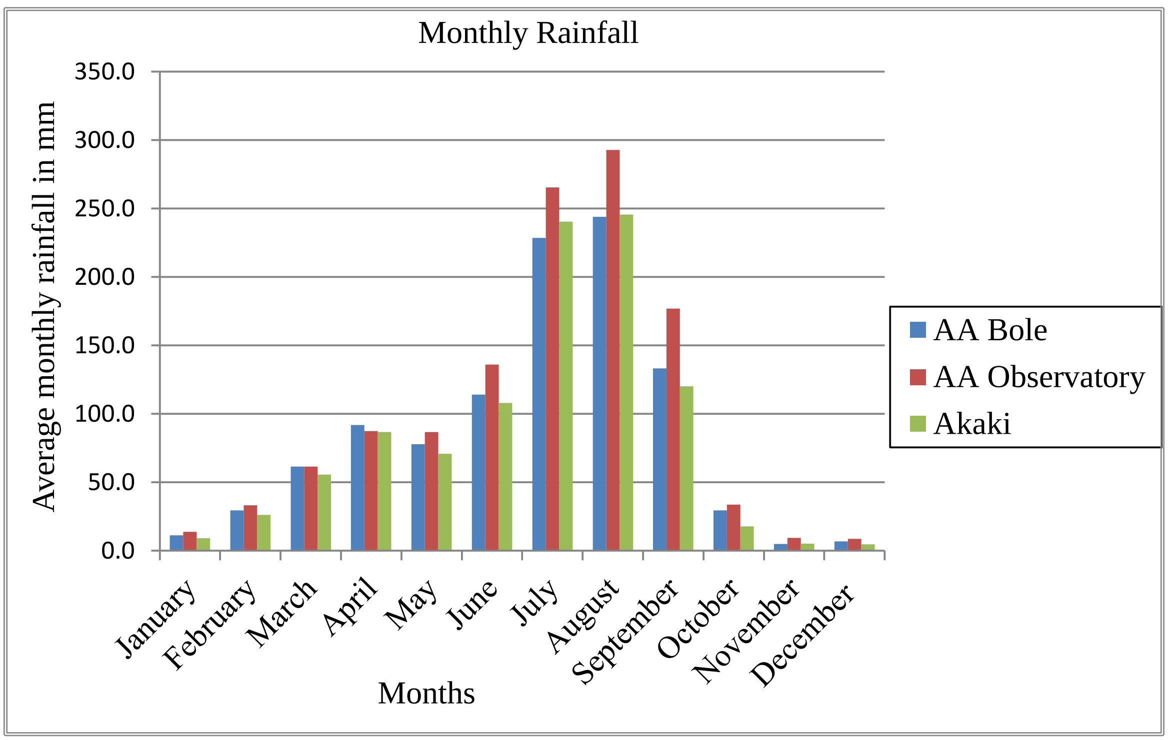

Figure 3.7. Average monthly rainfall of the study area from 1981-2016.

3.7 Temperature

The Mean annual maximum and minimum temperature of the study area varies from 25.7 to 15.4 C° and 12.6 to 6.9 C° respectively. Based on the mean monthly temperature distributions acquired from three stations of the national metrological agency of Ethiopia indicates that the area is more warmest in March and coldest in December and August as shown in fig. 3.8. Generally, the area has comfortable air condition to all living organisms.

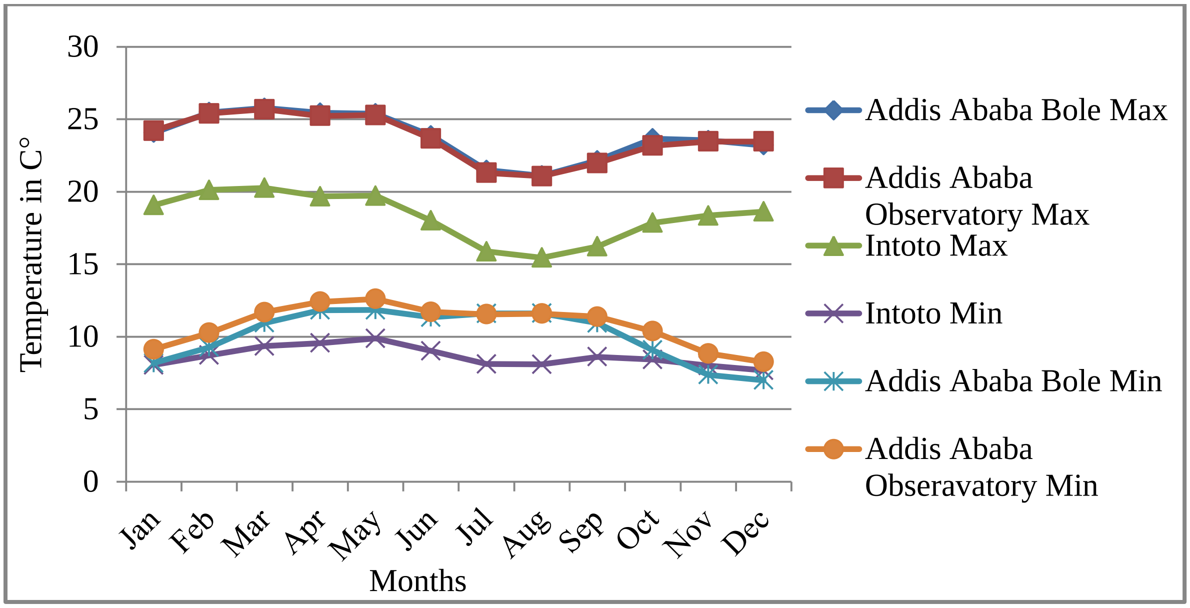

Figure 3.8. Average monthly minimum and maximum temperature from 1990-2017.

3.8 Physiography and drainage

Topographically the study area is located in the Central Western Margin of Great Ethiopian Rift Valley. The study area has rugged, undulating and flat physiography. The elevated land is located in the southwestern and western part of the study area this is due to scoria fallout, the flat land is located in the southwest and central part of the study area it is swampy and drained by big Akaki River this area used as irrigation purpose. The highest area range up to 2355m above sea level and the lowland area falls under 2020m above sea level.

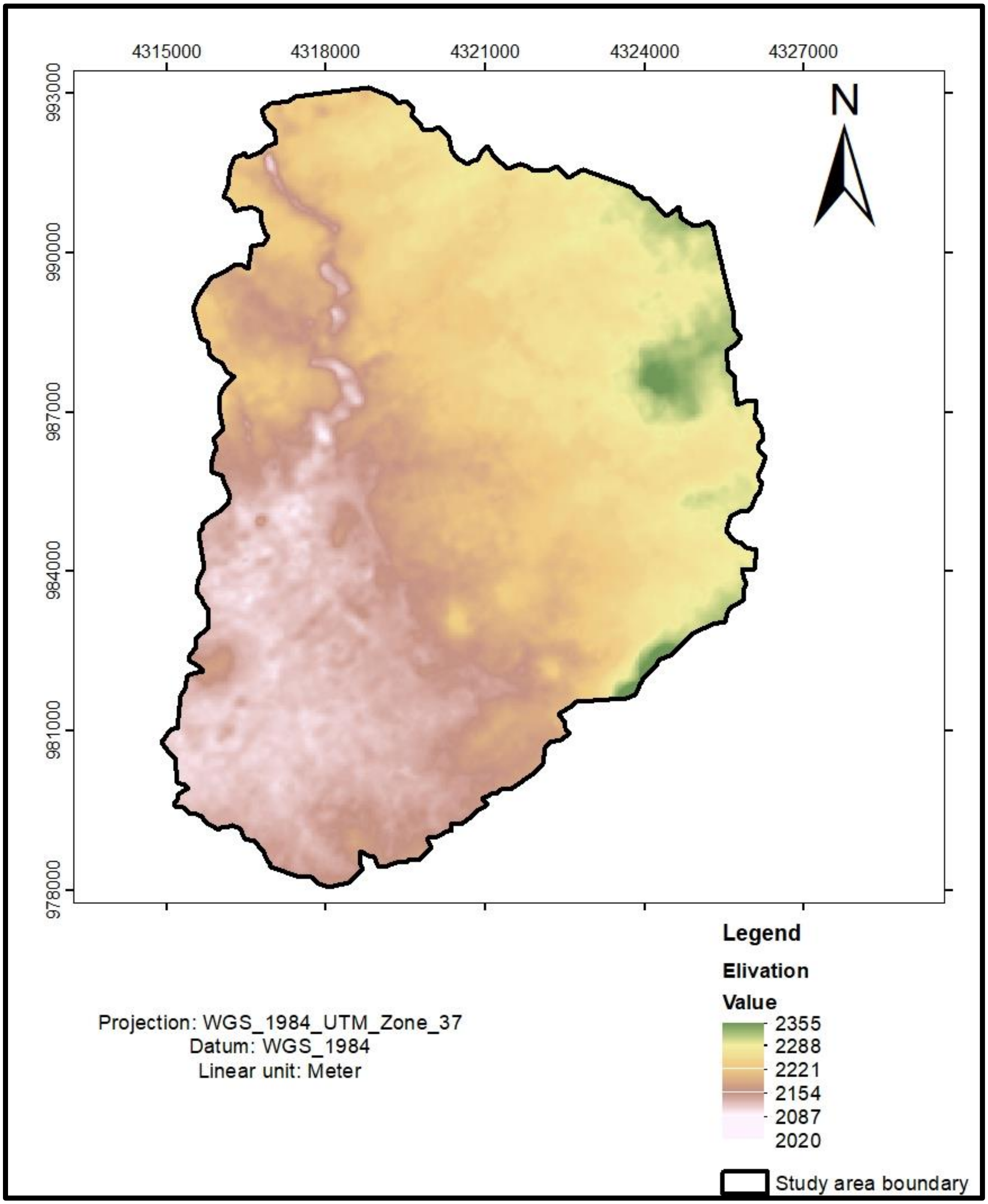

Figure 3.9. Elevation map of the study area.

The study area is part of the upper Awash basin, specifically in the part of Big-Akaki catchment, it begins from the foot of Intoto chained mountain (2162 m at the foot of the mountain) and drained Addis Ababa city from the northeast to the southeast up to Aba-Samueal reservoir. Akaki river from the starting up to the reservoir joined with many different small and big tributaries such as Kebena, Kotebe, Tafo, Bulbula, Beshale, Beseka, kilinto, Fanta and Dongora rivers. Big Akaki River after 52 Km long distance it is joined with little Akaki river at Aba Samueal reservoir and flow towards the eastern part of Ethiopia to feed Awash River which used to many purposes in the basin such as for irrigation, hydropower, cattleman and for domestic purpose to the community in the upper, middle and lower Awash basin. The current study area lay at the downstream section of Big Akaki catchment which is part of upper awash basin, the drainage pattern in the area is more distributed in the eastern and southeastern parts. The tributaries and Akaki river are pass through different lithological unites within the study area which is quarried for the construction purpose for various projects underway in and around Addis Ababa city.

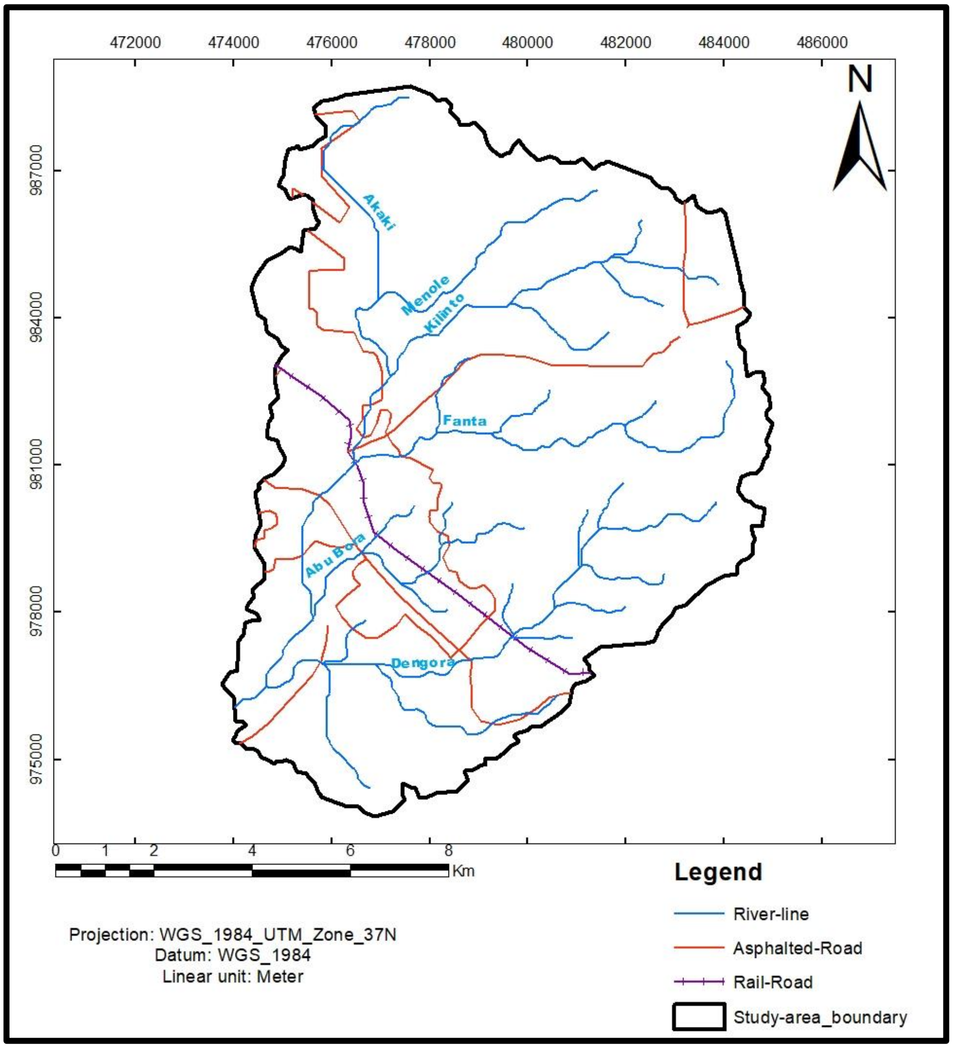

Figure 3.10. Drainage pattern and accessibility map of the study area.

3.9 Accessibility

The study area has different accessibility such as asphalted road, dry weathered road and railroad pass across it and there are also different streets and foot trials. Generally the area has good accessibility as try to show in figure 3.10. In addition to those major roads there are gravel roads used for those trucks which are transport construction material from the quarry site.

Chapter Four

Methodology and Materials

4.1 Methodology

To achieve the main and specific objectives of this study different methods have been used and followed, the methods are categorized under three stages.

4.2 Pre fieldwork

Before field investigation, different useful data have been gathered and studied very well in order to collect good and precise field data. The following operations are done before field study.

- ✓ Reviewing related published and unpublished Journals and articles.
- ✓ By using Google Earth software exploring the current status and accessibility of the study area.
- ✓ Delineating the drainage patterns across the study area by using Google Earth pro and Addis Ababa southeast map sheet 1:50,000.
- ✓ Data pre-processing and collection of information about the study area.
- ✓ Preparing open-ended and closes ended questioners to assess quarrying impact on the community and quarry worker.
- ✓ Data acquisition and preprocessing such as high-resolution temporal satellite image (temporal spot image for the year 2006 and 2016 from EMA, Quick Bird satellite image for the year 2020 those are high-resolution image with 5m, 1.5m and 0.3m spatial resolution respectively and Landsat-7 ETM+ panchromatic band with 15m spatial resolution for the year 2000 when quarrying activity initiated) were all the above image used for conduct land use land/cover change of the study area about 20 years back from the resent. Collection of Geological and hydrogeological map of the area from GSE, metrological actual data from a national metrological agency of Ethiopia to understand the climatic condition of the area.

- ✓ Fieldwork also planned at this stage and collection of necessary equipment's useful to on-site measurements of water physical parameter. The pH and EC meter calibration were done before the field and equipment were calibrated continuously on the field by using different buffer solutions.

4.3 During fieldwork

Field activities are followed three steps: the first step was reconnaissance survey undertaken to investigate the quarry ground truth and to select preferable surface water sampling location. On the second step representative surface water samples were collected and on-situ surface water physical measurements done. At the third step field work open and closed-ended questioners were addressed to the respondent it is completed by addressing the questionnaires for the quarry worker and community lives near to the quarry site.
Primary data collected and various parameters measured and observed on the field.

4.3.1 Field observation

Field observation or reconnaissance survey was aimed to evaluate the overall activity of quarry operation and aim to assess which natural environment is vulnerable to the impact of the quarry operation. During this time the author recognized surface-water, groundwater and cultivated lands are vulnerable to the quarry impact from the natural environment and also communities near to quarry sites are affected by dust and noise impact rise from the quarry sites.

4.3.2 Surface water sampling

The samples are collected from different up-stream, downstream and on the middle section of the big Akaki River and its tributaries locally named as Fanta and Dengora Rivers, the sampling rivers were selected from the whole area because those rivers are located adjacent to active quarry sites. This study will allow for observing a trend in the change in chemical parameters upstream and downstream for the specific quarry site which in-turn can imply any trend in chemical parameters of the river water has been influenced by the quarry activity. However, it should be noted that this might not suggest chemical pollution only because of quarrying. Totally 9 water samples are collected and analyzed in the laboratory. On-situ physical measurements are taken by using pH and EC meters from 7 points (pH, EC and T°) these measurements are excluding samples collected for a laboratory tests. Surface water samples were collected by 1 Litter polyethylene cleaned plastic bottle direct immersion into the rivers. The coordinates of sample location recorded by using Garmin GPS and saved on excel as CSV comma-delimited format to prepare a sampling map shown in fig. 5.1.

Figure 4.1. On field EC, pH measurement and surface water sampling.

4.3.3 Questionnaire surveying

Social impact of the quarry sites were assessed by using open and close-ended questionnaires surveying. From the total study area 5 representative sampling sites are selected based on the quarry operation using of dynamite and crasher because some of the quarry sites don't have crasher and some of them doesn't use dynamite or blasting, for instance ignimbrite (cobblestone) quarry sites doesn't use both techniques also quarrying site distance from the community were considered during this assessment, randomly selected 10 respondents were conducted from quarry workers and from residents separately from each site, Total of 100 respondents were conducted for this purpose. The collected questionnaire data from them was analyzed and presented by using SPSS software to generate frequency and percentage results.

4.4 Post fieldwork

After returning back from the field the data which have been collected during fieldwork and also the data were prepared before fieldwork has been studied in detail during this phase. The activities followed after fieldwork is discussed here:

4.4.1 Quarrying impact on surface water

Physiochemical parameters of the collected water from upstream, at the quarry and downstream were analyzed. These can indicate an involvement of quarrying activity on surface water pollution. This was accomplished by measuring the water physical parameter such as measuring pH, temperature (T°) and electrical conductivity (MS/cm) on the field. Additionally physical and chemical analyses of the samples were tested in the central laboratory of Saba engineering Pvt. Ltd. Co. This study use the term upstream downstream and at the quarry by using quarry sites as a reference point. But the result of hydrochemistry compares with the water chemistry recorded on the upstream (before passing the quarrying area).

4.4.2 Land use land covers classification and change detection

- **Image preprocessing:** Extraction of raster feature by vector study area boundary respective for the current study area and projection of the image was done using Arc map 10.8 and QGIS 3.10.1 version for all temporal images. Before classify directly the acquired image in Arc map 6 classes were created in Arc catalog 10.8 for RGB images only (SPOT 2006, 2016 and Quick Bird 2020). Image preprocessing includes layer stacking in ERDAS IMAGIN 2015 for Landsat 7 ETM+ 2000 image only, 6 bands black and white image was combined and created one multispectral image, after layer selection and stacking resolutions of the stacked image which is 30m with 8^{th} band which is 15m were merged to change 30m resolution into 15m. The stacked and merged image was classified by using supervised classification tools in ERDAS IMAGINE 2015. When giving signature samples for all classes to the area of interest supported by online Google Earth pro to identify the ground truth. Post classification of this image was done aim to increase the accuracy of the classified image this was completed by majority analysis, unwanted pixels also sieved and raster data were converted into vector polygon in ERDAS IMAGINE.

- **Land cover class identification**: Class of the area identified by using visual understanding such as objects, patterns and shape like features of the images they are pre-defined based on reflectance characteristics of the object on the ground comparatively with appearing clearly on 2006, 2016 and 2020 images because those are spatially high-resolution images, feature-based digitization and classification was done.

- In order to detect the temporal change 6 class are developed, such as Cultivated land, Bare land, Quarry, Shrub land, Forest and Built-up in Arc catalog as a form of polygon and add with the extracted image and digitized them on Arc map by zooming in and zooming out the raster data. Digitization of different class was completed then areal coverage/ha of all class in a specific year has been calculated. This aim to generate temporal land use map of the area separately for each year. Finally from this land use, land cover change map of the area generated and detection of quarry expansion rate were analyzed according to (Suliman et al., 2017).

- **Change detection:** The classified image for the year 2000, 2006, 2016 and 2020 demonstrates how the area diverts its use by anthropogenic activity through time and it can show how much the natural environment is affected by another land use such as quarrying activities. The detection analyses result is important to understand which land use is rapidly increasing and which land use is shrinking. Net change detection from 2000-2020 was done by intersecting the digitized and classified two temporal images on Arc map after intersection has been done the area of each polygon were calculated in a hectare. The calculated area was pivoted in excel sheet, as a type of row and column for considered years this is to compare the grand total change of every class in all LULC map to detect net spatiotemporal change.

Accuracy assessment for the year 2006, 2016 and 2020 Google Earth data were used to validate X and Y coordinate points of each class to validate the classified images accuracy. For the year 2000 accuracy assessment elderly interview was conducted in addition to Google Earth data. Finally, accuracy assessment was done for all classified images; it was supported by QGIS and Arc GIS.

4.4.3 Analysis and interpretations

The collected data from respondents has been entered and analyzed by using SPSS software, in order to generate frequency and percentage. Open-ended questionnaires were included in the assessment to analyze the community opinions on quarry impact. Therefore the gathered information from the open-ended questionnaires has been summarized by the author. Based on the output from the SPSS software and from open-ended questionnaires the quarry impact on resident's lives in the immediate vicinity of the quarry sites has been assessed.

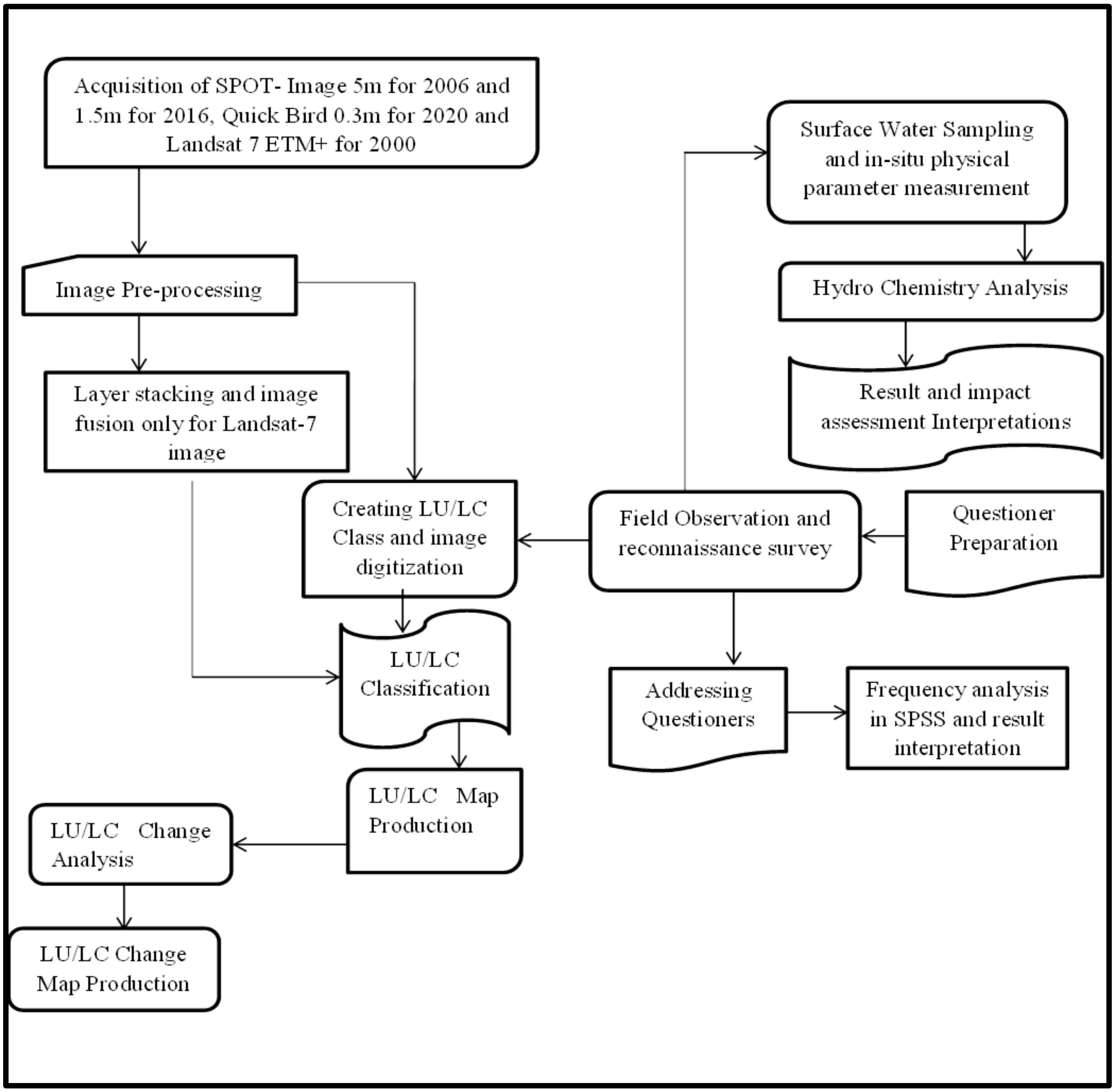

Figure 4.2. Summarized methodology flow chart.

4.1 Data and Materials

Spatiotemporal and multispectral images used to land use land cover change detection were acquired from Ethiopia Mapping Agency those high-resolution images namely SPOT-5 for

2006/5m and SPOT-7 for 2016/1.5m and Quick Bird 2020/0.3m. Landsat-7 ETM+ panchromatic band for the year 2000/15m is downloaded from the USGS web (Earth Explorer). All of them were projected into projected coordinate system WGS-1984-UTM-Zone 37, the data source and type are described in Table 4.1 with other data.

Table 4.1. Data source and description.

No.	Data Description	Data type	Date of acquisition	Spatial Resolution/meter, Scale/	Data Source
1	Landsat-7 ETM+ panchromatic bands	Raster	2000	15	USGS
2	SPOT-5 Satellite Image	Raster	2006	5	EMA
3	SPOT-7 Satellite Image	Raster	2016	1.5	EMA
4	Quick Bird Satellite Image	Raster	2020	0.3	EMA
5	Geological map	Raster	-	1:250,000	EGS
6	Hydrogeological map	Raster	-	1:250,000	EGS
7	Topographical map of south east Addis Ababa	Sheet	-	1:50,000	EMA

- Geological map of the study area simplified from Akaki Beseka geological map from Efrem Beshawred (2010), scale: 1:250,000.
- Physiographical map of the study area is prepared from DEM 15 m.
- Hydrogeological map of the study area is extracted from Akaki Beseka hydrogeological and hydrochemistry map from Bereket Fentaw and Mihret Manaye, 2011, scale: 1:250,000.
- Meteorological data acquired from the national meteorological agency of Ethiopia.
- Addis Ababa quarry owner’s data from Addis Ababa environmental protection and green development commission.

Surface water measurement equipment

- pH and EC meter from the Geological Survey of Ethiopia.
- Garmin Geographical Positioning System from Geological Survey of Ethiopia.

The software's used for the current study

- ✓ Arc GIS 10.8 was used to extracts and digitizes geological and hydrogeological maps, also extract and digitized satellite images for land use land cover change purpose and used to prepare surface water sampling site map also used to prepare study area location map.
- ✓ ERDAS IMAGINE 2015 used to layer stacking and image fusion (resolution merging)
- ✓ Google Earth Pro used for exploring the background and current use of the study area before field investigation, for accuracy assessment of the prepared LULC map.
- ✓ QGIS 3.10.1 used for classified image land use land cover change detection analysis and to generate random X and Y points for accuracy assessment.
- ✓ Global Mapper 12 and surfer 10 used to generating physiographical maps and drainage patterns of the study area.

Chapter Five

Result and Discussion

In these chapter results of the physical and chemical analysis of river water samples at the upstream, on selected quarry sites and downstream, social impact assessment using a structured questionnaire and the land use land cover change of the study area between 2000 and 2020 have been presented and discussed hereunder.

5.1 Hydrochemistry

5.1.1 Surface water physiochemical analysis

The selection criteria for the study of chemical and physical parameters for the surface water samples are based on the chemical composition of quarry materials and its expected flux into the river. For instance, if the excavated geological material is basalt it is expected more mafic (ferromagnesian) minerals like olivine within it. Therefore when crushed rocks of these basaltic materials come in contact with surface water bodies, they have the capability to dissolve more ions and the concentration is likely expected higher in the quarry site and downstream than the upstream (the more fine particles the more dissolve with water) section. So that the quarrying activity can aggravate weathering of rocks and dust a particle which lead to more mobile ions to be dissolved in the river. In the current study, the quarry site has been taken as a reference point whereby any sections of the river above the active quarry site has been taken as upstream and any below the active quarry site has been taken as downstream section in this text. Analysis of water samples at the quarry site and downstream have been compared with respect to the physicochemical characteristics of the upstream of the rivers. Generally from one river along with the quarry sites, three representative samples are taken and analyzed. A total of 9 water samples have been collected on selected rivers within the catchment. Due to their crosscutting of active quarry sites as shown in fig 5.1, three different rivers namely Dengora, Fanta and Big Akaki has been selected.

As sited in Enatfenta Melaku (2017) the impact of quarry activity will be significant if it is near river banks. The spring eye damaged, the natural flow of water changed and the quality of river water will decrease based on the quarry property. Runoff from the quarry yard and dewatering of the pit can produce pollutants discharged to the surface water; such as a total flow of steeled solid, turbidity and total suspended solids. The amount of pollution is depending on the composition of extracted geological material (Richard et al., 1999).

During field investigation diverted river channel has been observed due to accessibility road that connects the main get of the quarry site to the main asphaltic road has been constructed by the quarry owners whereby they fill with excavated materials across rivers which change the natural flow direction.

All the collected water samples are analyzed in central laboratory of Saba engineering Pvt. Ltd. Co. Geologically the area cover by volcanic rocks since it is located in the south eastern part of Addis Ababa near to the Ethiopian Great Rift Valley. It is mainly covered by scoria cones and younger basaltic rock; those rocks are main excavated construction materials within the study area. From the analyzed physiochemical parameter results, as shown in Table 5.1; 5.2 and 5.3 are selected based on the lithologies that could likely change the physicochemical makeup of the river. Basalts commonly contain Phenocrysts of olivine and plagioclase. Basalt infield with secondary material (amygdaloidal) and scoria cones are common at the south of Addis Ababa and near rift escarpment.

Human activities may modify water composition extensively through direct effects of pollution a knowledge of rock composition is essential to understanding the chemical composition of natural water, The chemical composition of the crustal rocks of the Earth is significant in evaluating sources of solutes in natural freshwater (John D., 1985). From the various activities, anthropogenic impact in the case of these study extraction of construction materials along a riverbank could likely impact the quality of natural water.

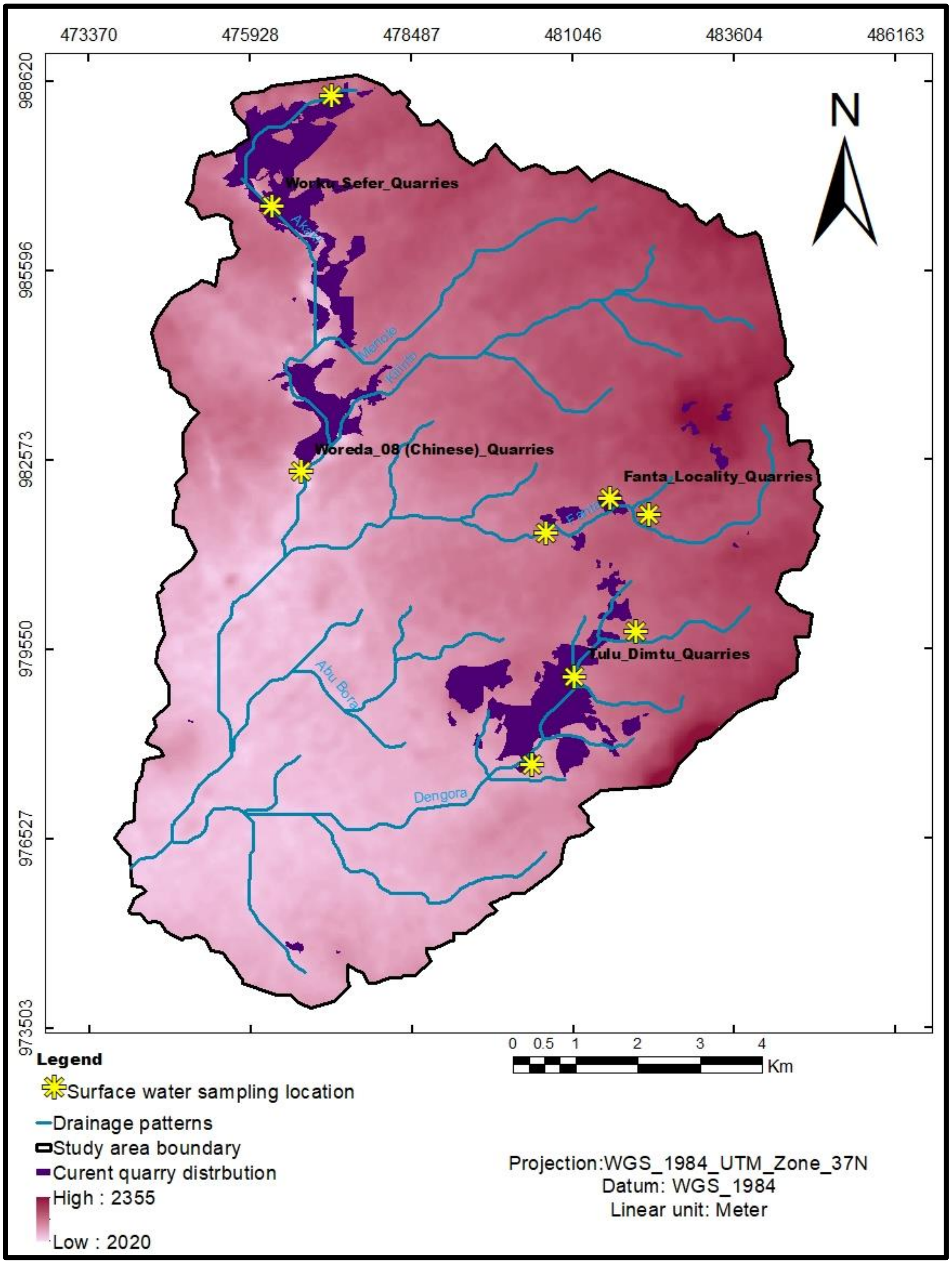

Figure 5.1. Surface water sampling and Social Surveying location map.

Table 5.1. Physiochemical result of Dengora River.

No.	Parameters	Results		
		Upstream of quarry site	At quarry site	Downstream of quarry site
1	Electrical conductivity (MS/cm)	531	714	677
2	pH	7.91	8.09	8.03
3	Turbidity	8.0	14	11.0
4	Temperature/C°	21.2	24.1	26.7
4	Total dissolved solid (Mg/l)	345.2	464.1	440.1
5	Total hardness (Mg/l)	265	280	300
6	Alkalinity (Mg/l)	260	245	280
7	Color (Mg/l cob. Unit)	10.0	30	30
8	Calcium Ca^{2+} (Mg/l)	22.4	38.0	50.0
9	Magnesium Mg^{2+} (Mg/l)	50.2	44.4	42.0
10	Iron Fe^{2+}(Mg/l)	0.04	0.05	0.07
11	Fluoride F^- (Mg/l)	0.95	1.65	1.60
12	Sodium Na^+ (Mg/l)	53.2	73.4	69.8
14	Potassium K^+ (Mg/l)	3.50	6.20	6.00
15	Manganese Mn^{2+} (Mg/l)	0.006	0.012	0.014
16	Bicarbonate HCO_3^-(Mg/l)	317	299	342
17	Phosphate PO_4^{3+} (Mg/l)	18.0	20.0	18.0
17	Nitrate NO_3^- (Mg/l)	0.97	1.36	0.97
18	Chloride Cl^- (Mg/l)	6.0	30.0	27.0

5.1.1.1 Physiochemical properties of water along the Dengora River

Electrical conductivity (EC) of the water sample taken at the quarry and downstream of the quarry site show higher values than the sample upstream of the quarry site, with the highest value recorded at the quarry site. This suggests that high dissolved solids and dissolved ions present within this site because the quarry site can discharge fine particles from quarry crusher and fine materials discharged during blasting this can increase dissolved ions. The weathered mass is also disturbed during quarry clearing leading to increase loading of ions into the river water. The ultimate source of most dissolved ions is in the mineral assemblage in rocks near the land surface. The presence of dissolved ions in water changes some of its physical properties, notably its ability to conduct electricity. The dipolar nature of the water molecule, however, is an important factor in the behavior of the solute ions as well as the solvent (John D., 1985). However at the downstream section of this river electrical conductance decreased slightly than within the quarry site, which is generally related to the decreased number of free ions in solution as they could be adsorbed into clay matrix. Temperature also plays a great role to dissolve minerals in water since it increases the chemical reaction rate. The temperature result recorded in the Dengora river increase from upstream to the downstream continuously, as heated water from quarrying operations is discharge into the river, and this could possibly affect the rate and type of chemical reactions in solution.

Total dissolved solids (TDS) at the reference point (upstream of the river) was lower than the result measured within the quarry and this can be due to mining activity because if there is the discharge of fine particles and weathering of rock mass the concentrations of anion and cation increases leading to higher total dissolved solids due to weathering and dissolution.

Turbidity is lower at the upstream section where there is no quarrying and significantly increases at the quarry site and slightly decreased at the downstream section of this river. This result is an indication for a high concentration of fine particles and/or course materials continuously being discharged into the river from the quarrying activity, and this could be aggravated due to blasting and continuous vibration from crushing activity, whose sphere of influence progressively decreases away from the quarry site, hence the lower turbidities in the upper and downstream sections. The color index of the river water increased within the quarry and at the downstream section, confirming the turbidity of the water which leads to color change. This was confirmed during field observation while sampling where the river water upstream the quarry was more naturally colored than those at quarry site and just downstream the quarry site.

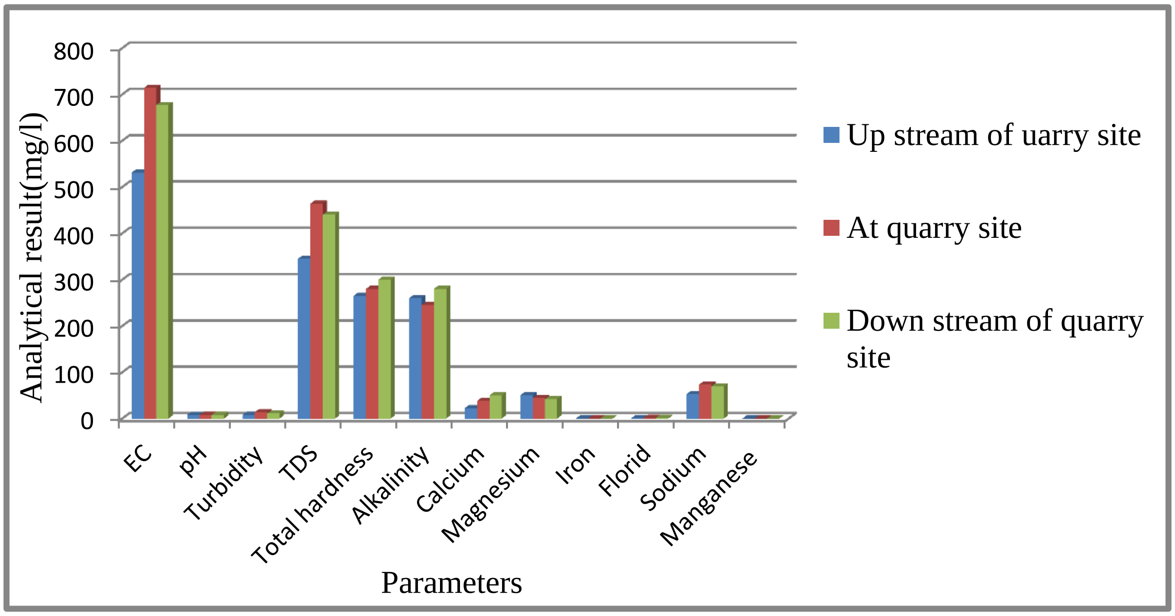

Figure 5.2. Physiochemical parameters change of Dengora River relative with quarry activity.

Total hardness of natural water can be expressed as the summation of Ca^{2+} and Mg^{2+} multiplying by 2.5 and 4.1, respectively. In the case of the Dengora River total hardness of the water increased from the upstream to the downstream continuously, indicating the increment of hardness constituents (Ca^{2+} and Mg^{2+}). These cations could be easily released from weathered minerals (olivine, plagioclase and pyroxene) in the basalts which are being crushed at the quarry sites. Disintegrated and weathered basaltic rocks within and downstream the quarry site led to higher input of those ions leading to increased water hardness.

Alkalinity could increase related to fast weathering of silicate minerals such as plagioclase and pyroxenes. In the current case, the alkalinity of Dengora River is higher in the upstream section, slightly lower within the quarry and significantly increased in the downstream section. The effect of quarrying can be observed downstream as alkalinity increased. However, it should be noted that alkalinity varies significantly unless measured in the field and the results should be considered with caution. The higher alkalinity at the upstream section could be related to clay minerals (formed by silica weathering).

The pH value shows a slight increment towards downstream. Most of the measured cations and anions, except Mg^{2+} show, increased values from the upstream to the downstream sections of the quarry site. The alkaline earth (Ca^{2+}) and alkalis (K, Na) are mobile and dissolvable elements and they are easily removed to the solution during and soil erosion or rock weathering), while Fe, Mn increment could be related to the clearing of quarry sites where these might occur in the soil as nodules, in addition to their release from ferromagnesian minerals (such as olivine). Mg^{2+} could significantly input from the thick clay rich black cotton soil in the area, hence its concentration might be significantly higher even upstream the quarry site and quarrying activity might not significantly change the baseline value of this element. Fluoride increases significantly (above the WHO safety limit) at the quarry site and downstream the quarry site and this could be related to its release from crushing of fluoride and other amygdales rich vesicular basalt and scoriaceous basalts (which are considered to be rich in volatile-rich amygdales which usually contain fluoride and other ions).

Phosphate and Nitrate increment could be easily associated with the fertilizer based agricultural activities which are common around the quarry sites, and the quarrying activity enhances their circulation in the river system by enhancing channeling of the ground. The increment in chloride could be related to the use of chlorinated water in the quarry site and this is easily associated with human impact.

Generally quarry sites on basalt and scoria bedrocks along Dengora River exert significant pressure on surface water resources by negatively impacting the physical and chemical properties of the river water as can be seen by the change in the physical situation of the river (higher turbidity, color change) and increasing values of most of the ions (higher TDS, EC, alkalinity, hardness, etc.). This could be disastrous to human health (such as increased fluoride), strongly

Table 5.2. Physiochemical result of Fanta River.

		Results		
No.	Parameters	Upstream of quarry site	At the Quarry site	Downstream of quarry site
1	Electrical conductivity (MS/cm)	608	467	998
2	pH	8.01	7.69	8.57
3	Temperature/C°	24.9	28.6	27.3
3	Turbidity	11.0	8.0	205
4	Total dissolved solid (Mg/l)	395.2	303.6	648.7
5	Total hardness (Mg/l)	198	250	390
6	Alkalinity (Mg/l)	170	225	425
7	Color (Mg/l cob. Unit)	20.0	10.0	20.0
8	Calcium Ca^{2+} (Mg/l)	26.4	26.4	46.8
9	Magnesium Mg^{2+} (Mg/l)	31.7	44.2	65.5
10	Iron Fe^{2+}(Mg/l)	0.04	0.05	0.01
11	Fluoride F^- (Mg/l)	1.70	0.70	1.80
12	Sodium Na^+ (Mg/l)	81.8	46.3	171.7
13	Bicarbonate HCO_3^-(Mg/l)	207	275	519
14	Potassium K^+ (Mg/l)	5.40	2.90	9.20
15	Manganese Mn^{2+} (Mg/l)	0.007	0.006	0.013
16	Nitrate NO_3^- (Mg/l)	0.79	0.53	1.98
17	Phosphate PO_4^{3+} (Mg/l)	21.0	14.0	24.0
18	Chloride Cl^- (Mg/l)	25.0	25.0	26.0

-affects the ecosystem (such as eutrophication due to increased phosphate and nitrate), and limits the use of the river water for societal activities. As observed during fieldwork, the local people using the river water for domestic purposes in the upstream and for agricultural use downstream of the quarry site feel the change. Their systematic responses are given in the socio-economic impact assessment section.

5.1.1.2 Physiochemical properties of water along the Fanta River

The electrical conductivity of the water taken at the upstream of the quarry is higher than the value within the quarry site but it significantly increases at downstream of the active quarry site. This can be due to weathered mass of scoria and basalt are exposed at abandoned quarry sites located at downstream of the active quarry. Along Fanta River only one basalt aggregate quarry site was active and its operation started recently this implies there is no more weathered mass and fine dust particle at active quarry than abandoned scoria and basalt quarry at downstream section. Most likely the concentration of ions increased at downstream it can be from abandoned quarry weathered mass leads to higher dissolved ion concentrations in solutes as a result increased EC of the river water.

Along Fanta River, there is only one active and younger quarry site and it is not expected to produce more fine materials into river banks as much as quarry sites exposed along Dengora River. As result turbidity and total dissolved solids of the river water lower at the active quarry site than the upstream and downstream.

The pH value of the water taken from upstream higher than the value measured at the quarry site downstream of the quarry pH value increases and the water became more basic than.

The measured value of the total hardness of the water at the active quarry site and downstream section is higher than upstream. This is directly related to the value of Ca^{2+} and Mg^{2+} cation concentration, also as try to show in table 5.2 and fig 5.3 the result of those cations are increases at the active quarry site and downstream section of the quarry. Both cations are released from clay soil when at the beginning of quarry excavation since it started recently. Besides total hardness Ca^{2+}, Na^{+} and Mg^{2+} concentration is also increased relative to quarry activity; those are constituents of clay matrix. Fluoride concentrations increased in upstream and downstream than of active quarry site. It is above the limit safety of WHO.

Nitrate and phosphate concentration of Fanta River is higher at the upstream and downstream than active quarry sites. It implies agricultural activities are going on and the cultivators are used more fertilizer and pesticides which are released those ions into the river at the upstream and downstream section of the quarry site.

However, the concentrations of measured parameters show some fluctuation on Fanta River overall activity of quarry directly or indirectly can adversely impact on river water additional to another anthropogenic impact.

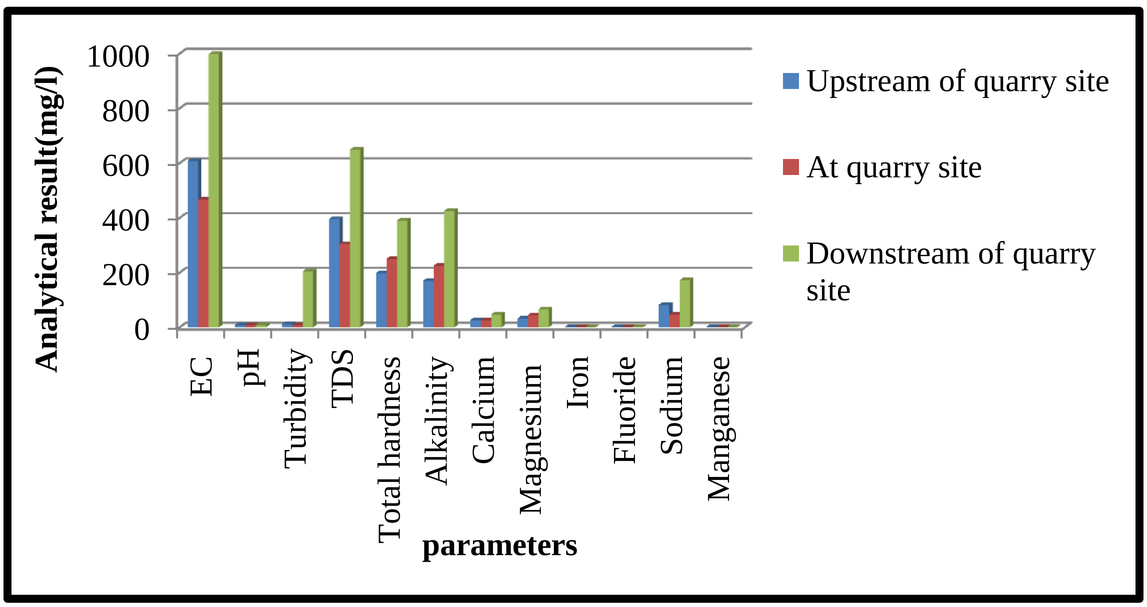

Figure 5.3 Physiochemical parameters change of Fanta River relative with quarry activity.

5.1.1.3 Physiochemical properties of water along the Akaki River

As shown in table 5.3 and fig 5.5 turbidity of Akaki river as higher in water samples taken within quarry rather than water samples taken from downstream and upstream of the quarry, this is most likely related to the higher amount of fine particles discharge from quarry dust and upper cleared soil from quarrying area. The upper cleared soils of the quarry were discharged directly into the river as try to show in fig 5.4 and can aggravate turbidity of the Akaki River in addition to other pollutants discharged from different sources in the city. The pH value of the water measured at the quarry site is decreases and has the same value in the upstream and downstream of the quarry site.

Total dissolved solids and the total hardness value of the water significantly increased at the quarry site. Total dissolved solids of the water is related with the residue of total ions which presented in the river water, the result that shows higher value in the water sample taken at the quarry site of Akaki River than the value of the water taken from upstream and downstream of the quarry site, based on the analyzed physiochemical result quarrying activities along the downstream section of big Akaki river play an important role to pollute the river water quality in addition to another anthropogenic impact.

The alkalinity of the Akaki River is lower at the reference point (at the quarry site) than upstream and downstream. This is most likely related to other pollutants that discharged from other sources to increase the acidity of the water indirectly decrease the alkalinity value.

Calcium, Magnesium and Sodium concentrations are increases at the quarry site than upstream and downstream. Those ions may dissolve from clay matrix of upper cleared soil of the quarry because those are major cations of silica mineral, shown at fig 5.4.

Nitrate and phosphate increased at downstream of the quarry sites than the analyzed value at the quarry site and upstream, obviously nitrate and phosphate increments related to agricultural activity. The result could be more related to concentrated irrigation activity is going on at the downstream section of the quarry sites.

Table 5.3. Physiochemical result of Akaki River.

No.	Parameters	Results		
		Upstream of quarry site	At the Quarry site	Downstream of quarry
1	Electrical conductivity (MS/cm)	400	460	530
2	pH	6.7	6.6	6.7
3	Temperature/C°	19	19.4	20.5
3	Turbidity	45	135	110
4	Total dissolved solid (Mg/l)	264	825	381.6
5	Total hardness (Mg/l)	240.2	466	265
6	Alkalinity (Mg/l)	228.4	194.8	252
7	Color (Mg/l cob. Unit)	30	125	140
8	Calcium Ca^{2+} (Mg/l)	21.6	64.2	38.4
9	Magnesium Mg^{2+} (Mg/l)	42.3	72.5	40.6
10	Iron F^{2+}(Mg/l)	0.04	0.05	0.07
11	Fluoride F^- (Mg/l)	0.35	0.7	0.95
12	Sodium Na^+ (Mg/l)	55	72.7	63.2
13	Nitrate NO_3^- (Mg/l)	0.4	0.42	0.57
14	Potassium K^+ (Mg/l)	4.5	4.5	5.60
15	Manganese Mn^{2+} (Mg/l)	0.006	0.004	0.009
16	Bicarbonate HCO_3^-(Mg/l)	309.2	332	307.4
17	Phosphate PO_4^{3+} (Mg/l)	25	12.4	19.0
18	Chloride Cl^- (Mg/l)	14.8	27.2	19.4

Figure 5.4. Trucks disposing cleared upper soil from quarry in to Akaki River.

One question was included with impact assessment questionnaire were conducted for workers (presented in Annex-C) about training and follow up from the governmental body to protect quarry activity into river water a result shows 23 (46%) of workers from the total demonstrates there is no any training and follow-up from the governmental body and 13 (26%) of them said the follow-up and training is low to protect the impact of the quarry on the adjacent river.

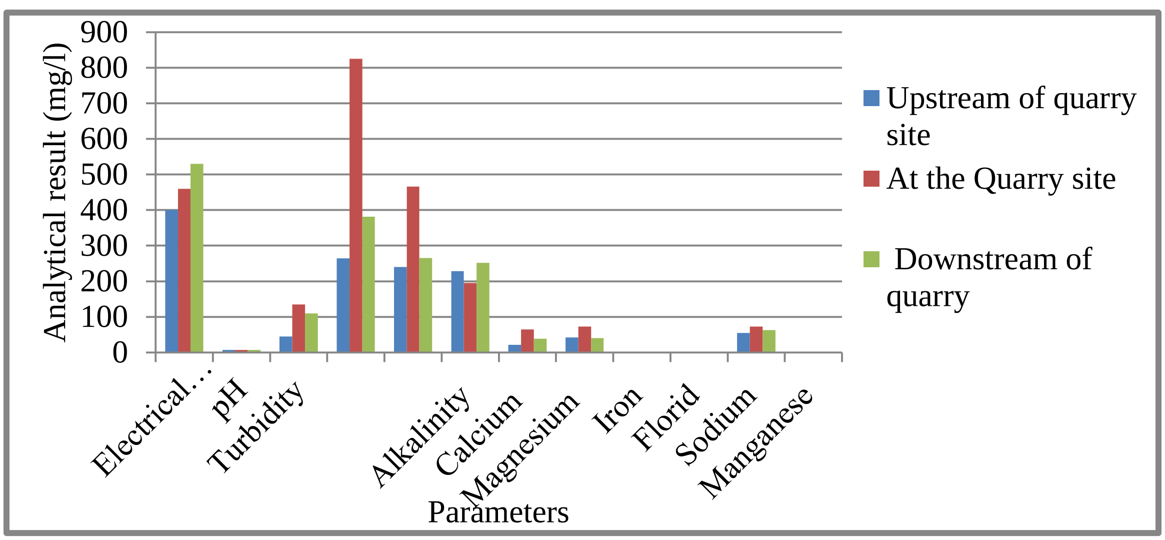

Figure 5.5. Physiochemical parameters change of Akaki River relative with quarry activity.

Generally, in addition to other sources of pollutants Akaki River is impacted by quarrying activity, as shown on fig 5.4 the upper soils cleared from quarry sites are discharged into Akaki River this can adverse a great problem on river ecosystem and this may indirectly affect socioeconomic development. Additional to controlling other sources of pollutants in the city of Addis Ababa responsible agencies should take into consideration quarry impact on river water resources.

5.2 Land use land cover of the study area in 2000, 2006, 2016 and 2020

5.2.1 Land use land cover of the area in 2000

Land use land cover classification of the study area in 2000 (fig 5.6) demonstrated that cultivated land was the largest land use from the total study area during the considered year, and as presented in Table 5.4 about 9564 ha which is 83% of the area covered with cultivated land, while built-up has more areal extent than other class after cultivated land it covers about 1360.5 ha of the area which means 11.81% of the area. Whereas bare land and the forest were the smallest land use in 2000 those land were cover by about 330.13 ha (2.86%), 238 ha (2%) of the land use respectively. Based on the classified image quarry site was prospecting as a new field in 2000, however it was cover about 27.61ha (0.23%) of the study area and there was no classes of shrub-land (0%).

5.3.1 Land use land cover of the area in 2006

The classified image fig 5.8 shown that the largest is in 2006 was covered with cultivated land but slightly decreased from the past classified year (2000) image, also as presented in Table 5.4 about 8333.5ha (72.41%) of the study area was covered with cultivated land. Built-up was the second-largest class in 2006 which means 1875.8ha (16.2%) of the study area covered with built-up it shows an increment from the past classified image (2000). About 103ha (0.98%), 85ha (0.73%) and 916.23ha (7.96%) were covered with forest, shrub land and bare land respectively. In this year the result shows that bare land was expanded significantly this can be due to soils were disturbed for the quarry purpose, as a result in the classified image showed bare lands were located beside small quarry sites.

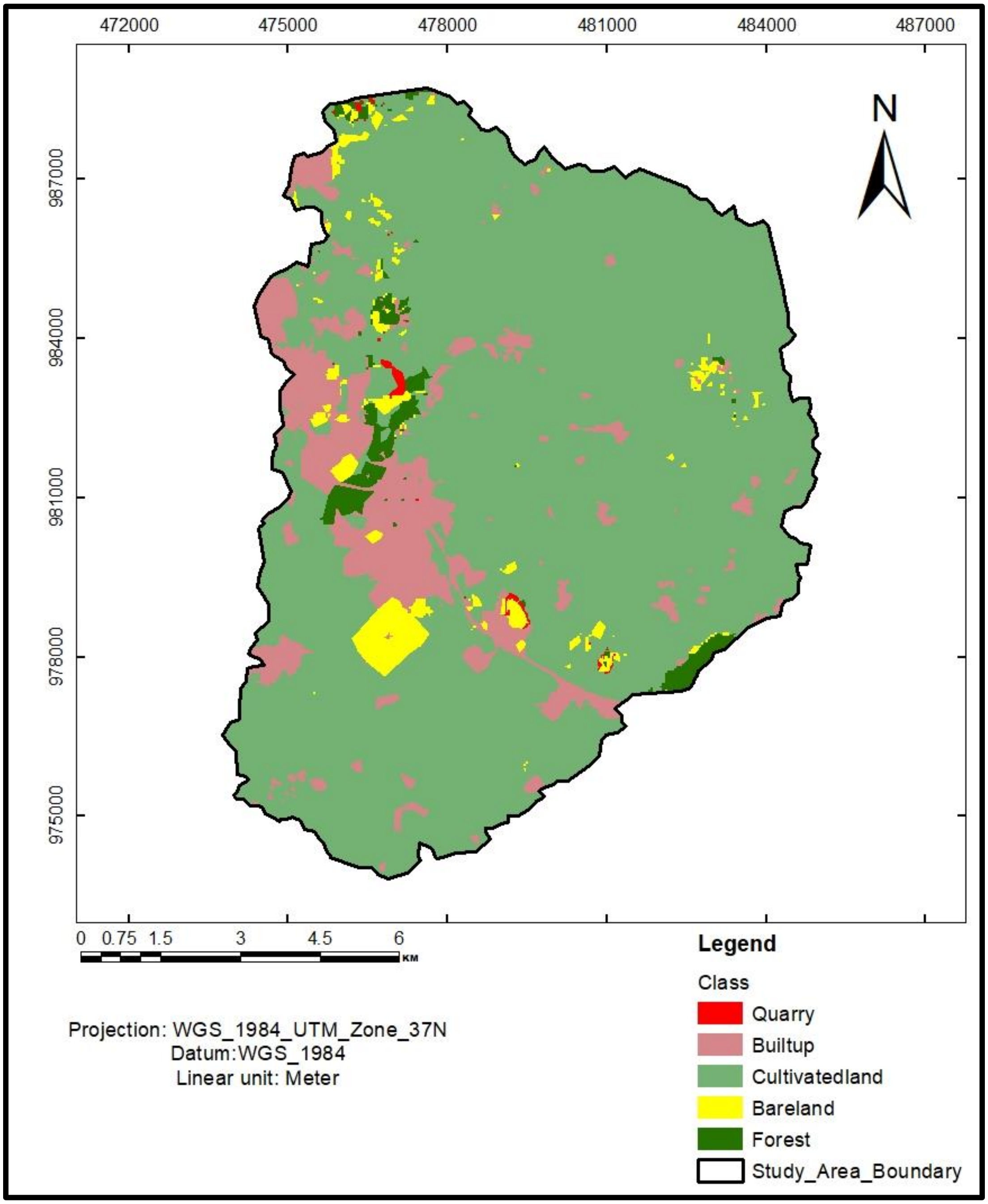

Figure 5.6. Land use land cover map of the area in 2000.

As try to show in fig 5.8 quarry sites showed slight increment relative to the past classified image, as presented in table 5.4 about 202.9 ha (1.76%) of the study area was covered with quarry, its increment was parallel to build up beside this the development of the study area infrastructure was beginning in 2006.

Table 5.4. Land use land cover class and areal extent of the study area with in 2000, 2006, 2016 and 2020.

	2000		2006		2016		2020	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Cultivated land	9564	83	8334	72.41	6362	54.9	5634	48.86
Built up	1361	11.8	1876	16.29	3930	33.9	4724	40.98
Quarry	27.6	0.24	203	1.76	729	6.3	740	6.42
Forest	238	2	104	0.98	178	1.54	145	1.26
Shrub land	0	0	85	0.73	130	1.13	125	1.1
Bare land	330	2.86	916	7.96	251	2.17	159	1.38
Total	11520	100	11517	100	11581	100	11529	100

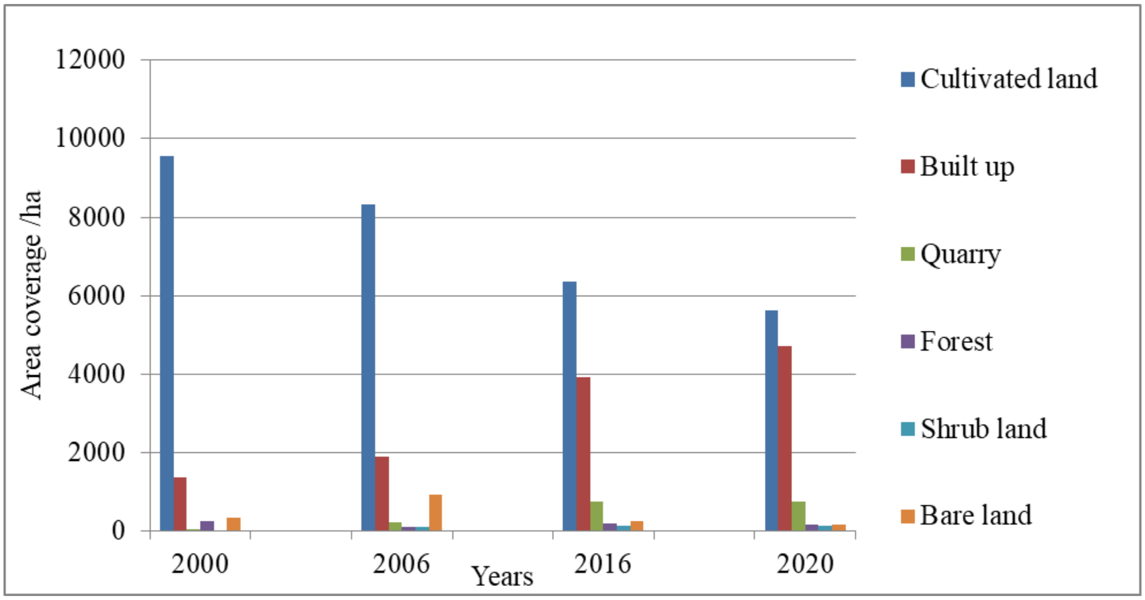

Figure 5.7. Land use land covers class distributions of the study area from 2000 to 2020.

The rate of quarry expansion for all year interval calculated according to (Suliman et al., 2017) equation;

$$R = \frac{a2 - a1}{t}$$

a_2-belongs to recent year land use land cover, **a_1**-referred to past year land use land cover, **t** belongs to time interval between initial and recent year and **R**-belongs to rate of change per year.

Areal coverage of quarry site in 2000 was 27.61 ha, and 202.9 ha in 2006 and year interval between them is 6 years. Therefore the calculated rate of quarry expansion between 2000 and 2006 shows 29.215 ha/yr.

5.2.3 Land use land cover of the study area in 2016

Land use land cover classification result in 2016 shows dramatic expansions of quarry sites were recorded. As try to show in fig 5.9 and table 5.4 729.35 ha (6.3%) of the study area was covered with quarry sites. Additional to quarry expansion there was built up increments during the considered year, about 3930.04 ha (33.9%) of the study area was covered with built-up it was the largest land use after cultivated land in 2016. Cultivated land was cover about 6361.57 ha (54.9%) of the study area, cultivated land still cover the largest area but from the beginning classified and analyzed image the class is shrinking.

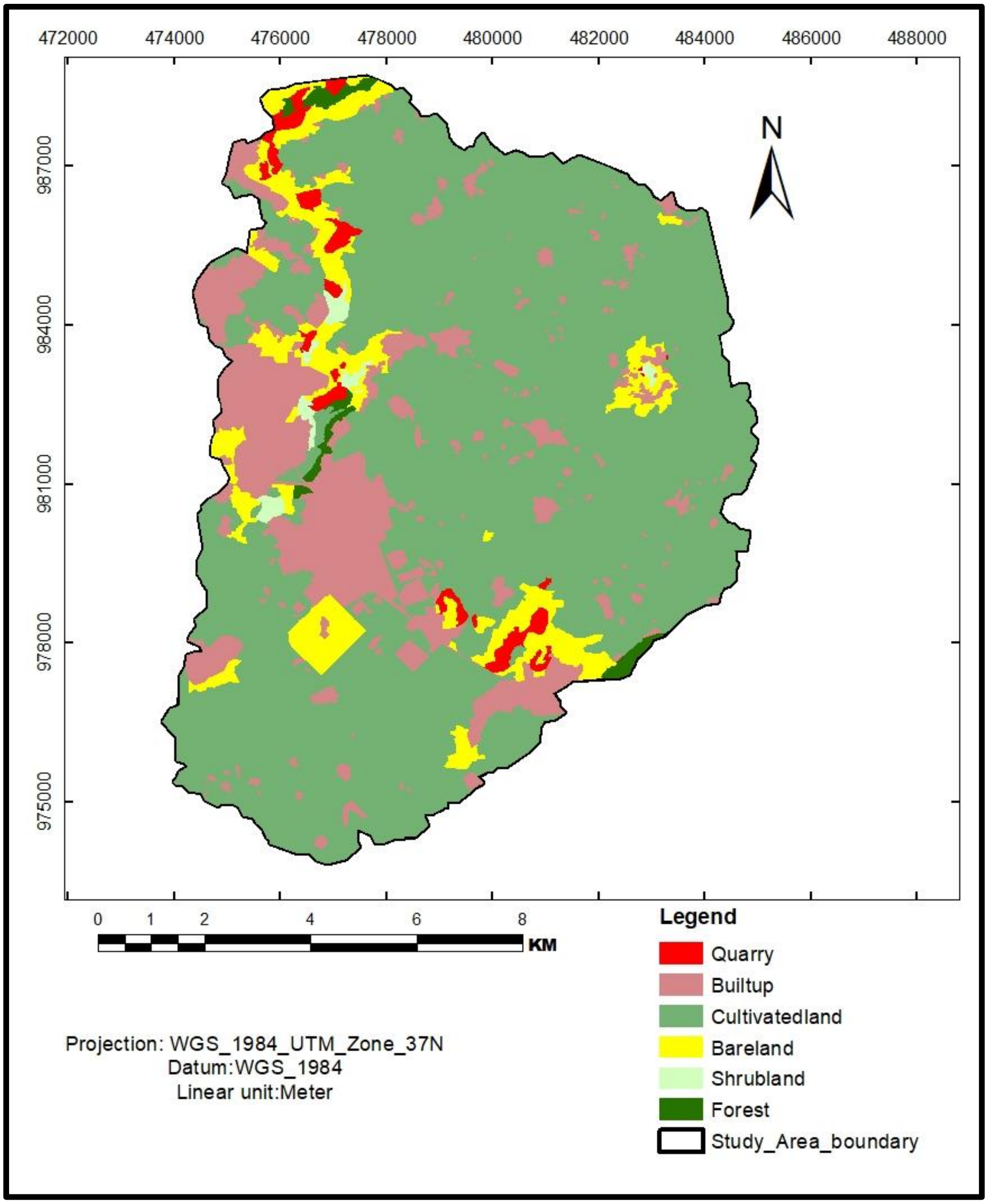

Figure 5.8. Land use land cover map of the study area in 2006.

In 2016 251.6 ha (2.17%), 130.51 (1.13%) ha and 178.3 (1.54%) ha of the study area were covered with bare land, shrub land and forest respectively; they were cover the smallest area.

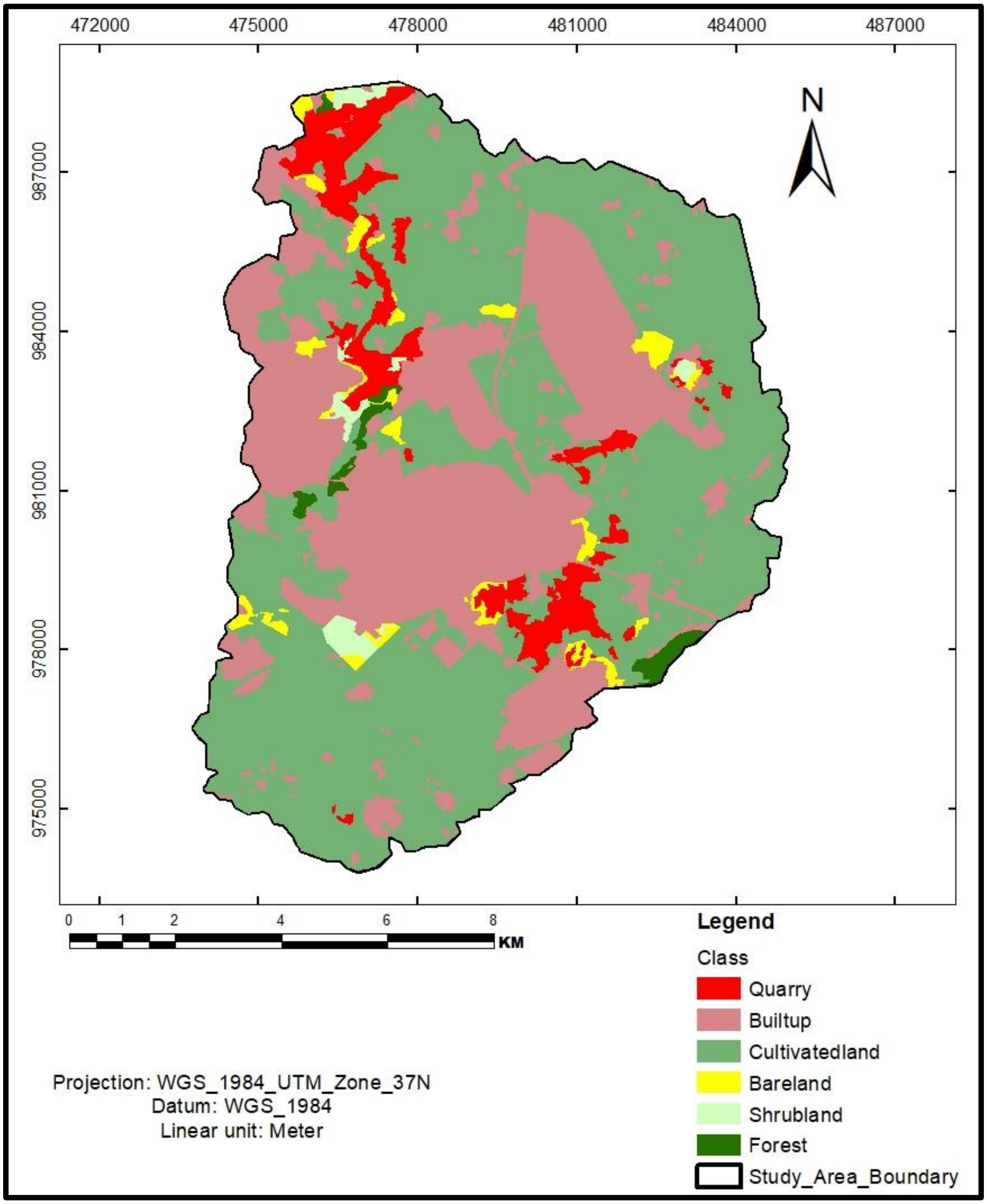

Figure 5.9. Land use land cover map of the study area in 2016.

The calculated rates of quarry expansion demonstrate that 52.645 ha/year increments between 2006 to 2016 it indicated quarry expansion doubled relative to the rate in between the past computed result. Also as shown in fig 5.9 it is visible and can be detected how quarrying activity expanded in this year additional, besides this fig 5.8 and fig 5.9 shows built-up class expansion as the expense of cultivated land.

5.2.4 Land use land cover of the study area in 2020

In this year the classified land use land cover map of the study area indicates about 5634 (48.86%) ha of the area covered with cultivated land from the starting year it is declined, and about 4724.6ha (40.98%) of the study area was covered with built-up which impacted the cultivated land. In 2020 quarry sites were slight increases relative to 2016; it was cover about 740 (6.42%) ha of the study area. Bare land, shrub land and forest again cover a small part of the study area which is 159.2 ha (1.38%), 125.8 ha (1.1%) and 145.12 ha (1.26%) respectively, obviously, the southern part of Addis Ababa topographically flat and undulating and the most known land use is cultivated land which includes farmland grassland and irrigation, from the produced four LULC maps of the study area recognized that the largest are of the land covered with cultivated land; however, in all considered year the LULC maps show the area covered with this class is declined, besides this built up and quarry site were expanded this is an expense of cultivated land. The calculated rate of quarry expansion between 2016 and 2020 show 2.73 ha/year expansion was recorded.

5.3 Change Detection

Net LULC change detection was made between 2000 and 2020 to recognize which natural environment is impacted by quarry expansion. The temporal change of land use land cover of the study area shows cultivated land were decreases by 3941.19 ha within 2000-2020. The detected result of this study also indicated built-up expanded about 3366.05 ha in between the last 20 years. The overall expansion of quarry sites were about 698.68 ha, it were cover only 27.61 ha of the study area at the beginning of the considered year in this study (2000), the significant expansion of quarry sites was recorded within such small study area, implies mainly cultivated land is affected by built up and quarry expansion.

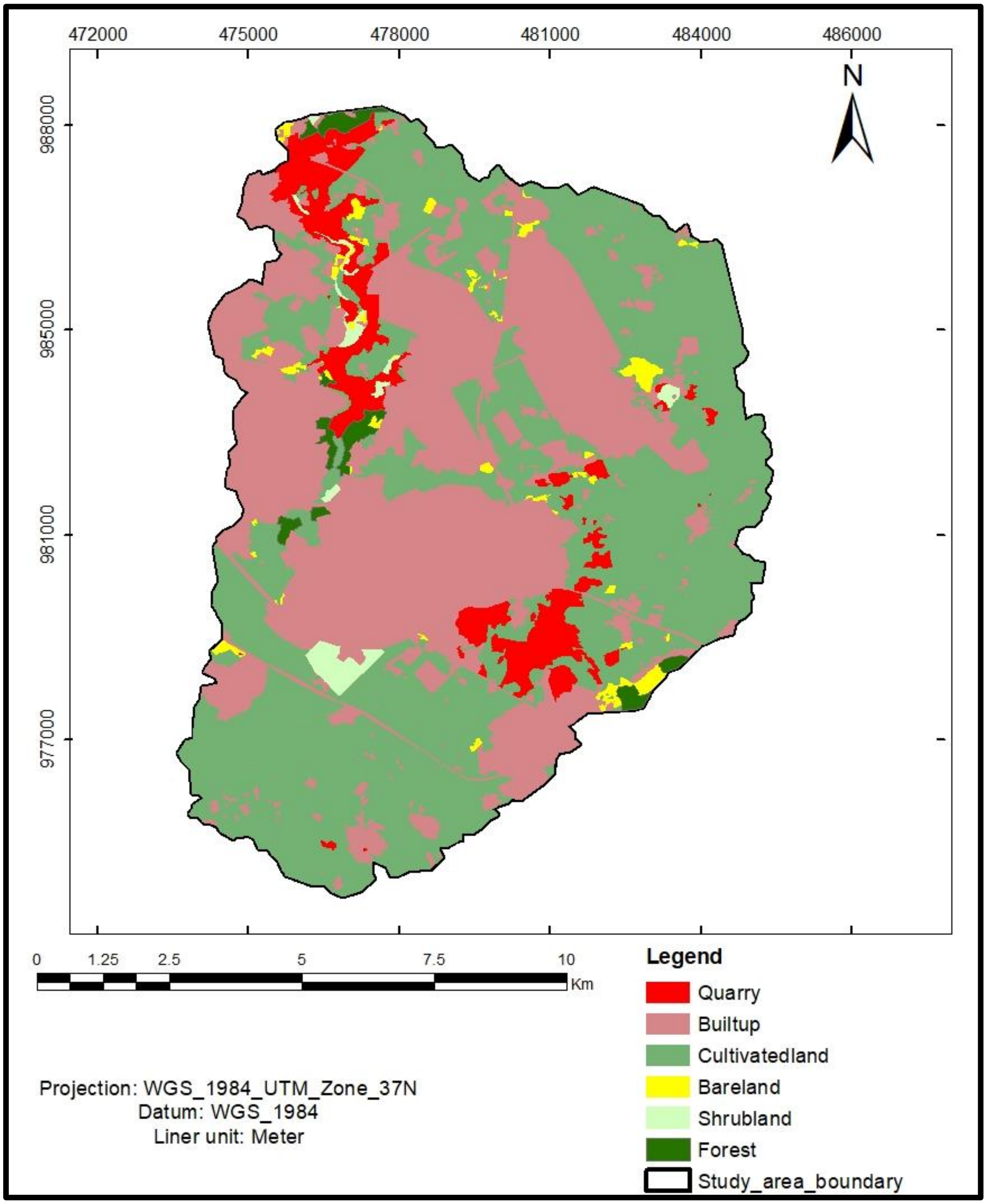

Figure 5.10. Land use land cover map of the study area in 2020

Based on the detected LULCC of the study area forest and bare land declined about 92.15 and 151.21 ha respectively; shrub land was 0% in 2000 which is the first considered year however in 2020 it covers 125.82 ha this can be due to forest degradation. As try to show in fig 5.11 and table 5.6 cultivated lands were highly impacted mainly due to built-up and quarry class expansion.

Table 5.5. LULC Classes Transition matrix.

		LULC 2020 (ha)							
		Bare land	Built up	Cultivated land	Forest	Quarry	Scrubland	Grand Total	changed class
LULC 2000 (ha)	Bare land	4.6	140.1	20.6	6.6	85.8	72.6	330.3	-151.2
	Built up	6.1	1237.6	79.8	6.2	17.6	4.9	1352.2	3366.1
	Cultivated land	146.6	3291.5	5478.6	31.6	577.2	29.2	9554.7	-3941.2
	Forest	21.4	48.5	34.4	98.5	16.2	18.6	237.5	-92.2
	Quarry	0.4	0.6	0.15	2.4	23.4	0.5	27.5	692.7
	Grand Total	179	4718	5613.5	145.3	720.2	125.8	11502.1	

Generally, this study implies there is a significant change of land use land cover in the downstream section of the big Akaki River between 2000 and 2020; especially the expansion of quarrying was recorded in the last 20 years. If the quarry sites not rehabilitate and managed very well in and around the urban center the area will lost its beauty because mining activity creates an unpleasant and scared place.

Table 5.6. Net change of LULC Classes from 2000-2020.

LULC Class	2000 (%)	2020 (%)	Net change 2000-2020 (%)
Quarry	0.24	6.42	5.18
Built up	11.8	40.98	29.18
Bare land	2.86	1.38	-1.48
Cultivated land	83	48.86	-34.14
Shrub land	0	1.1	1.1
Forest	2	1.26	-0.74

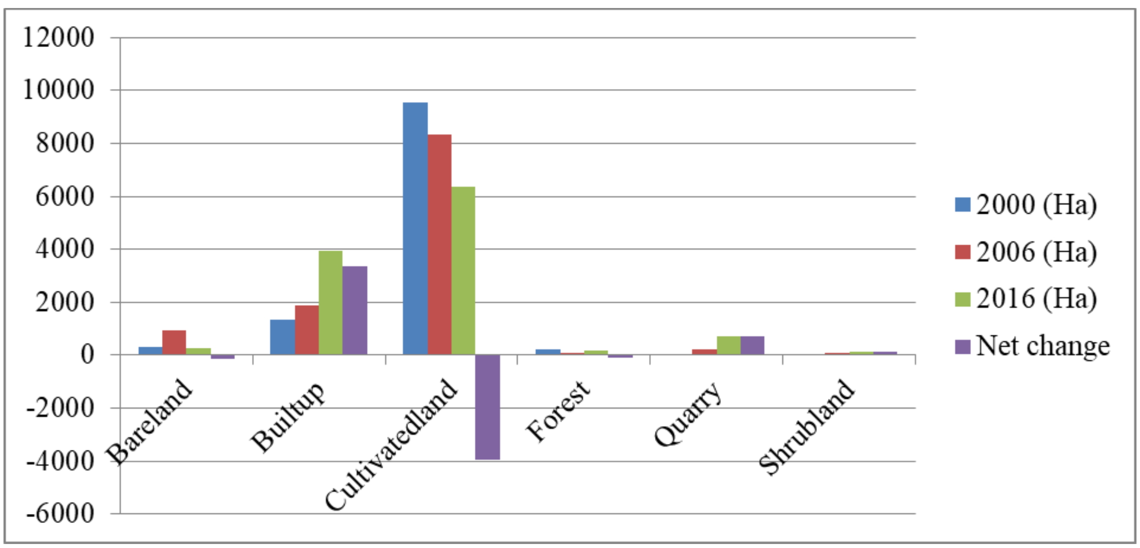

Figure 5.11. LULC class distribution and net change detection (2000-2020).

Additional to spatiotemporal land use land cover change detection this study also assesses LULCC of the study area by using questionnaires, 50 respondents were conducted in selected 5 quarry sites to assess the use of the land before it to be a quarry. As try to show in table 5.7 and fig 5.12, from total respondents 42% of them said the area was farmland before quarry operations started and 16 (28%) respondents have been responded that they don't know the place before quarrying operations started. Based on this and spatiotemporal analysis result quarrying activities are more affected the cultivated land, from their response the left land was covered with bare range land, grass land and forest, the questionnaires are presented in appendixes part.

The accuracy assessment result for the classified image of 2020 is 95% and for quarry, class is 100% accurate. The accuracy assessment result in 2016 shows 94.6% of the classified image and 100% of quarry class are accurate. Accuracy assessment results for 2006 and 2000 classified images demonstrated that about 85.7% and 86.1% is accurate respectively. For more detail, user and producer accuracy result from it is presented in the Appendixes part. However, the result of accuracy assessment up and down Jams et al. (1976) stated that if the result of accuracy assessment is more than 85% the classification is accurate.

5.4 Social impact of quarrying activities

5.4.1 Quarrying impact on quarry workers

Demographic description of the respondent

To assess quarry impact on the workers total of 50 respondents were conducted. They are working in five randomly selected representative quarry sites in the study area; such as Kontake business Pvt. Ltd. Co. located around Tulu Dimtu, I. F. H. Engineering Pvt. Ltd. Co. located around Woreda 08 at Akaki Kality sub-city locally named Chinese quarry, Kider Mohamed private quarry, located around Worku Sefer below the junction of Bulbula and Akaki rivers, Orkide business group Pvt. Ltd. Co. located around Fanta locality. The criterion to select quarry sites were first if they are located within the vicinity of the community, also based on the amount of construction materials processed and produced and if they are following different operation methodologies such like blasting dynamite and crushing rocks with machinery because those methods can aggravate the quarry impact on the community and quarry workers.

From the total respondent, 90% of the quarry workers were male and 10% were female. They are participating in different operations from heavy to light quarry work activity, such as operating machines, dynamite installations and controlling, driving tracks and working on the security field. Their age ranges from 19 to 50 years and 30 is the mode. The highest number (42%) of quarry workers have less than 5-year work experience, 36% of them have 5-10 years' work experience and 22% of them have more than 10 years' work experience, the most experienced workers are expected to know more difficulties and problems in quarrying activities. Demographical distributions of respondents presented here under table 5.8 and Fig 5.13. A questionnaire to assess the impact on quarry workers is presented in the Appendixes.

Table 5.7. Demographic description of quarry workers.

Gender	Frequency	Percent	How long you involved in quarry work	Frequency	Percent	Age	Range
Male	45	90	<5 years	21	42	Minimum	19
Female	5	10	5-10 years	18	36	Maximum	51
			>10years	11	22	Mode	30
Total	50	100	Total	50	100		

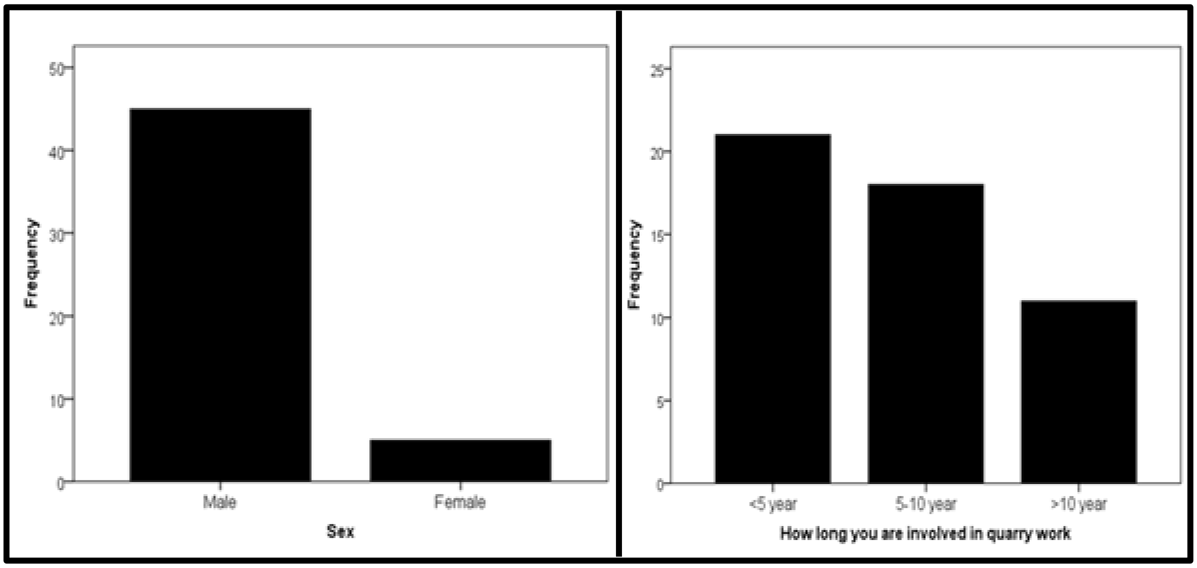

Figure 5.12. Demographical descriptions of quarry workers.

The collected questionnaires from quarry workers are discussed here, as shown in fig.5.13. from the total 50 respondents 32 (72%) of them said they had an accident during quarry work and the remaining 18 (28%) had not. In open-ended questionnaire they mentioned accidents ranges from light (fly rock) to heavy (death from dynamite blasting and machinery accidents). Some accidents are related to a misunderstanding with each other during work time; for instant, they said one worker has lost his two arms when he tries to clean the rock crasher because another machine operator switched on the crasher at the monitoring room without checking if there is anything to be harmed. The workers also mentioned that most accidents are caused by fly rocks and injuries during machine maintenances, according to their explanations this is caused due to safety equipment's supply shortage from the company as shown in Table 5.9, 37 (74%) of quarry workers don't use on job safety equipment's this can be related to safety equipment supply problem.

Totally more than half 27 (54%) of respondents said there is no safety material supply from the company and 38% of them said the supply is moderate (per six months). Workers indicated that the companies only focus on their income from a resource without the health and safety, consideration of the workers.

Table 5.8. Questionnaire result of quarry workers.

No.	Items	Answers	Frequency	Percent
1	Do you ever faced accident during quarry activity	No	14	28
		Yes	36	72
		Total	50	100
2	Dust related problem you are facing from quarry work	Low	2	4
		Moderate	15	30
		High	23	46
		Very high	10	20
		Total	50	100
3	Noise related problem you are facing from quarry activity	Low	2	4
		Moderate	10	20
		High	24	48
		Very high	14	28
		Total	50	100
4	Do you use on job safety equipment's?		13	26
		Yes		
		No	37	74
		Total	50	100
5	How do you see continuous Safety equipment supply from quarry owner	Good	2	4
		Very good	2	4
		Moderate	19	38
		None	27	54
		Total	50	100

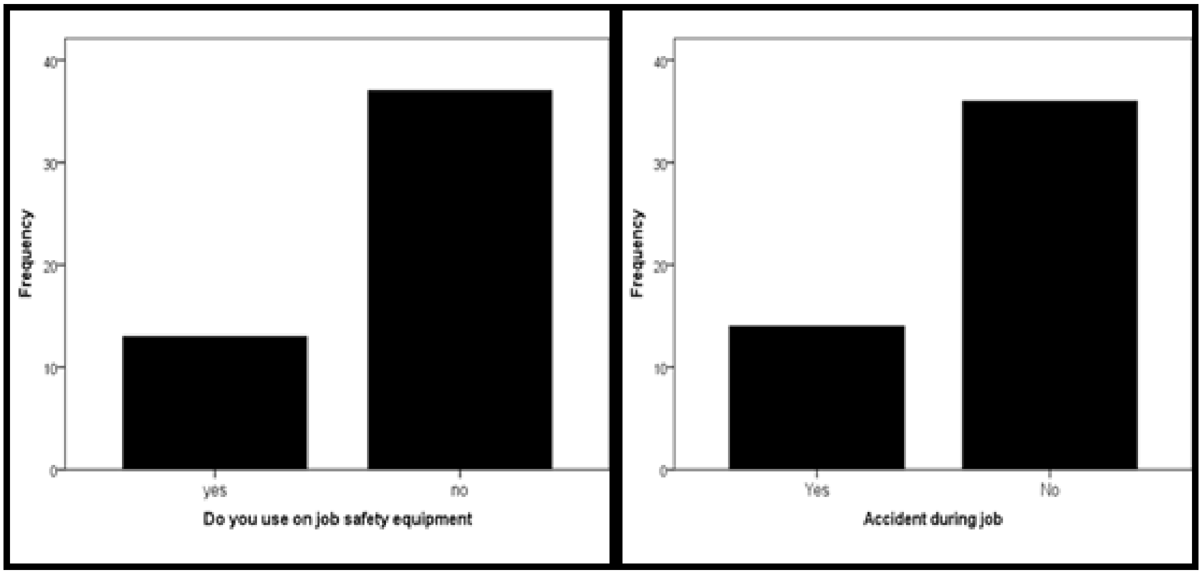

Figure 5.13. On job safety equipment use of workers at left and accident during quarry work at right.

They asked the government to have strong regulation on quarry work-related problems, in order to improve quarry owners and the company's carelessness and give safety first mechanisms for the employee. Workers indicated responsible governments must give care to minimize work-related problems as followed in other projects like road construction and other projects, the responsible body should give follow-up and measurements for the companies (quarry owners) to provide a standard on job safety materials and support. In open-end questionnaire some respondents indicated that they need additional support from the company, as they said quarry owners should supply soap, milk, clean drinking water and shower room at workplaces.

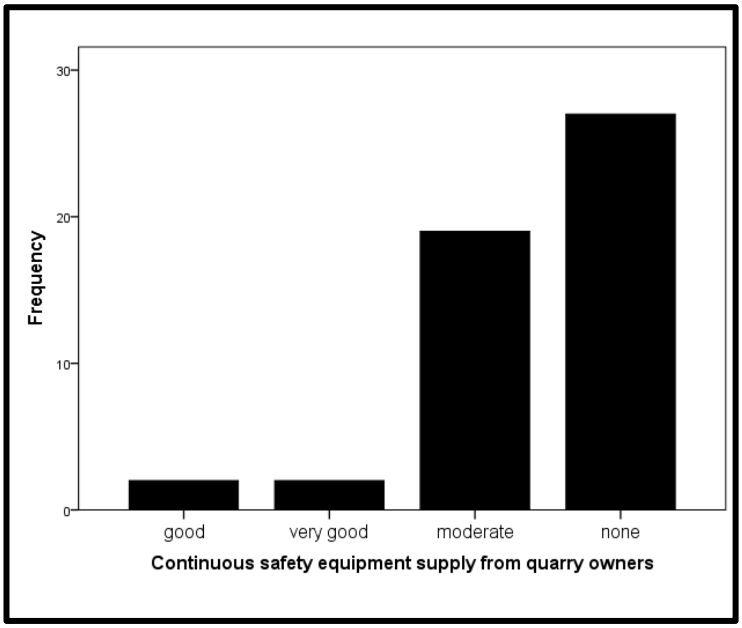

Figure 5.14. Safety equipment supply from quarry owners.

From close-ended questionnaires, 23 (46%) of workers are vulnerable to a higher amount of dust-related problems and 10 (20%) of them to very high dust related problem. In open-ended questionnaires they added dust fallout and noise impact of the quarry activities adverse many health problems. They said their breathing system is affected by repeated common-cold. They indicated long term exposure of dust without safety equipment caused permanent lung and other breathing diseases (sinus allergy) when they breathe the air with fine particles and it is most significant on some of the long years experienced workers. Beside the fine particles of dust causes eye problem. Water jut is used to minimize the dust arising from crushers however it is not consistent since there is the shortage of water if this water problem is improved there may not be significant dust-related problems effect on the worker.

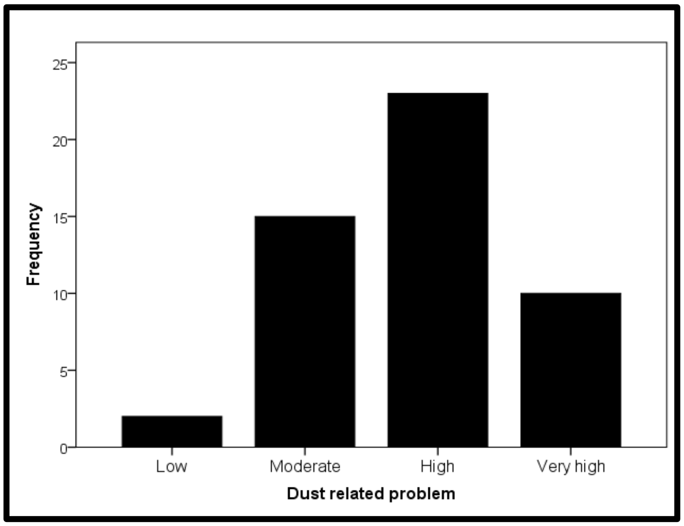

Figure 5.15. Dust related problems which affect workers.

Another major impact they indicated is a noise of the quarry activates, 48 % (23) of respondents demonstrated they are vulnerable for a highly noisy environment, as they said in open-ended questionnaires mainly the noise is high during rock crashing and dynamite blasting. Also, they are adverse by repeated headache, permanent hearing problem from noise and trauma from dynamite blasting.

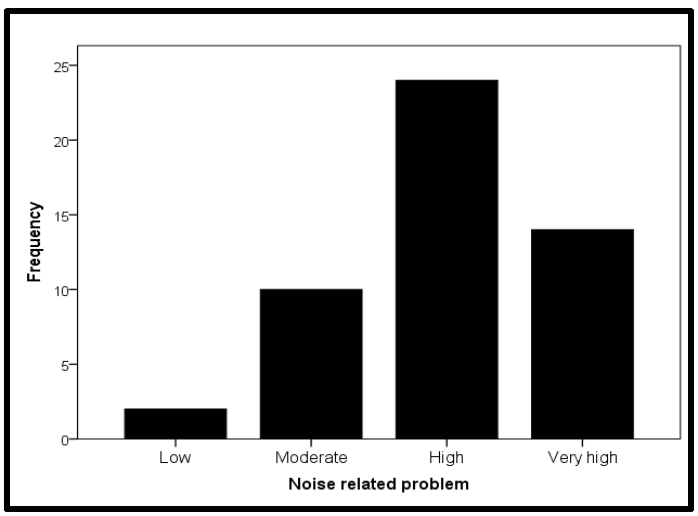

Figure 5.16. Noise related problems which affect worker.

Figure 5.17. Dust impact from the quarry create hazy environment.

Generally, this study recognized those quarry workers are impacted by different problems beside extracting and processing of quarry materials. In addition to questionnaire analysis, the author investigated that most of the quarry workers are more vulnerable for multi problems of quarry activities than the community since all workers do not use on job safety equipment. Therefore responsible governmental or non-governmental bodies should take into consideration their related quarry work problem. Fig 5.18 shows dust impact during rock crushing, in addition to worker problem dust impact also expand to the environment and create a hazy, polluted and unpleasant environment.

5.4.2 Quarrying impact on residents near to quarrying area

Demographic description of respondents from the community

Social impact of quarry activities was assessed by conducting open-ended and close-ended questionnaire in five different localities in the study area. The assessment considered the people who live in the vicinity for quarry sites. For this purpose, 10 respondents were selected randomly from each locality a total of 50 respondents were contacted from Tulu Dimtu, Worku Sefer, Akaki Kality Worda 08 near the Chinese quarry and Fanta localities. Totally 36 (72%) male and 14 (28%) female respondents were contacted. 22 (44%) of them have lived for more than 25 years and 25% have lived for less than 5 years around the area. 36 (72%) of them were residing before quarry sites started and 14 (28%) of them reside after quarrying activity started, as try to show in Table 5.10. Questionnaires are presented in the Appendixes.

Table5.9. Demographic description of communities

Sex	F	%	Have you resided here before quarries start	F	%	Age	Range	How long you lived around this area	F	%
Male	36	72	Yes	36	72	Minimum	17	< 5 year	12	24
Female	14	28	No	14	28	Maximum	66	5-15 year	8	16
Total	50	100	Total	50	100	Mode	36	15-25 year	8	16
								>25 year	22	44

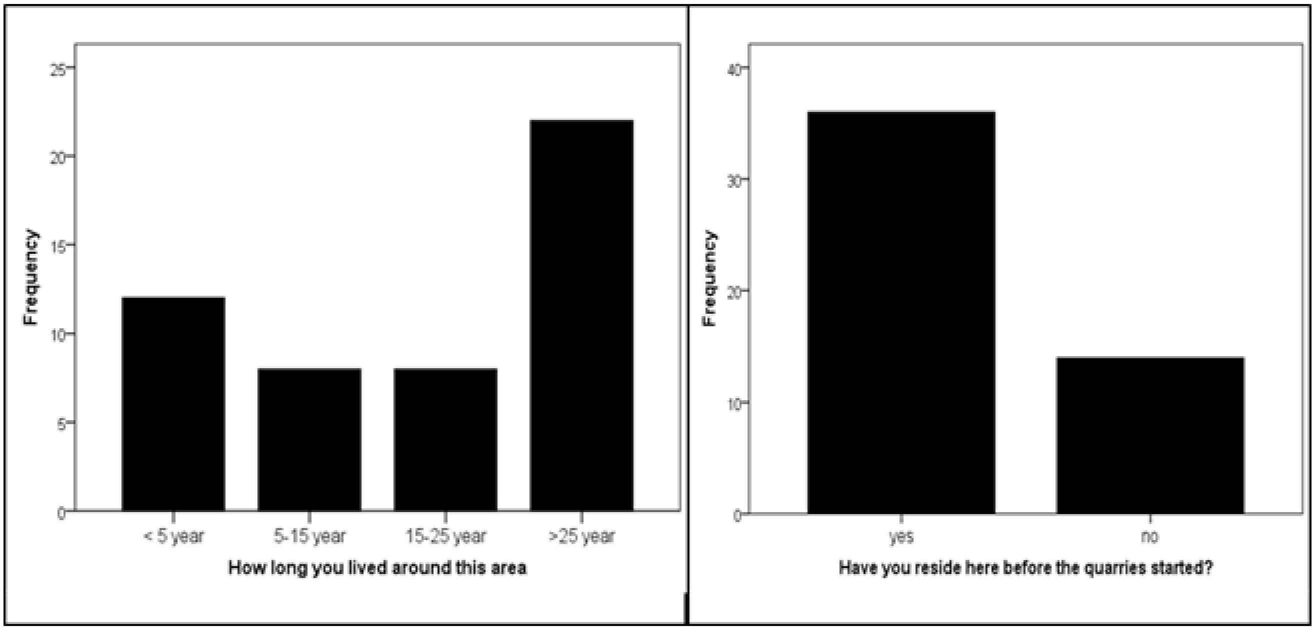

Figure 5.18. Demographic distribution of respondents.

As shown in table 5.11 community respondents said they are adverse by multi problems during quarry operation. From the total 62% of them said three of the mentioned problems (dust, vibration and noise) adverse significant impact. Respondents said vibration problem highly affected them. In open ended questionnaires they explained vibration is bombastically and fearful during blasting, the problem extends up to human death and injuries. They said flying rock has harmed elderly man on his head while sleeping. Blasting also creates cracks on house walls and floors after a time the cracked wall becomes damaged as shown in fig 5.20. House equipment such as TV, Refrigerators fall from shelves and became damaged. According to their explanation sleeping during day time is difficult for those who work in the night shift, they want to take a rest at a day but it is not possible because of blasting vibration caused trauma and nosiness of the area due to rock crashers.

According to their explanations, vibration problems also affect pregnant women, elderly peoples, children's and patients; even if patients want to recover from their pain at home it is difficult due to vibration and noise impact from the quarry. In addition to this fly rocks were damage electricity cables and the communities are faced with electricity-related problems such as burning of electrical materials at home. They said their house roofs are making perforation due to flying rocks. Finally, most of the respondents are angry due to multi-impact of quarry activity in the study area.

Figure 5.19. Cracked house due to quarry blasting.

In open-ended questionnaires respondents said the dust problem from quarry is significant during a quarry operation (during rock crushing and dynamite blasting). They indicated that it is difficult to eat their foods polluted with fine sand particles caused due to quarry activity. Based on their response they are significantly affected by dust-related health problems such as by repeated common cold, sinus allergy and by asthma, they can’t wear clean cloth due to dust impact of the quarry activity and also it is difficult to have clean home equipment because of dust pollution.

Farmers around the quarry site said it is not possible to cultivate lentil and pea due to dust impact. Therefore they have cultivated only Teff every year and have no choice to cultivate another type of crops. Generally, quarrying impact directly or indirectly affects the agricultural activity

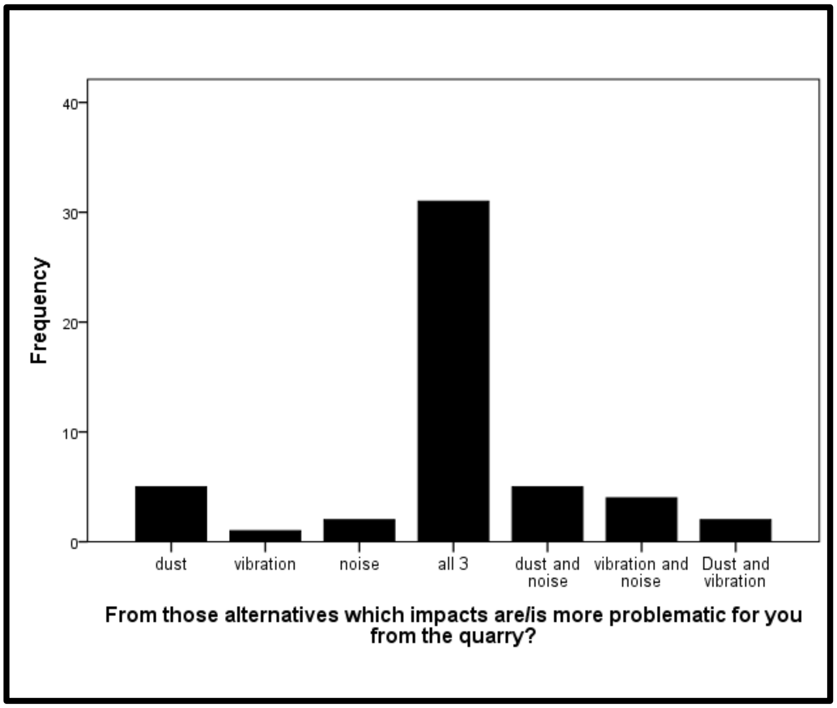

Figure 5.20. Problems adverse community from the quarry.

Additional to quarry operation dust problems also are comes from heavy trucks which used to transport processed quarry materials. Respondents said even it is difficult to cult in religious place because of dust fall from trucks. Residents explained other main problem adverse them from the quarry sites is unpleasant noise. According to their explanations, it is significant when quarry operations ongoing for 24 hours at this time they can’t sleep well at night time, also this problem extends in day time.

Table 5.10. Questionnaires result from community.

No.	Item	Answers	Frequency	Percent
1	From those alternatives which impact are/is more adverse you from the quarries? You can select more than one.	Dust	5	10
		Vibration	1	2
		Noise	2	4
		All 3	31	62
		Dust and noise	5	10
		Vibration and noise	4	8
		Dust and vibration	2	4
		Total	50	100
2	Do you know accumulated water within the quarry sites	Yes	24	48
		No	26	52
		Total	50	100
3	Do you remember human and/or animal deaths due to accumulated water within quarry	No	23	47
		Yes	27	53
		Total	50	100

They said the noise problem is extended to schools that are located near to the quarry sites; they said noise from quarry activity is significantly affects the teaching-learning system. Also, the residents said when quarry operate for 24 hours repeated domestic animals lost was occurs because the thievery used the quarry noise as a lampshade at night time. Specifically, women respondents said it is difficult if they try to sleep children due to quarries noise and vibration problems.

As shown at table 5.11 and fig 5.22, abandoned quarries and even active quarry sites can accumulate water, 48% of respondents said they don't know accumulated water around their area but 52% of them said there is accumulated water within the abandoned or active quarry sites. In open-ended questionnaires respondents said accumulated waters are causes human and animal death, they said as maximum as in one season 6 friends were passed due to accumulated water in the quarry site. Most of the time boys and girls are vulnerable to this problem; because boys are trying to swim and girls are trying to fiche water from the accumulated water in the quarry. Also, they expressed animals have died when they try to drink water.

Figure 5.21. Accumulated water in abandoned quarry site picture captured at winter.

Chapter Six

Conclusion and Recommendations

6.1 Conclusions

The present study aimed as assessing the impact of quarrying activity in the downstream section of the Big Akaki catchment. The investigation revealed that water resources are impacted by quarrying operation as evidenced by the significant variation of the physiochemical parameters (turbidity, TDS and fluoride concentration) of river water from upstream to downstream of a quarry site. The Dengora River is particularly affected. The quarrying activities flux fine particles of rock and soil increasing the turbidity and TDS, in addition to physical damage (channeling and/or blocking of river courses, damage to river banks, dumping of overburden and by products of quarrying supplies, construction of access roads across river courses etc.). However, it should be noted that this might not suggest chemical pollution only because of quarrying.

In addition to the adverse impact on surface water the quarrying activities have a potential of affecting the groundwater systems in the catchment over a long term. This is a serious impact as most of the water supply wells for the Addis Ababa city such as the Akaki well field are located in this area. As the groundwater table in the area is shallow and a groundwater recharge zone, the impact on the surface water will be directly impacting the shallow groundwater system due to surface water and groundwater interaction. In addition, deep quarries are directly affecting the saturated zone leading to the destruction of the highly productive fissured aquifers.

The study confirmed that there has been an extensive land use land cover change during the last 20 years in the Big Akaki catchment. The quarrying activity has been extending in an unprecedented manner at the expense of the cultivated land. Urban expansion occurred at even pronounced rate at the expense of cultivated land within the same catchment. All these led to the degradation of the land and soil, indirectly affecting the surface and groundwater resources in the area.

The quarrying activity is also affecting the local community, particularly residents in the immediate vicinity of the quarry sites. The social impacts include unsafe working environments to the quarry workers (accidents, health problems particularly respiratory problems due to dust intake) due to lack of safety equipment, measures and procedures, as quarry owners prioritize profits over safety and the social impact assessments are conducted only as a precondition for securing mining/quarrying license with no regular follow up from the regulating agencies. The quarry workers have emphasized the problems and risks during the social impact survey for the current study.

In addition, some incidents of loss of human and domestic animals life due to accidents and drowning in water accumulated in abandoned and non-reclaimed and non-rehabilitated quarries have been reported, calling for a serious consideration of such incidents by the responsible agencies. In all quarry sites, communities are affected by fugitive dust, unconditional noise at night and day time, flying rock injury, and vibration problems.

6.2 Recommendations

- The problems due to quarrying should be managed by rehabilitating or properly closing the abandoned quarries.
- The responsible government agency should provide continuous training to the quarry owners and quarry workers on proper quarrying operations, and conduct regular follow up of the quarrying operations to ascertain if the proper procedures as stipulated in the pertinent regulations are implemented. The agency should regularly implement corrective measures including closing of the quarries if they are not adhering to the environmental impact assessment proclamations of the country.
- With the expansion of urbanization, most quarry sites are now within residential areas and proper land use planning should be conducted and measures should be taken to close

and relocate some of the active quarry sites and to properly rehabilitate the abandoned and those to be closed quarry sites.

- Measures by the agency should include protection of the vital resources (surface and groundwater, fertile soil, and the larger ecosystem) including securing the quarry sites are at least 100 m far from river banks; however, many of the quarry sites in the study area are at or close to river banks .
- The agency should regularly consult the major stakeholders such as the residents about the operation and impacts of the quarry sites, in order to devise a proper management plan of the quarry operations and their impact on the environment.
- The agency should also properly plan the issuing of new quarrying licenses in the area considering the land use land cover change of the last 20 years as indicated in the current study. It is recommended that some sections of the catchment should be prohibited from quarrying activities.
- Quarry owners should provide safety equipment and measures to their workers, and quarry workers should follow the safety procedures and properly wear their safety equipment; this has to be regularly checked by the regulatory agency.
- The quarry owners should be made aware of the environmental problems of the quarrying operation on the community nearby and they should contribute to the remedial measures as stipulated by the proclamations and regulated by the responsible agency.
- Finally the current study indicated that it is high time that a more detailed systematic study of the surface and groundwater in the quarrying areas should be conducted to properly evaluate the overall effect of the quarrying operations in the Akaki catchment in particular and in the whole Addis Ababa region in general.

References

Abdullah Fisne and Cengiz Kuzu, 2010. Prediction of environmental impacts of quarry blasting operation using fuzzy logic, Springer Science online published.

Awoke Endalw, Endalew Tasew and Solomon Telahun, 2019. Environmental and social Impact of stone quarrying: south western Ethiopia, in case of Bahrdar Zuria Wereda Zenzelma Kebele. International journal of research in Environmental Sciences Vol. **5** (2): pp 29-38.

Ayodele A, E. and Lameed G.A. (2010). Effects of quarrying activity on Biodiversity: case study of Ogebere site, Ogun state Nigeria. Journal of Environmental Sciences and Technology Vol. **4**(11): 740-750.

Bereket Fentaw and Mihret Manaye, 2011. Hydrogeology and hydrochemistry of the Akaki Beseka area, Geological Survey of Ethiopia, PP (142).

C. Peiter, R.C. Villas Boasb and W. Shinya, 2000. Implementing a consensus building methodology to address impacts associated with small mining and quarry operations, Natural resources forum Vol. **24:** 1-9.

D.B. Adia, J.A OTUB, C.A Okufuc, A. Nasirud, 2012. Assessment of Noise Generated by Operations Within The groundwawa quarry in kano state, Nigerian Journal of Technology Vol. **32** (3): pp 314.

Dejene Worku, 2016. Environmental and Social Impacts of Stone Quarrying: In Dire Dawa Administration, Unpublished Master’s Thesis.

E.C. Ukpong, 2012. Environmental Impact of Aggregate Mining by Crush Rock Industries in Akamkpa local Government Area of Cross River State, Nigerian Journal of Technology Vol. **32** (2): pp. 128.

Efrem Beshawered, 2010. Geology of the Akaki Beseka Area, Geological Survey of Ethiopia, pp (93).

Eirnesto Abbate, Piero Bruni and Mario Sagari, 2015. Landscape and Landform of Ethiopia, springer Science media, Page (33-34).

Enatfenta Melaku, 2007. Impact assessment and restoration of quarry site in urban Environment: the case of Augusta quarry, Unpublished Master’s Thesis, PP (102).

Eshiwani M. Florence, 2014. Effects of Quarrying Activities on the Environment in Nairobi Country: A Case Study of Embakasi District, Unpublished Master's Thesis.

Fekerte Arega Yitagesu, Freek van der Meer, Harald van Werf and Wolter Zigterman, 2009. Quantifying engineering parametrs of expansive soils from the reflectance spectral, Science direct journal of engineering geology Vol. **105** page (151-160).

Hailu Worku, 2018. Environmental and socioeconomic impacts of cobblestone quarries in Addis Ababa and implication for resource use efficiency, environmental quality and sustainability of land after-use, Environmental Quality management **27(**2): pp 41.

James R. Anderson, Earnest E. Hardy, John T. Roach and Richard E. Witmer, 1976. A Land Use Land Cover Classification System for use with Remote Sensor Data, U.S.Geological Survay, Vol. **964**: pp (41).

Johon D. Hem. (1985). Study and interpretation of the chemical characterstics of natural water, U.S geological Survey therd edition, pp (272).

Lad R.J. and Samant J.S., 2014. Environmental and Social Impacts of Stone Quarrying: A case study of Kolhapur District. International Journal of Current Research, **6:** 5664-5669.

Leta Gudissa, 2010. Analysis of Subsurface Contaminant Transport in Akaki Well Field and Surrounding Areas, Central Ethiopia, Global journal of researches in engineering.Vol.**10** (Ver 1.0).

M.A.Oyinloye and B.O. Olofinyo, 2017. Environmental impact of quarry activities on resident of Akure Region, SCIREA Journal of Environment, Vol. **2**(2).

Mengesha Tefera, Tadiwose Chernet and Workineh Haro, 1990. Geology of Ethiopia (Geologicalmap of Ethiopia),

Nanor Jacob Nene, 2011. Assessment of the Effect of quarrying activities on some selected communities in the lower Manaya Korobo district, Msc thesis.**http://ugspace.ug.edu.gh**

Orkan Ozen, Nebiye Musaoglu and Dursun Zafer Seker, 2012. Quarrying Activities Established on and near a river Bed by Using Remotely Sensed Data, Fresenius Environmental Bultin, Vol. **21(**11): Page (3147).

Rassim Navas, Vishnu J Nair, Muhammed Akhil, Minhaj Khan, Tressa Priyanka Raju, 2008. Environmental Impact Assessment on Quarry, International Research Journal of Engineering and Technology, Vol. **06**(05):6123.

S.L. Hobbs and J. Gunn, the hydrogeological effect of quarrying Karstified limestone: options for prediction and mitigation Quaternary Journal of Eng. Geo., Vol. **31:**147-157.

Semere Mulatu, 2013. Environmental Impacts of Coarse Aggregate Production in and Around Addis Ababa, Unpublished Master thesis.

Setegn Berie, 2013. Quarrying Rehabilitation Planning: The case of 'Worku Sefer' Quarry projects Addis Ababa. M.S.c Thesis. PP (123).

Solomon Tadesse, Jean Pierre Milesi Yves Deschams, 2002. Geology mineral potential of Ethiopia a note on geology and mineral map of Ethiopia, Vol. **8**.

Solomon Waltenigus, 2007. Analysis Models of the Emptying Curves Of five Selected Spring in Addis Ababa. M.S.c thesis, pp. (147).

Sthouwer, Rick L, Day and Kirsten E, Macneal, 2006. Nutrient and Trace Element Leaching Following Mine Reclamation with Biosolids. Journal of environmental Quality, **35:**1118-1126

Suleiman, M.S., Wasonga, O.V., Mbau, J.S. and Elhadi, Y.A., 2017. Spatial and temporal analysis of forest cover change in Falgore Game Reserve in Kano, Nigeria. Ecol. Proc. 6:

Tadiwose Chernet, William K. Hart, James L. Aronson and Robert C. Walter, 1998. New Age Constraints on the Timing of Volcanism and Tectonism in the Northern Main Ethiopian Rift–Southern Afar Transition Zone, Journal of Volcanology and Geothermal Research Vol. **80:** Page (267–280).

Tilahun Mammo, 2005. Site specific ground motion simulation and seismic response analysis at the proposed bridge sites within the city of Addis Abab, Scincedirectelisivier publisher engineering geology, Vol. 79 page (120-150).

Vincent Kodzo Nartey, Joseph Nii Nanor, 2012. Effects of Quarry Activities on Some Selected Communities in the Lower Manya Krobo District of the Eastern Region of Ghana. Journal of Atmospheric and Climate Sciences, Vol. **2**: page (362-372).

William H. Langer and Belinda F. Arbogat, 2002. Environmental impact of mining natural aggregate, U.S. Geological Survey, Deposits of Geo-Environmental Moduls, page (151-169).

Yayesh Mihiritie, 2017. Assessment of Environmental Impact of Quarrying Activities in Eastern Addis Ababa; Implications on Urbanization, Unpublished Master Thesis. PP (96).

Appendixes

Appendix A-1 Accuracy assessment for the year 2020.

	Reference data							
Map data	Bare land	Built-up	Cultivated land	Forest	Quarry	Shrub land	Grand Total	User accuracy
Bare land	4	0	0	0	0	2	6	66.6
Built-up	0	25	0	0	0	0	25	100
Cultivated land	0	0	11		0	0	11	100
Forest	0	0	0	7	0	0	7	100
Quarry	0	0	0	0	16	0	16	100
Shrub land	0	0	0	1	0	4	5	80
Grand Total	4	25	11	8	16	6	70	
Producer accuracy	100	100	100	87.5	100	66.6	Total accuracy= 95%	

Appendix A-2 Accuracy assessment for the year 2016.

	Reference data							
Map data	Bare land	Built-up	Cultivated land	Forest	Quarry	Shrub land	Grand Total	User accuracy
Bare land	4	0	1	0	0	0	5	80
Built-up	0	18	0	0	0	0	18	100
Cultivated land	1	1	8	0	0	0	10	80
Forest	0	0	0	7	0	0	7	100
Quarry	0	0	0	0	13	0	13	100
Shrub land	0	0	0	0	0	3	3	100
Grand Total	5	19	9	7	13	3	56	
Producer Accuracy	100	94	88.8	100	100	100	Total accuracy = 94.6%	

Appendix A-3 Accuracy assessment for the year 2006.

			Reference data				
Map data	Bare and	Built up	Cultivated land	Quarry	Shrub land	Grand Total	User accuracy
Bare land	14	0	2	0	0	16	87.5
Built up	0	15	3	1	0	19	78.9
Cultivated land	0	0	18	0	0	18	100
Quarry	2	1		10	1	14	71.4
Shrub land	0	0	0	0	3	3	100
Grand Total	16	16	23	11	4	70	
Producer accuracy	87.5	93.75	78.2	90.9	75	Total accuracy=85.7%	

Appendix A-4 Accuracy assessment for the year 2000.

	Reference data						
Map data	Bare land	Built up	Cultivated land	Forest	Quarry	Grand Total	User accuracy
Bare land	7	1	0	0		8	87.5
Built up	0	15	3		1	19	78.9
Cultivated land	0	1	25	0	0	26	96.1
Forest	1	0	2	4	0	7	57.1
Quarry	0	0	0		5	5	100
Grand Total	8	17	30	4	6	65	
Producer accuracy	87.5	88.2	83.3	100	83.3	Total accuracy =86.1 %	

Appendix A-5 Questionnaires were addressed for residents

Questioners were answered by residents around the quarry to assess quarry impact on them.

N.B-You could not write your name, please put your answer by using ☑ or ☒ signs on provided box beside the choice or expresses your answer on the provided open lines.

1. Sex

A. Male ☐ B. Female ☐

2. Age _________

3. How long you have live around this area.

A. <5 years B. 5-10 years C. 10-25 years D. >25 years

4. Have you resided before quarry operates?

A. Yes ☐ B. No ☐

If your answer is yes what was the land use before quarry started

A. cultivated land B. Shrub land C. Forest D. Bare land E. If other you can mention here ____

6. From the following problems which are/is more adverse you from the quarries activity? You can select more than one.

A. Dust ☐ B. Vibration ☐ C. Noise ☐ D. Other__________________

10. Do you remember human and/or animal death caused by accumulated waters stored inactive and/or abandoned quarry sites?

A. Yes ☐ B. No ☐

11. Can you discuss about dust related problems you have faced from the quarry activities?

____
____
____

12. Can you discuss about vibration problems you have faced from blasting and during quarry operation?

____
____
____
____

13. Can you discuss about noise problems you have faced from the quarry activities?

____
____

14 If you have remained ideas or problems you have been faced from quarries activity and if it is not included in these questioners please mention here under.

____

____

____

____

Appendix A-6 Questionnaires were addressed for quarry workers

Questionnaires have been answered by quarry workers to assess quarry impact on them.

N.B- You could not write your name, please put your answer by using ☑ or ☒ signs on provided box beside the choice or expresses your answer on the provided open lines

1. Sex

A. Male ☐ B. Female ☐

2. Age ______

3. How long you have work on quarry operation.

A. ≤ 5 years B. From 5-10 years C. ≥ 10 years

4. Do you use on job safety equipment.

A. yes ☐ B. No ☐

5. What looks the supply of continuous safety equipment from the quarry company?

A. Low (per year) ☐ B. Moderate (2 times a year) ☐ C. High (4 times a year) ☐

D. none ☐

6. Do you ever face accident from the quarry activities? A. yes ☐ B. No ☐

If your answer is yes please indicate the rate and type of accident you or your friends faced.

____

7. Could you indicate if you have faced dust related problem from the quarry operations.

A. Low ☐ B. Moderate ☐ C. High ☐ D. Very High ☐

8. Could you indicate if you have faced noise related problem from quarry blasting and machineries.

A. Low ☐ B. Moderate ☐ C. High ☐ D. Very High ☐

9. Training and follow-up given from responsible agencies to control an impact from the quarry to adjacent river water.

A. Low ☐ B. Moderate ☐ C. High ☐ D. Very High ☐

10. Can you list dust related problems faced from the quarry

____

11. Can you list vibration and noise related problems from machinery and blasting during quarry operation.

____

12. If you have remained idea or problems you are facing from quarry work and if it is not included in this Questioners place mention here under.

____