University of Venda

Development of guidelines for dealing with morphological and environmental impacts of sand mining along the Nzhelele River, Limpopo Province of South Africa

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DECLARATION

I, **Mathada Humphrey**, declare that this dissertation submitted to the Department of Geography and Geo-information Sciences, University of Venda for the degree Master of Environmental Sciences has not been previously submitted at this University or any other University and that it is my own in design and execution. All references, material combined therein have been duly acknowledged.

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ABSTRACT

The demand for construction sand is increasing in many parts of South Africa and the rest of the world due to rapid economic development and subsequent growth of construction activities. This has resulted in the indiscriminate mining of sand from stream channels and floodplains, whose major impact is significant alterations to the river basin environment. The dearth of research scholarship and resultant lack of adequate information on the environmental impacts of sand mining is a major challenge in the regulation of sand mining in South Africa.

This study aims at developing guidelines for dealing with the impacts of sand mining on the morphology of Nzhelele River. The study employed a more objective approach in developing guidelines for sand mining. The Binary Logistic Regression Model was employed to determine morphological and environmental factors that determine observed changes in the river system as a result of sand mining activities. Participatory Rural Appraisal methodology was used in developing questionnaires and interviews to gather community perspectives on sand mining. The Influence and Importance Matrix technique was used to determine various stakeholders to be involved in developing guidelines and implementation of the proposed guidelines. The study revealed that sand mining affects all spheres of the community. Floodplain mining has more threat to the community than instream mining. This was revealed by the interviews and questionnaires administered in the field. Severe infrastructural damage, channel degradation and some cases of livestock and children drowning in the open excavations were noted during this study.

It was recommended that, even though there are no specific guidelines on sand mining operations, it is advisable that local municipalities develop bylaws to help preserve their ecological beauty of their areas. The Department of Water Affairs (DWA) and Environmental Affairs (DEA) need to implement the proposed guidelines to prevent any form of environmental change as a result of sand mining. All the relevant stakeholders should be involved in developing the guidelines. It was further recommended that environmental awareness training be conducted for the communities in the vicinity of the extraction sites. This will help in monitoring and enforcement of the bylaws developed.

Key words: *Sand mining, Participatory rural appraisal, channel degradation, binary logistic regression model*

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CHAPTER ONE: INTRODUCTION

1.1 Background to the Research Problem

The demand for sand is growing around the world, particularly in developing countries, such as South Africa, where rapid economic development has been encouraging a huge growth in the construction industry (De Leeuw *et al*, 2009). The globalizations of sand mining is raising concern about environmental impacts and are increasingly reported from other countries such as China (Wu *et al*. 2007), Ghana (Mensah, 2002) and India (Padmalal *et al*. 2008). Consequently, it has been argued that, because of this globalizing extent and the magnitude of its impact, sand mining should be considered as an aspect of global environmental change (De Leeuw *et al*, 2009).

Rivers are the most crucial life supporting systems of nature. Humans have been enjoying the benefits of these ecosystems for centuries (Padmalal *et al*, 2008; De Leeuw *et al*, 2009). Over exploitation of resources, such as sand, from river ecosystems threatens the very existence of river ecosystems. Previous studies (Padmalal *et al*, 2006, 2008; Kondolf *et al*, 2002) revealed that sand mining is taking place more than natural replenishments, which lead to significant environmental degradation and ecological disorders.

Sand mining is a common practice in many rivers and floodplains across South Africa. The demand for sand is escalating at an alarming rate as a result of massive infrastructural development. Sand is extracted directly from the streambed (Hayer & Irwin, 2008) and the adjacent floodplains of the Host Rivers. This extraction of sand has significant environmental impacts which were first reported in the developed world (De Leeuw *et al*, 2009). Sand mining can thus impose significant environmental impacts in the long run depending on the geologic and geomorphic structure of the area (Padmalal *et al*, 2008; Kondolf *et al*, 2002). The most common morphological changes in rivers turn out to be channel incision, changes in channel pattern, channel widening and narrowing. Hence, several anthropogenic activities like sand mining and dam construction have been indicated as the driving forces behind changes in the river morphology (Surian & Rinaldi, 2003).

1.2 Statement to the Research Problem

The use of natural resources is inevitable and accordingly, anthropogenic changes of the environment cannot be avoided (Dulius, 2010). Mining of sand is the main source of construction aggregates used throughout the world (Robinson *et al*, 2004). In natural conditions, floods have been the main driving force for change in the morphology of rivers (Ollero, 2010). However, the mining of sand on the floodplains and from the streambeds leads to the occurrence of significant changes on the morphology of rivers. The sand mining occurring in Nzhelele has also been noticed to be changing the morphology of Nzhelele River and the surrounding natural environment. The morphological changes of the river channel have several significant impacts on the hydraulic structures, infrastructures like bridges and the natural environment in general (Surian & Rinaldi, 2003). The collapsing of river banks and aggradation due to instream sand mining results in channel capacity alteration and increases flood risks (Kondolf, Piegay & Landon, 2002), as well as habitat destruction and degradation of the aesthetic beauty of the surroundings. The impacts of sand mining include increased sediment load, deforestation of floodplains, modified stream structure and functionality (Hayer & Irwin, 2008; Kondolf, 1997; Brown *et al*, 1998).

Excessive extraction of sand from the floodplain and the river channel significantly distort the natural equilibrium of the river channel. Instream sand mining results in diversion of flow, altered bed elevation and deposition of pollutants in the river (Ghani *et al*., 2010). The demand for sand for construction activities is causing the mushrooming of sand mining activities which are causing significant environmental impacts which need to be addressed in this era of sustainable development. The overall impact of sand mining causes disequilibrium in the channel (Ghani *et al*., 2010) and, as a result of this unbalanced system, many land areas in the Nzhelele river valley are prone to flash flooding due to the deteriorated channel conditions. Thus, improper sand mining methods are resulting on the degradation of the Nzhelele River and its floodplains.

1.3 Rationale and Justification of the Study

The rationale for this study emanates from the need to develop guidelines for dealing with morphological and environmental impacts of sand mining along the Nzhelele River. These guidelines are important for future planning.. The mining of sand is capable of significantly changing the morphology of rivers and landscapes (Milgrom, 2008). There is limited information on the impact of sand mining in the Limpopo Province in general and the Nzhelele River valley in particular. The extraction processes cause environmental degradation which needs to be addressed in this era of sustainable development. Therefore, it is of paramount importance to conduct a study focusing on the environmental and morphological impact of sand mining along Nzhelele River.

1.4 Research Objectives

The broad objective of this research was to develop guidelines for sand mining along the Nzhelele River. The specific objectives of the study were:

- to examine the South African legislative environment for sand mining activities
- to map the locations of sand mining sites along the Nzhelele River
- to assess the morphological and environmental impacts of sand mining along the Nzhelele River
- to come up with strategies for preventing, controlling and mitigating the morphological and environmental impacts of sand mining

1.5 Scope of the Study

The study focused on the morphological and environmental impact of sand mining along the Nzhelele River. It covered the area from Khalavha village, which hosts the source of the river, to Musekwa village, the mouth of the river. The study focused on floodplain and instream mining, activities that can alter the morphology of Nzhelele River and cause significant environmental impacts. Aspects that were considered include, channel width, braiding, floodplain deforestation, riparian zone degradation, meandering and meander migration and channel incision. However, chemical and biological changes were not considered. This is because of some other external factors might also trigger the changes in the river system.

1.6 Description of the Study Area

Nzhelele River is located in the northern region of the Limpopo Province of South Africa. It lies between the Soutpansberg mountain range, roughly along latitudes 22° 20′ S and 23° 05′ S and longitudes 29° 45′ E and 30° 25′ E at an elevation of approximately 903m above mean sea level (Kabanda, 2004). Figure 1.1 shows the locality of the study area.

Nzhelele River is in the subtropical climate. The lowveld and the northern part of Soutpansberg mountain range is a hot, dry region with an irregular rainfall of approximately 200mm to 350mm per annum that is received from October to February (Kabanda, 2004). During summer, the valley is characterized by hot temperatures, varying between 16ºC and 40ºC and in winter, the temperature ranges from 16ºC to 22ºC. The area is windy during autumn and slightly cold during late spring (Kabanda, 2004).

The study area is composed of two types of soil which are sand and loamy soil (Rashid *et al*, 2005). In some areas, the soils are mixed, giving rise to sandy-loamy soil. The weathering of sedimentary and igneous rocks is the origin of the soil in the study area (Kabanda, 2004).

Land use types are governed by the physiography and climate of the area with more cultivation closer to the source of the river and less towards the Nzhelele Dam. Cultivation on the floodplains is very dominant with stock farming also forming part. Sand extraction activities pose a threat to both the land use types.

Residential and commercial construction activities are in full swing in the study area, leading to a higher demand for sand. This results in aggravation of sand mining from the river and its floodplains leading to severe environmental change along the study area.

The study area is located just 40 kilometers from Thohoyandou located along the R523 road linking Sibasa and Wylliespoort. Louis Trichardt now known as Makhado is located 70 kilometers from the study area.

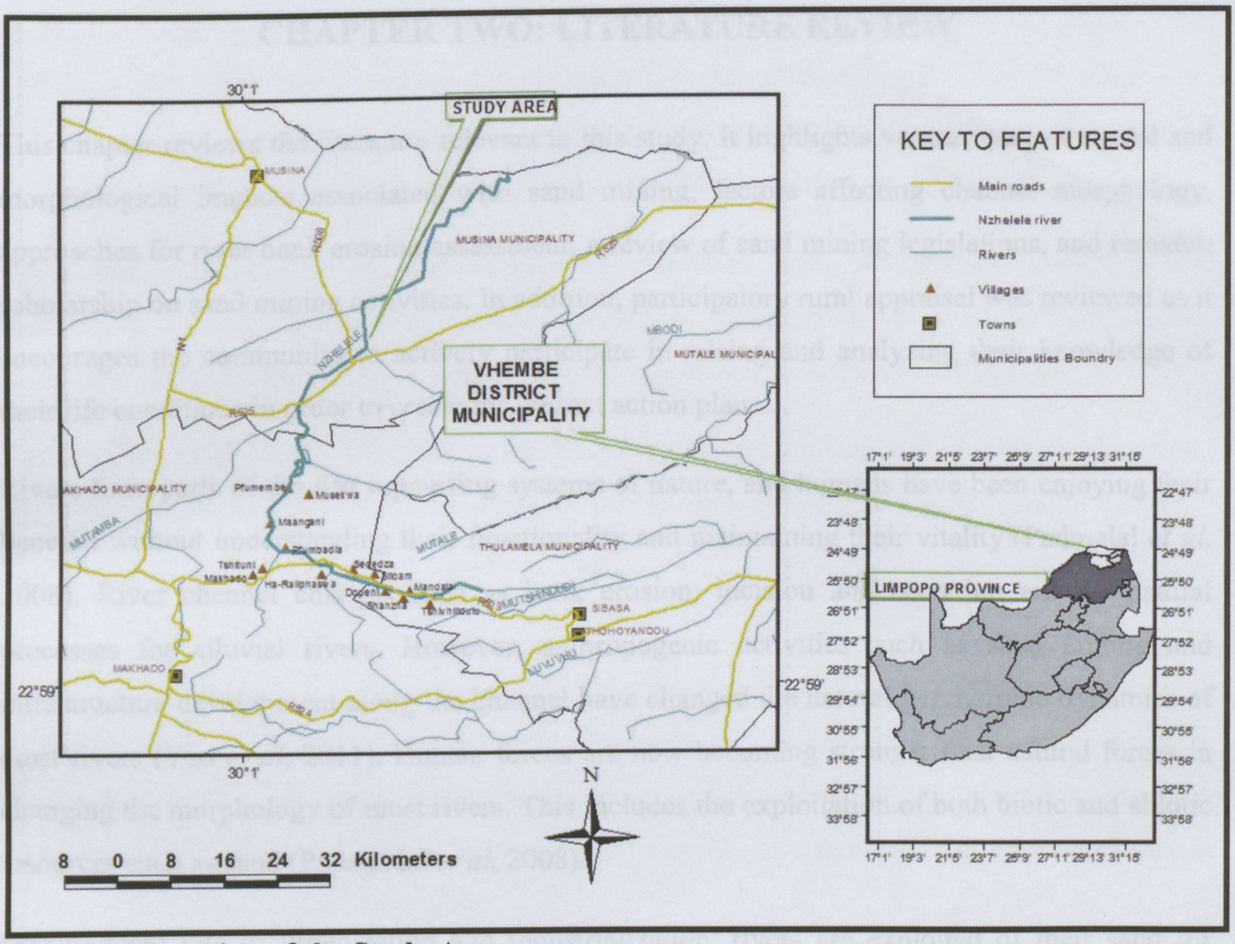

Figure 1.1 Location of the Study Area

1.7 Chapter Summary

This chapter focused on the outlining the background of the research problem, statement of the research problem, justification of the study, research objectives, description of the study area and the scope of the research. Various impacts of sand mining were highlighted and these have helped in developing the problem statement as well as the research objectives.

For any research to be well focused a background check on other works in the same field is necessary. This constitutes the focus of chapter two which is on literature review.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews the literature relevant to this study. It highlights various environmental and morphological impacts associated with sand mining, factors affecting channel morphology, approaches for river bank erosion assessment, a review of sand mining legislations, and research scholarship on sand mining activities. In addition, participatory rural appraisal was reviewed as it encourages the community to actively participate in raising and analyzing their knowledge of their life conditions in order to create the correct action plan.

Rivers form parts of the life supporting systems of nature, and humans have been enjoying their benefits without understanding their functionality and maintaining their vitality (Padmalal *et al*, 2008). River channel changes such as bank erosion, incision and accretion are the natural processes for alluvial rivers. However, anthropogenic activities such as sand mining and infrastructure development along the channel have changed the natural geomorphic dynamics of most rivers (Yao *et al*, 2011). Human forces are now becoming stronger than natural forces in changing the morphology of most rivers. This includes the exploitation of both biotic and abiotic resources such as sand (Padamalal *et al*, 2008).

Due to rapid rate of urbanization and industrialization, rivers are exploited of their sand for infrastructure development (Sreebha & Padmalal, 2010). When sand extraction exceeds the natural river replenishment, the channel undergoes degradation and incision further changing the channel morphology (Sreebha & Padmalal, 2010). Sand mining hosts both short and long term environmental and morphological impacts (Wishart *et al*, 2007). Changes in channel morphology can be initiated through incision from sand mining (Rinaldi *et al*, 2005). The degradation of the channel bed results in the creation of the knick point (Kondolf, 1997). The magnitude of the channel to adjust in response to sand mining is controlled by the quantity and rate of material extracted (Rinaldi *et al*, 2005). High sediments delivery rate as a result of sand mining has dramatic effects on the hydraulic regime of the channel (Raven *et al*, 2010). Channel morphology is essential to a channel's capacity to contain and transport its load (Raven *et al*, 2010).

A river adjusts its planform in order to maintain equilibrium where both the water discharge and sediment are transported through the channel without causing significant changes in the channel's morphology (Field, 2011). However, excessive sand mining from the floodplains and in the channel distort the natural equilibrium of the channel (Ghanie *et al*, 2010). This results in the alteration of the geomorphological and hydrological characteristics of the channel. This further impacts the quality and quantity of both surface and ground water (Mori *et al*, 2011).

Sand mining disrupts the equilibrium between sediments supply and transportation capacity, resulting in channel incision and riverbed degradation. Deformation and erosion of the channel can migrate both upstream and downstream of the extraction point (Mori *et al*, 2011).

Various factors affect the morphology of the river channel and the surrounding environment. These range from natural to anthropogenic factors. These are discussed in details in this chapter.

2.1 Sand Mining

Sand mining is the process of extracting sand from the stream bed in active streams and from the floodplains (Langer, 2003). Numerous extraction methods exist. Mechanical extraction involves the use of a dragline, hydraulic excavator, backhoe loaders and bulldozers to extract sand from its occurrence. Manual extraction involves the use of picks and shovels for extraction (Mathada & Kori, 2012; Meador & Layher, 1998).

The method of extraction depends on the nature of the deposit, operator's preference and equipment (Langer, 2003). The extraction techniques include, bar scalping which is the extraction of sand from the surface of sand bars, dry-pit mining, which involves the excavation of pit within the active channel on dry intermittent or ephemeral stream beds with conventional bulldozers, scrapers and loaders and Wet-pit channel mining, which involves excavation of a pit in the active channel below the surface water in a perennial stream or below the alluvial groundwater table, requiring the use of a dragline or hydraulic excavator to extract sand from below the water surface (Kondolf *et al*., 2002).

Sand is one of the vital materials in construction industry. The demand for this material is escalating rapidly due to infrastructure development. The extraction of sand causes a variety of impacts on the natural environment as well as the rivers from which it is extracted (Martin-vide, Ferrer-Boix & Ollero, 2010). This activity is one of the direct causes of environmental degradation (Kondolf *et al*, 2008).

Many studies (Padmalal *et al*, 2008; Kondolf *et al*, 2008; Langer, 2003; Kondolf, 1997) have documented that instream sand mining affects the structural integrity of the host rivers and floodplains. Kori and Mathada (2012) observed the collapsing of the river banks due to instream sand mining in Nzhelele river of Limpopo province.

The extraction of sand from the riverbed into its sediment depositions leads to a shift in the river's erosion mechanism, which causes incision of the river's tributaries. This drops the water table in vicinity of the river leading to severe alterations of activities on the flood plains and riparian ecosystem (Karagiozova & Ninov, 2012).

Two major types of sand mining exist. These are; (1) instream sand mining which is a practice of extracting sand directly from the riverbed. Instream sand mining has been found to have severe impacts on the geomorphic structure of river system and the impacts are mostly cumulative and irreparable either naturally or anthropogenicaly (Melton, 2009). (2) Floodplain sand mining which is the extraction of sand from the floodplains and the riparian land of rivers. Floodplains mostly provide fine sand for building and plastering.

Various factors ranging from natural to human induced affect the morphology of rivers. These are outlined in section 2.2.

2.2 Factors Affecting Channel Morphology

Channel morphology is defined as shape or form of a river along its length and across its width. It is the result of dynamic processes occurring within the river, riparian zone and the floodplain (Kusimi, 2008; Matsuda, 2004). Transportation and deposition of material and sediments plays a major role in developing the morphology of every river. Rivers have altered their channels through erosion and deposition or human intervention over time.

Channel morphology is influenced by both natural and anthropogenic factors. Natural factors include, riparian and floodplain vegetation as well as erosional and depositional process. Anthropogenic factors include sand mining and agricultural land use in the river system. The following sections provide a review of these factors.

2.2.1 Natural Processes

In a natural setting, the river is dynamic and changes its course overtime. Processes such as erosion, transportation, deposition shapes the channel form. Riparian and floodplain vegetation also determine the rate of changes they reduce the erosion and collapsing of the river banks by root binding. Natural factors such floods and drought may alter the sediment process of the river.

a) Riparian and Floodplain vegetation

The riparian vegetation plays a crucial role in mediating the morphodynamics of river systems because the type and size of riparian vegetation play a crucial role in increasing bank strength against erosion whether natural or human induced (Mao *et al,* 2011). The significant role of vegetation growing on bars and floodplains on channel morphology has been proven in the field (Simon & Collison, 2002), numerically (Murray & Paola, 2003) as well as experimentally (Tal & Paola, 2007). These studies have revealed the influence of riparian vegetation in stabilizing banks, significantly reducing the braiding index and increasing the ecological value of the riverine area (Mao *et al,* 2011). Figure 2.1 provides the schematic representation of the riparian area and floodplains.

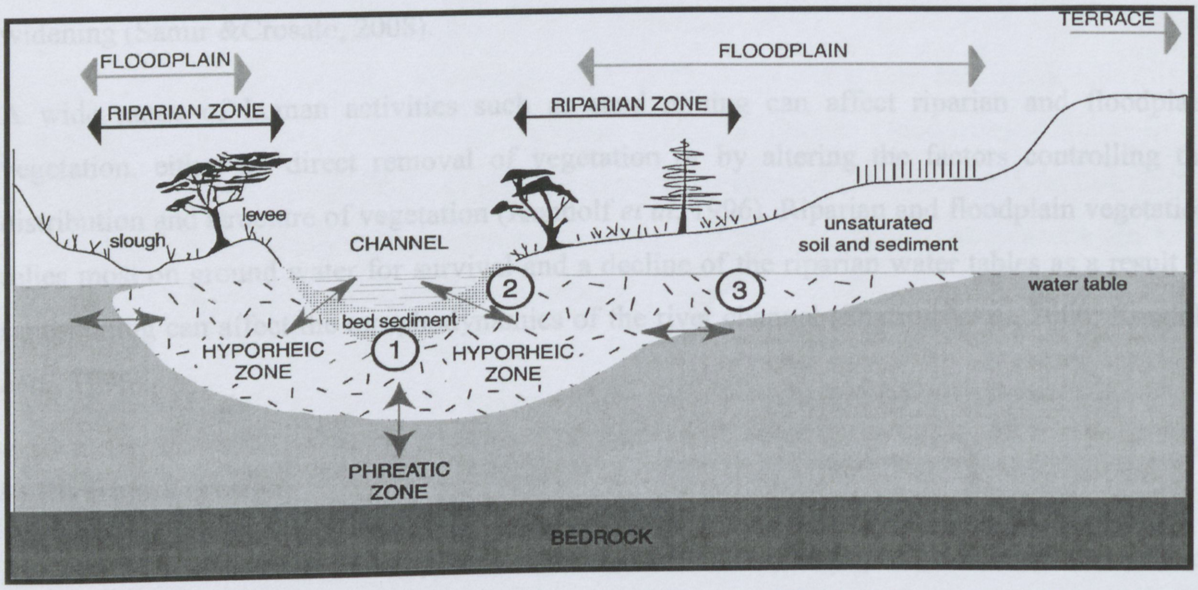

Figure 2.1Schematic representation of Riparian zone and Floodplain (*adopted* from Steiger *et al,* 2005)

The riparian vegetation enhances the river bank resistance against erosion by root binding and by enhancing local deposition of organic material and fine sediments which strengthens soil cohesion (Samir & Crosato, 2008; Darby, 1999). The lower flow between plants results in a decrease in bed shear stress, riverbank erosion and sediment transport as the plants deflects the main flow towards the center of the channel (Samir & Crosato, 2008). The riparian vegetation reduces the braiding degree of the river (Kurabayashi & Shimizu, 2003).

Riparian vegetation develops a buffer zone. Wynn (2004) defined a buffer zone as a band of vegetation adjacent to a body of water that forms the transition between aquatic and upland environments. Riparian vegetation ranges from grasses and trees and are effective in influencing lateral channel erosion and sediment deposition (Wynn, 2004). Changes in the state of the riparian vegetation along a river can influence bank integrity and channel form morphology (Clear Water Biostudies, 2003).

The presence of riparian vegetation deflects the main flow towards the river channel and enhances riverbank accretion which leads to smaller width-depth ratios. It reduces the degree of braiding by the river (Erskine, 2002). The greater the density of the riparian vegetation, the lesser the rate of lateral erosion and therefore less vegetation density increases the rate of channels widening (Samir &Crosato, 2008).

A wide range of human activities such as sand mining can affect riparian and floodplain vegetation, either by direct removal of vegetation or by altering the factors controlling the distribution and structure of vegetation (Kondolf *et al*, 1996). Riparian and floodplain vegetation relies most on ground water for survival and a decline of the riparian water tables as a result of sand mining can affect the morphodynamics of the river channel (Shafroth *et al*, 2000; Kondolf *et al*, 1996).

b) Riverbank erosion

Riverbank erosion occurs laterally and contributes to sediment transport. It controls the channel width and influence other channel processes such as sedimentation and stream flow (Ritter *et al*, 2002). Bank erosion is influenced by a combination of processes and factors ranging from natural to human induced and differs from location to location. This can be triggered by fluvial entrainment and channel incision and other processes such as weathering, the flow velocity, type and density of the root system of vegetation along the channel banks, cohesiveness of material on the banks (Ritter *et al*, 2002) including sand mining.

The extraction of sand on the river bed results on the undermining of material supporting the banks leaving the banks hanging and this further results in the collapsing of the banks (Ritter *et al*, 2002).

2.2.2 Anthropogenic processes

These are human induced factors such as sand mining and construction of bridges. These processes negatively affect the river channel conditions and morphology. Types of sand mining activities were the main factor under discussion in this section.

a) Floodplain sand mining

Tockner and Stanford (2002) defined a floodplain as a low lying area that is subjected to inundation by lateral overflow water from the river it is associated with. Four sources of water contribute to the inundation of this area. These are lateral overflow, ground water, upland sources and direct precipitation (Tockener & Stanford, 2002). These areas are said to be ecotones that extend from the low-water mark to the high-water line and include terrestrial vegetation influenced by elevated groundwater tables or floods. Floodplains develop in all geographic regions and at different locations along river channel (Tockener & Stanford, 2002). Floodplains store sediments from streams deposited during inundation and can contain large quantities of sand that can be mined economically.

The important characteristic of floodplain mining pits is their distance from the host channel (Kondolf *et al.*, 2002). Many floodplain pits are deeper than the adjacent river (Norman *et al.* 1998). The pits are often dug adjacent to the active channel because cleaner, better sorted sand may be available there. Pits adjacent to the channel are frequently separated from the active channel by a narrow strip of unmined land (Kondolf, 1997).

Sand mining on the floodplains transforms the riparian woodland into open pits and water ponds which alter the composition of the water table (Kondolf, 1997) and alters the flow of the adjacent river. Floodplain pits capture the active channel during floods, converting formerly floodplain mines to instream mines. This occurs when the land dividing the pit from the active channel is breached by lateral channel erosion or by overflowing floodwaters.

b) Instream sand mining

Rivers are complex geomorphic systems whose major functions are to store and transport water and sediments. The geologic, vegetative, climatic, land-use character and topography of the drainage basin determines the functionality of the river including the discharge and the load it must handle under various flow rates (Langer, 2003). Every river develops a hydraulic geometry that allows the functionality of the river in a good manner. Once recognized, the pattern will be maintained as long as variations in discharge and load are within the hydraulic geometry limits (Shafroth *et al*, 2000).

Rivers are the source of well drained sand for construction aggregates. Large quantities of sand are extracted from streams because of its well sorted character and durable value. Instream Sand mining results in a range of physical impacts on the streams concerned (Langer, 2003). The extraction activities negatively impacts the geomorphic structure of the channel, often resulting in channel degradation and erosion from extraction operation located in or near the stream (Kondolf *et al*, 2002).The nature and magnitude of the impacts from instream mining is a function of the geology, characteristics of the stream, excavation mechanism, the location of the site and the quantity of the material extracted (Kondolf, 1997).

Instream mining of sand is a common practice worldwide (Hayer & Irwin, 2008; Kondolf *et al*, 2002) and the demand for sand is increasing. The primary impacts of instream sand mining include, increased sediment load, channel incision, riverbank erosion, channel morphology alteration, riparian vegetation deforestation and habitat loss (Hayer & Irwin, 2008; Langer, 2003; Kondolf *et al*, 2002; Kondolf, 1997).

Instream mining involves extensive clearing of riparian vegetation for preparation of haul roads and storage of stock piles. Channel modification affects the bank stability, stream flow, vegetative cover of the riparian vegetation and species diversity instream and off-stream (Hayer & Irwin, 2008).

The relocation of thalweg occurs when flooding connect the pits on the floodplain with the stream (Kondolf, 1997). The increase in water velocity exacerbates channel scouring and erosion and decrease in sediment load from the mined sites (Meador & Layher, 1998).

Channel incision causes vertical instability in the streambed and causes acceleration in the stream flow and widens the channel when the riverbanks collapse (Kondolf, 1997). The incision of the channel bed drains the alluvial aquifer to a lower level, resulting in a loss of aquifer storage (Sear & Archer, 1998; Kondolf, 1997). Instream mining causes imbalance between sediments supply and transportation capacity of the river channel.

Excavation of pits in the active channel disturbs the profile of the stream bed which creates a steeper gradient (Knick point) upon entering the pit. The over-steepened nick point commonly erodes upstream in a process called head ward erosion. The migration of the nick point upstream triggers the incision of the stream and erosion of the stream banks which release excess amount of sediments downstream. This causes channel aggradation leading to instability of the stream and increased turbidity.

Streams have a specified amount of flow energy. Steep channel slopes have a greater amount of flow energy (Micheal, 1999). A natural stream develops an armoring mechanism. This is a layer of coarse alluvium produced by natural selective erosion that protects channels against erosion (Gallart *et al*, 1999), along its bed and banks. The extraction of sand in the stream decreases the stability of the stream as a result of the removal of the streambed armoring (Wishart *et al*, 2007) which makes the riverbed more vulnerable to fluvial erosion. The armoring is stronger than the sand beneath and helps in protection from erosion during flooding. In the absence of this armoring, even a small increase in river flow can cause erosion that can degrade the river. The alteration of this armoring by mining is difficult to restore naturally or with human interventions and can affect the river even when the mining has long ceased (Melton, 2009).

Channel incision increases the stream velocity, which actuates the riverbed and bank erosion and sediment transport. In the upstream of the excavated pit, bank failure and high sediment transport rate occur and on the downstream of the pit, high sediment deposition occur as a result of decreased stream gradient (Osterkamp & Hupp, 2010). The collapsing of river banks as a result of sand extraction occur as way to fill the excavated pit and this leads to the widening and shallowing of the channel both upstream and downstream of the excavation (Osterkamp & Hupp, 2010 ; Kondolf, 1997). Channel incision can lower the floodplain water table and also increases the bank heights triggering the banks to collapse and lateral channel instability (Osterkamp & Hupp, 2010; Sear & Archer, 1998; Kondolf, 1994).

Instream sand extraction disturbs the preexisting balance between sediment supply and transporting capacity (Meador & Layher, 1998). Stream flows have a given amount of flow energy, where the greatest flows moving on the steepest channel slopes have the highest energies. Flow energy is formed as friction in internal flow turbulence, on channel obstructions and on channel bed and banks. Depending on the channel properties, additional flow energy can be utilized in the transportation and deposition of sediments. Erosion and transportation of large sediments require a higher amount of flow energy than the smaller sediments. The excess flow energy leads to additional erosion of the streambed and banks and transportation of sediments, thereby causing more deposition (Michael, 1999).

2.3. Environmental Impacts of Sand Mining

Various environmental impacts of sand mining can be observed at extraction sites and their proximity. The resulting impacts include loss of habitat, ground water quality alteration, noise, dust, vibrations, chemical spills, increased erosion, and degradation of the aesthetic beauty of the surrounding environment. These impacts may be short-term or long-term and most are easy to predict and observe. The nature and magnitude of the impacts depends on the physical properties of the location, the technology used for extraction (Langer, 2001) and size of the operation.

2.3.1 Effects on ground water quality

The extraction of sand on the floodplains and in streams alters the ground water flow and quality. The extraction of sand from the river and floodplains has a significant impact on the groundwater resources beneath the streambed since changes in the river can affect its ability to recharge these resources. The presence of vegetation helps deflect and absorbs overland flow during rainfall. The removal of vegetation during site clearing for sand mining affects the infiltration rate and overland flow on the particular site and this negatively impacts the ground water and makes it vulnerable to pollutants (Tom *et al*, 2009).

Channel incision lowers the alluvial water table, because the channel determines the level down to which the alluvial groundwater drains. As the channel bed lowers down, the alluvial water table migrates downward as well resulting in ground water quality and quantity alteration (Kondolf *et al*, 2002).The lowering of the alluvial water table results directly in loss of groundwater storage. Lowering of the alluvial water table can induce profound ecological and landscape changes, including loss of hyporheic habitat as adjacent banks are dewatered and the loss of riparian vegetation as the water table drops below the root zone of riparian plants (Kondolf *et al*, 2002).

Another potential effect of reduced alluvial groundwater storage is reduced summer baseflow due to reduced contributions to the stream from the adjacent alluvial aquifer in which groundwater storage has been reduced (Kondolf, 1997; Brown *et al*, 1998).

2.3.2 Habitat degradation

Habitat degradation is defined as a decline in the state of specific types of habitat. A stream habitat is dynamic in space and time, even under immaculate conditions (Tockner & Stanford, 2002). It is essential to consider historic as well as current habitat status in order to see how it has changed through time and whether the rate of change has accelerated, decelerated, or remained constant.

Vegetation provides many ecological functions essential to the terrestrial species. It provides habitat and is a source of food for both terrestrial and aquatic species. Semi-aquatic and terrestrial wildlife species dependent upon the rivers and floodplains for habitats. Floodplain habitats have a high level of species richness and unique species composition (LaBonte, 1998). Riparian vegetation provides habitat and breeding ground for many bird species than any other vegetation association (Tockner & Stanford, 2002). The loss of habitat results from the clearing of vegetation to facilitate better extraction of materials.

The loss or alteration of the vegetation providing habitat has deleterious effects on wildlife and the functionality of the ecosystem as the ecosystem functions as a unit and if one part of the system is affected the whole system is affected.

Habitat destruction includes the degradation of the natural landscape and alteration of the hydrologic function (Tockner & Stanford, 2002) resulting in extinction and change in behaviour of other species. Sand mining degrades alluvial features (riffles, pools) important for enhancing habitats and their diversity (Rinaldi *et al*, 2005).

Sand mining affects habitat structure, function, and availability by altering or disrupting the processes that create, connect, and maintain habitat. These processes include the supply and transport of water, sediment and organic material to the stream, floodplain, and riparian zone.

2.3.3 Effect of noise on human beings

Noise has both psychological and physiological effect on any human being (Ogunsote, 2010; Adedeji & Folorunsho, 2010). These effects may range from annoyance to permanent or immediate loss of hearing, stress, weakness in children, mental fatigue, and tension. The extraction equipment forms the primary source of noise on site and in the surrounding areas. Factors such as the sound source, the topography, land use and ground cover of the surrounding site determine the magnitude of the impact (Langer, 2001).The beat, rhythm, pitch of noise, and distance from the noise source affect the impact of the noise on the receiver (Langer, 2001).Topographic barriers or vegetated areas can shield or absorb noise, and if these are absent the magnitude of the impact is enhanced. This is usually the case because vegetation is cleared to expose the desired sand.

An important factor in determining a person's tolerance to a new noise type is the ambient noise to which one has adjusted (Langer, 2001). In general, the more a new noise type exceeds the existing background noise level, the less acceptable the new noise type will be. The land use of the area also determines the magnitude of the noise produced by the operations. For example, in an urban or industrial environment, background noise may mask noise from a quarry operation, whereas the same level of noise in a rural area or quiet, residential neighborhood may be more noticeable to people.

2.3.4 Effect of dust on human health and the natural environment

Dust is the most visible, invasive, and potentially irritating impact associated with sand mining especially on dry areas like floodplains. Its visibility often raises concerns that are not directly proportional to its impact on human health and the environment. Dust may occur as fugitive dust from excavation and transportation of the sand (Langer, 2001). Natural conditions that determine the magnitude of the impact of dust generated during extraction of sand include moisture in the sand, ambient air quality, air currents and prevailing winds. The anthropogenic factors include the size of the operation, proximity to population centers, and other nearby sources of dust. Dust concentrations, deposition rates, and potential impacts tend to decrease rapidly away from the source (Howard & Cameron, 1998).

Uncontrolled dust may spread over the surroundings during dry weather and create harmful conditions for the flora and fauna. When dust smothers leaf surfaces, vegetation can be damaged through the blocking of leaf stomata, thus inhibiting gas exchange in plants and reducing photosynthesis rate (Howard & Cameron, 1998).

2.3.5 Riparian and floodplain deforestation

The riparian zone represents the transitional area between floodplains and river channels. It is a transitional feature with varying zones of flooding, moisture, and vegetation. A stable functioning riparian zone offer various benefits such as reduced flooding, reduced soil erosion, improved water quality, groundwater recharge, increased water quantity and riverbank stability for the host river.

Riparian and floodplain vegetation are adapted to the physical river processes of flooding, sediment transport, and channel meandering (Griggs, 2009).The riparian zone functions as an important sediment sink during flood events and buffers surface runoff produced on the floodplains. Sand mining activities are certainly among the most common processes contributing to the destruction of riparian zone (Steiger *et al*, 2005).

The riparian zone includes stream banks and stream bank vegetation. It serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the river system. Destruction of the riparian zone during sand extraction operations has multiple negative effects on instream habitats, some fish species and aquatic invertebrates.

2.3.6 Increased erosion rate

The operation of heavy equipment, processing plants and the stock piles close to the mining site destroys the vegetation (Packer *et al*, 2005) which helps in soil cohesion and this increase the erosion rate. The lower flow velocities between the plants result in a decrease in bed shear stress, soil erosion and river bank erosion (Samir & Crosato, 2008). Vegetation causes deflection of the main flow towards the centre of the river channel (Tsujimoto, 1999), reduces bank erosion and enhances bank stability. Heavy equipment compact the soil, thereby increasing erosion through sheet wash. The disturbance of the riparian zone during sand mining causes river bank destabilization culminating in increased erosion rate (Packer *et al*, 2005).

2.4. Morphological Impacts of Sand Mining

The transportation and deposition of sand is important in determining the river's form. Alteration of these processes may affect the channel morphology (Kondolf, 1997). River morphology is controlled by a balance between the water flow in the channel, the quantity and size of sediment delivered from upstream, the composition of the river bank and bed material, and vegetation composition and density on the banks. These components work as a system and when any of these components are altered, channel adjustments occur until a new equilibrium is reached.

The degree of sand mining impacts depends upon the scale and type of sand mining operation, the geology of the area, hydrology and sediment transport characteristics of the watershed. Effects may be delayed due to the frequency of flood events required to transport the available sediment and thus modify channel and floodplain characteristics. Thus, effects that are attributed to large flood events may actually be the result of previous years activities that have "set the stage" for major morphological changes. Rivers do not respond the same way to the same disturbance, and the same river's response change over time. The following sections reviews some of the more widely observed changes initiated by sand mining.

2.4.1 Channel migration

A natural stream develops an armoring mechanism along its bed and banks (Melton, 2009). This armoring layer protects the riverbed and banks against flowing water. The disturbance of this layer affects the structural integrity of the river system leaving it to be more vulnerable to erosion.

When sand is extracted on the floodplain forming pits near the river only separated from the active channel by a narrow strip of land, an avulsion or a more gradual channel migration may cause the pits to be captured during floods (Kondolf, 1997). The former riparian pits are then converted into an instream pit having similar impacts to those of instream mining (Rinaldi *et al*, 2005). This occurs when unmined strip of land collapse as results of lateral channel erosion or flooding. Floodplain pits typically intersect the water table, and therefore constitute a preferential path of groundwater contamination (Kondolf, 1997).

2.4.2 Riverbed degradation

Riverbed degradation, also known as channel incision, occurs through headward erosion. In the first, excavation of a mining pit in the active channel lowers the stream bed, creating a nick point that locally steepens channel slope and increases flow energy (Kondolf 1998). During high flows, a nick point becomes a location of bed erosion that gradually moves upstream in a process called headward erosion (Kondolf 1997). Headward erosion mobilizes substantial quantities of stream bed sediments that are then transported downstream to deposit in the excavated area and locations further downstream. In sand-rich streams, effects downstream of mining sites may be short term after mining, because the balance between sediment input and transport at a site can reestablish relatively quickly (Kondolf 1997). Effects in sand-poor streams may develop rapidly and persist for many years after mining. Regardless of downstream effects, headward erosion in both sand-rich and sand-poor streams remains a major concern. Headward erosion often move long distances upstream and into tributaries (Kondolf 1997). In some watersheds moving as far as the headwaters or until halted by resistant surfaces in the stream bed such as bedrock or man-made structures. Headward erosion is more recognizable in the field and represents the greater risk to aquatic resources (Pringle, 1997).

River bed erosion occurs when sand mining increases the gradient of the channel (Kondolf 1997). Both conditions produce slower stream flow velocities and lower flow energies, causing sediments arriving from upstream to deposit at the mine site. Channel incision not only causes vertical instability in the channel bed, but also causes lateral instability in the form of accelerated stream bank erosion and channel widening.

2.4.3 Water quality

An increase in suspended fine sediments increases the amount of contaminants in the water. This decreases the quality of water. The decrease in water quality affects both aquatic and terrestrial ecosystem served by the host river (Ashraf *et al*, 2011). The clearing of riparian vegetation expose the river to more addition of nutrients which later causes algal bloom in the river. Algal bloom raises biological oxygen demand in the river affecting other aquatic species (Melton, 2009).

Instream sand mining has cumulative impacts on water quality of the host river system. The impacts include increased short-term turbidity at the mining site, increased sedimentation and oil leakage from excavation and transportation equipment. Excessive riverbed and bank erosion increases suspended load in the river leading to high turbidity. Increased erosion creates greater turbidity of the river. Excavation machinery and transportation vehicles may pollute the river water through spillages and leakages.

2.4.4 River bank erosion

River banks derive their strength and resistance to erosion from vegetation. River bank resistance to erosion can be reduced when bank heights increase because of sand mining and when riparian vegetation is cleared during the creation of access roads to instream mining sites. Sand mining initiate channel instability. It alters channel geometry and creates local inflection of channel gradient. The increase in channel gradient increases channel velocity which results in high erosion rate along the steeper slope. A higher velocity will have an even greater impact, leading not only to erosion of the streambed but also to sloughing off of the channel banks.

Root systems provide plants with anchorage to the substrate. This function is important for enhancing river bank stability (Abernethy & Rutherfurd, 2000, 2001). However, regardless of the bank texture, vegetation increases bank stability only to the root depth. If bank height exceeds the depth of roots, the weight of the vegetation may in fact increase the probability of river bank failure (Thorne, 1990).

River bank erosion is a process whereby the river banks scour or collapse into the river. This can be due to natural factors or human factors. River bank erosion provides sources of sediments in the river. River bank erosion process can be categorised into three. (1) Scour, this involves the gradual erosion of the sediments as a result of wind or by waves of the river. Wind is mostly the primary factor triggering this action. (2) Mass failure, this is when large pieces of the river banks collapse into the river (Cavanough, 2007). This may be trigger by undermining of the river banks and riverbed degradation. Instream sand mining is the major contributory factor triggering this action. (3) Sub-aerial erosion mechanism, this is caused by external factors such as cattle trampling and clearing of the riparian vegetation. When cattle walk just next to the river bank edges, they add more weight which the banks cannot support leading to the collapsing of the banks. Clearing of the riparian vegetation mostly for sand mining activities, leave the river banks with no protection from other external factors of erosion such as wind.

2.4.5 Approaches for River Bank Erosion Assessment

Various approaches for river bank erosion assessment exist in the literature. Some of the approaches are discussed in the following sections

(a) The Bank Erosion Hazard Index

This is one of the procedures for river bank erosion assessment. It was developed by Rosgen (2001). This method provides point values to many aspects of the river bank conditions and overall scores that can be utilised for stream bank condition inventory. This method is composed of five metrics which require four observations and one measurement. These are (1) ratio of the bank height to bank full height which requires identification of bankfull indicators such as vegetative cover, (2) ratio of root depth to bank height which is the average plant root depth to the river bank height, (3) root density which is a proportion of river bank cover by plant roots, (4) river bank angle which is measured at the lower bank and (5) surface protection which is the percentage of river bank cover by the vegetation.

(b) Geographic Information Sciences Approach

Mossa and Coley (2004) used GIS to determine changes on the boundary of the Pascagoula River. Channel boundaries were digitized from the aerial photographs using Arcview 9.2 software. Overlays of the digitized channel boundaries were produced to show channel migration and planform changes of the river. The polygons produced by overlaying channel boundaries were labeled according to whether and how they have changed into the following categories: Erosion, Deposition, between or unchanged.

(c) Erosion Pin Method

Laderoute and Bauer (2013) conducted a study on long-term bank erosion of Shu River. They inserted 60 cm pieces of re-bar (reinforcement bar) into the river bank with a sledge hammer at 90 degrees. The pins were installed in pairs at each site. This was done to enhance reliability of the readings. The methodology involves installing the re-bar and then returning to the site periodically to measure the amount of erosion that has taken place during the set time frame. A metal detector was used to detect the pins. The study revealed erosion differed from site to site. That was a result of vegetation cover, soil cohesion, and root structure and channel form geometry.

2.5 Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is an approach to development planning that involves careful consideration of the views of members of the affected community (Turyatunga, 2004). It is considered to be one of the popular and effective approaches to gather information in rural areas and learning rural life and the environment from the rural people (Chambers, 1992). It requires researchers to act as facilitators to help local people conduct their own analysis, plan and take action accordingly. It is guided by the principle that local people are creative and capable and can do their own investigations, analysis, and planning. PRA emphasizes local knowledge and involves communities in the inventorying, monitoring, and planning of local natural resource management (Asia Forest Network, 2002). Because of its collaborative nature, it actively empowers marginalized communities, de-emphasizes hierarchies, and helps to identify resource use challenges and sustainable use systems.

The PRA approach uses a variety of practical methods to generate essential data for planning and ensure the quality and timeliness of these data. The process is designed to endow the community with a strong sense of recognition and belonging. It involves the practice of role playing to present problems and explore possible solutions. It also employs triangulation and cross-checking of data to ensure a sound, appropriate basis for assessments and development decisions. Another unique feature of the PRA process is the use of multidisciplinary teams which, when properly coordinated, ensure the integration of various sectoral interests (Turyatunga, 2004). There are five key principles that form the basis of any PRA activity and these are outlined as follows;

(1) Participation, which involves the credit and belief of the norms, significance of the traditional community knowledge and the community's capability to solve their own problems. The community is viewed as part of the team and not only as sources of information (Turyatunga, 2004), but as partners with the PRA team in gathering, analyzing the information and sustainable planning.

(2) Flexibility which involves combination of techniques that is appropriate in a particular development context will be determined by such variables as the size and skill mix of the PRA team, the time and resources available, and the topic and location of the work.

(3) Team work which involves the representation of women, sector specialist, social scientists according to the topic. The selected team should be composed of local people with very few outsiders.

(4) Optimal ignorance, this involves the gathering of only specific information relevant to the study.

(5) Systematic which involves the selection of the sample and ensuring the representativeness of the sample (Asia Forest Network, 2002).

2.6 A Review of Legislation of Sand Mining

This section seeks to review important legislations that are relevant to sand mining activities. These include, National Water Act 36 of 1998 and Mineral and Petroleum Resources Development Act 28 of 2000.

2.6.1 National Water Act 36 of 1998

The National Water Act 36 of 1998 establishes the national government as the public trustee of the nation's water resources. This means that the Government must ensure that water resources are used and conserved in a sustainable manner so that the public's water needs shall be met. The Act states that most water use must be authorized through a system of licensing by the Minister of Water Affairs.

Section 26(4) of the National Water Act 36 of 1998 stated the need for conserving and protecting water resources and monitoring the use of water and its resources. In terms of these needs the Minister of Water Affairs promulgated the regulations in terms of water use for mining and related activities aimed at protecting water resources. These regulations were published in government notice no 704 on 4 June 1999.

Regulation 10 on government notice no 704 of june 1999 has provisions related to sand extraction from the watercourse. The provisions highlighted the protection of the stability of the watercourse, erosion prevention and prevention of damage to instream and riparian habitat. It also highlighted the prevention of pollutants like oil and other lubricants from the equipment from entering into the watercourse (Department of Water Affairs, 2000).

This regulation was developed specifically for sand mining and other alluvial minerals. Before practicing any of the activities within the watercourse, the water use licence should be applied for in terms of section 40 of the National Water Act 36 of 1998. Although this regulation was developed with the specific focus on sand and other alluvial mineral extraction, it has not addressed sand mining in full. It has left several activities involved in sand extraction processes and therefore created a loop hole.

2.6.2 Mineral and Petroleum Resources Development Act 28 of 2000

After a thorough review of the Mineral and Petroleum Resources Development Act 28 of 2000, it was revealed that the Act's specific focus is on high income minerals like gold, diamond and other minerals. Sand mining is never addressed. This can be proved by the objectives set for this Act. The objectives of this Act are highlighted below:

''(a) recognise the internationally accepted right of the State to exercise sovereignty over all the mineral and petroleum resources within the Republic;

(b) give effect to the principle of the State's custodianship of the nation's mineral and petroleum resources;

(c) promote equitable access to the nation's mineral and petroleum resources to all the people of South Africa;

(d) substantially and meaningfully expand opportunities for historically disadvantaged persons, including women, to enter the mineral and petroleum industries and to benefit from the exploitation of the nation's mineral and petroleum resources;

(e) promote economic growth and mineral and petroleum resources development in the Republic;

(f) promote employment and advance the social and economic welfare of all South Africans;

(g) provide for security of tenure in respect of prospecting, exploration, mining and production operations;

(h) give effect to section 24 of the Constitution by ensuring that the nation's mineral and petroleum resources are developed in an orderly and ecologically sustainable manner while promoting justifiable social and economic development; and

(i) ensure that holders of mining and production rights contribute towards the socio-economic development of the areas in which they are operating.''

The above listed objectives have not made any provisions for sand mining activities. This draws a conclusion that sand mining activities are not of major concern in the South African legislative environment.

2.7 Research Scholarship on Sand Mining

A number of studies on different aspects of sand mining have been carried out in a number of countries around the world. This section seeks to review a sample of these cases. Important cases to review include case experiences from Spain, Nigeria and lastly South Africa.

2.7.1 Spain

Ollero et al (2009) conducted a study on incision of the Gállego River due to gravel mining. Although their study focused on gravel mining, the impacts are similar to those of sand mining. Gállego River drains an area of about 400km^2 on the southern slopes of the Pyrenees. It then empties into the Ebro River which is the largest river in Spain.

The study revealed that Gállego River experienced a severe incision of more than 5 meters between the years 1970 and 2004. Gravel mining was the plausible cause for that severe incision. The cumulative impacts of the operation still exist in spite of the mining activities being stopped. The study indicated that the loss of alluvial material as a result of the severe incision experienced is twice the volume of the gravel mined. Instream extraction of the material directly causes channel incision.

2.7.2 Nigeria

Lawal (2011) conducted a study on the effects of sand/gravel mining in Minna Emirate area of Nigeria. The study examined sand and gravel mining activities on land and rivers of Minna Emirate area of Nigeria. It identified various stakeholders involved in the sand mining activities. This ranged from the communities, local government authorities and the sand miners.

The impact of noise on the local community and fauna was also identified. The Fauna in the vicinity are frightened by the noise generated by the equipment and the local people are also irritated by such noise. Impacts such as channel incision, infrastructure damage and alteration of ground water system were also noticed.

The study recommended that indiscriminate extraction of sand should be discouraged by the local authorities. It further indicated that a policy should be developed compelling miners to rehabilitate the area after mining has ceased.

2.7.3 Malaysia

Ashraf *et al* (2011) conducted a study on sand mining causes and concerns. From this study, it was observed that sand mining is a common practice in Malaysia and is disturbing public assets and infrastructures. Turbidity was also observed to be high at extraction sites and reducing with distance downstream. The study concluded that the principal cause of adverse impacts of sand mining is over extraction of the material. It further concluded that instream mining can be conducted in many rivers if the extraction is kept within the hydraulic limits of such river.

The rapid infrastructural development in Malaysia has led to mushrooming of sand mining activities in rivers and their floodplains. The Malaysian department of Irrigation and Drainage (DID, 2009) observed various impacts of sand mining activities and conducted a study on sand mining activities with an objective of developing guidelines for sand mining activities. The guidelines highlighted sediment transport theory to determine the volume of sand that can be extracted from the river reach of the river channel. Recommendations for long-term management of sand mining were also set.

2.7.4 South Africa

The study conducted in the province of Kwazulu Natal by Demetriades (2007), aimed at providing an inventory of sand mining operations in Kwazulu Natal estuaries. The study was conducted to provide an understanding of the current situation to facilitate management of sand mining industry.

The study has provided some indications on the negative impacts of sand mining operations and has not provided a thorough understanding of sand mining impacts and the ecological functions of the estuaries.

The study could not identify the number of sand mining operations and operators along the KZN estuaries. It again failed to achieve its third objective of identifying unpermitted operations. This was because of failure of the Department of Minerals and Energy to supply the information on permits issued for mining operations.

2.7.4 A Synopsis of the Reviewed Studies

All the studies reviewed in section 2.7 have not focused on the development of guidelines for dealing with morphological and environmental impacts of sand mining. It was therefore important to conduct a study focusing on the development of guidelines for dealing with sand mining impacts.

2.8 Chapter Summary

The chapter reviewed literature on the morphological and environmental impacts of sand mining activities, studies from other countries focusing on sand mining impacts, development of guidelines for sand mining activities. The South African legislative environment relative to sand mining activities was also examined.

The following chapter focuses on the methodologies and techniques used in data collection, analysis and presentation.

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter focuses on the methodology and techniques used in data collection. Aspects considered were, desktop study which was done to acquire information in relation to morphological and environmental impacts as a result of sand mining and to check the researchability of the topic, reconnaissance survey which was conducted to familiarize oneself with the study area. Research approaches like mapping of sand mining activites, interviews, visual observation, river bank erosion assessment and water quality assessment were conducted to acquire data for this study.

3.1 Preliminary Studies

3.1.1 Desktop Study

The desktop study on the environmental and morphological impacts of sand mining was conducted. This involved reviewing existing literature on environmental and morphological impacts of sand mining activities. Information was obtained from published sources (books and journals), various websites and unpublished sources. This was done to acquire information on the issues related to sand mining activities from various authors and to see how other authors tackled challenges that can arise when studying the impacts of sand mining.

3.1.2 Reconnaissance survey

Reconnaissance survey was done to familiarize oneself with the area of study before doing the actual field work or detailed survey. This involved physically visiting the study area which include going to the river and floodplains where the sand is extracted. This was done to get a glimpse of what to expect when doing a detailed survey and to introduce the researcher to the communities hosting sand mining activities and sand miners.

3.2 Detailed Field Survey

Detailed field surveys were carried out in the study area mainly for mapping locations of instream and floodplain sand mining sites. Areas of river degradation were identified and data on mining operations were also collected. The purpose of the survey was to identify and address the key environmental issues in order to develop acceptable guidelines for dealing with the morphological and environmental impacts of sand mining. Observations were conducted in all the active extraction and abandoned sites. The types of equipment and methods used for extraction were also considered a priority during this survey.

Method of *Pattern matching* was conducted to determine changes in the river activities observed by the communities. *Pattern matching* involves the comparison of two data sets to determine whether they match or do not match. The data sets could either be the same or different. This method is the most desirable approach in case study research (Hak & Dul, 2009).

3.2.1 Size of extraction Pits

When determining the size of the extraction pits, depth was the ranked as the first priority. This was because of the nature of impacts which arises as a result of open excavations left by sand miners. A tape measure was used to measure the depth of the pits from floodplain extraction sites. Changes in the total area of the pits were documented by identifying the edge from aerial photographs (Lehotský *et al*., 2009). The edge of the pit was determined by the area cleared of the vegetation around the extraction site. The extraction site was determined by brown colour or area cleared of vegetation as shown in figures 4.6 and 4.7.

Google earth was also used to create a cross section of excavated pits as shown in Figure 4.6. This was done to supplement the data collected in the field. Satellite images were used to determine the changes in size of the area covered by the excavations.

3.2.2 Assessment of water quality

When assessing the quality of the water of the river, only physical factors such as suspended material and the turbidity of water were considered. This was due to the fact that other contaminants from nonpoint sources could contribute to the deteriorating water quality of the river. The turbidity of the water and suspended material constituted the main focus. Turbidity is defined as the degree to which transparency is lost in the water as a result of suspended material. The turbidity of the water downstream of the extraction site was compared that of the water upstream of the mining site.

Visual assessment of the state of water was used to measure the rate of turbidity at both extraction sites and undisturbed sites. This was done to help understand the normal water condition of the water at an undisturbed site. Turbidity is the cloudiness or murkiness of water, which is an expression of the optical properties of water, which cause the light to be scattered and absorbed rather than transmitted in straight lines. It is therefore commonly regarded as the opposite of clarity (Wass *et al.*, 1997).

3.2.3 Interviews

Interviews were used to collect data on the mining operations and perceptions of people from the host villages. These were directed to the people involved in the extraction of sand and the host community members. A purposive sampling method was adopted to selected respondents. This field research method uses the researcher's judgment in selecting respondents (Nueman, 2006). The respondents were selected according to their location in relation the mining site and their involvement in the activity. This activity was guided by the philosophy and methodology of Participatory Rural Approach (PRA) as discussed in chapter two section 2.6.

With the objective of identifying and assessing the morphological and environmental impacts of sand mining along the Nzhelele River, target groups were selected for interviews. These included individual landowners, individuals actively involved in the activity, and selected individuals from nearby communities.

The aim of the selection was particularly to give broad views on sand mining. For individual community members and miners, qualitative interviews were used since this approach allows a more in-depth investigation into the unique understanding of each interviewee on sand mining (Huntington, 2000). It also allows people to speak for themselves without their answers being biased by predetermined hypothesis- based questions (Huntington, 2000; Rubin J. & Rubin S., 2005). Most of the questions raised during the interview were to elaborate the interviewee's understanding of the impacts of sand mining. The questionnaire was paying attention to gather respondents′ views from the study areas on the impacts of sand mining and how it affected/affecting their livelihood. The responsibility for opening and closure of extracting sites and ownership were also considered.

3.2.4 Riverbank erosion assessment

Riverbank erosion controls the channel width and exerts a direct influence on other channel processes (Ritter *et al*, 2002). Bank erosion involve three forms; cantilever failure, which results in vertical fall of material undermined at the base ; toppling slab failure, which results from tension cracks, and rotational slip failure, where the original slope slides to the riverbed (Ritter *et al*, 2002).

Field surveys were carried out to assess existing erosion on both riverbanks. For each selected river reach, the bank erosion severity was classified according to the following classes (Cavanough, 2007):

Class 1 Includes areas where erosion is highly evident, as is demonstrated by mass failure of slabs of material, and significant stress lines visible on the bank itself.

Class 2 Areas are in the process of being eroded, but the erosion would not be as severe as Class 1. Physical indicators include loose aggregates at the foot of the bank and/or the exposure of tree roots.

Class 3 Sections of the riverbank are not presently being visibly eroded, however, they remain vulnerable to future erosion (i.e. lack vegetation);

Class 4 Sections of the riverbank are not being eroded, and are unlikely to be eroded in the near future. This may include areas of the riverbank which have been completely subsumed by development.

3.2.5 Determination of area cleared of vegetation

To determine the average area cleared of vegetation, a ranking of the area was developed. The areas were ranked from small to large using a 3-point likert scale, where small =1, medium= 2 and large= 3. Visual observation was used as a baseline. However, Google earth images were also used to help supplement what was observed in the field.

Vegetation assessments were done in areas in the vicinity of sand mining sites. One site was selected per village to be used as a representative for each particular host village. This was done to avoid complexity in ranking the sites. The results obtained in this exercise where captured into SPSS for analysis in the binary logistic regression model as this is one of the parameters that were used in the development of guidelines.

3.3 Development of Guidelines

The broad objective of this study was to develop guidelines for dealing with the morphological and environmental impacts of sand mining along Nzhelele River. With the broad objective of the study, the study employed a more objective approach to developing guidelines for sand mining.

The binary logistic regression model was employed to achieve this goal. The binary logistic model was employed to determine morphological and environmental factors that determine observed changes in the river system as a result of sand mining activities. The model has the advantage that it eliminates parameters that are not significant. It is the more significant parameters as estimated by p-values that form the hallmark of the guidelines. The model is applicable mostly on situations where the observed changes can have two possible answers (ie; yes/no). The model requires a minimum of 100 questionnaires to achieve good results. A total of 100 questionnaires were distributed in host communities.

When dealing with a dichotomous dependent variable in binary logistic regression analysis, the main interest was to assess the probability that one or the other characteristics was present (Peng & So, 2002; Peng *et al*, 2002). The model answers the question; what determines the probability that the answer is yes/no? The special features of the model guarantees that probabilities estimated from the logistic model will always lie within the logical bounds of 0 and 1. The adopted logistic regression model can be expressed mathematically as follows (Peng *et al*, 2002);

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + ui\ldots \quad (01)$$

Where Y = Prob (household negatively affected =1)

β = regression coefficient

X_1 = distance of sand mining site from nearest water source

X_2 = Type sand mining

X_3= Method of extraction

X_4= Amount of sand extracted

X_5= Frequency of water resources usage

X_6 = Gender

X_7=Age

3.3.1 Model evaluation

Parameters in the logistics were estimated using the maximum likelihood method. The maximum likelihood method estimates parameters that are most likely to produce data. The statistical significance of each coefficient was evaluated using the Wald test. In this model, the numerated regression coefficient represents the change in the logit of the probability from a unit change in the associated predictor, assuming other factors are constant (Gujrati, 2003). The goodness-of-fit test of the regression model in this study was analyzed using;

- The Omnibus test, which is a likelihood ratio chi-square test that test whether the coefficient of the variables in the model are all jointly equal to zero
- The Hosmer & Lemeshaw (H-L) goodness-of-fit test, which examines the null hypothesis that the model adjust well to the data and
- The Cox and Snell (1989) and Nagelkerke (1991)- two descriptor measures that reveal the amount of variation in the outcome variable that is explained by the models (Long, 1997; Hosmer and Lemeshaw, 2000).

3.4 Estimation of Sand Extraction

The quantity of sand extracted per month was of paramount importance in this study. This data was important in order to determine the rate of land degradation and size of operations. The data acquired was on number of loads produced a month and labour or technology involved in extraction. This data was acquired through the use of interviews. The respondents were the people involved in the mining of sand. A minimum of four miners were selected to provide information on their mining operations. The sample was selected purposively in order to avoid selecting respondents not sure of the activities. The selected respondents where actively involved daily with sand mining activities. A formula was developed to calculate the approximate amount of sand extracted per month in the study area. This formula was developed based on the activities involved in sand mining activities in the study area.

This formula has never been used in earlier studies anywhere and can be expressed numerically as follows:

$$A = 7m^3 \; x \; L \; x \; N \ldots \qquad (02)$$

Where;

A= amount of sand extracted

L- Number of loads produced per day defined mathematically as follows;

L= 5T where

T= number of trucks loading per day

N- Number of days per week

$7m^3$= size of the truck

5= number of loads produced per day per truck.

3.5 Assessment of Environmental Impacts of Sand Mining

To assess the environmental impacts of sand mining, Environmental Impact Assessment (EIA) Guidelines for Sand and Stone Mining by Environmental Conservation Department of Malaysia (2000) was adopted.

The guideline states that environmental assessment for sand mining activities depends on several factors, namely the size of the operation which is the amount of sand extracted per month, the complexity of mining methods which determines whether the extraction is by mechanical means or manually using pick and spades, and locality (site characteristics). The operations were regarded sensitive if they were conducted within 500 meters from the active channel, river mouth and riparian land. Table 3.1 illustrates the clarification of impact variables based on site characteristics.

Table 3.1 Clarification of impact variables based on site characteristics (Environmental Conservation Department of Malaysia, 2000)

Size	**Capacity**
Small	500 m^3/month or less
Medium	1 000 to 2000 m^3/month
Large	More than 2000 m^3/month
Complexity	**Activity**
Simple	Manual method; mechanical method
Complex	Use of hydraulic dredger; dragline or suction equipment
Sensitivity	**Activity**
Normal	Anything not listed as 'sensitive'
Sensitive	River mouth; Riparian zones; high risks channel degradation sites; localities within 500 m of the main river channel

The criteria used for assessment of environmental impacts of sand mining activities were:

- The **magnitude** of change/effect, which is a measure of the importance in relation to the spatial boundaries
- The **permanence** of the impact, which defines whether the condition is temporary or permanent
- The **reversibility** of the condition, which defines whether the condition can be changed and is a measure of the control over the effect of the condition
- To what extent the impact is **cumulative**, which is a measure of whether the effect will have a single direct effect or whether there will be a cumulative effect over time, or a synergistic effect with other conditions.

The matrix was adopted because it is comprehensive in its criteria for impact assessment. It gives a clear guideline to classifying mining activity size, complexity and sensitivity.

3.6 Review of Legislation and Regulation of Sand Mining

One of the specific objectives for this study was to examine the South African legislative environment on sand mining. With that objective, regulations on the mining of sand in South Africa and the Malaysia were used as a guide when assessing the impacts. Malaysia has very clear and straight forward guidelines on sand mining. Hence it is chosen as a control on examining the South African legislations.

Sand mining in South Africa has received less attention in both the academic and regulatory environments. South African environmental regulations were examined on sand mining to identify gaps that can help in developing guidelines and recommendations for policy development.

Regulations from the Malaysia were used as a control in examining the South African regulations. The following South African environmental legislations related to sand mining activities were examined:

- Mineral and Petroleum Resources Development Act of 2002
- National Water Act 36 of 1998

The above legislations were selected because of their comprehensive nature in protecting the natural environment.

3.7 Stakeholder Analysis

As defined by Kammi (1999), stakeholder analysis is the process of collection of qualitative data to determine whose interests should be considered more important in the development or implementation of a program. With this definition in mind, stakeholder analysis was conducted to identify various stakeholder required in developing the guidelines for dealing with the morphological and environmental impacts of sand mining along the Nzhelele river. The data acquired from stakeholder analysis was used to develop guidelines for sand mining activities.

The influence and importance matrix tool (IIM) was also employed to help identify the level of importance and influence of the stakeholders identified in the development and implementation of guidelines for dealing with the morphological and environmental impacts of sand mining activities along the Nzhelele River.

A five point likert scale (where 1= low importance; 5= high importance) was used to gauge the relative importance of each identified stakeholder in the development of sand mining guidelines. A five point likert scale (where 1= low influence; 5= high influence) was also used to gauge the relative influence of each identified stakeholder in the development of sand mining guidelines.

CHAPTER FOUR: ASSESSMENT OF IMPACTS OF SAND MINING

This chapter presents and discusses the data collected for the research. The results of the visual observation, sand production records, questionnaires administered and the interview questions are presented in this chapter.

Sand mining, whether small or large scale, degrades the natural environment and results not only in health-related problems for neighbouring communities, but may also cause negative impacts on the environment as well (Makweba & Ndonde, 1996). The purpose of the survey was to identify, assess and address the key environmental issues of sand mining in order to propose acceptable mining guidelines and to enhance positive impacts, if any during process of extraction. The observation was conducted in all the active extraction and abandoned sites. The type of equipment and methods used for extraction were very significant when conducting field surveys.

4.1 Sample Characteristics

This section reviews the characteristics of the chosen sample. Variables that were analyzed were frequency of water resource use, age of respondents, and gender of respondents.

4.1.1Frequency of water resource use

Statistical data from the field questionnaires reveal that most frequent water resource users constitute 83 % of the chosen sample. Specific statistics shows 39% of the respondents use the water resources most often and 44% use the water resources occasionally. Respondents who never used water resources from the river only constitute 17 % of the chosen sample. For this reason, it is evident that the most affected people are those using the resources more often and they are the ones to notice any changes in the river and its floodplain as a result of sand mining. The respondents who have never used the water resources from the Nzhelele River are unlikely to notice any changes in the river system and may not be affected by sand mining activities at all. This is because they might not even know how the river was before and after sand mining operations.

Table 4.1 Frequency of water resource usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	39	39.0	39.0	39.0
	sometimes	44	44.0	44.0	83.0
	never	17	17.0	17.0	100.0
	Total	100	100.0	100.0	

4.1.2 Gender of respondents

The selected sample is composed of both male and female respondents. The gender profile shows that males are 50% and females 50%. When administering questionnaires, it was considered a priority to try balance the gender issue in the study. This was done to create equilibrium of the views from the respondents and avoid biasness of the sample. It further helped in showing who is mostly affected by sand mining in the host communities. As shown in table 4.2, males are the most frequent water resource users. Therefore, they are the most affected group than their female counterparts.

4.1.3Age of respondents

As depicted in Figure 4.1, the majority of respondents (27%) fall within the group of 36-40 years. However, these statistics show that the sample is composed of generally older people (36 years and above). Specific statistics in Table 4.2 shows that the most elder age group are the most affected as they are the most frequent water resource users. This is because the elderly age has more activities in the river and the environment in its proximity. This ranges from irrigation of cultivated lands to spiritual activities.

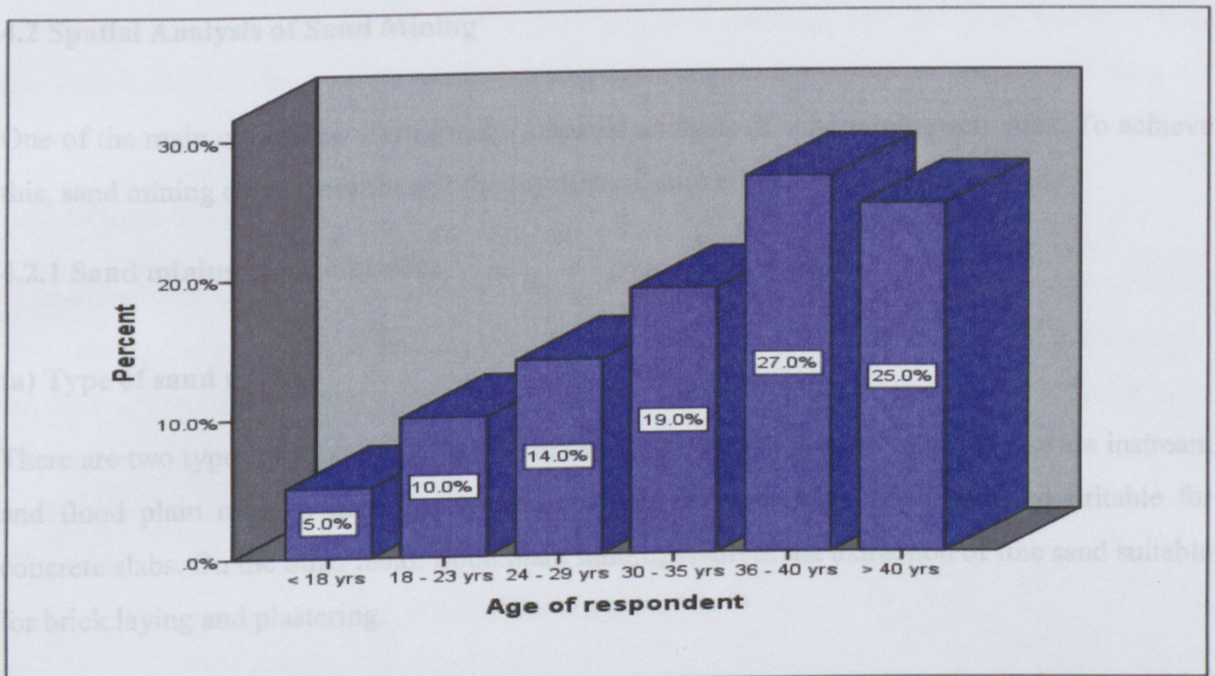

Figure 4.1 Age of respondents in the study

Table 4.2 Age of respondent and Frequency of water resource usage Cross tabulation

Age of respondent	Frequency of water resource usage			Total
	very often	sometimes	never	
< 18 yrs	3	2	0	5
	7.7%	4.5%	0.0%	5.0%
18 - 23 yrs	1	5	4	10
	2.6%	11.4%	23.5%	10.0%
24 - 29 yrs	2	7	5	14
	5.1%	15.9%	29.4%	14.0%
30 - 35 yrs	5	12	2	19
	12.8%	27.3%	11.8%	19.0%
36 - 40 yrs	14	10	3	27
	35.9%	22.7%	17.6%	27.0%
> 40 yrs	14	8	3	25
	35.9%	18.2%	17.6%	25.0%
Total	39	44	17	100
	100.0%	100.0%	100.0%	100.0%

4.2 Spatial Analysis of Sand Mining

One of the main objectives was to make a spatial analysis of sand mining activities. To achieve this, sand mining characteristics and the location of sand mining sites were analyzed.

4.2.1 Sand mining characteristics

(a) Type of sand mining

There are two types of sand mining practiced along the Nzhelele river valley. These are instream and flood plain mining. Instream mining involves the extraction of coarse sand suitable for concrete slabs. On the other hand, flood plain mining involves the extraction of fine sand suitable for brick laying and plastering.

Results from field visits shows instream mining (51%) is the most common type in most of the host communities, whereas flood plain mining only constitute 44%. There is a very small percentage (5%) where both instream and floodplain mining is practiced in the same community. These findings are depicted in Figure 4.2. Communities with no floodplain mining were observed towards the mouth of the river. These communities are Pfumbada, Tshituni, Maangani and Musekwa. This is because of more deposition of river sand along these communities.

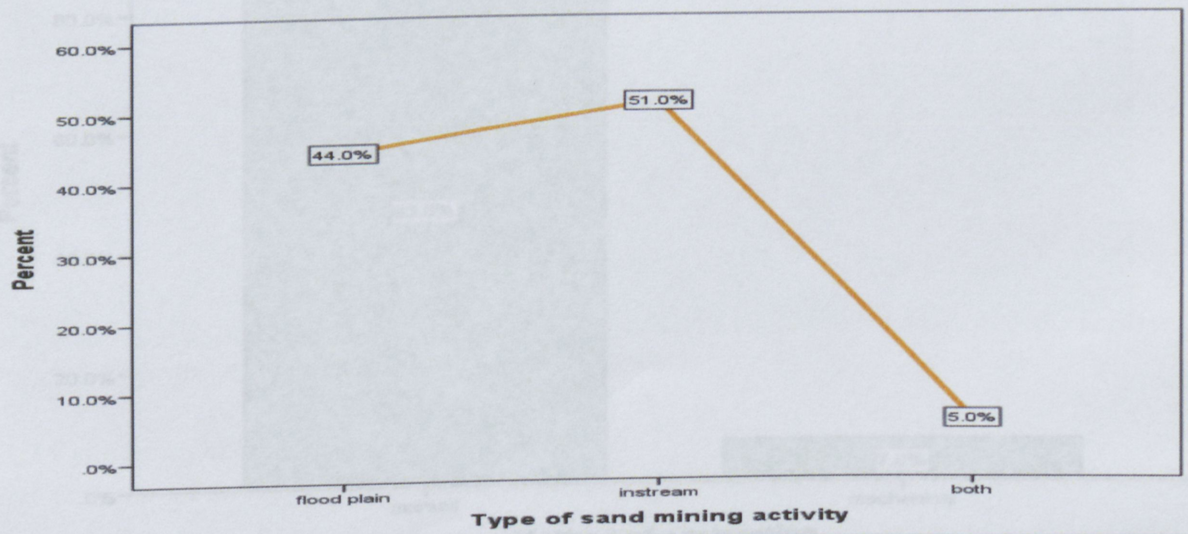

Figure 4.2 Types of sand mining activities

Communities closer to the source of the river host both instream and floodplain mining. These are Tshivhilidulu, Mandala, Fondwe and Dopeni villages. Floodplain extraction activities are mostly impacting the agricultural land and the vegetation on the floodplains.

(b) Methods of extraction

Numerous types of sand extraction exist, the method chosen commonly depends on the nature of the material and the type of equipment the miner has for extraction. Mining activities are carried out by both manual and mechanical means. Data from the field in Figure 4.3 reveal that sand mining activities are mostly carried out manually (93%). Picks and shovels are the commonly used tools for manual extraction of the material. Extraction by mechanical means constitute only 7%. Most mechanical extraction activities occur when the sand is required for mostly large construction projects. However, this is occasionally done.

Manual extraction is practiced daily and therefore causes more threats to the natural environment. In this method workers use picks to expose the materials and shovels to load the material onto the trucks.

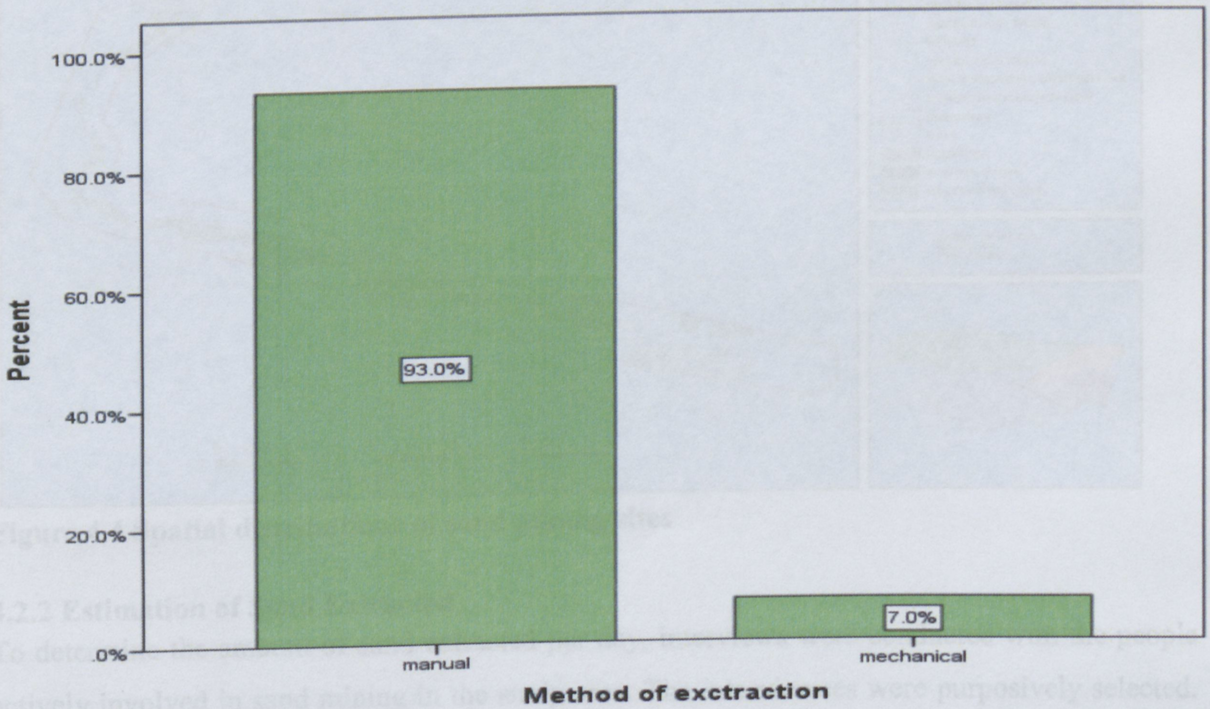

Figure 4.3 Method of sand extraction

(c) Mapping the location of sand mining activities

One of the specific objectives of this study was to map the location of sand mining sites along the Nzhelele River. To achieve this objective, a spatial distribution map of sand extraction sites was created and is depicted in Figure 4.4.

In the spatial distribution map (Figure 4.4), sand mining sites are shown in red along the Nzhelele River shown in blue. More sand mining sites are located just some few kilometers from the source of the river. At this area, deposition rate is higher proving more sand. This is because of the gradient of the river. Steeper gradients promote more erosion whereas gentle gradients promote more deposition. This also attracts the miners in large numbers as the sites are easily accessible and the material is in abundance. Distance to the market is considered also a factor of choosing these sites. During the interview with some of the miners, they indicated that the closer the site is to the market the more profit they make as they save on transportation costs.

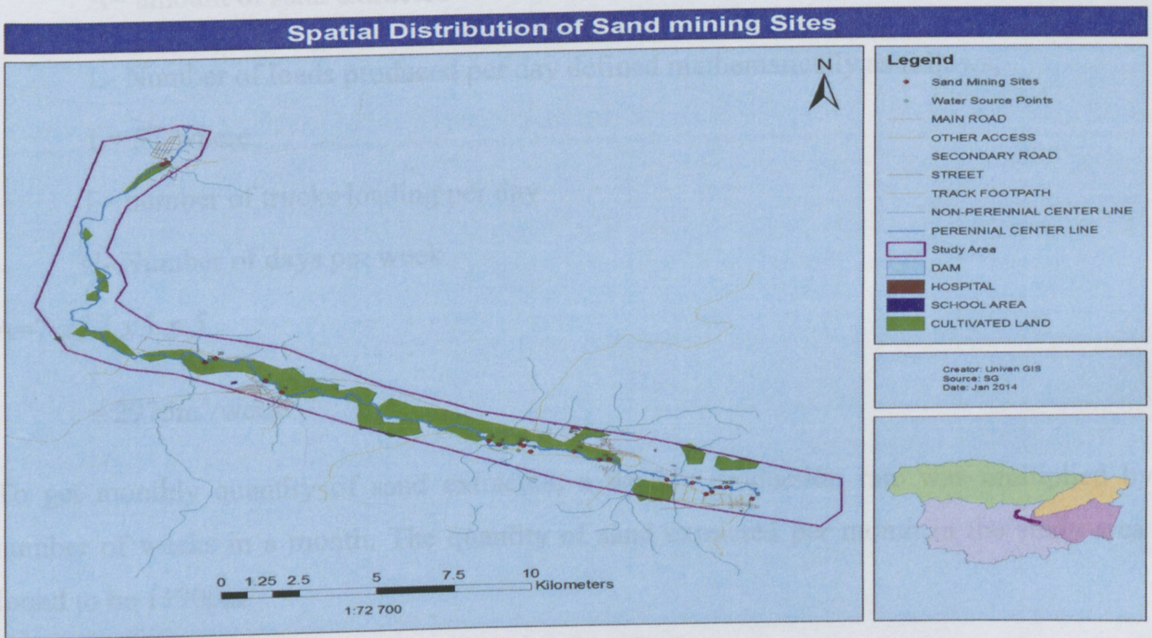

Figure 4.4 Spatial distributions of sand mining sites

4.2.2 Estimation of Sand Extracted

To determine the amount of sand extracted per day, interviews were conducted with the people actively involved in sand mining in the study area. The interviewees were purposively selected. To estimate the quantities of sand extracted per day, number counts of loads was conducted. It was revealed that the number of loads produced per each truck depends on the number of people the truck has for loading. It was also mentioned that additional loads are done if agreements are made between the employee and the employer. It was however not possible to acquire the correct number of loads produced per month as that information was classified as confidential.

It was observed that the average number of people loading the sand were five (5) per truck, producing five (5) loads per day for five days a week. The approximate total number of trucks/ miners extracting the sand in the study area is 17.

A simple mathematical formula was developed to quantify the amount of sand extracted per week. The formula is presented below;

$A= 7m^3\ x\ L\ x\ N$

Where;

A= amount of sand extracted

L- Number of loads produced per day defined mathematically as follows;

L= 5T where

T= number of trucks loading per day

N- Number of days per week

$A=7\ x 17\ x 5\ x\ 5$

$= 2975m^3/week$

To get monthly quantity of sand extracted, a weekly production rate was multiplied by the number of weeks in a month. The quantity of sand extracted per month in the study area was found to be 11900m^3

4.2.3 Size of extraction pits

When determining the size of the extraction pits, depth was the considered a first priority. This was because of the number of issues the community has raised as a result of open excavations left by sand miners. The incidents range from high mosquito rate to death of children by drowning. A tape measure was used to measure the depth of the excavations. Google earth was also used to create a cross section of excavated pits. This was done to supplement the data on the depth of excavations collected in the field. The average depth of the extraction pits were found to be six (6) meters. Figure 4.5 shows the cross-section of one of the excavations at Tshivhilidulu village

Figure 4.5 Cross-section of Tshivhilidulu excavation site (Google earth, 2013)

To determine the changes in size of the area covered by the excavations, satellite images were used. Satellite images selected were for the year 2008 and 2012. Satellite image for the year 2012 was used as a base when digitizing. The edge of the excavation was then digitized from the images. The size of the excavation in the year 2008 was represented by red colour and that of the year 2012 is green line in Figure 4.6(A). Some area has transformed to wetlands creating more green around the excavation site. This was due to the alteration of the water table and a halt in extraction of sand for some years as a result of the conflict between the chief and the miners. However, an agreement was reached to continue sand extraction. Some trees were excavated around them leaving them with minimal soil cover, this promotes habitat degradation. This can be seen in Figure 4.5 and 4.6A as green spots within the main aerial image.

As shown in Figure 4.6 B and Figure 4.6 C, the truck can easily go in and cannot be seen from the outside of the extraction pits. Several cases of banks collapsing and injuring/ killing the miners have been reported during field surveys as the miners always go for the softer material underneath the original ground. A truck shown in Figure 4.7 B is loading sand at one of the oldest extraction sites at Tshivhidulu village. The extraction site is shown in Figure 4.7A and B.

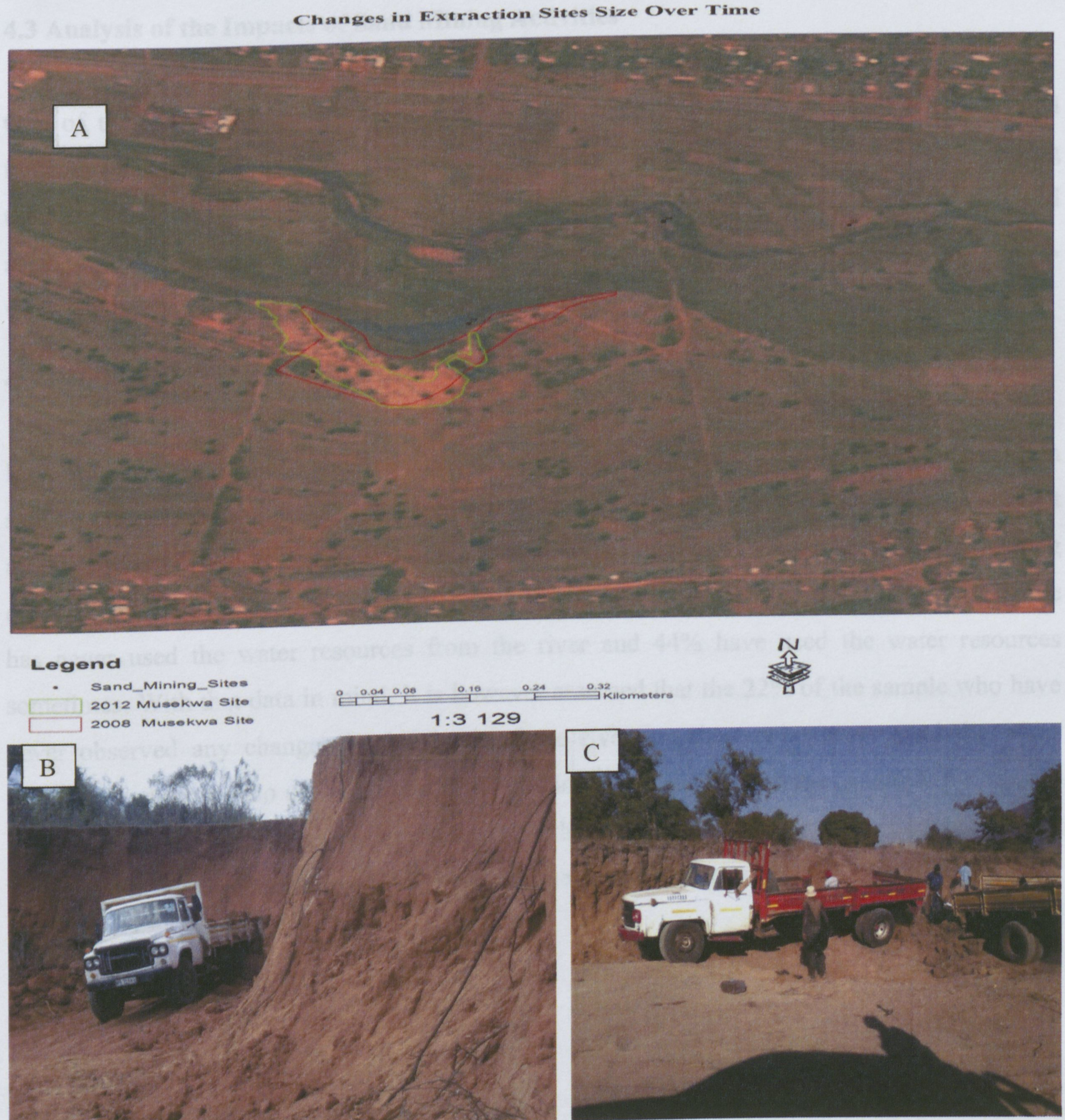

Figure 4.6 Size of extraction pits

Figure 4.6 C shows trucks loading from a recently opened extraction pit at Dopeni village. The site is approximately 100 meters in length with a depth of about 4 meters. The size of this excavation is directly related to its age. After interviewing the miners, they indicated that the site is less than a year old. The material proves to be the best in the market as by the number of trucks loading simultaneously. This was observed during field surveys.

4.3 Analysis of the Impacts of Sand Mining Activities

One of the major objectives of the study was to analyze morphological and environmental impacts of sand mining along Nzhelele River. This analysis was done under the following thematic sections; observed changes in river depth, changes on water resources usage, observed social impacts, change in land use, infrastructure damage, artificial lakes, riverbank erosion, water quality and river channel capture.

4.3.1 Observed changes in river depth

Data from the field questionnaires and plotted in figure 4.7 revealed that 78% of the chosen sample has noticed changes in the depth of the river, while 22% have not observed changes at all. Figure 4.8 also indicate that 9% of the sample indicated that they have observed less fishing and swimming pools along the river. Statistical data in Table 4.1 indicate that 17% of the sample has never used the water resources from the river and 44% have used the water resources sometimes. With that data in mind, it is however assumed that the 22% of the sample who have never observed any changes in the depth of the river are those who never used the water resources and those who used the resources occasionally. It is also however possible for one not to have observed any changes in the river depth although the water resources are frequently used. This could be due to ignorance of individual or other societal factors.

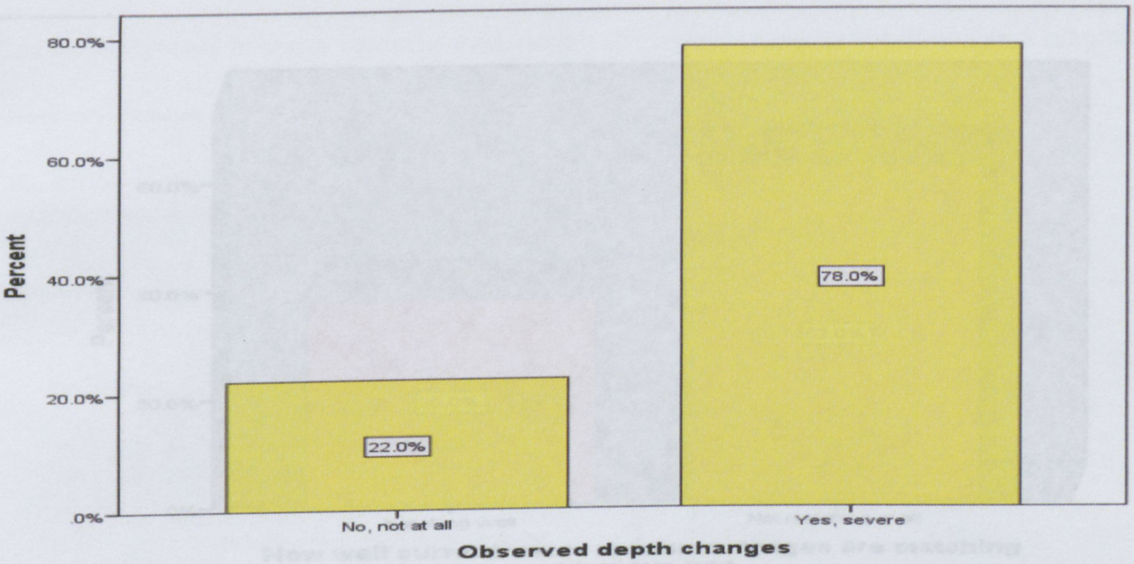

Figure 4.7 Observed depth changes

4.3.2 Changes in water resource use

It was possible to obtain information from respondents on whether water resource use had changed over the last 20 years. This was done in order to get a sense of the extent to which sand mining activities had impacted on or brought about changes in water resource use over time. To detect any possible changes in water resource use, the study employed the method of *pattern matching*. Pattern matching entailed comparing the current water resource usage with previous water resource usage over the last 20 years. Pattern matching exercises require quantitative analytical strategies to attain good quality results. To achieve that, the data from the field questionnaires on changes of the water resources usage over time was captured into the SPSS to help improve the overall quality of pattern matching exercises. Results are summarized in Figure 4.8.

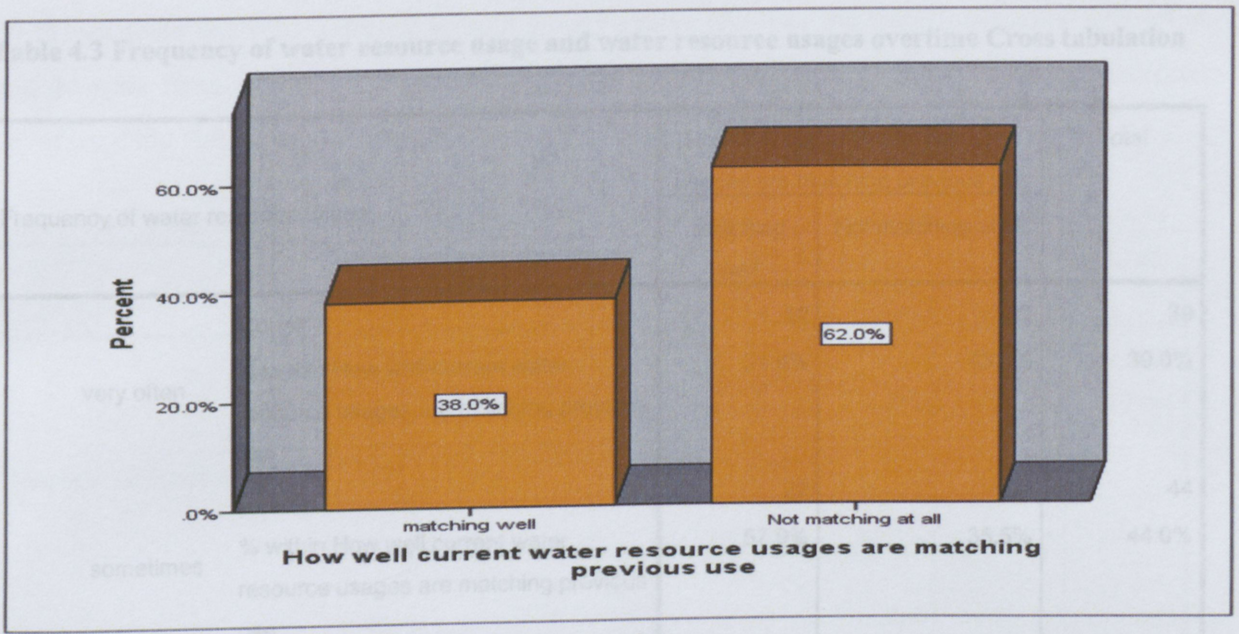

Figure 4.8 Changes in water resources use over time

The majority of the respondents (62%) witnessed changes in the use of water resources over the last 20 years due to increase in sand mining activities. A relatively smaller proportion of respondents (38%) maintained that water resources use had remained the same in the last 20 years. Further analysis as depicted in Table 4.3 shows that observed changes in water resource use are significant as the majority of water resource users access the resources most frequently. Statistics in Table 4.3 reveal that most of the frequent water resource users (43.5%) witnessed changes in water resource use. The respondents who use the water resources very often witnessed changes due to the fact that they spend most of their time along the river. However, the respondents who use the water resources occasionally have observed fewer changes. It is further assumed that the respondents who use the water resources occasionally might not notice any change even if there are changes.

Table 4.3 Frequency of water resource usage and water resource usages overtime Cross tabulation

Frequency of water resource usage		How well current water resource usages are matching previous use: matching well	How well current water resource usages are matching previous use: Not matching at all	Total
very often	Count	12	27	39
	% within How well current water resource usages are matching previous use	31.6%	43.5%	39.0%
sometimes	Count	22	22	44
	% within How well current water resource usages are matching previous use	57.9%	35.5%	44.0%
never	Count	4	13	17
	% within How well current water resource usages are matching previous use	10.5%	21.0%	17.0%
Total	Count	38	62	100
	% within How well current water resource usages are matching previous use	100.0%	100.0%	100.0%

4.3.3 Observed social impacts

Changes in water resource use as a result of sand mining have affected certain social categories of water resources users more than others. Results in Table 4.4 shows that male water resource users have been affected more than their female counter parts. This is because the bulk of frequent water resource users are male. Specific data from the questionnaires indicated that from the 100 questionnaires distributed, 26 of the respondents were males who use the water resources very often and 18 respondents uses the resources sometimes. Only six (6) of the male respondents have never used the water resources from the Nzhelele River.

39 respondents from the selected sample were females who use the water resources very often and 44 were females using the water resources occasionally, while 17 female respondents have never used the Nzhelele river water resources.

Table 4.4 Gender of respondent and frequency of water resource usage Cross tabulation

			Frequency of water resource usage			Total
			very often	sometimes	never	
Gender of respondent	Male	Count	26	18	6	50
		% within Frequency of water resource usage	66.7%	40.9%	35.3%	50.0%
	Female	Count	13	26	11	50
		% within Frequency of water resource usage	33.3%	59.1%	64.7%	50.0%
Total		Count	39	44	17	100
		% within Frequency of water resource usage	100.0%	100.0%	100.0%	100.0%

Specific statics shows that 66.7% of frequent water resource users are male while 33.3% are their female counterparts. Males have more activities along the river than females, for example, fishing and agriculture.

The most vulnerable groups to changes as a result of sand mining do not vary only according to gender but also according to age of resource users. Data from Table 4.1 shows that the most affected age group is the elderly who are at least 36 years old and above. The selected respondents have indicated various livelihood challenges associated with sand mining activities. Figure 4.9 shows some of the various challenges listed by the selected sample.

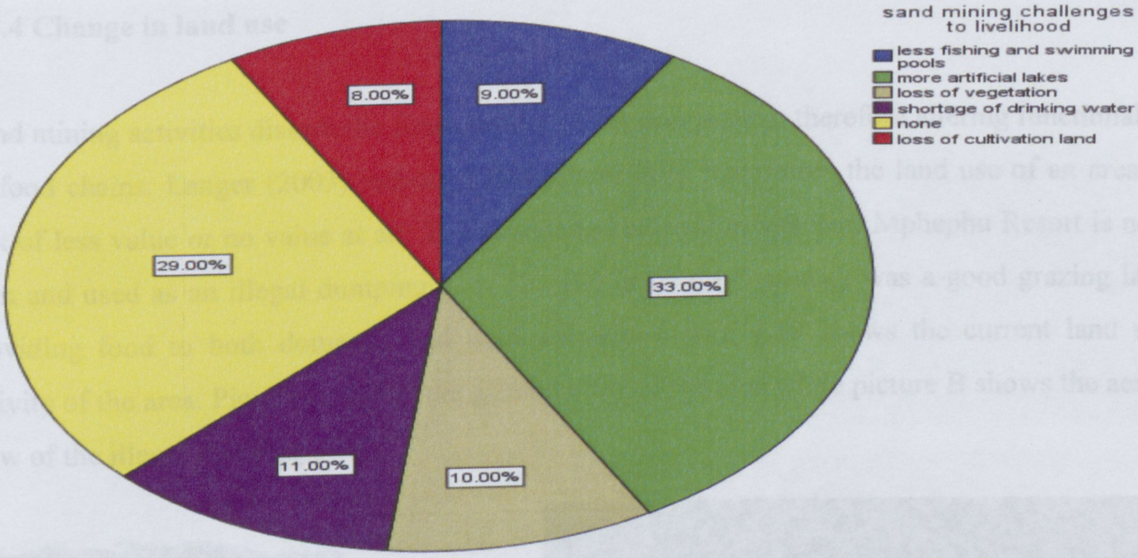

Figure 4.9 Livelihood challenges

Specific statistics from the questionnaires shows that 33% of the selected sample indicated open excavations, in this case listed as artificial lakes are the most problematic challenges. This is because of the cases of children and livestock drowning in the pits and harboring of mosquitoes by the pits.

29% of the respondents indicated that they have never experienced any challenges as a result of sand mining. These respondents either live far from the extraction sites or have never used the water resources from the Nzhelele River.

11% of the selected sample indicated that there is a shortage of drinking water. This was observed at Tshivhiludulu village as the community uses water from the springs in the vicinity. Loss of vegetation was also experienced by 10% of the sample. This is because of the creation of access roads and clearing of the vegetation to expose the underlying material.

Less fishing and swimming pools were also observed by 9% of the sample. In this case, males and the younger age group are the most vulnerable as they are the ones practicing swimming and fishing most often. A lower percentage (8%) has experienced loss of cultivation land. This is the group whose land was invaded for sand mining by the chief of the respective villages and also other illegal miners. A loss of land for cultivation has a direct impact on the food security of the households and the community at large.

4.3.4 Change in land use

Sand mining activities disturb the functionality of the ecosystems, therefore altering functionality of food chains. Langer (2003) indicated that this activity transforms the land use of an area to that of less value or no value at all. The abandoned extraction site near Mphephu Resort is now seen and used as an illegal dumping site. The site in its original state was a good grazing land providing food to both domestic and wild animals. Figure 4.10 shows the current land use activity of the area. Picture A shows the ground view of the area while picture B shows the aerial view of the illegal dumping site.

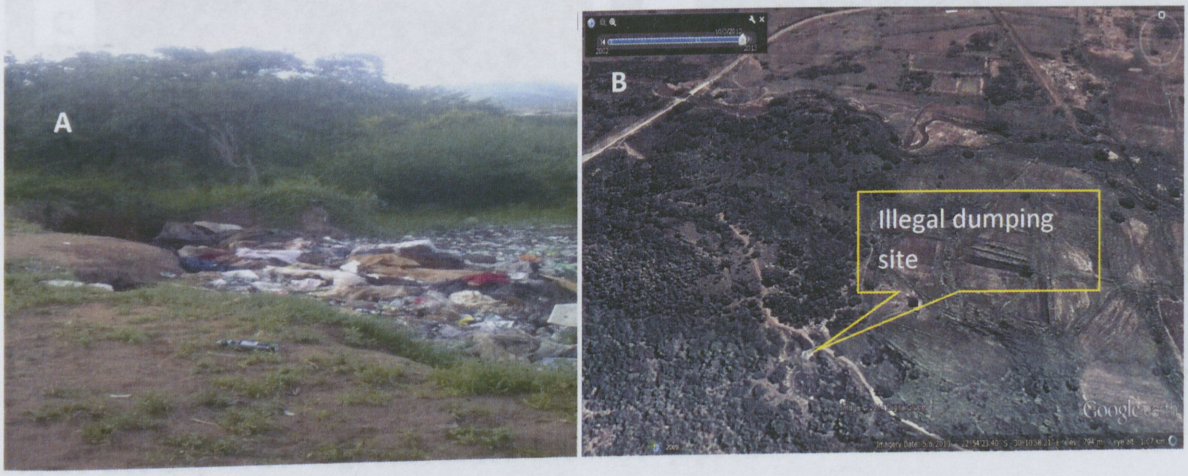

Figure 4.10 Changes in land use at Siloam village (Google earth, 2013)

4.3.5 Infrastructure damage

Instream sand mining alters the channel morphology directly resulting in erosion of river banks, channel incision, channel instability and infrastructural damages (Kondolf, 1997. The erosion of the river banks degrades the habitat of both aquatic and terrestrial species in the vicinity. The degradation might even extend further down or upstream of the area. It was observed that the erosion of the river banks is exposing the foundation of bridges and exposing the water pipe lines. This was also observed by Kondolf (1997) in study on the effects of dams and gravel mining on river systems. This can pose a threat to availability of drinking water for the communities were sand mining is conducted. Figure 4.11 shows exposure of bridge foundations, water pipelines and the road under threat of erosion. The distances from the road to the extraction pits is about 4 meters.

Figure 4.11 Exposed bridge foundation and water pipe line

The exposed foundation in picture B is a result of sand mining on the riparian land adjacent to the river. The excavations on the riparian land captured the main river during heavy rains. This has resulted in the change of location of the river channel leading to the exposure of bridge foundations and erosion threat to the road in proximity. Picture A in Figure 4.11 shows the depth of the pits before the pit captures the main river. Picture A was taken before the heavy rain, which is before capturing the main river channel. Picture B in the other hand is the result of the pit capturing the main channel. This has resulted in the change of channel plan form. Kondolf (1997) mentioned that the impacts of flood plain pits are similar to those of instream mining when the floodplain pits capture the river channel. This was evident during field survey as depicted by picture A and B in Figure 4.11.

The exposed water pipe line is a result of instream sand mining at Tshivhilidulu village. The pipe is located just few meters to an abandoned instream mining site. After interviews with some of the community members, it was revealed that the pipe was once broken during heavy rains. This pose water shortage stress to the community as water supply to the village was cut. The other sand miner indicated that the site was abandoned because it was now inaccessible due its depth. After a careful assessment of the area, it was revealed that the collapsing of river banks and exposure of the pipeline was due to the severe incision (Kondolf, 1997) which triggered the banks to collapse leading to the exposure of the pipeline. As also noted by Ritter *et al* (2002) the original bank has slided to the riverbed exposing the pipeline.

4.3.6 Artificial lakes

Floodplain sand mining transforms the land into open pits. This has formed open-water ponds which pose a threat to the community in the vicinity. The open ponds may harbor mosquitoes in summer and this escalates the chances of malaria in the area. It was observed that kids use the ponds as swimming pools and risks of drowning are very high. During the interview with some of the community members, cases of livestock drowning in the ponds were mentioned. Figure 4.12 shows children swimming in one of the artificial lakes formed after sand mining.

Figure 4.12 Children swimming in the artificial pond formed after sand mining

4.3.7 Alteration of water table

The extraction of sand alters the physical characteristics of the land and therefore decreases the distance between the ground water table and surface area. This excavation penetrates the shallow aquifers, leading a direct access to ground water (Depreeze, 2000). The exposure of the water table changes the entire land use of the area into open water ponds creating breeding grounds of mosquitoes. Picture A shows water seeping out of the ground some weeks after the extraction and picture B shows sedges plants now growing in the excavation. This succession of plants will transform the pit into deep wetlands in the long run as observed just 20 metres west of the excavations shown in Figure 4.13. The area is now a fully-fledged wetland as a result of water table alteration by sand miners. This can be seen in Figure 4.5 and Figure 4.6 as the dark green areas next to the huge area cleared of vegetation.

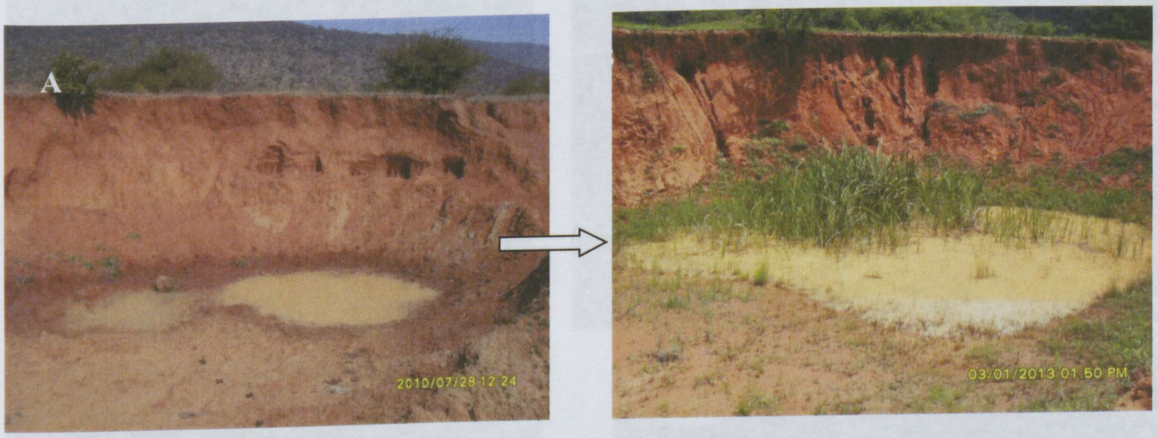

Figure 4.13 Altered water table at Tshivhilidulu village

4.3.8 Riverbank erosion assessment

Channel shape, bed and bank material, and river hydraulic characteristics are factors that affect riverbank erosion (Buer *et al*, 1989). Anthropogenic factors such as sand mining may exacerbate these natural factors leading to severe morphological change of the channel and its riparian land. River bank erosion as a result of sand mining leads to incision of river bed and channel widening resulting in loss of land and infrastructure damage (John, 2009). In assessing the severity of Nzhelele river banks erosion as a result of sand mining, the following classes were used (Cavanough, 2007).

Class 1 Includes areas where erosion is highly evident, as is demonstrated by mass failure of slabs of material, and significant stress lines visible on the bank itself.

Class 2 Areas are in the process of being eroded, but the erosion would not be as severe as Class 1. Physical indicators include loose aggregates at the foot of the bank and/or the exposure of tree roots.

Class 3 Sections of the riverbank are not presently being visibly eroded, however, they remain vulnerable to future erosion (i.e. lack vegetation);

Class 4 Sections of the riverbank are not being eroded, and are unlikely to be eroded in the near future. This may include areas of the riverbank which have been completely subsumed by development.

Field surveys revealed that river bank erosion at selected river reaches fall within class 1. This was classified because of mass failure and collapsed banks as shown in Figure 4.14 A&C. Picture A in Figure 4.14 shows the collapsed river banks as a result of instream sand mining. It is evident that the banks were undermined leaving them hanging with no support underneath.

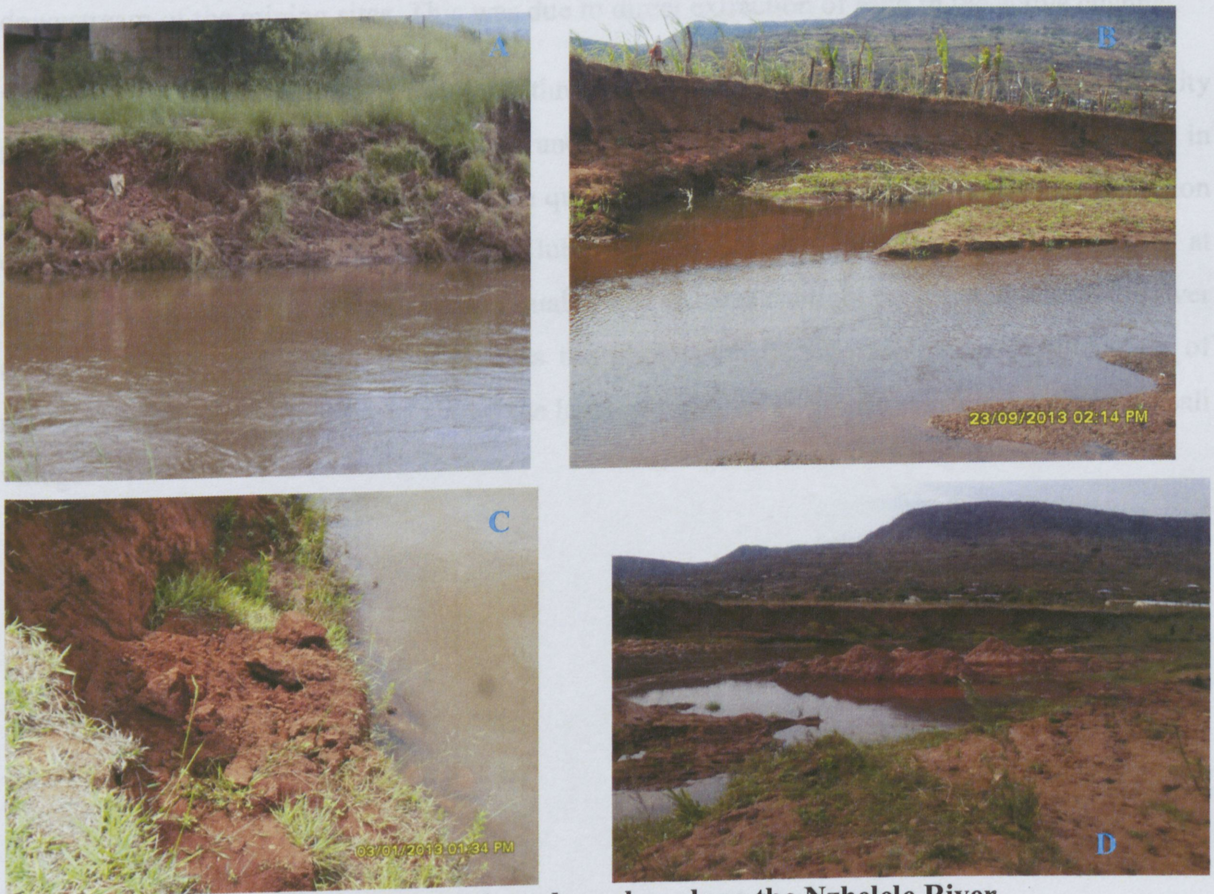

Figure 4.14. Riverbank erosion at selected reaches along the Nzhelele River.

Picture B shows the eroding river bank encroaching into the cultivation land at Mandala village. The stock piles of sand in picture D is located just10 meters from the location of picture B.

The stock piles are created to drain water from the sand. This increases the turbidity rate which reduces the amount of sunlight entering the water. Picture C fall within class 2, however severe erosion to the banks may occur anytime if instream mining persists. Some sections falling within class 4 were observed during field survey. However, those sections were at areas where less or no sand mining was practiced in the vicinity.

4.3.9 Water quality

Physical factors were considered for assessment for water quality. This was due to the fact that other contaminants from nonpoint sources could contribute to the deteriorating water quality of the river. The turbidity of the water and suspended lubricants from the haul trucks was the main focus. The turbidity of the water upstream of the mining site was observed to be low and higher downstream of the mining sites. This was due to direct extraction of sand in the active channel.

Sand mining affects surface runoff rate through vegetation clearing and groundwater quality through contamination with dissolved and suspended materials. The lubricants used in machineries and sand extraction affect the quality of the aquatic system leading to deterioration of some aquatic species. The suspended lubricants were observed mostly at instream sites at Rabali village. Turbidity degrades water quality and reduces sunlight penetration within the river (Peck & Rohasliney, 2011). This reduces the photosynthetic rate and primary production of nutrients in the river. Figure 4.15 shows the level of turbidity at an instream mining site at Rabali village.

Figure 4.15 High turbidity rates at a mining site

4.3.10 Channel migration

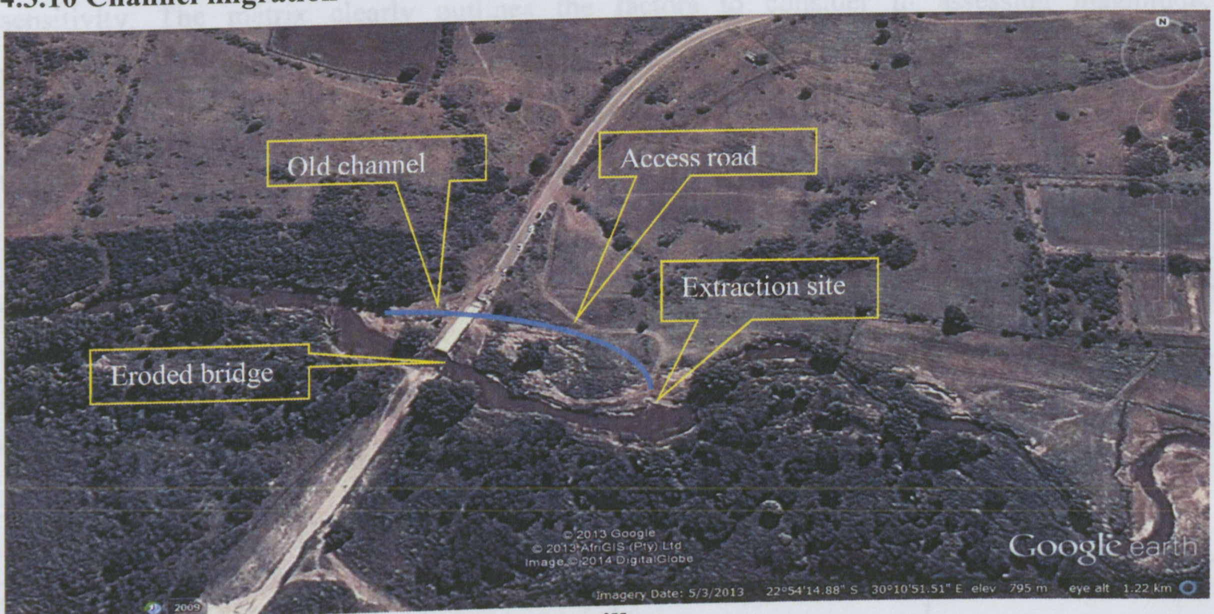

Figure 4.16 Channel migration at Sendedza village

The adverse of sand mining activities on rivers is a function of the rate of the deficit in the sediment balance of the reach, which develops when the extraction rate is greater than the river replenishing rate (Sear & Archer, 1998; Langer 2001, 2003; Meador & Layher 1998). As figure 4.16 depicts, the river has changed its cause because of sand extraction site located at one of the meandering points of the river. The blue line in the figure represents the old channel. An access road is clearly visible in the figure. The creation of that access road involved clearing of the riparian vegetation and alteration of the river bank to access the sand in the river channel. The erosion has extend downstream of the extraction site and has caused a severe erosion of the soil around the bridge. This has left Mphephu resort inaccessible leaving people with no recreational facility in their vicinity. This has obvious implications on the economic wellbeing of the province.

4.4 Assessment of Environmental Impacts

To assess the impacts of sand mining along the Nzhelele River, certain variables had to be clarified. The clarification adopted is based on the work of the Environmental Conservation Department of Malaysia (2000) who developed a matrix of sand mining impact variables. The matrix was adopted because of its comprehensive nature in sand mining impact assessment. It gives a clear guideline to classifying sand mining activity based on size, complexity and sensitivity. The matrix clearly outlines the factors to consider in assessing magnitude, permanence, reversibility and cumulative aspects of environmental impacts. Such qualities of a matrix enable one to do an objective environmental assessment. Such clarification is depicted in table 4.5. The final assessment of the impacts of sand mining is given in Table 4.6.

Table 4.5 Clarification of impact variables based on site characteristics

Variable	**Small**	**Medium**	**large**
Size order			X
	Simple	**Complex**	
Complexity	X		
	Normal	**Sensitive**	
Sensitivity	X		

The definition of the variables in Table 4.5 is depicted in Table 3.1. The size of the operations is considered to be large as guided by the chosen impact assessment matrix. This is because an approximate amount of 11900m^3 is extracted per month. Data from the field revealed that most of the extraction sites are located within 500m from the main river channel and on riparian area disturbing the entire ecosystem functionality of the river system. This classifies the extraction activities as very sensitive.

The method of extraction is simple as manual and mechanical extractions are the only activities practiced in the study area. The use of hydraulic dredger dragline or suction equipment is not available in the study area. This confirms that the extraction activities are simple. However, severe impacts are arising as a result of sand mining.

Table 4.6 depicts the assessment of some environmental and morphological impacts of sand mining activities. The assessment was based on site characteristics. Variables such as magnitude, permanence, reversibility and cumulative nature of the impacts were considered during impact assessment as shown in Table 4.6.

Table 4.6 Assessment of Impacts Based on Site Characteristics

Environmental impacts	**Magnitude**	**Permanence**	**Reversibility**	**Cumulative**	**Total impact**	**% impact**
River channel degradation	1	3	3	3	**10**	**100**
Landuse change	1	3	2	3	**9**	**90**
Infrastructure damage	2	2	2	2	**8**	**80**
Alteration of water table	2	3	2	3	**10**	**10**
Water quality	2	2	2	2	**8**	**80**

Magnitude of effect: 1= within project site; 2= local conditions; 3 = regional/national/international

Permanence of effect: 1= no change/not applicable; 2 = temporary; 3 = permanent;

Reversibility of effect: 1= no change/not applicable; 2 = reversible; 3 = irreversible;

Cumulative: 1= no change/not applicable; 2 = non-cumulative/single; 3 = cumulative/synergistic

Channel degradation in the form of collapsing river banks and excessive depth changes triggers changes in the physical, biological and chemical structure of the river as a result of sand mining activities. This affects the channel at a local scale and this brings permanent change in the character of the channel. The resultant changes are not reversible and are cumulative in nature as they affect the biological, chemical and physical structure of the river channel.

The change in land use occurs at the extraction site and proves to be permanent and is irreversible as the miners do not rehabilitate the area after mining. The sites tend to be of no value after mining and this permanently changes the type of land use which was practiced. The change in land use is cumulative in nature and affects both the environmental and socio-economic character of the area. After mining has ceased, the area is mostly transformed to a waste land (Figure 4.10). The impact could be reversible if the area could be rehabilitated after mining has ceased.

The damage to the infrastructure affects the local people and it could be temporary as the affected infrastructure could be repaired. The impact proves to be reversible and non-cumulative. A proper management and rehabilitation plan can help avoid this impact from occurring.

The alteration of the water table affects the local condition of the ground water. This could lead to a reduction in species diversity in the vicinity. A permanent change in the state of water availability may occur. Resulting in permanent change is land uses around the extraction site. The impact could be reversible if adequate plans are put in place. Although the impacts arising could be cumulative, constant monitoring of changes in the area could help bring the area to an acceptable state which can gain support some life forms.

Changes in water quality as a result of sand mining are not permanent as the normal water quality conditions could be regained if sand mining is stopped. This may affect the local conditions of the river. If sand mining is ceased, the river could regain its normal state after several heavy rains. The heavy rains will wash away all the pollutants leaving the river clean.

4.5 Review of Legislation of Sand Mining

One of the major objectives of this study was to review the South African legislative environment on sand mining. This took into considerations issues such as a qualitative assessment of existing legislations and evaluation of the influence and importance of various stakeholders in the development of sand mining guidelines.

4.5.1 A qualitative assessment of existing legislations

A thorough review of the legislations listed in the table was conducted to point out the assessment in the table. The main area of focus in the table depicts the objectives and principles of the acts. Provisions relating to sand mining activities reveal any part or section of the acts which are related to sand mining activities. Table 4.5 has proved effective in examining South African and Malaysian legislations on sand mining activities.

Sand mining in South Africa is regulated in section 21 C and I of the National Water Act 36 of 1998. However, these sections do note state sand mining activities clearly. The sections cover most of the infrastructural development with the river or watercourse.

Table 4.5 A qualitative assessment of existing legislations in South Africa and Malaysia

Policy/ legislative instrument	Main area(s) of focus	Provisions relating to sand mining	Evidence of guidelines relating to sand mining			Comments (if any)
			yes	Yes, but	*No*	
National Water Act 36 of 1998	• Control the use of all water resources • Protect the water resources from	Section 21 (c)- impeding or diverting the flow in a watercourse Section 21 (I) Altering the bed, banks, course or		X		•The act is vague and has not made any provision of sand mining. The act has not protected the river and its floodplains fully from sand mining. •Sand mining is not

	degradation and pollution • Equitable access to water resources by every person.	characteristics of a watercourse				specifically addressed in the context of the act which opens loop holes and therefore creates more chances for illegal sand mining. •A lack of clear regulatory framework has increased the environmental impacts of sand mining
MPRDA 28 of 2002	• recognition of the finite nature of mineral and petroleum resources • Rehabilitate impacted areas to natural or agreed standards, in line with sustainable development principles. • promotion of sustainable development and protection of the environment	None			X	Sand mining is not specifically addressed in the context of the act. However, in the application for mining rights form, it is indicated but not addressed in detail.
State Policy on River Sand and Stone Mining (Malaysia)	Management of river sand and stones based on stakeholder engagement and locations of the mining sites • Enforcement of the state policy of sand and stone mining • enforcement of socio-economic measures in	The policy is developed specifically for sand mining activities.	X			The policy is very significant in addressing sand mining activities.

	the management of river sand and stone mining • Awareness of the impacts of sand and stone mining and the existing legislations on sand mining. • strengthening of the framework on cooperation, control and management of sand mining activities					
Guidelines for minimising impacts of sand mining on quality of specific rivers in Sabah (Malaysia)	To provide guidance to government and other stakeholders in monitoring and minimising sand mining impacts on rivers quality Provision of guidance to miners in Best Management Practices implementation and sustainable extraction methods Community engagement in compliance monitoring and enforcement of rehabilitation plans	Sand mining policy and guidelines	X			The guidelines are clear and specific to sand mining operations in river systems.

4.5.2 Stakeholder involvement in the development of guidelines

In identifying various stakeholders, the following issues were taken into consideration; potential beneficiaries, vulnerability assessment and the relationships among the stakeholders. In the case of this study the potential beneficiaries are the communities in proximity to the extraction sites. The communities are the most vulnerable as they are the ones facing the challenges brought by sand mining activities. The livestock and children drowning in the pits left open belongs to the community not the local municipality or the government. Stakeholders such as the local community, local municipalities, sand miners, buyers and the government were identified. A very strong relationship among the stakeholders is evident, as depicted in Figure 4.18.

However, community perceptions should be considered a high priority as they can enforce the implementation of the proposed guidelines.

The influence and importance of stakeholders in the development of sand mining guidelines was evaluated using the influence and importance matrix (IIM) technique. This was done in order to get a sense of which organizations or institutions will oversee the development and implementation of the proposed guidelines. Results are summarized in Figure 4.18.

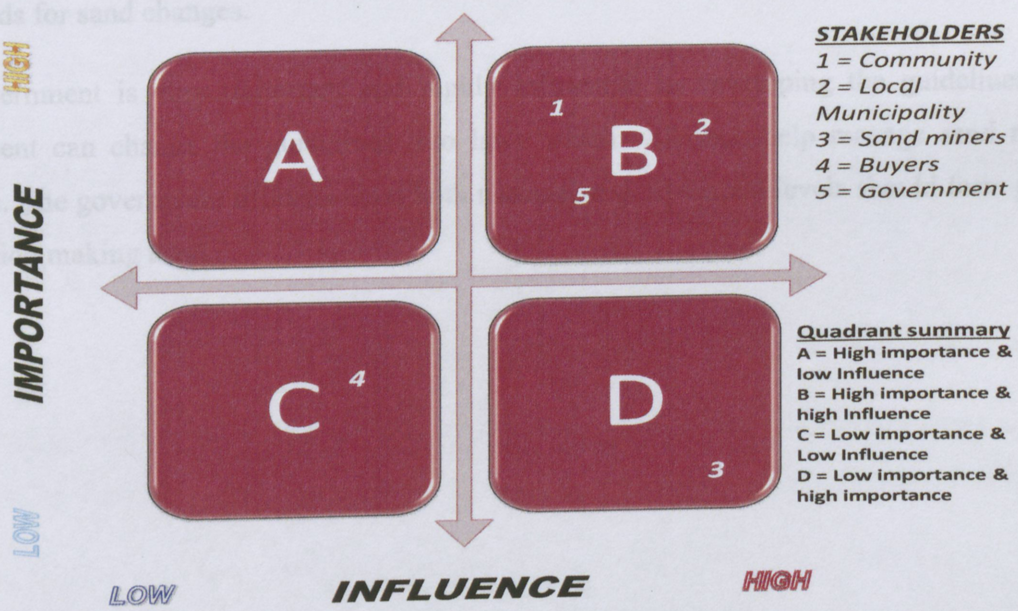

Figure 4.18 Influence and importance of stakeholders in developing guidelines

The community is very important and influential in developing guidelines for dealing with morphological and environmental impacts of sand mining as shown in Figure 4.18. This means that the community should be actively involved in decision making. Their voice should be heard as they are the ones experiencing the impacts of sand mining. The community can actively enforce compliances with the guidelines as they are in the vicinity of the activities.

The local municipality is also highly influential and important in developing and enforcement of the guidelines. The municipality could easily train and assign its environmental personnel to inspect and enforce compliance with the guidelines.

Sand miners are less important in developing guidelines but highly influential as they are the cause of the impacts on the natural environment. Their views are important in that they can suggest the alternative ways of extracting the material. The environmental experts can then assess and evaluate their views. These are the people actively involved in the activity and they should also be actively involved in decision making process.

The buyers are of low importance and low influence and should not be involved in decision making. They can never agree on some aspects of planning as some aspects may involve increasing the price of sand per load. The other reason is that the buyers will always change as their needs for sand changes.

The government is very important and highly influential in developing the guidelines. The government can change the guidelines into laws which will then help manage sand mining activities. The government officials from both national and provincial levels should form part of the decision making team.

CHAPTER 5: PROPOSED GUIDELINES FOR SAND MINING ACTIVITIES

The overall aim of the study was to develop guidelines for dealing with morphological and environmental impacts of sand mining. This chapter seeks to achieve this main objective by first developing the rationale for such guidelines. For this reason, it has been divided into two important sections namely; rationale for developing guidelines and development of guidelines

5.1 Rationale for Developing Guidelines

In order to achieve the overall aim of the study, the rationale for developing guidelines was divided into three thematic sections. These are: institutional level, community concerns and resource depletion.

5.1.1 Institutional or Policy level

An examination of how other countries address sand mining in river systems could be instructive (Meador & Layher, 1998). However, the search was limited to Malaysia and South Africa in order to achieve the objective of examining South African legislative environment on sand mining activities.

The Constitution of the Republic of South Africa (Act No. 108 of 1996) has momentous implications for environmental management. The main effects are the protection of environmental and property rights, the radical change brought about by the section dealing with administrative law such as access to information and broadening of the locus standi of litigants. Section 24 in the Bill of Rights of the Constitution specifically states:

•"Everyone has the right - to an environment that is not harmful to their health or well-being"

•"To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation

•Promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development

Specific Acts like the NWA 36 of 1998 and MPRDA have not specifically addressed sand mining in details. This left a gap in the Acts which needs to be filled. This section seeks to fill the gap by developing guidelines for dealing with the impacts caused by sand mining.

5.1.2 Community concerns

Various concerns were raised by the host communities on sand mining activities. These concerns are depicted in Figure 5.1.

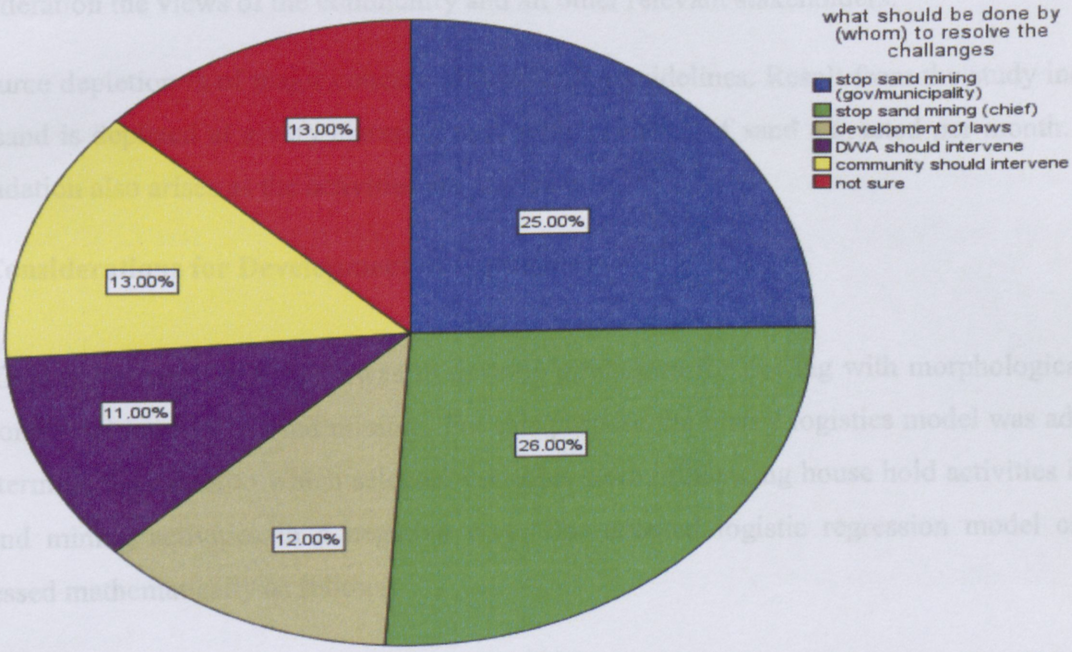

Figure 5.1 Community concerns on sand mining activities

Data from the field questionnaires reveal that sand mining is of major concern in the host communities. 26% of the selected sample indicates that the chief should stop sand mining. However, this would be a major challenge as the miners pay the chief to extract sand in the host villages. Other respondents (25%) indicate that the government or the municipality should stop sand mining. A very little percentage (11%) indicated that the Department of Water Affairs (DWA) should intervene. 13% of the respondents indicated that the community should join hands and stop sand mining. 12% of the sample indicated that there should be development of laws to deal with sand mining. However, 13% of the respondents indicated that they are not sure of what should be done. These results show that something should be done on sand mining activities and they fit well with the main objective of this study.

5.1.3 Resource depletion

Management strategies or guidelines for dealing with sand mining should be based on the principle of sustainable development, not only on the material but also on water resource use and values. Sustainable development could be only achieved if the future of the river systems is taken as a major priority. The development of management strategies or guidelines needs to take into consideration the views of the community and all other relevant stakeholders.

Resource depletion is of major concern in developing guidelines. Result from the study indicate that sand is depleted at a very alarming rate, with 11900m^3 of sand extracted per month. Land degradation also arises as the activities are carried out.

5.2 Considerations for Development of Guidelines

The final objective of this study was to develop guidelines for dealing with morphological and environmental impacts of sand mining. For this purpose the binary logistics model was adopted to determine the extent to which selected variables were influencing house hold activities linked to sand mining activities in a negative way. The adopted logistic regression model can be expressed mathematically as follows;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + ui \ldots.(01)$$

Where Y = Prob (household negatively affected =1)

X_1 = distance of sand mining site from nearest water source

X_2 = Type sand mining

X_3= Method of extraction

X_4= Amount of sand extracted

X_5= Frequency of water resources usage

X_6 = Gender

X_7=Age

The interpretation of the results from this model is given in the following subsections.

5.2.1Model evaluation

The goodness-of-fit test of the regression model adopted in this study shows that the observations fit the model very well.

Table5.1 Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	89.592[a]	.388	.517

Results from the Cox & Snell (1989) and Nagelkerke (1991) R square show that 38.8% to 51.7% of variations in the dependent variable are explained well by variations in the independent variables (Refer to table). The inferential goodness-of-fit test employed is the Hosmer & Lemshaw (H-L) test which yielded a chi-square of 11.638 that was insignificant ($p > 0.05$), suggesting the model fitted the data well.

5.2.2 Interpretation of the results from the binary logistics

Study results reveal that 78% of household have been affected negatively by changes in river depth owing to increasing sand mining activities. A number of socio-demographics and technical factors that explained sand mining related problems at household level were deciphered. These are summarized in Table 5.2.

Table 5.2 Results from the binary logistics

	β	S.E.	Wald	df	p-value	Exp(β)
Distance from water source	.000	.000	1.294	1	.255	1.000
Type of sand mining activity	1.414	.536	6.963	1	.008	4.112
Method of extraction	.836	1.055	.628	1	.428	2.306
Amount of sand extracted	.268	.226	1.409	1	.235	1.307
Frequency of water resource use	-.882	.383	5.294	1	.021	.414
Gender	.960	.562	2.925	1	.087	2.613
Age	-.422	.194	4.727	1	.030	.656

The beta coefficient for type of sand mining activities is positive, suggesting that there is a positive relationship between the type of sand mining activity and the probability that a household has experienced problems relating to high incidents of sand mining activities. Since instream sand mining was coded 1 and floodplain was coded 2, these results suggest that as one moves from instream sand mining to floodplain mining problems experienced at household level increase by 4.112 [ie.Exp(β)= 4.112]. These results were found to be very significant statistically with a p-value of 0.008 (ie.P< 0.01). These results suggest that the type of sand mining activity is an important variable when developing guidelines for dealing with morphological and environmental impacts of sand mining.

The beta coefficient for the method of extraction is positive, suggesting that there is a positive relationship between the method of extraction and the probability that a household has experienced challenges relating to sand mining activities. Since manual extraction was coded 1 and mechanical extraction was coded 2, these results suggest that as one moves from manual to mechanical extraction sand mining problems experienced at household level increase by 2.306 [ie. Exp(β)= 2.306]. These results were found to be important but not statistically significant with a p-value of 0.428 (ie.p> 0.1). These results show that the method of extraction is important in developing guidelines but not a major priority as suggested by a relatively high p-value.

The beta coefficient for the amount of sand extracted is positive, suggesting that there is a positive relationship between the amount of sand extracted and the probability that a household has observed the impacts of sand mining activities. This simply means that when more sand is extracted more impacts will be experienced. This can be explained by the Exp(β) of 1.307. These results were found to be important but not statistically significant with a p-value of 0.235. These results show that the amount of sand extracted is important in developing guidelines but not a major priority as suggested by a relatively high p-value.

The beta coefficient for the frequency of water resource use is negative, suggesting that there is a negative relationship between the frequency of water resource use and the probability that a household has experienced changes relating to sand mining activities. Since the respondents who use the water resources very often was coded 1 and those who uses the resources sometimes was coded 2 and those who have never used the resources were coded 3, these results suggest that as one moves from the respondents who have never used the resources to those using the resources very often, sand mining problems are most experienced by those using the resources very often. This is shown by Exp(β) of 0.414. These results were found to be significant and statistically important with a p-value of 0.21. These results show that the frequency of water resource usage is important in developing guidelines as suggested by a relatively high p-value.

The beta coefficient for gender is positive, suggesting that there is a positive relationship between gender and the probability that a household has experienced problems relating to high incidents of sand mining activities. Since male was coded 1 and female was coded 2, these results suggest that as one moves from male to female problems experienced at household level increase by 4.112 [ie. Exp(β)= 2.613]. Since Exp(β) 2.613 results suggest that female are 2.613 more likely to experience problems relating to sand mining that their male counterparts. These results were found to be very significant statistically with a p-value of 0.087 (ie.P< 0.01). Despite man being the most frequent water users, the results from the binary logistics shows that women are the most affected. These results suggest that gender is an important variable when developing guidelines for dealing with morphological and environmental impacts of sand mining.

The beta coefficient for the age is negative, suggesting that there is a negative relationship between the age and the probability that a household has experienced changes relating to sand mining activities. As one moves from the elderly age to the younger age, the problem related to sand mining increases. The results show that the younger age is more vulnerable to the impacts of sand mining. The Exp (β) 0.656 shows that the younger age is 0.656 times likely to be affected by the impacts of sand mining than their older counterparts. These results were found to be significant and statistically important with a p-value of 0. 030. These results show that age is important in developing guidelines as suggested by a relatively high p-value. Data from the questionnaire also indicate that there have been cases where kids have drowned in the excavations left open.

5.3 Development of Guidelines for Sand Mining Activities

The development of guidelines for sand mining activities is a complex issue and is driven by changes in the natural environment and legislative environment. Stakeholders involved and their interaction with the natural environment adds to the complex nature of sand mining activities (Van Lancker *et al*, 2008).

The overall goal for this study was to develop guidelines for dealing with morphological and environmental impact of sand mining. To achieve this goal, the following guidelines have been developed and are presented in the following sections.

5.3.1 Guidelines from the Binary Logistics Model

The guidelines listed below are according to their level of significance from the results of the binary logistics model as shown in Table 5.2.

- Type of sand mining activity had a p-value of 0.008 which means that it is very significant and should be placed a first priority for every sand extraction activity. Floodplain extraction should be done with proper care. Environmental management plan and social impacts studies should be the minimum requirements.

- For every sand extraction activity, the needs of the people who frequently use the water resources for a particular river should be noted and assessed. This can be confirmed by a p-value of 0.021. Impact studies should be conducted to help mitigate the identified impacts of the project.
- As shown in Table 5.2, the youth are more vulnerable to the impacts of sand mining as shown by the p-value of 0.030. Data from the interviews also indicated that there are many cases where children have drowned in the excavations left open during rainy seasons. It is important to make the extraction pits to have shallow banks and drain the water on their own to avoid drowning.
- Although men are the most frequent water resource user as shown in Table 4.1, data from the binary logistics indicated women as the most vulnerable to the impacts of sand mining. These results were found to be very significant statistically with a p-value of 0.087. This means that women should be involved in decision making on any sand mining activities.

5.3.2 Best Practice Related Guidelines

The diversity of challenges confronting communities living in sand mining infested areas is not unique to Nzhelele river valley. Such challenges are widely reviewed by others in different environments. Interventions through the development of appropriate guidelines have been varied with differing levels of success. It is important for this analysis to also borrow what are deemed to be best practice guidelines. For this reason, the following guidelines are proposed.

- The first 30 meters of the riparian zone, measured from the stream bank landward, should not be disturbed by mining related activities in order to protect the buffering functions the riparian zones provide to the river channel.
- Rehabilitation plan should be prepared and submitted to the relevant authority and the community for compliance monitoring and enforcement purposes.
- Extraction of sand on the floodplains should not be located within the flood line. A minimum of 500 meters from the stream should be allocated. This will limit channel migration to the open extraction pits. This is significant because the impacts of floodplain mining are directly related to the pit's proximity to the community and the river (Langer, 2003).
- For any instream sand mining, there should be shifting of activities from one site to another. Giving the other site time to replenish its resources (Kondolf, 1994).
- Indigenous vegetation should always be used when afforesting the abandoned sites. Afforestation must be done during spring or autumn when the plants are at their dormant stage (Norman, 1998).
- Extraction of sand should only be done on sand bars to protect the entire river channel and its system.
- Access road to the mining site should be limited to single track only. Multiple tracks should always be avoided by any means necessary.
- Sand extraction should be conducted at least 1.2 km for any infrastructure along the river (bridges and pipelines).

5.4 A synopsis of the Proposed Guidelines

A summary of the proposed guidelines is presented in Table 5.3 to ease the understanding of the proposed guidelines.

Table 5.3 A Synopsis of the Proposed Guidelines

Area of focus	**Requirements**	**Function**
Distance from the water resource	32 meter buffer zone. As in the NWA 36 of 1998	Buffering
Frequency of water resource usage	Social impacts assessment	Identification of the frequent water resource users
Vulnerable social group	Vulnerability assessment	Identification of the most vulnerable group
Gender	Gender balance	Identification of the vulnerable group
Access road	Single track	Reduction of foot print
Rehabilitation	Indigenous vegetation	Maintain the natural state of the area

5.5 Suggested Implementation Schedule

The implementation of the proposed guidelines should be a holistic approach. The identified stakeholders should be engaged with and form part of the decision making team. The proposed guidelines should be considered for every sand extraction activities in South Africa and Nzhelele River in particular. Effective implementation of the proposed guidelines should follow the proposed cycle depicted in Figure 5.2.

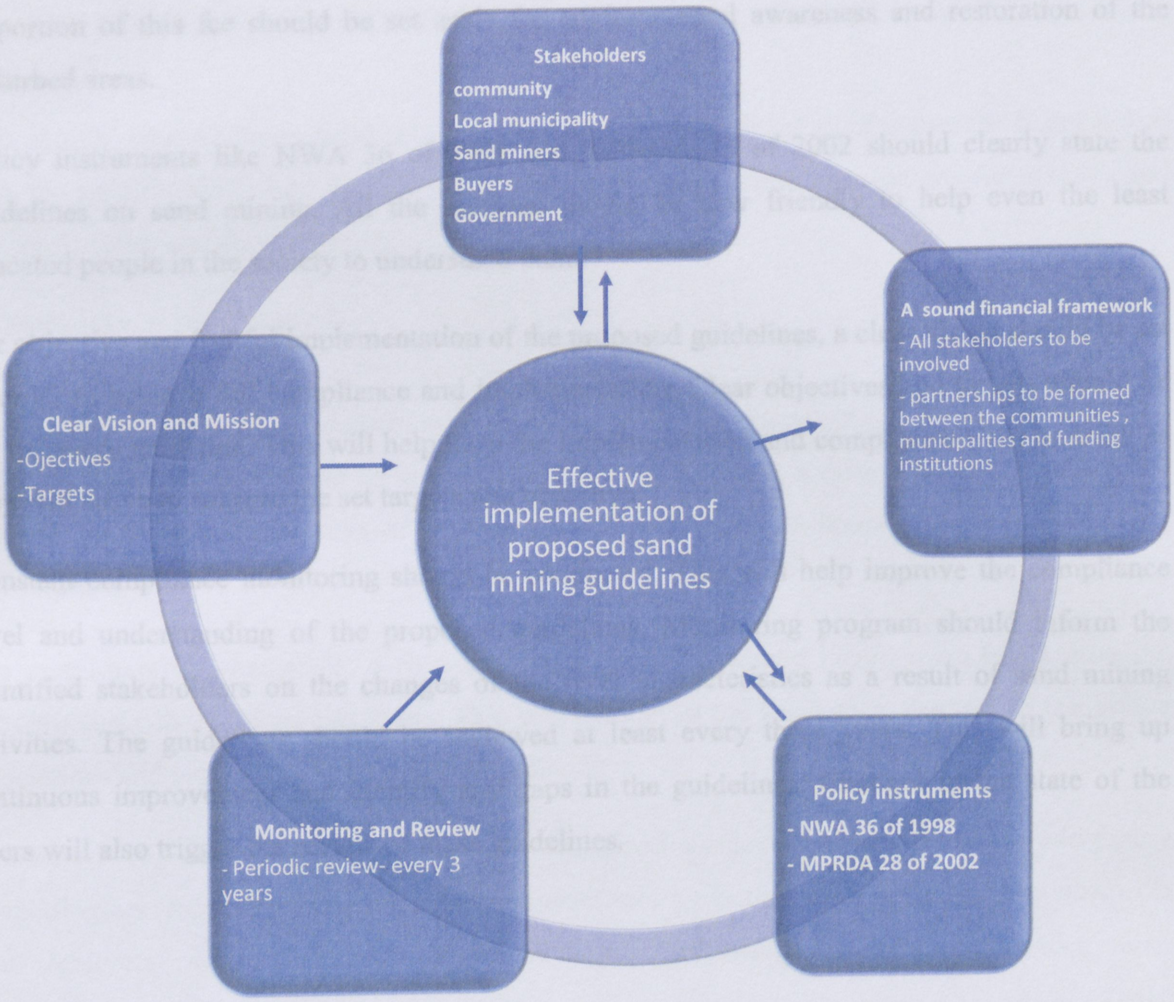

Figure 5.2 Suggested implementation schedule

All stakeholders identified should form part of decision making and compliance monitoring teams. This will increase the level of awareness and compliance as all the stakeholders will own the process. Environmental awareness training on the impacts of sand mining should be conducted annually with refresher awareness every six months. This will help keep the entire stakeholders on track with the best practice guidelines.

A sound financial framework should be developed for proper implementation of the proposed guidelines. Partnerships should be developed between the local municipalities, the communities hosting sand mining activities and funding institutions. For proper and effective awareness on the impacts of sand mining, good funding should be made available. An extraction fee should be set.

A portion of this fee should be set aside for environmental awareness and restoration of the disturbed areas.

Policy instruments like NWA 36 of 1998 and MPRDA 28 of 2002 should clearly state the guidelines on sand mining. All the sections should be user friendly to help even the least educated people in the society to understand them.

For objective and fruitful implementation of the proposed guidelines, a clear vision should be set in order to achieve full compliance and implementation. Clear objectives and targets should be set for every guideline. This will help keep the implementation and compliance team on track as they will strive to achieve the set targets and objective.

Constant compliance monitoring should be conducted. This will help improve the compliance level and understanding of the proposed guidelines. Monitoring program should inform the identified stakeholders on the changes of the river characteristics as a result of sand mining activities. The guidelines should be reviewed at least every three years. This will bring up continuous improvement and identify any gaps in the guidelines. Changes in the state of the rivers will also trigger the review of these guidelines.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusions which are based on the findings of the research and linked with the specific objectives. In addition, it provides practical recommendations for practice and further research and development.

6.1Summary of the Research

Residential and commercial construction activities in developing countries and in Nzhelele river valley in particular are placing an immense pressure on the rivers and their floodplains. This has resulted in severe degradation of the morphology of Nzhelele River and the surrounding environment.

The morphological changes of a river as a result of sand mining have severe impacts on the infrastructures like bridges and roads. This was evident in the study area as some of the bridge foundations and water pipelines were exposed.

The binary logistic regression model was employed to develop guidelines for addressing morphological and environmental impacts of sand mining in the study area. The social aspects were clearly defined by this model. It has revealed that some social aspects should be considered when developing guidelines.

The study revealed that the impacts of sand mining are interrelated. The morphological impacts are not only affecting change in the state of the river but also affect some social aspects in the community. It was however revealed that the environmental impacts of sand mining affect almost all social aspects in the study area.

6.2 Conclusions

The conclusions drawn from this study were arranged according to the research objectives set out in chapter one. These are discussed in the following sections.

6.2.1 South African Legislative Environment on Sand Mining

The regulatory environment for sand mining activities is vague and passive which makes the implementation difficult and tedious. The chiefs of most host villages are the legal custodians of the land and most individuals/ community members do not have rights over the land which leaves them with no authority to dispute sand mining proximity to their households.

Legislations such as NWA 36 of 1998, MPRDA of 2002 and NEMA 107 of 1998, which are the related government-mandated legislations on environmental protection, do not give precise and detailed guidelines on sand mining activities. Lack of clear and precise guidelines for dealing with sand mining operations makes monitoring and enforcement of these legislations a very difficult task.

6.2.2 Locations of sand mining sites along the Nzhelele River

Sand mining has degraded and altered Nzhelele River and its floodplain at an alarming rate. The impacts arising as a result of sand mining are affecting many people in host communities. Sand mining sites along the Nzhelele River are found in large numbers. Accessibility to the materials was also a factor in site selection. That can be confirmed by very few or no sand extraction sites at areas with rough terrains. A map has been created which depicts the sand mining sites along Nzhelele river.

6.2.3 Morphological and environmental impacts of sand mining along the Nzhelele River

Various impacts such as the alteration of the water table, change in land use, infrastructure damage and collapsing of river banks were noticed in this study. The most severe impact posing life threat to the communities was the creating of artificial lakes after the miners leave the pits without rehabilitating them.

6.2.4 Strategies for mitigating impacts of sand mining

Guidelines were developed for sand mining activities based on the Binary logistic regression model. Other best practice guidelines for sand mining activities from other scholars internationally were incorporated in the guidelines. A suggested implementation schedule was also proposed on how to implement the proposed guidelines for sand mining activities.

6.3 Recommendations

Based on the findings of this study, the following recommendations have been set:

- The Department of Water Affairs (DWA) and the Department of Environmental Affairs (DEA) need to implement the proposed guidelines suggested in this study to prevent any form of environmental damage as a result of sand mining.
- Even though there are no specific guidelines on sand mining operations, it is advisable that local municipalities come up with bylaws to help preserve the ecological beauty of their areas.
- Environmental awareness training should be conducted for the communities in the vicinity of the extraction sites. This will help in monitoring and enforcement of the bylaws.
- Studies focusing on the impacts of sand mining on water quality should be conducted. This will help the community and the government authorities to know and understand the nature and severity of impacts of sand mining on water quality in the area.

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APPENDIX

Questionnaire

University of Venda

Questionnaire

Admin

Distance to nearest sand mining site: .... (m)

Questionnaire number: ....

Distance to nearest water source: ....(m)

Place.................................

Type of sand mining..................................

method of extraction....................................

Socio- Demographics

1. Gender : Male ☐ Female ☐

2. Age: less than 18 ☐ 18-23 ☐ 24-29 ☐ 30-35 ☐ 36-40 ☐ Above 40 ☐

Sand Mining

3. How often do you use water resources at Nzhelele River?

   Very often (2) ☐ sometimes (1) ☐ Never (0) ☐

4. Have you noticed any changes in the depth of the river due to sand mining?

   Never (0) ☐ Yes, severe (1) ☐

Explain:..
....
....

5. Has sand mining affected your livelihood?
   No (0) ☐ Yes (1) ☐

   Explain:..
   ....
   ....

6. What are the main uses of water resources from Nzhelele River?

Usage	Current usage	In the last 10 years	In the last 20 years
1. Agricultural			
2. Domestic			
consumption			
washing			
3. Recreational			
swimming			
Fishing			

7. Have your activities in the river changed over the years as a result of sand mining?
   No, not at all (0) ☐ Yes, very much (1) ☐

Explain:..
....
....

8. What challenges do sand mining activities pose to your livelihood?
   ....
   ....
   ....
   ....

9. What should be done by (Whom) to resolve the challenges?

....
....
....
....