ASSESSMENT OF SUITABILITY ON CONSTRUCTION MATERIAL OF FILTER: -THE CASE OF AGUATWUHA EARTH DAM ON SAYINT WOREDA, AMHARA REGION, ETHIOPIA

MSc. THESIS

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ADVISOR ‘APPROVAL SHEET

This is to certify that the thesis entitled ‘’ Assessments Of Suitability Of Construction Material With Special Emphasis On Filter: - Case Of Aguat Wuha Earth Dam Project” submitted in partial fulfillment of the requirement for the degree of Master’s with specialization in Dam Engineering, the Graduate program of the department of Hydraulics and water resource Engineering, and been, and has been carriedout by **Henok Dessalegn**. No PGDEng/003/2010 under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirement and hence here by can submit the thesis to the departement.

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DECLARATION

I, Henok Dessalegn, hereby declare that this MSc thesis entitled "Assessments of Suitability of Construction Material with Especial Emphasis on Filter: Case of Saint Woreda, Amhara Region, Ethiopia" is my original work and has not been presented for degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Signature:________________________

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TABLE OF CONTENTS PAGES

ABBREVATION AND ACRONYMS

AASHTO American Association of State Highway and Transportation Officials

ADSWE Amhara Design & Supervision Works Enterprise

AGCOTP Aguat wuha Core Taste Pit

AGWDF Aguat Wuha Dam Filter

ANRS Amhara National Regional States

ASTM American Standard for Testing of Materials

Av Average

CU/Uc Coefficient of Uniformity

d_{85B} The particle size diameter in millimeters of the 85th percentile passing grain size of the base

d_{15B} The particle size diameter in millimeters of the 15th percentile passing grain size of the base

D_{15} The particle size diameter in millimeters of the15th percentile passing grain size of the filter

D_{10} The particle size diameter in millimeters of the 10th percentile passing grain size of the filter

D_{60} The particle size diameter in millimeters of the 60th percentile passing grain size of the filter

D_{30} The particle size diameter in millimeters of the 30th percentile passing grain size of the filter

D_{100} The particle size diameter in millimeters of the 100th percentile passing grain size of the filter

D_5 The particle size diameter in millimeters of the 5th percentile passing grain size of the filter

D_{90} The particle size diameter in millimeters of the 90th percentile passing grain size of the filter

dep dependency

FEMA Federal Emergency Management Agency

n.d not dated

NEH National Engineering Handbook

NRCS Natural Resources Conservation Services

QA Quality Assurance

QC Quality Control

UFGS Unified Facilities Guide Specifications

USACE U.S. Army Corps of Engineers

USBR United States Base Requirements

USSC United States Soil Conservation Services

UTM Universal Transfer Mercator

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDICES

ABSTRACT

Aguat-wuha dam is an earth fill dam, which is one of the Irrigation Projects undertaken by AWDSE found in South Wello Zone, Sayint Ajibar Woreda. As it was observed, during the construction process the construction material, the filter material in particular, was not properly prepared while placement. This could result in malfunctioning of the filter zone as a because of material poor gradation and contamination. Hence, this work was aimed to evaluate the suitability of construction material especially on filter material assessments. During this research work materials for analysis were taken from the dam which is on construction and filter material samples stored in stoke. The geometrical criteria have been mainly checked using the formulas and recommendations proposed by scholar and standard. In addition to this, the final gradation or grain size distribution of a suitable filter material has been prepared based on the gradation of the base material following the design procedures prepared by USSCS and Sherard recommendations. It was found that the filter material taken from the dam and analyzed for grain size distribution doesn't satisfy most of the filter criteria. On the other hand the treated sample of this same filter material showed better in satisfying most of the filter criterion and also the stocked filter material was contaminated due to improper placement and poor prevention. The analysis result (especially USSCS method) indicated that the treated (washed) filter material almost satisfies the geometrical criteria and it had a little bit fine (1.7-2.2 %.), which was still in the limit of the filter band. On the other side, the constructed sample was not satisfied the gradation curve. Because it was over fined, that 5.5-5.8% passes the fine limit of filter which can result clogging, poor permeability, weak draining capacity and crack for coming serviceability. Additionally the material contamination result shows, mostly on the underneath of stoke especially from ground to 80 cm because the material was near to unexpected runoff entry. Therefore the field manager or site engineer should apply efficiency checking and giving remedial measure carried out not only at quarry site but also during construction. Additionally design of quality control and quality assurance should properly apply.

KEYWORDS: Aguat-wuha dam, Filter material, Geometrical analysis, Gradation Curve, USSCS

1. INTRODUCTION

1.1 Background

In Ethiopia under the prevalent rain-fed agricultural production system, the progressive degradation of the natural resource base, especially in highly vulnerable areas of the highlands coupled with climate variability have aggravated the incidence of poverty and food insecurity. The major source of growth for Ethiopia is still conceived to be the agriculture. To achieve the development of agriculture, one of the strategies followed by the government is to increase irrigation practices in the region by implementing modern water harvesting at different scales; from household level storage ponds/ tanks to small scale/micro earth dams that benefit a community, and presently even larger projects (ADSWE, 2008). Accordingly, due to that different types of micro earth fill dams are also being studied, designed and implemented in present in the different areas of the region. From this Aguat-wuha earth fill dam is one of them constructed around south Wollo, in Sayint Woreda of Amhara national regional states.

As with the design process, cautious consideration of contextual preconditions is crucial to selecting appropriate construction materials or products (Rahman et al, 2008). In addition, selecting suitable construction material options can be a very complex process, being influenced and determined by numerous preconditions, decisions, and considerations (Wastiels et al 2008). In other words, in choosing the right material, there is not always a single definite criterion of selection, which means designers or architects have to take into account a large number of material selection factors (Rahman et al, 2008), (Wastiels et al 2008) and (Trusty et al,2008). Therefore, the available information or data on building material and product options must be constantly evaluated to make well-considered and justifiable material choices, during the design decision making and selection processes (Chan et al, 2007 and Trusty et al, 2008).

The study on dams requires a thorough engineering geological investigation to ensure that the structures meet the primary purpose of storage and its stability against the horizontal forces exerted by the impoundment. The investigations at dam site are aimed at finding Suitability of construction material is studied for the quality and the quantity required for the dam construction especially on filter. According to Lock (2001) geometric, Indraratna and Vafai (1997) physical, de Geoot et al. (1993) hydraulic, Reddi and Bonala (1997) also Indraratna et al

(1996) chemical and Lock (2001) biological effects are identified as factors that influence filtration. Filters in embankment dams are composed of specifically-designed entities (zones) of coarser-grained soils placed at specifically-targeted locations within or adjacent to the dam structure. It designed and constructed to achieve specific goals such as preventing internal soil movement and controlling drainage. Filters have also been added to existing dams to meet specific requirements. As water flows through a soil, fine particles can be washed out, leading to internal erosion (piping) and eventually failure and also excessive settlement may rupture the upstream membrane or cause joint separation (FEMA, 2011).

The proper choice of the method of construction is dependent, in part, on the character of material availability due to quantity like over exploration and leads to fine. So that the present research determine about the assessment of suitability of construction materials with special emphasis on filter of already 94% constructed Aguat-wuha dam. Based on the availability of natural embankment materials, a zoned type of earth dam has been constructed. The dam has a crest length of about 312m and height of 28 m.

1.2 Problem Statement

In Ethiopia many embankment dams are constructed (ADSWE, 2008). According to Jean-Pierre et al (n.d), to build economical construction often material availability should be found a reasonable hauling distance, which must be excavated from the dam foundation, spillway, outlet works and other appurtenant structures, the suitability of the material in terms of engineering properties, chemical composition and site condition should be assessed. So on preliminary investigation evaluating material durability of filter and quantity should not be identified before processing of material such as water abrasion taste, soundness, chemical composition and also mineralogy (Messerklinger, 2013). According to ADSWE (2008) source area is natural sand is not found along the course of Aguat-wuha stream beds in case of this borrowed materials justified from "Mersa" because Natural deposits of such materials couldn't be found when assessed within the beds of the stream in the project area, rather very coarser sediments and rock exposures are found covering almost the entire bed of the Aguat-wuha stream. But the constructed filter materials not fulfill the required quality because it has silt/extra fined problem. Quality, economy, and safety should all be given careful consideration William et al., (1945) cited by Mulatu (2010). This paper aimed to check this problem by implementing investigation and assessment of construction material suitability of constructed filter. Then action placed and identify quality of material fulfillment comparisons of the actual constructed and the research treated filter material on constructed Aguat-wuha dam filter by investigating material suitability of constructed silt sand and how much it satisfy different country and author filter criteria regarding design aspect criteria and clogging criteria and gave recommendations.

1.3 Objectives of the study

1.3.1 General Objectives

- The general objective of this study is to investigate the suitability of construction materials with special emphasis to filter case of Aguat-wuha earthen embankment dam.

1.3.2 Specific Objectives

- To identify constructed filter material silt or over fineness
- To identify the effects of the percentage of fineness in the filter material
- To show contamination of filter material on the stocking place and protection of climatic disturbance of unfinished constructed filter zone

1.4 Research question

The study was answered the following research questions.

- How is extra fineness identified in the filter material?
- What are the effects due to fineness of filter material?
- How the filter material contaminated on the stockpiling place and how protect and re-medial measures for climatic disturbance of unfinished constructed filter zone?

1.5 Scope of the Study

The scopes of this study were to asses and evaluate constructed Aguat-wuha micro earth dam filter material. Accordingly these researches focus on perception and practice on assessment of construction material suitability especial emphasis on filter excess fine material entrance. So this research was work on the above mentioned site so that it was favorable to collect data and carry on the research and was provide suitable filter material for previous constructed silt or fine content filter of the dam.

1.6 Significance of the Study

According to Talbot and Pabst (2006), since improper use of construction material is one of the main causes for embankment failure by piping and seepage and other coordinated failures. So the result and findings of the research work was expected to have stable embankment dam filter structures regarding have great importance of economic design by using more suitable material usage. The structure must be stable enough to withstand the forces to which it was subjected and it should be capable of resisting clogging, crack, internal erosion or piping and other related failures on a structure regarding material contamination. Hence, it becomes important to select the appropriate construction material for the requirements most efficiently and economically by checking efficiency before and during construction of Aguat-wuha dam and then determine and also fix remedial measures for coming dam construction of filter material conservation. The most likely problems was associated with the embankment dams are piping due to internal erosion and other related failure from the main dam body especially on filter due to inadequate investigation and poor selection and treatment before and during construction. Based on the recommendation the constraints of construction material were solved.

2. LITERATURE REVIEW

2.1 General

The filter material will taken from designated borrow areas or exploration. It should be free of roots, stumps, wood, rubbish, stones greater than 6”, frozen or other objectionable materials (NRCS, 2000). Tschuschke et al, (2017) argued on criteria for the selection of material for the dam construction due to the necessity to continuously increase the depositary capacity, the processes of engineering design, tailings deposition and dam constructions realized in parallel. Van Kesteren, et al (2005) cited in Ogunkah and Yang (2012) determines a material-selection consideration model where product-personality, use, function, material characteristics, shape, and manufacturing processes are represented as the elements that are considered by the designer during the material selection process.

For suitability of embankment, soil material has to be water insoluble and should contain inorganic substances as long as possible (Rajeeth, 2011). According to Brown (2004) cited in Rajeeth (2011), fine grained soils are very suitable for embankment construction but, those should be within a particular range of moisture content and fulfill the requirements for compaction. Because in the case of fine grained soils with higher water content, the self-weight of the embankment may develop the higher pore-water pressure within the embankment dam.

Materials must be durable and resistant to wet/dry and freeze/thaw cycles. Materials must resist weather and erosion over long periods of time. According to USSD (2011), for engineering purposes inorganic soils are divided into two broad categories: fine grained soils and coarse-grained soils. Fine grained soils are often used in homogeneous dams, and in impervious core sections of zoned embankment dams and Coarse grained soils are used in structural fill zones, or shells, and in specialty filter and drain zones within embankment dams. Grained soils are also used in core zones, especially when the fines content is greater than 20 percent.

Moreover, The principal characteristics that distinguish fine grained soils from coarse grained soils for purposes of embankment dam design are that fine grained soils have lower permeability, lower shear strength and higher compressibility but the important properties of interest in embankment dam engineering, namely shear strength, compressibility, and permeability are determined by the gradation, grain size and shape, relative density, and durability of the coarse grained soil.

The additional embankment constructing material does broadly graded soil, which is many natural soil deposits, comprise a large range of particle sizes, and their engineering behavior is intermediate between fine grained and coarse grained soils.

Sherard (1967) cited in Mulatu (2010) suggested that stability of zonal dam is mostly due to the weight of the heavy outer zone. Zones of lower permeability can be formed in homogeneous embankment by using either more compaction or higher water content during construction. In this case the material for zones like: Core, Shell, Filter and Riprap should be checked individually. But for the case of this research filter material checked as much as possible.

The major function of the filter is to prevent erosion and piping. In order to have this ability, filters must restrain the particles of the protected soil (the base soil) and allow water to pass freely out of the base soil. Since Terzaghi (1922) developed grain size criteria for granular soils in dam filters and also specify the requirements for selecting filter materials. He proposed design criteria based on cohesionless base soils. Two basic requirements he identified were related to particle distribution of base and filter materials: retention ratio ($D_{15}/d_{85} <= 4\text{-}5$) and permeability ratio ($D_{15}/d_{15} >= 4\text{-}5$), where D_{15} is the diameter of filter particles for which 15% by mass is finer, d_{15} and d_{85} are the diameters of base particles for which 15% and 85% by mass respectively finer. Sherard et al. (1984) modified these criteria for cohesive soils, and developed the concept of "critical filters," that can prevent erosion even under the severe condition where the base soil is cracked, and where concentrated flow occurs through the crack.

Developments in filter design continued and Bertram (1940), United States Army of Civil Engineers (USACE) (1953), Karpoff (1955), Zweck and Davidenkoff (1957), Sherard et al. (1984b) greatly contribute to the filter requirements related to Particle Size Distribution. Extensive laboratory testing programs were done, beginning with work by Bertram (1940) who worked under the direction of Terzaghi and Casagrande, followed by the work of United States Bureau of Reclamation (USBR) and US Corps of Engineers (1941). These experiments showed that the basic requirements could best be met by designing the particle size of the filters in relation to the particle size of the soil being protected (Fell et al. 1992). The

USBR method which has been modified from time to time, for example USBR (1977) has been used widely and successfully for design of filters. Most recently further experiments have been carried out by the United States Soil Conservation Service (Sherard et al. 1984a, b and Sherard and Dunnigan 1985) and by Kenney and Lau (1985).

In many cases filter design rules originally developed for cohesionless soils have been used for dam sections made up of cohesive soil. Although it has been generally recognized that retention ratio is an effective criterion, some doubts have been expressed (Vaughan and Soares, 1982; Sherard et al., 1984b; International Commission on Large Dams (ICOLD), 1994). As relevant factors cannot be determined directly, various design criteria for safe filters have been developed considering different approaches. Various factors such as retention ratio, permeability of filters, hydraulic gradient, erosion resistance, particle sizes and shapes are not treated with equal importance. For example, traditional filter design has involved the retention ratio (i.e. Terzaghi's criteria), while filter permeability has been considered as the main design factor by some researchers (Vaughan and Soares, 1982; Vaugham, 2000). More emphasis was given to the filter material as it is a critical zone from the stability and performance point of view for an embankment dam.

2.2 Filters/Transition in Embankment Dams

Filters are placed in embankment zones, foundations, or other areas of hydraulic structures for the greater life expectancy and safety of structure when it constructs by suitable material. It has different important purposes. Mitttal and Anamika (2016) argued that filters and the drains associated with them help in lowering the phreatic surface within the dam and forbid water from transpiring through the downstream side of the slope, where flow could provoke erosion that may put at risk the integrity of the whole structure. Besides, both materials meet particle retention and drainage criteria (FEMA, 2011).Embankment filters are particularly important in areas with seismic hazards and in cases where the embankment may desiccate or differentially settle, as core material may become cracked, creating the potential for uncontrolled seepage and erosion (Robert, 2012). In addition, filters are used in embankment dams to protect against internal erosion through both the embankment and foundation. Specifically, they can be used to protect against cracks that may develop after a seismic loading event (Pabst, 2015).

Filters are used in embankment dams to protect against migration of fine grained core or foundation materials that could lead to internal erosion (piping) failures, and to provide drainage to relieve excess pore pressures that may build up in the embankment. So In order to meet the above revised purpose, filters and drains must contain qualified and available materials for the project life and for minimum maintenance.

Drain/filter material must be clean, free draining and not liable to chemical degradation. Processed fine natural gravels, crushed rock and coarse to medium sands are suitable, and are used in sequences and grading determined by the nature of the adjacent core and/or shoulder fills (Novak et al., 2001). Cendergren (1977) cited in Mulatu (2010) if filters and drains are required to serve their intended purpose, the materials used in their construction must have the correct gradation and they must be handled and placed with care to avoid contamination and segregation. Although naturally occurring gravel and sands sometimes can be used for filters and drains with little or no processing, drainage aggregates usually need to be treated. Efforts to save money by using untreated local materials almost always produce marginal or unsatisfactory filters and drains. Most natural sand and gravel deposits are highly variable in grading from point to point in a borrow area, or they are covered or interbeded with silt and clay which is difficult to remove. As a result of Messerklinger (2013) for the design of state of filter materials, considered aspects are: Filter ability, internal stability, Self-healing, Material segregation, Drainage capacity and Material durability.

Important steps involved in a quality control inspection of filter, by NEH (2007) (1) Materials should be visually inspected to determine whether they likely meet the material specifications. If a doubt exists, testing should be requested to verify the gradation and quality of the furnished filter sand and gravel, (2) the placed materials should be visually inspected to determine that segregation has not occurred from transporting and placing the filters. Broadly graded sands are most prone to segregation. Dropping the materials from heights more than 4 feet also can promote segregation, (3) Placement and compaction should be accomplished in lift thicknesses that are no thicker than specified, (4) Observations should determine if sands are either placed very dry or that they were wetted immediately prior to compaction with equipment and (5) Clean water should be used to wet filter zones to avoid adding clay fines.

Additionally, all earth and rock-fill dams are subjected to seepage through the embankment, foundation, and abutments. Seepage control is necessary to prevent excessive uplift pressure, instability of the downstream slope, piping through the embankment and/or foundation and erosion of material by migration in to open joints in the foundation and abutments (Earth Manual). Placement of more pervious material in the outer zones in the embankment is one of the methods to control seepage. For this filters are essential to control seepage and for the safe functioning of any embankment dam. It should be placed inside the embankment where it should be more effective in controlling seepage and reducing pore pressure. Safe interception and passage of seepage are necessary to ensure vital embankment performance Sherard (1963). Moreover, the filter drains ensures foundation material not to be washed away with the seeping water and transition filters check the development of destructive internal water pressures. Therefore, the zone immediately downstream of the core is designed to serve as filter which prevents the migration of particles from the core into the downstream shell. The design of drainage system is primarily governed by height of the dam, cost and availability of the pervious material, nature of pervious material and foundation conditions (Jansen, 1988).

Proper testing has to be done to ensure durable particles that will not be unacceptably altered or changed during excavation, hauling, placement and compaction or by long term weathering and erosion. Testing should include grain size distribution, hardness, mechanical breakdown, design stress, density, abrasion, chemical resistance and freeze thaw (USBR, 1987).

The basic requirements of filters are that they are sufficiently fine grained to prevent erosion of the soil they are protecting, and are sufficiently permeable to allow drainage of seepage water. Extensive laboratory testing programs, beginning with work by Bertram, 1940, who worked under the direction of Terzaghi and Casagrande, followed by the work of the USBR and others, showed that the basic requirements could best be met by designing the particle size gradation of the filters in relation to the particle size gradation of the soil being protected. More recently further experiments have been carried out by the United States Soil conservation Services (USSCS). These experiments led to recommended modifications of the design rules suggested by USBR (Fell et al, 1992).

In addition to grain size criteria that ensure restraint of the base soil while allowing free passage of water, a filter must also be graded so that the filter itself will not crack. To ensure that filters will not support cracks, most current filter gradation criteria require that no more than 5% of the filter material should be finer than the #200 sieve, and that the fines within the filter should be non-plastic (Parck et al, 2001-2003). Additionally progressive accumulation of fines may result in the clogging of filters thus considerably affecting the drainage, which leads to build up of excessive pore pressures and consequently to instability of earth structures.

To minimize crack and piping failure, Sherard and Dunnigan in 1985 (Fell et. al., 1992) proposed multiple lines of defense to guard against leaks in cracks. These include reducing differential settlement cracking and sealing concentrated leaks.

Additionally, during filters construction Mohammed (2006) stated general basic requirements of filters are:

- Meet the design specification (material type, graduation, size, and compatible with other material used to construct embankment.
- Sufficiently fine grained to prevent erosion of the soil they are protecting.
- Sufficiently permeable to allow drainage of seepage water.

  The common compaction specifications for filter are
- Horizontal filters can be placed in layer as 150 mm or as thick as 500mm.
- Density index 70-80% and may reduced to 60%.
- Density index > 80% is likely to result in excessive breakdown of filters under the compactive effort.

Generally purpose of the filter material is to provide a safe drainage and to check the migration of the particles from the protected zone. Therefore it is essential that the material selected for the filter must qualify basic requirements. So various filter criteria are available which helps as a useful guide in selecting the appropriate material for filter.

2.3 Factors Influencing Filter Performance

The process of filtration, which includes prevention of base soil erosion and permitting controlled seepage, is not a simple but a complex phenomenon. Filtration is considered as particle migration in porous medium, where all involved factors such as particle sizes, pore sizes and seepage and other forces vary in wide ranges as stated by Schuler and Brauns, in 1993. Contributing factors are divided into five different groups: Geometrical, physical, hydraulic, chemical and biological factors.

Geometrical filter criteria determine whether mobilized (detached) soil particles will pass through filter openings. If the geometrical filter criterion is not met by a grain size distribution, no erosion will occur until seepage forces exceed the resisting forces. For cohesive soils, the resisting force is generally represented by cohesion, which plays a significant role in filtration. Geometrical factors include particle size distribution (PSD), shape of grains of both base and filter materials. The uniformity coefficient and internal stability of base and filter materials are described below. The constriction size distribution (CSD) and non-homogeneity (Segregations) of filter materials during placement are also included as geometrical factors (Schuler and Brauns, 1993; Mullner, 1993).

Sherard et al. in 1984 had conducted filter tests for cohesive base soils considering filter action only (properties of filters needed to prevent erosion of base soils) but not considering permeability factors (properties needed for a filter to act as a drain).

Identical results were reported for each method tested. Although there was a general correlation between d_{85} and D_{15}, there was a wider scatter. For all kinds of cohesive base soils, ratio D_{15}/d_{85} was in excess of 9, for some clay the ratio was 25 and for some, it even exceeds 50. For typical clays without content of sand sized particles, with d_{85} = 30 to 80µm, the retention ratio, D_{15}/d_{85} ranges from 19-56, and this indicates that the requirements of filter design for cohesive soils do not correlate with general criteria used for cohesionless soils, where $D_{15}/d_{85} <= 4\text{-}5$.

According to Sherard et al. the slot and slurry tests are very severe in the sense that the velocity of the initial concentrated leak imposed on base (10m/s) is much larger than that occur in leak through a dam. Vaughan and Soares in 1982 stated that due to slow leak, only fine particles reached the filter face and silt- sized particles were left behind as debris in the leakage channel. Contradicting the concepts of perfect filter, Sherard et al. (1984b) noted that the perfect filter approach was unduly conservative; the main reason being that nearly all clay soils contain a considerable amount of silt sized particles with diameter 50- 80µm and these particles are easily available to the filter face, even for a slow flow. It is not necessary to provide a filter to protect clay flocs of 10µm. They summarized that for fine grained clays, a sand filter with D15<= 0.5mm was conservative. For sandy clays and silts, a filter criterion $D_{15}/d_{85} <= 5$ is conservative and reasonable.

A soil is said to be internally stable when its finer particles do not move through pores of coarse particles (Kovacs, 1981). Internal stability of soils has great effect on clogging. It is generally considered that coarse broadly graded soils are internally unstable. Lafler et al. (1989) showed that internally unstable soils, which were safely protected by fine filters, might self-clog. Particles move from base layers, accumulate at interface, and produce a layer of very low permeability there by initiating clogging. This finally results in an increase of pore pressures at interface. A further problem associated with broadly graded soils is that they are very difficult to place without segregation (Milligan, 2003).

Indraratna et al. in 1990 reported a relationship between the coefficient of uniformity and clogging. They studied the effectiveness of cohesionless filters for protection of lateritic residual soils. Several series of tests were conducted in fine to medium sand filters, and a clogging filter was detected with uniformity coefficient Cu = 3.8. It is summarized that fine to medium sand filters are effective for lateritic soils and clogging only occurs when the uniformity coefficient is close to 4.

The following are considered as physical factors that affect filter performances;

I. Base soils- cohesion, weight of grains, particle surface roughness, density, and specific gravity,
II. Filter particles fines content and surface roughness.

For the base soils, among all other physical factors, cohesion plays the major role in filtration performance. It is generally recognized that when conventional filter design criteria based on PSD are used for cohesive dam fill sections, it ignores the resistance to erosion owing to cohesive forces. A small quantity of water seeps through compacted clay soils, which has little energy and subsequent little chance for fine clay particles to enter into filter pores as indicated in Sherard et al., in 1984. Kassif et al. in 1965 also mentioned that the flux was small through the clay layers, hence design criteria may be less stringent and range of possible filter materials becomes wider.

Kassiff in 1965 carried out experimental investigation of filtration of cohesive soils through coarse granular filters. Their experimental results were compared with the results of the analytical model of Zaslavsky and Kassiff in 1965. The critical hydraulic gradient (i_{cr}) from both methods showed surprisingly high values. Tests had been carried out for compacted clays in contact with actual filter materials as well as perforated plate simulating filter materials. Experimental results indicated that a fair coarse filter could protect fat clay. Higher average gradients were required to cause failure, even when clay was allowed to swell under zero pressure.

Wolski in 1970 examined erosion resistance of silty clay at base-filter interface by measuring the changes in porosity and pore pressures through x-ray examination. The results were reported in two stages. In the first stage, at relatively low hydraulic gradient, removal of base particles at filter interface was observed until arching of several small particles over the filter pores stopped erosion. Later on, at higher hydraulic gradients, breakdowns of arches and further erosion were reported trough progressive particle loss and formation of piping failure. Thus, it was recommended that filter design based on PSD was conservative if used for intact soils. However, there were two problems with filter design for cohesive soils: the formation of cracks, and the dispersion of clays with flow water.

Filters should be given minimal compaction. Excessive compaction, particularly of crushed rock, can lead to the criterion of fines to result the filters susceptible to cracking.

When there is a crack in a cohesive soil fill, a filter, to become effective must be non cohesive. A filter with cohesive properties may sustain an open crack without collapse and thus fail to prevent the base material crack. The inclusion of more fines might result in a more cohesive filter. Mantz in 1977 found that quartz particles possessed surface attraction at sizes less than 50 microns (coarse silt). However, provided that filters do not contain surface-active clay minerals, filter cohesion is very small compared to cohesion in the base impermeable zone as mentioned by Vaughan and Soares in 1982. Milligan in 2003 reported that when a core cracked, a downstream filter became a secondary interface. If both base and filter crack, it is inevitable that piping and subsequent erosion will occur. To avoid filter materials becoming cohesive, there is a maximum limit of fines content of 5%.

The main hydraulic factors that have influence on filter design are total hydraulic head, hydraulic gradient, pore fluid velocity, and the angle between direction of flow and gravity. Mullner in 1993 pointed out that the well- known filter rules neglected hydraulic parameters, which are influenced by the erosion resistance of cohesive soils. If hydraulic factors are not taken into consideration, this leads to an economical design of filters. Water flowing through porous media may cause the destabilization of soil structures, if the filter is not geometrically stable. Stability is also affected by changes in hydraulic load conditions. Variation in seepage pressure due to a sudden change in hydraulic head has a great impact on particle movement. Compressibility of filter media due to sudden increase in hydraulic load affects particle movement too. Transport of moveable soil particles is greatly dependent on the hydraulic gradient.

The US Army of Corps of Engineers (USACE, 1971) performed extensive filtration experiments varying hydraulic gradient. At higher gradients, susceptibility to piping increases when the filter is subjected to vibrations.

Kenny and Lau in1985 their study of granular filters stated that stability based on grading curve basically depended on three factors: PSD, porosity and the severity of seepage and vibration.

2.4 Focus of Current study

The current research focuses on engineering geological assessment of the various constructed and being constructed filter/drain for the base/core soil that were used for embankment fill. This quality performance assessment is based mainly on the geometrical, physical and chemical factors or criteria proposed by the various scholars. All constructed and on the process of construction filters are examined for their relative suitability and analyzed accordingly.

2.4.1 USDA-SCS (1986) Method

The geometrical suitability of the granular soils suggested for filter is analyzed using basically the USDA-SCS, Engineering Division 1986 design procedures. It is based on the type of base soil in terms of its grain size or gradation. These showed that the basic requirements could best be met by designing the particle size of the granular filters in relation to the particle size of the soil being protected. There are about 12 steps to design the lower and upper limits or envelops of filter gradations for a certain base soil category. This procedure determines the filtration capacity or base soil retention suitability of the granular soils or the piping requirement. The second important function of the soils, i.e. the permeability criteria or the requirement that seepage move more quickly through the filter than through the protected soil, is again analyzed by a grain-size relationship criterion based on experience.

The design manual presents criteria for determining the grain size distribution (gradation) of sand and gravel filters needed to prevent internal erosion or piping of soil in embankments or foundations of hydraulic structures. These criteria are based on results of an extensive laboratory filter study carried out by the Soil Conservation Service at the Soil Mechanics Laboratory in Lincoln, Nebraska, from 1980 to 1985 (USDA National Engineering Handbook, 1994).

2.4.2 USBR (1977) Method

The USBR method or criteria used here is as follows (Fell et al.1992);

i. D15F/d15B = 5 to 40, provided that the filter does not contain more than 5% passing 0.075mm. This criterion ensures that the filter is more permeable than the base soil.
ii. D15F/d85B <= 5, and the grain Size of the filter should be roughly parallel to that of the base material. This criterion ensures that the filter is sufficiently fine to control erosion of the base.
iii. Maximum size particles in filter equal to 75mm to prevent segregation during placement.
iv. For base materials which include gravel particles, the base material d_{15B}, d_{85B}, etc. should be analyzed on the basis of the gradation of the soil finer than 4.75mm.

2.4.3 Terzaghi Criteria

These criteria have been used since 1930 for the design of filters for dams and other works. Although known to be conservative and originally developed for cohesionless uniform base soil and filter materials, the well known Terzaghi retention criteria are given by (Baharat Singh, 1995);

1. The 15% size of the filter material, D_{15}, must not be more than 4 or 5 times the 85% size, d_{85} of the protected soil to prevent the piping, i.e

$$\frac{D_{15} of\ filter}{d_{85}\ of\ protected\ layer} < 4 \text{ to } 5 \quad \textbf{(2.1)}$$

2. The 15% size of the filter material, D_{15}, must be at least 4 or 5 times the 15% size, D_{15} of the protected soil, to ensure adequate permeability or,

$$\frac{D_{15} of\ filter}{d_{15}\ of\ protected\ layer} > 4 \text{ to } 5 \quad \textbf{(2.2)}$$

Other requirements for a good filter are;

I. Its gradation curve should be approximately parallel to the gradation curve of the protected soil, especially in the finer range.
II. Filters should not contain more than 5% fines (-0.075 mm) and fines should be cohesion less. This is to ensure that filter remains adequately pervious and does not sustain a crack.
III. The filter does not have particles larger than 75 mm so as to minimize segregation.
IV. If the base material ranges from gravel (over 10% > 4.75 mm) to silt (over 10% passing 75m), the base material should be analyzed on the basis of gradation of fraction smaller than 4.75 mm.

2.4.4 Sherard Recommendations

Experiments conducted at the Soil Mechanics Laboratory, in USDA-SCS on different soils revealed the following criteria (Baharat Singh, 1995)

i. The filter is successful in its function of arresting particles migration if;

$$\frac{D_{15} of\ filter}{d_{85}\ of\ base} < 9 \qquad \textbf{(2.3)}$$

This shows that Terzaghi's criterion includes a factor of safety of 2 and conservative.

ii. The size of the pore channel, which governs permeability is determined by the size of finer filter particles and will be represented by D_{15} size.
iii. The coefficient of permeability (K) of dense filters is generally in the range of K = 0.2 to 0.6 $D15^2$ with average 0.35 $D15^2$ (K in cm/s and D_{15} in mm)
iv. The filter gradation curve need not necessarily be parallel to the base material.

2.4.5 Recommendations as per Indian Standard

The recommendations for filter selection as per IS code are as follows (Baharat Singh, 1995);

i. $$\frac{D_{15} of\ filter}{d_{85}\ of\ base} < 5 \qquad \textbf{(2.4)}$$

ii. $$\frac{D_{15} of\ filter}{d_{15}\ of\ base} > 4 \text{ and } < 20 \qquad \textbf{(2.5)}$$

iii. $\frac{D_{50} of\ filter}{d_{50}\ of\ base} < 25$ **……………………………………………..…(2.6)**

iv. The gradation curve of filter material should be nearly parallel to the gradation curve of the base material.

Different criteria give different emphasis to these particle sizes. As basic filter criteria it is required that the gradation curve of the filter material must be parallel to the gradation curve of the core material.

2.5 Chimney filter with Blanket drain

Chimney filters are an effective method of protecting an impervious core from potential internal erosion failures and, at the same time, effectively controlling the phreatic surface through the embankment.

Chimney Filter is Zone that protects the core from internal erosion and piping. Usually, this zone is composed of sand-size particles. But Chimney Drain is Zone that carries away seepage coming through the chimney filter and delivers it to the blanket drain. Blanket Drain is Zone that provides foundation hydrostatic pressure relief for pervious foundations and protects against particle movement in soil foundations. It also provides an outlet for seepage water collected by the chimney. In this regard, FEMA (2011:24) states that:

> *"…The use of a chimney drain is dependent on the expected amount of seepage through the core; cracking potential, especially related to seismic loading; and composition of the downstream shell. If the downstream shell is coarser than the filter (as defined by the filter criteria),a chimney drain will be required. If rock fill is used for shell material (due to its high strength and low cost), an additional zone or zones may be required between the chimney drain and the shell. Since the drainage function has been met by the chimney drain, these zones are usually called transition zones. Particle retention criteria should be met between these transition zone(s) and the shell."*(FEMA, 2011:24)

Using those in collection has great structural quality and availability if they are constructed by suitable construction material that fulfills applied qualification or suitability criteria and requirements. Generally, the materials were thoroughly washed before being separated into component parts for the stockpile, since the presence of dust, clay particles, and organic matter might have considerable effect on filter testing (U. S. Army, 1953). Because, in this investigation the aggregates were limited to natural sands and gravels of rounded or sub rounded form.

Comparing the various indicated filter design criteria, an emphasis is given on the USSCS and related Sherard and Dunnigan recommendations for this particular research work regarding clogging criteria and filter design aspects or criteria such as self healing, draining capacity and material durability. This is because the methods considers to the type of base soil to be protected, and accordingly proposes unique procedures for the filter design or criteria.

Filters are required to be constructed of sand and gravel which is sufficiently durable so as not to breakdown excessively during mechanical action of placement in the dam, under the chemical action of seepage water, or under wetting and drying within the dam (Fell et. Al1992). The Los Angeles abrasion and wet strength, wet/ dry strength variations largely assess the susceptibility to breakdown during the placement. The sodium sulphate soundness test assesses the susceptibility to breakdown under wetting and drying, with the added involvement of sodium sulphate in the solution used for soaking. These tests and recommended standards are likely to be more rigorous for high hazard dams, and dams with seepage water which is highly acidic or has high salt content (example, some tailings dams).

The other mineralogical consideration is proportion of carbonate minerals in the filter material. It is probably not suitable for use in filter zones because of susceptibility to solution and re-deposition as cement between the particles. Filters from rocks containing significant amount of gypsums are highly susceptible to the same solution problem.

In the light of the above it is recommended that (Fell et. al. 1992) the following should always be considered in characterizing the proposed filter material;

- The mineral composition of the particles should be determined,
- If the material is found to contain even small amounts (e.g. 1-5%) of carbonate, gypsum or sulphide minerals, then care has to be taken while designing the filters.

2.6 Core Material

Core is located either at the center or upstream of the dam. It is made up of impervious material. It prevents water from seeping through the embankment. The initial requirement for core material is suitable material availability from selected dam site then available quantity and relevant soil properties investigated. In this respect, Novak et al. (2001) suggested that the core is the basic element in an embankment and demanding in terms of material characteristics and uniformity and also compacted clay core properties has long-term watertight integrity.

The core shall be parallel to the centerline of the embankment and shall be compacted with compacting construction equipment like rollers, or hand tampers to assure maximum density and minimize permeability. In addition, the core shall be placed concurrently with the outer shell of the embankment (NRCS-MD, 2000). Core should have low permeability and ideally be of intermediate to high plasticity to sustain a limited degree of deformation without risk of cracking (Novak et al., 2001). Generally the core is the impervious barrier constructed within the main dam body. Its primary purpose is to check the seepage of water through the dam. This function will only be performed effectively if the construction material, to be used for the core, has desirable engineering properties (Nigatu, 2006). Therefore, Bharat Singh (1995) cited in Mulatu (2010) the important soil properties to be considered are; permeability, compacted density, shear strength, compressibility, flexibility and erosion resistance. Besides, the index properties, such as grain size distribution and Atterberg's limits are also equally important as a fair idea of engineering performance of the material can be known by classifying the soils (Nigatu, 2006). Sherard (1963) cited in Mulatu (2010) states that material classification based on their erosion resistance and an experimental investigation carried out for fine grained soils indicates that erosion resistance normally increases with plasticity index and also increases with compacted density.

2.7 Filter contamination

Stockpiled materials can become contaminated by airborne dust and drainage runoff, resulting in an increased amount of fines in the material. Dust abatement procedures should be used to prevent contamination of fines into the stockpiled material. Positive drainage should be maintained so that suspended sediment is not carried into the stockpile (Navin 2006). A stockpile pad should also be used to minimize contamination between the stockpile and ground surface. Stockpile pads can consist of concrete, geomembrane, or an over-excavation backfilled stockpile material.

3 MATERIAL AND METHODS

3.1 General Overview of the Study Area

3.1.1 Location of the Project Area

The project area is located in South Wollo, in Sayint Woreda from Shengo Defar/04/ Kebele and intersects Feres Bar/06/ Kebeles of ANRS. The dam site is found within the Abay river basin at the middle section specifically, the dam is constructed along a small stream called Aguat, left tributary of Abay River. The dam site and reservoir area laid in peasant associations (PA). The project area is defined by Geographic co-ordinates (UTM) of 1214001mN and 0486044mE, at dam site. The project site is found at about 160 Km from Dessie city, Zonal capital also 570 km from regional capital, Bahir Dar. From the Woreda capital, Sayint Ajibar, the dam site is situated at about 15km in the south East direction. The first 13km is accessible with gravel road, while the last 2km is a foot path along moderate to steep slope, which needs road construction. The Aguat-wuha dam project is one of the Projects undertaken by Amhara Water Works Design and Supervision Enterprise (AWWDSE). The drainage unit has historically been an important watershed area as it is among the earliest sources of water to its environs. It lay within a key agricultural area and has seen significant expansion in agricultural activity over the years. The watershed found in Sayinit is limited within 959.4 hectares (Watershed Management report Volume I, 2015).

The borrow area for sand, to be used for fine aggregate and transition filters, are collected at a stream is known as ‘Mersa’ (Technical Specification report, 2015).

3.1.2 Hydrology and Climate

Hydrology deals with the waters of the earth, their occurrence, circulation, and distribution, their chemical and physical prosperities and their reaction with the environment including their relation to living things. Hydrological study includes the important parameters such as precipitation, evaporation and run-off data use for design of engineering project, site selection and the land use planning. Hydrology is used in engineering mainly in connection with the design and operation of hydraulic structures, what flood flows can be expected over a spillway, what reservoirs capacity is required to assure adequate water for irrigation or municipal water supply during droughts(Fetter.1987). Hydrology of a given basin determined by climate, geology, topography & land cover.

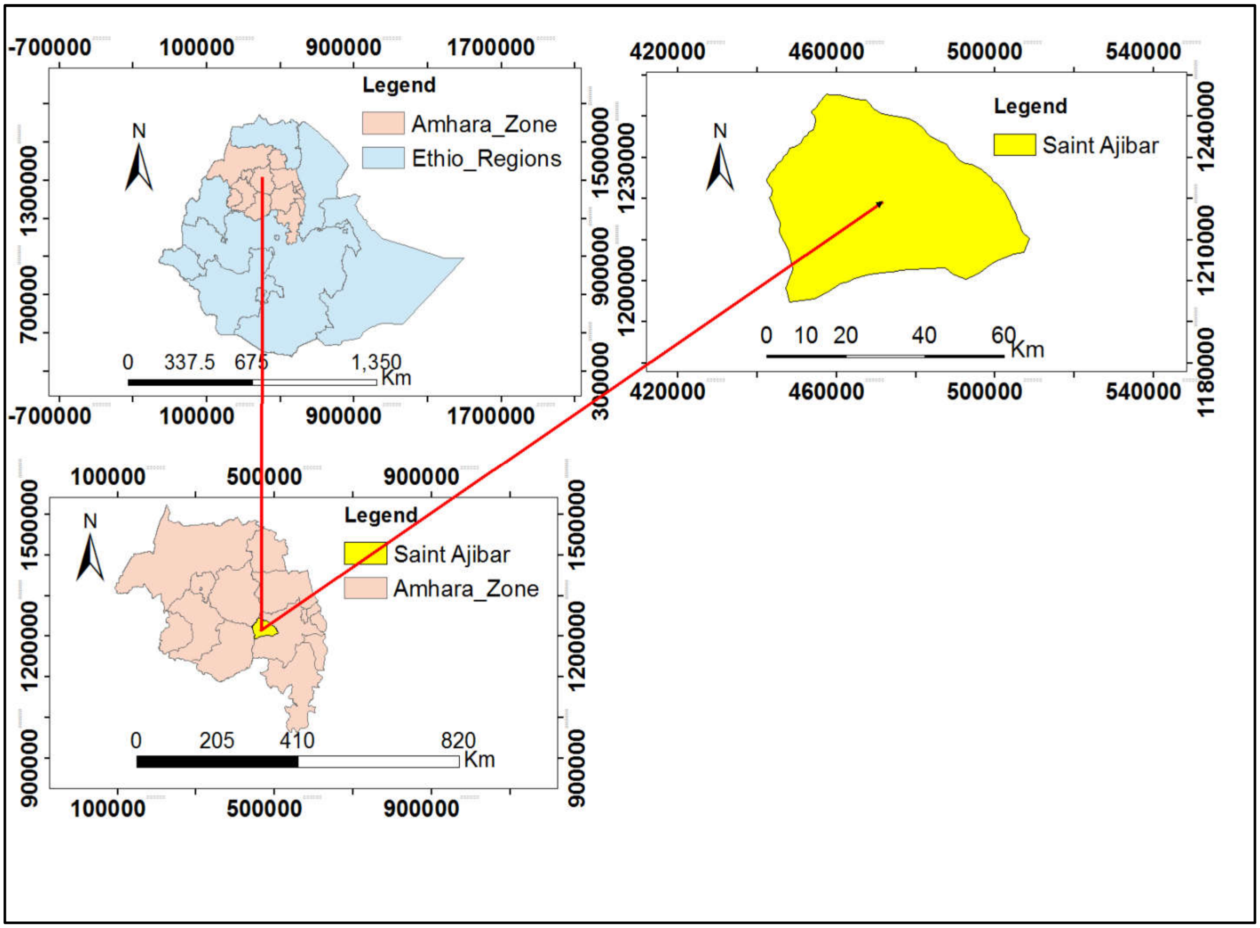

Figure 1: Location map of the project area

The climatic data of the basin like temperature, precipitation, evaporation, wind speed, relative humidity and sunshine duration are important parameters in the analysis of hydrology of the basin (Fetter.1987).

There are three National meteorological stations near the project area namely Sayint-Ajibar, Mekaneselam and Wegdi stations. On the basis of the traditional Ethiopian Agro-Ecological Zones (MOA, 2001), Aguat-Wuha Dam Project, which is located at the vicinity of Ajibar town, is basically classified as Dega (Moist cold) agro-ecological zone that indicates rainfall distribution problem and poor moisture condition in the area. There is no Belg rain season in the project area. Although Meher rain is considered adequate, there is notable variation in terms of onset, distribution and withdrawal of rain season from year to year affecting crop production and productivity.

Mekaneselam meteorological station data (rainfall) and LocClim, 1.0 softer (local climate estimator) for estimation of climate data (temperature, relative humidity, wind speed and sunshine hour) were used. In general, the source of meteorological data is the National Meteorology Service Agency (NMSA).The main rainy season (Meher/Kiremt) occurs from Mid-June to Mid-September. Meher/Kiremt rainfall is largely received in the months of June, July, August and September. Had the annual amount of rainfall been well distributed throughout the rainy seasons, where Meher crops are grown, the amount of rainfall may have been sufficient for the crops grown in the wet seasons.

Five years rainfall data was used for the computation and analyses of irrigation water requirements. The monthly total rainfall data recorded from 1995-2008 was analyzed. The average annual rainfall at Mekaneselam station is about 877.29mm.The monthly rainfall distribution has better rainfall distribution from June to September. More than 87% of the annual rainfall occurs from June to September. As shown on figure below

Source; ADSWE Aguat-wuha Irrigation Agronomy main report III, 2015

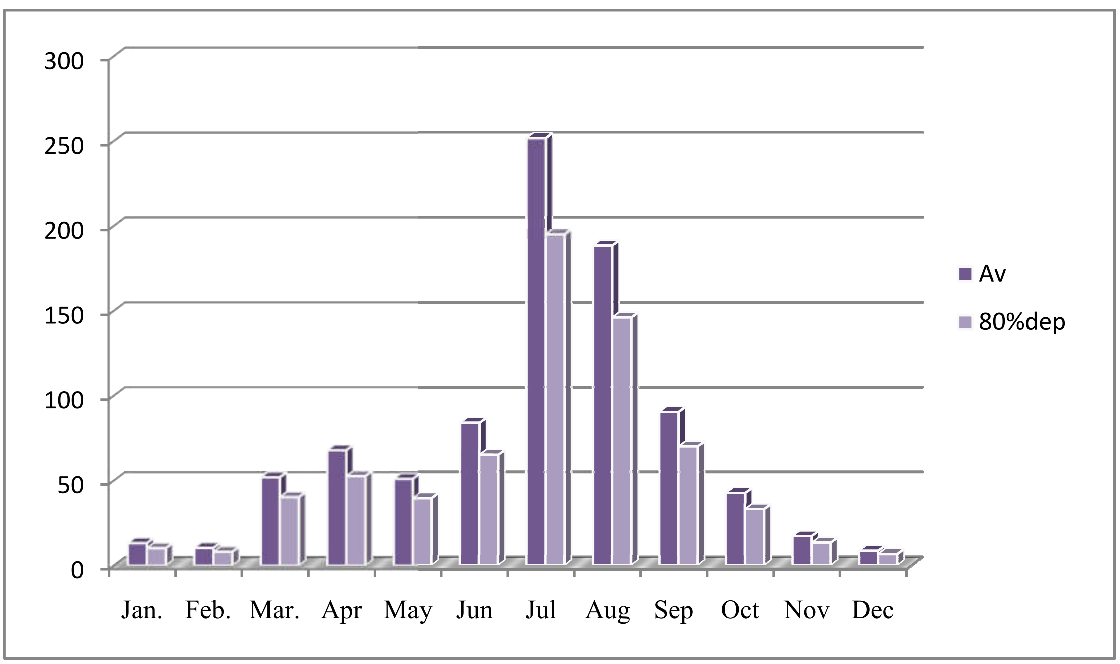

Figure 2: Average and 80% dependable rainfall at Mekaneselam Station

The pattern of the seasonality of rainfall in the project area is determined by computing mean monthly rainfall ratio with that of rainfall module as rainfall coefficient, rainfall coefficient which is defined as the ratio of mean monthly rainfall to rainfall module (one-twelfth of the annual total) is shown in Table1.

Table 1: Monthly and Dependable Rainfall and Rainfall coefficients

month	Jan.	Feb.	Mar.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av	13.19	10.42	51.99	67.94	51.02	83.91	251.3	188.42	90.7	42.3	17.9	8.5
80%dependency	10.22	8.08	40.29	52.66	39.55	65.04	195.1	146.05	70.4	33.0	13.3	6.6
RF CV	0.18	0.14	0.71	0.93	0.70	1.15	3.44	2.58	1.24	0.58	0.24	0.1

Source; ADSWE Aguat-wuha Irrigation Agronomy main report III, 2015

The mean minimum and maximum temperature at Ajibar meteorological station is 7.3 and 20.6°C, respectively. The monthly mean minimum temperature varied from 4.3°C (December) to 9°C (May); and the monthly mean maximum temperature varied from 17.7°C (July) to 22.9°C (April).The sunshine hours duration at Saint Ajibar ranges from 2 (July and August) to 8.1 hours/day (November). The mean annual sunshine hour duration is 5.6.The relative humidity (RH) at Saint Ajibar also varies from 70% (July) to 96% (May) and the mean annual RH is 82%. The wind speed at Saint Ajibar ranges from 1m/sec to 2 m/sec which is low and not likely to cause damage to the crops. The mean annual wind speed is 2 m/sec.

The evaporation loss from the reservoir water is estimated using U.S geological survey method as shown below.

$$E = \frac{4.57*T+43.3}{1200}$$ ………..U.S geological survey method **......………………… (2.7)**

Where E = Monthly evaporation loss in m,

T = Mean annual temp. (0^0)(Bihar Dar)

63

Table 2: monthly evaporation rates estimation

Month	°C	°C	Mean	Evaporation loss(m/month)
Jan	5.9	22.4	14.15	0.090
Feb	6.6	22.3	14.45	0.091
Mar	7.9	22.6	15.25	0.094
Apr	8.7	22.9	15.80	0.096
May	9	22.7	15.85	0.096
Jun	8.4	21	14.70	0.092
Jul	8.5	17.7	13.10	0.086
Aug	9.3	17.8	13.55	0.088
Sep	7.6	18.9	13.25	0.087
Oct	6.5	19.3	12.90	0.085
Nov	5.4	19.5	12.45	0.083
Dec	4.3	20.2	12.25	0.083

Annual evaporation = 1.072m=1072.0mm (***Source;*** ADSWE Engineering Design report Volume IV, 2015)

3.1.3 Geological Settings

Mohr (19710), Kazmin (1972), Mengesh et al. (1996) cited in UFGS (2008) the bedrock geology of Ethiopia embraces a great variety of rock types within a wide age range. Precambrian metamorphic and igneous rocks cover 23% of the country and include rocks such as gneiss, schist, marbles, granitoids and soapstone. Thick successions of Palaeozoic and Mesozoic sediments (25%) overlie the Precambrian. These include limestone and sandstone. A large part of the country is covered by Tertiary and Quaternary volcanic rocks (44%), and in these areas, basalts, tuffs and ignimbrites are extensively observed (ADSWE, 2015).

The structural trends of the Western Ethiopian escarpment and associated marginal grabens depict complex structural trends (ADSWE, 2015). Accordingly, The trends of the Southern Red Sea (NW-SE), the main Ethiopian Rift (NE-SW), and the Gulf of Aden trend (E – W) are thought to be present in the region.

3.1.3.1 The project site Geology and Structure (ADSWE geological report, 2015)

The solid local geology of the project site is characterized by two kinds of rock, which are portion of the tertiary volcanism. They distinctly forming separate lava flow and reveal characteristic texture, occurrence (stratigraphy), and mass properties, although having nearly similar basic/basaltic chemical composition. For the sake of this project, the two rock types are classified as (from their stratigraphic position):-

a. Aphantic (fine textured) Basalt- Younger lava flow
b. Agglomerates Basalt- older lava flow

a. Aphantic Basalt Rock

This rock unit is found at relatively elevated and moderately slope areas of the project site, and normally forms hill slope, peaks and valley floor area. It has dark color, very fine grain size, and limited thickness, which is in the ranges of 8 to 10m. In the area, the rock is affected by joints having very close spacing and is not persistent and its spaces are filled by clay soil. It is also reveals slight to moderate degree of weathering, mainly physical disintegration that for certain depth the rock is limited. This lave layer is underlain by the Paleo soil and the thickness of the soil unit pitchout out in the bank of Aguat River that we go in the dam axis.

b. Agglomerates basaltic rocks

This lava flow is found underlying the Aphantic basalt rock, and it is observed at relatively lower elevations of the area. Out crops of the rock are observed mainly along the stream beds, banks and lower slopes of nearby the banks of Aguat stream. It has red gray color, and block texture, with feldspar phenocrists. The rock unit is affected by slight degree of weathering at some places, otherwise it is fresh. It is also mainly massive in nature that there is no observed defined joint set or system.

At most part of the project site, the bedrocks are covered with superficial soils. Based on origin, and texture there are three types of soil in the project area. From origin point of view, these are Colluvial, silt clay and floodplain deposit.

The residual soil is formed from in situ physical weathering of the younger aphanitic basalt unit. It is observed at relatively elevated areas and upslope of hill sides. It is characteristic dark brown color. The soil is dominated by gravel with few sand and some fines.

The alluvial soil is found along the gentle bed or course of the Aguat stream in small existents. It is a soil deposited by the stream during flood times. It is dark gray in color having small amounts of cobbles with little silt. The gentle and plain areas surrounding the stream course in both sides is covered with bed rocks and flood plain deposit. This soil has dark brown color, and composed of dominantly clayey Silt soil. Generally the geological x-section of the research aimed dam was shown in figure 3.

To summarize the superficial soils in the project area, there are three soil types. These are:-

a. Recent Alluvial deposit,
b. Colluvial soil,
c. Silt clay soil

3.1.4 Seismicity of the Study Area (*Source*; ADSWE Geological Report, 2015)

The degree of seismicity of the area should be taken in to account with great emphasis as an important design parameter by evaluating the seismic nature of the area from history and records of previous earthquakes and knowledge of local geology.

Source; ADSWE geological report, 2015

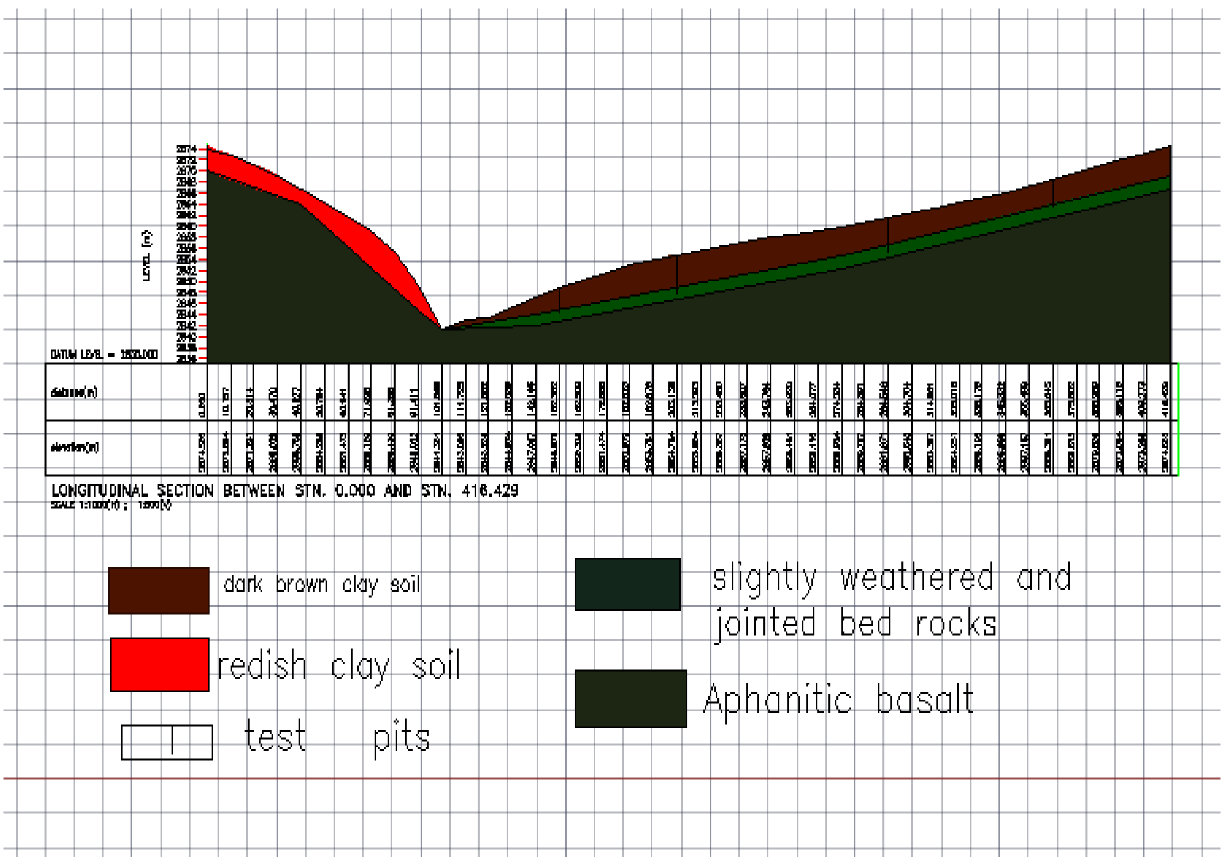

Figure 3: Geologic X-Sections Aguat-wuha dam

To construct effective and long-lasting hydraulic structures, assessments on susceptibility to seismic hazards are fundamental issue. Judgment and modification to the expected intensity can be depending on the ground conditions, immediately beneath the site because thick soil deposited and outcropping bed rocks do not have similar response for the same earthquake magnitude i.e. soils are more susceptible to liquefaction before rocks will be forced to collapse. The most famous edition in the Ethiopian context is the seismic susceptibility map of the country by Like Mariam Asfaw, 1986 (Figure 4). According to the seismic hazard map of Ethiopia, the country has been subdivided in to five seismic Zones as: Zone (o), Zone (1), Zone (2), Zone (3) and Zone (4), the no hazard, the low hazard, the moderate hazard, the higher hazard and the highest hazard zones, respectively. The project area is found within the zone 2 where seismic activities are active that dynamic design approach is also important for the engineering structures.

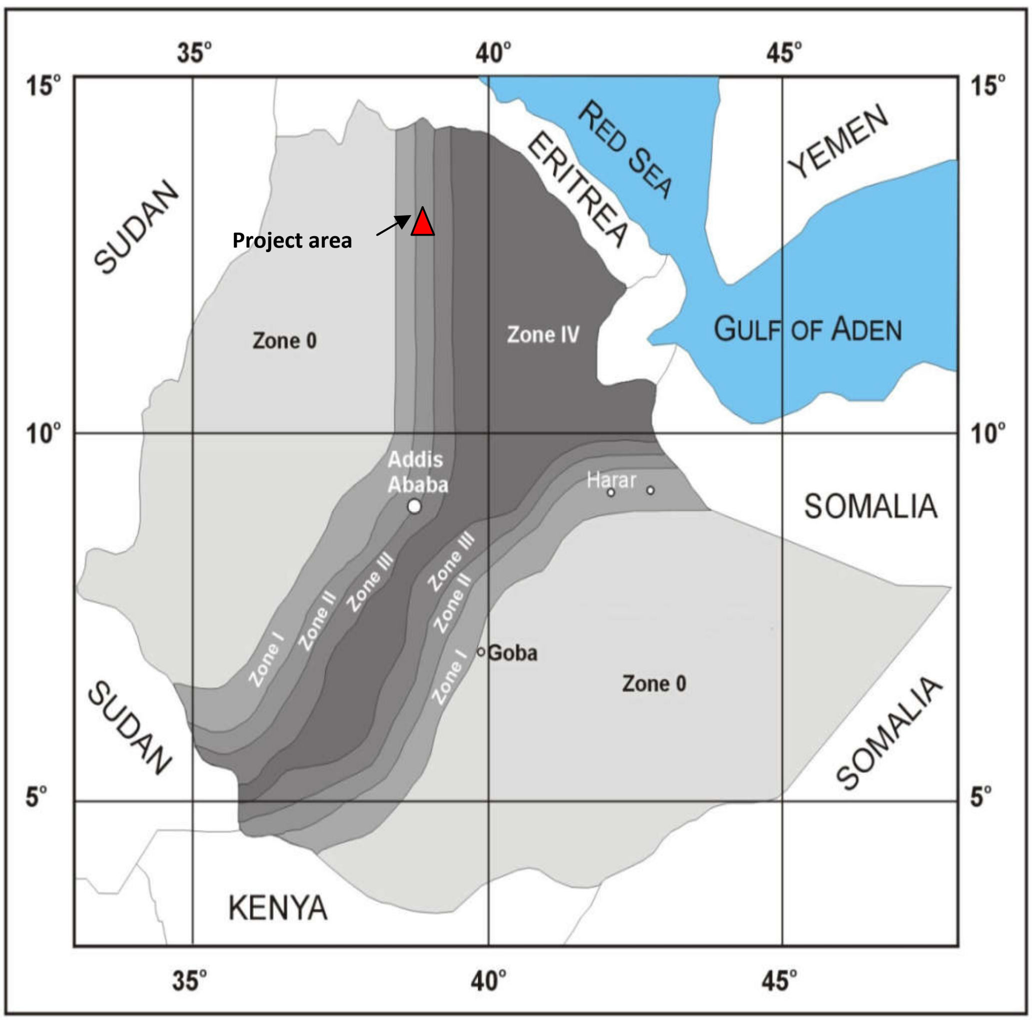

Figure 4: Seismic Risk Map of Ethiopia (*Source;* ADSWE engineering geological report volume II, 2015)

3.2 Data Collections

Various data collection method should exercise to accomplish the above objectives of the research. The two data collection types of the research follows are secondary data collection and primary data collection. Both primary and secondary data used to characterize the local geological and geotechnical condition of the dam site, and proposed borrow areas/quarry sites for required natural construction materials. After collection of the data, systematic data processing and analysis was carried out.

3.2.1 Primary Data Collection

This data was collected from the Aguat-wuha dam site. Accordingly, primary data was collected from test pitting (disturbed) of already constructed Aguat-wuha dam filter material and physical observation of the geological condition of site including description and characterization of the soil was made by visual observation and also by interviewing the workers that has on profession of construction, how they processed assessment of material suitability and how carried out placements of filter material and quality check on filter. Test pit (disturbed) sample taken from actual site from 25-30cm depth from different constructed filter zone of the ending filter being constructed layer. In this case the research takes 4(four) different 1550gm sample at different being constructed filter material.

3.2.1.1 Field data collections

During field data collection description and characterization of the soil was made by visual observation. In many cases it is preferable to measure the properties of soil and rock in dam filter using in site tests, rather than taking samples and testing in the laboratory.

3.2.1.2 Material Exploration

The explored sample was taken from the constructed dam and also from stocked filter material, the main purpose of this are to take sample to check material gradation regarding material suitability and durability of filter after the material already constructed to check effectiveness criteria before and after the filter material constructed.

Spacing of the test pits or exploring varies from 60-100 m, being closer spaced in excesses of filter sample shown because the filter was already constructed and also wider spaced for the sample difficult to explore constructed sample areas. The spacing should not be arbitrarily uniform but rather should be based on availability of sample for exploration

The depth of exploration was from 23cm to 45cm, because the explored sample of filter being constructed filter that means the end layer was explored up to 45cm but the covered or already finished filter was explored from 23-25cm of on the edge side of being constructed filter layer.

3.2.1.3 Laboratory Tests

The purpose of laboratory tests are to investigate the physical and hydrological properties of filter materials, determines the finer contents and correlation by means of classification tests and define the engineering properties in parameters usable for filter material suitability and also hydrometer for classification of core material gradation. Testing programs generally consist of determine gradation material fines content only on representative samples of being constructed Aguat-wuha dam filter part and for core from provided borrow area.

3.2.2 Secondary Data Collection

The data was collected from laboratory report and geotechnical investigation with an intention literature review to have an overview of the impacts of the current procedures used for selecting over fined materials on the overall performance of dam filter; and how the prevailing design-decisions in the choice of such materials and also during construction have affected the construction material-selection performance;. Besides, soil properties and classification data was also collected to estimate the suitability of construction filter material. The review was made to understand the investigation methods, analysis and final interpretations for various dam sites and also identifies a lack of adequate information for the selection and evaluation of construction material suitability basically on special parts of filter. The data, which are collected and analyzed by Amhara Design & Supervision Works Enterprise (ADSWE), are the basic secondary data for this research.

3.3 Data Analysis

The basic requirements of filters are that they are sufficiently fine grained to prevent erosion of the soil they are protecting, and are sufficiently permeable to allow drainage of seepage water. Extensive laboratory testing programs, beginning with work by Bertram, 1940, who worked under the direction of Terzaghi and Casagrande, followed by the work of the USBR and others, showed that the basic requirements could best be met by designing the particle size gradation of the filters in relation to the particle size gradation of the soil being protected. More recently further experiments have been carried out by the United States Soil conservation Services

(USSCS). These experiments led to recommended modifications of the design rules suggested by USBR (Fell et al, 1992).

Important properties of the filter material are gradation, compacted density, and permeability. Filters are designed to permit free passage of water and prevent migration of fines through the filter. The average in-place relative density of the filter should be at least 85 percent and no portion of the filter should have a relative density less than 80 percent. Special care must be taken to assure that compaction does not degrade the filter material (by grain breakage and/or segregation) and reduce its permeability. When the filter material is sand or contains significant portions of sand sizes, the material should be maintained in as saturated a condition as possible during compaction to prevent bulking. The filter material should pass the 3-in. screen for minimizing particle segregation and bridging during placement. The permeability of sands and gravels varies significantly with the amount and type of fines present (material smaller than the No. 200 sieve). Also, the amount and type of fines present influence the capacity of a filter to self-heal by collapsing any cracks within the filter (USACE Design Manual, 1886).

To analyze the relative suitability of the residual, and also the alluvial sands to filter/ drain material for the base red tropical soil (impermeable homogeneous fill soil), filter design procedures provided by USSCS Engineering Division is basically utilized. In addition to this, design criteria suggested and recommended by other scholars, and various standards available for this purposes are implemented, and analyzed for their applicability. Based on these design procedures and criteria, the relative suitability of the granular soils, obtained from the different proposed source areas, is analyzed and interpreted. In general, all relevant parameters considered during the design of critical filter/ drains are analyzed with respective empirical approaches. The filter materials, in this regard, are examined mainly for their geometrical suitability as filter/ drain materials for the base soil.

Filters and drains allow seepage to move out of a protected soil more quickly than the seepage moves within the protected soil. Thus, the filter material must be more open and have a larger grain size than the protected soil. Seepage from the finer soil to the filter can cause movement of the finer soil particles from the protected soil into and through the filter. This movement will endanger the embankment. Destruction of the protected soil structure may occur due to the loss of material. Also, clogging of the filter may occur, causing loss of the filter's ability to remove water from the protected soil. Criteria developed by many years of experience are used to design filters and drains which may prevent the movement of protected soil into the filter.

This criterion, piping or stability criterion is based on the grain-size relationship between the protected soil and the filter. In the following, the small character "d" is used to represent the grain size for the protected (or base) material and the large character "D" for the grain size for the filter material.

The possible source or origin of sample for evaluation of filter for this research was the constructed or on the way of finishing Aguat-wuha dam and also stocked filter material around the dam not the quarry site. Four possible sources have been selected on different Aguat-wuha's Dam Filter sample 1-4 and they have been represented by AGWDF 1, AGWDF 2, AGWDF 3 and AGWDF 4.
All the samples were taken to Lalibela Study, Design and Supervision Soil Laboratory Section. In this lab, mainly grain size analysis and determination of percentages of fines were conducted. The grain size analysis table and curves of the filter soils are summarized and presented below Here the average grain size distribution of the filter materials secured from the dam filter part also presented, and suitability analysis is performed on this material.

3.3.1 Fineness for Filter material (Less Than 75 µm (No. 200) Sieve)

These test methods cover determination of the amount of material finer than a 75-µm (No. 200) sieve by washing. The research carried out this test to remove the finer material namely silty particles from dam filter and at least to be in the limit of less than 5% and also lowering of silt content in the filter. According to ASTM, two methods for determining the amount of material finer than the No. 200 sieve are provided. Those are Test specimen is not dispersed prior to wash sieving and Test specimen is dispersed by soaking in water containing a deflocculating agent prior to wash sieving. From this the research agrees with the method on the way of finding and determination of finer content. To get the clean filter material proper wash carried out. The wash continuity for soils containing a relative high percentage of material finer than 75 µm (No. 200) sieve, after the initial washing disperse the particles passing the 425 µm (No. 40) sieve in the stirring device for one minute. Return the dispersed sample on to the 75 µm (No. 200) sieve and wash until the wash water is clear. While washing, tap the sieve to expedite the operation (Construction Division, 2014).

Additionally to calculate the amount of material passing the 75-µm (No. 200) sieve by washing using the following formula:

$$\mathbf{A = [(B-C)/B]*100} \quad \text{..} \quad \mathbf{(3.1)}$$

Where: *A* = percentage of material finer than the 75-µm sieve by washing,

B = original dry mass of sample, g, and

C = dry mass of specimen retained on the 75-µm sieve including the amount retained on an upper sieve after washing, g

3.3.2 Hydrometer Method

It uses for determining the specific gravity of liquids. Besides the specific gravity of the soil suspension depends on particle size, it can be also used for particle size analysis (Arora, 2004). Therefore the following table 3 showed the hydrometric analysis value of the fill material or the clay core for Aguat-wuha dam. Because the sample taken from the borrow area was similar on their behaviors. This analysis used for evaluating filter of satisfies the filter band based on the gradation size the fill material d85 and d15.

Table 3: Hydrometric Analysis for Fill Material

Hydrometric Value

Sieve size	% passing
4.75	100
2	99.8
0.425	99.40
0.075	97.32
0.0667	71.74
0.0475	69.74
0.0341	65.76
0.0221	59.78
0.0157	57.79
0.013	53.80
0.0093	51.81
0.0067	47.82
0.0047	42.84
0.0033	40.85
0.0023	38.86
0.0014	32.88

3.3.3 Sieve Analysis

It is done for coarse grained soils can be divided into gravel fraction (size >4.75mm) and sand fraction (75µ<size <4.75mm) (Arora, 2004). The actual observation indicated below table 4 of Aguat-wuha dam filter material sieve result carried out. It was taken from already constructed filter material so that this interpretation taken for comparing the actual on site with treated filter material sieve result (table 5) of this research analysis. Before any suitability and wellness analysis of filter the research checked weather the filter material have or not have silt content.

3.3.4 Particle Size Distribution Curve (Gradation curve)

It displays the distribution of particles of different sizes in the soil mass (Arora, 2004). It uses:

- In the classification of coarse-grained soils
- An approximate value of permeability can be determined
- To know susceptibility of a soil to frost action and For design of drainage filters

- Provides an index to the shear strength of soil. Generally well graded ,compacted sand has high shear strength
- Compressibility of soil can be judged and Indicates mode soil deposition

For soil stabilization design of pavements

Table 4: Sieve analysis for Filter Materials Before wash

Gradation for Filter Materials Before wash					
S/S	AGWDF 1 % Passing	AGWDF 2 % Passing	AGWDF 3 % Passing	AGWDF 4 % Passing	AGWDF Average % Passing
37.5	100	100	100	100	100.00
25	100	100	100	100	100.00
20	100	100	100	100	100.00
12.5	100	100	100	100	100.00
9.5	100	100	100	100	100.00
6.3	100.0	100.0	100.0	100.0	100.00
4.75	96.5	96.5	96.5	96.5	96.46
2.36	88.4	88.4	88.4	88.4	88.43
1.18	74.9	74.9	74.9	74.9	74.92
0.6	51.5	51.1	52.2	51.6	51.63
0.425	32.4	32.3	33.6	32.9	32.81
0.3	19.7	20.1	20.7	18.4	19.72
0.15	11.8	12.0	12.2	10.2	11.58
0.075	**5.7**	**5.8**	**5.8**	**5.5**	**5.72**

Table 5: Sieve analysis for Filter Materials after wash

Gradation for Filter Materials After wash						
S/S	AGWDF 1 **washed** % Passing	AGWDF 2 **washed** % Passing	AGWDF 3 **washed** % Passing	AGWDF 4 **washed** % Passing	AGWDF Average % Passing	AGWDF Regraded
37.5	100	100	100	100	100.0	100
25	100	100	100	100	100.0	100
20	100	100	100	100	100.0	100
12.5	100	100	100	100	100.0	100
9.5	100	100	100	100	100.0	100
6.3	100.0	100.0	100.0	100.0	100.0	100
4.75	96.3	96.2	96.2	96.3	96.2	99.9
2.36	87.7	87.6	87.6	87.8	87.7	91.1
1.18	73.4	73.2	73.2	73.6	73.4	76.2
0.6	48.7	47.7	49.0	49.1	48.6	50.5
0.425	28.4	28.1	29.0	29.5	28.8	29.9
0.3	15.1	15.3	15.2	14.4	15.0	15.6
0.15	5.4	5.4	5.5	5.3	5.4	5.6
0.075	**1.8**	**2.0**	**2.5**	**2.4**	**2.2**	**2.2**

According to Das (1994), soils are usually comprised of more than one particle size and the principal particle sizes of soils are; gravel, sand, silt and clay therefore all soils are made up of one or all of these distinct components in combination and each component has a definite grain size range characteristic reaction in the soil mass.

The grain size distribution of a coarse-grained soil is generally determined through sieve analyses, where the soil sample is passed through a stack of sieves and the percentages passing different sizes of sieves are noted. The grain size distribution of the fines are determined through hydrometer analysis, where the fines are mixed with distilled water to make 1000ml of suspension and a hydrometer is used to measure the density of the soil-water suspension at different times and hydrometer analysis is effective for soil fractions down to about 0.5µm (Das, 1994).

In the present study the particle size distribution analyses of the disturbed soil samples have been carried out by sieve analysis for materials coarser than 0.075mm and by hydrometer test for fine material (AASHTO, 2008). Mostly soils containing both coarse and fine grains therefore it is necessary to do sieve and hydrometer analysis to obtain the complete grain size distributions data (Das, 2011).

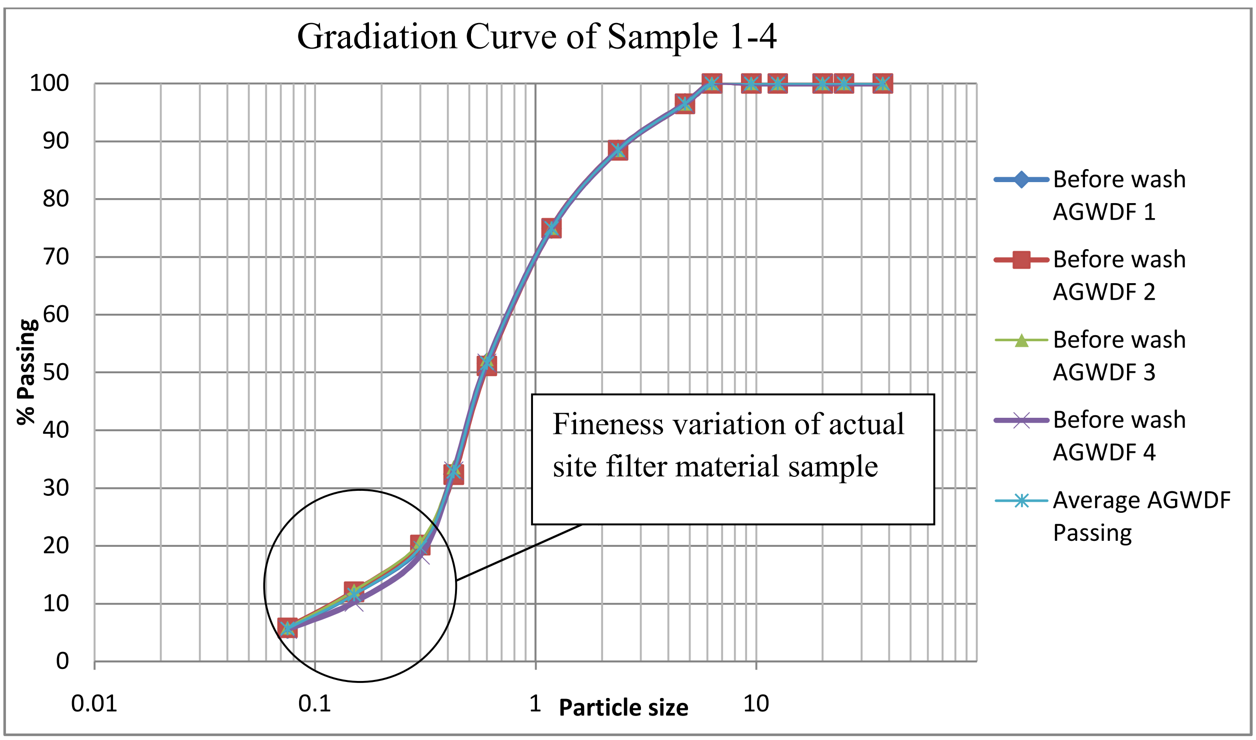

Figure 5: Gradation Curves of the Filter before wash

The above figure (fig 5) shows the actual observation of Aguat-wuha dam filter material without any analysis carried out so that this interpretation taken for comparing the actual on site with treated filter material of this research analysis. Before any suitability and wellness analysis of filter it was checked weather the filter material have or not have silt content.

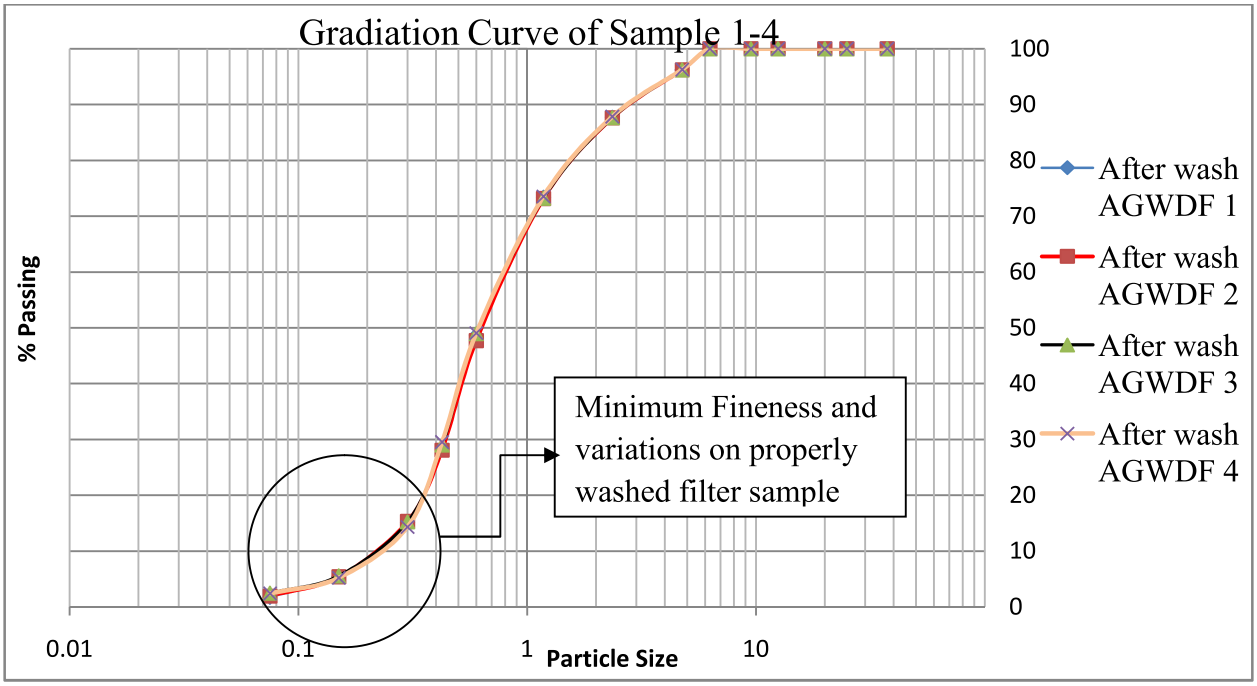

Figure 6: Gradation Curves of the Filter after wash

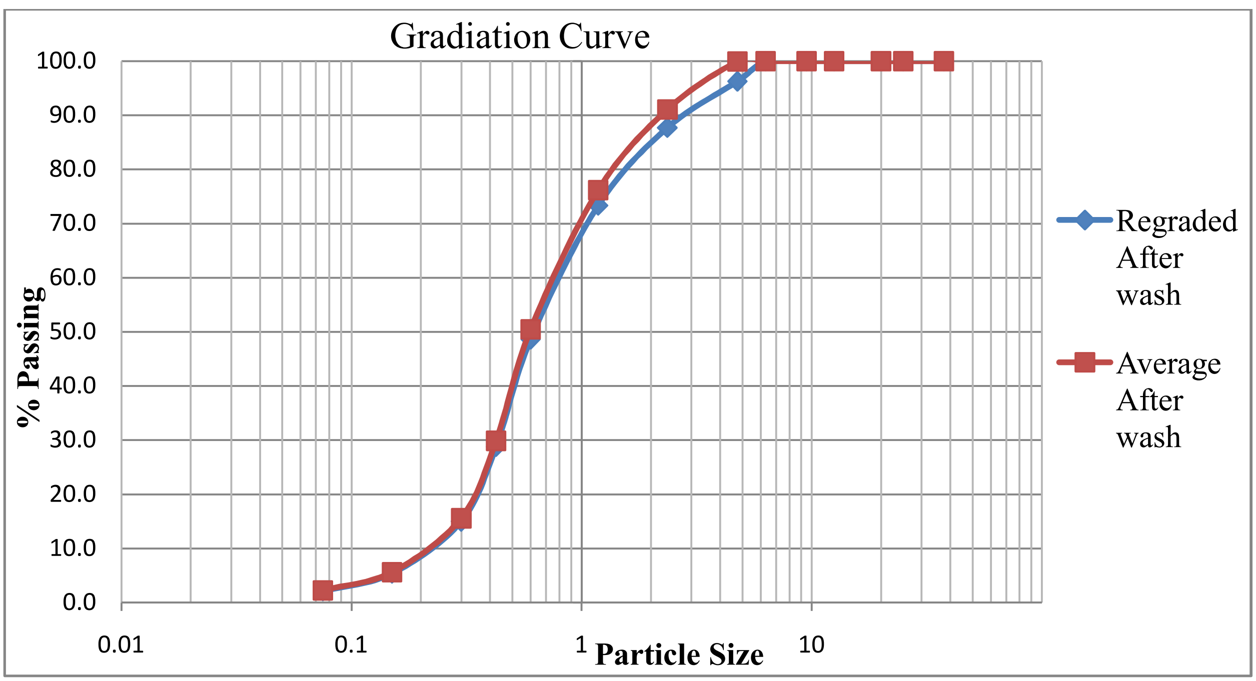

Figure 7: Gradation Curves of the Regraded and Average results of Filter after wash

3.3.5 Geometrical Factors Analysis and Empirical criteria

Geometrical factors (filter openings smaller than base particles) are mainly influenced by particle size distribution (PSD) and the shape of grains of both base and filter materials. The constriction size distribution (CSD) and non-homogeneity (segregation) of filter materials during placement are also included as geometrical factors (Schuler and Brauns; Mullner, 1993). Designing, and checking the PSD factors for the materials of the present research project have been done in the coming sections using various known criteria. Therefore the criteria analyzed by using the following tabulated parameter as shown below (table 6 and 7).

Empirical criteria are very useful during the investigation and design phases of a project. Filters can be quickly assessed to determine their suitability. Empirical criteria have been used to design filters for most major dam projects throughout the world, with success. Hence they can be relied upon to determine safe filters, provided the materials are suitable for the criteria being used.

Different empirical criteria may have a laboratory bias due to different testing methods, definitions of failure etc. Moreover, most empirical criteria only relate to selected points on the gradation curve rather than the entire particle size distribution, and hence, may not apply to unusually graded materials (Fernando Delgado Ramos, 2000).

Therefore the research basically follows the Sherard's Recommendations and also used the Sherard principal findings. Additionally, uses USDA-SCS Method to evaluate the material fulfillment of the filter band by using the 12 steps of USDA-SCS method and then analyze using the graphical result of the filter material whether the material satisfied or fall on the band or not.

3.3.5.1 USDA-SCS Method

There are about 12 steps to design the lower and upper limits or envelops of filter gradations for a certain base soil category. This procedure determines the filtration capacity or base soil retention suitability of the granular soils or the piping requirement. The second important function of the soils, i.e. the permeability criteria or the requirement that seepage move more quickly through the filter than through the protected soil, is again analyzed by a grain-size relationship criterion based on experience.

The design manual presents criteria for determining the grain size distribution (gradation) of sand and gravel filters needed to prevent internal erosion or piping of soil in embankments or foundations of hydraulic structures. These criteria are based on results of an extensive laboratory filter study carried out by the Soil Conservation Service at the Soil Mechanics Laboratory in Lincoln, Nebraska, from 1980 to 1985 (USDA, 1994).

The first step is to determine the gradation curve (grain-size distribution) of the base soil material, by using enough samples to define the range of grain sizes for the base soil or soils and design the filter gradation based on the base soil that requires the smallest D_{15F} size. For this research work the samples designated by ADSWE Soil Laboratory as a core (base) soil of Aguat-wuha dam. Therefore the base soil data taken from them namely AGCOTP 1, AGCOTP 2, and AGCOTP3 were used to define the range of grain sizes for the base soil. But the authority said they have almost similar gradation curves, and the data analysis or filter design is performed based on one of them, therefore the research taken the base soil data AGCOTP1.

Based on the values the gradation curves of the authority data base soil samples , as shown below (appendix 1)the soils are classified as Category 2 (Silty and clayey sands) on the percentage of soil finer than US standard sieve No. 200 (0.075mm) because the value 97.32% fall on **> 85**.

Following this procedure, soil categorization is done to determine the maximum allowable D_{15} size of the filter to satisfy the filtration requirement. For this soil category the maximum D_{15} size is less than and equals to 9 times the d_{85}. Using the appropriate value of d_{85} (0.07 mm) of AGCOTP1, the maximum D_{15} is calculated as 0.63 mm. Similarly, the minimum allowable size for D_{15} is determined to satisfy the permeability requirement. For the same soil category, the minimum D_{15} is greater than or equals to 4 times d_{15}, but not less than 0.1. This base soil has no meaningful d_{15} size, and a default value of 0.1mm is used.

The following step focuses on the width of the filter band. The width of the allowable filter design band must be kept relatively narrow to prevent the use of possibly gap-graded filters. To achieve this, two criteria should be considered; the width of the designed filter band should be such that the ratio of the maximum to the minimum diameter at any given percentage passing values less than and equal to 60% is 5 or less. From this the value of actual site sample needs adjustment properly because the value of maximum to minimum ratio equal to 6.3 greater than 5 but the washed one treated and adjusted properly and the result satisfied for the maximum and minimum D_{15} sizes as their ratio is 5. The research took the adjustment of the washed Aguat-wuha dam filter $D_{15}fMax$ (mm) and $D_{15}fMin$ (mm) according to NEH, (1994) at Gradation Design of Sand and Gravel Filters step 7 sub step (ii) the band at the minimum D_{15} side of the range if it is probable there are finer base materials than those sampled and filtering is the most important function of the zone. With the minimum D_{15} size as the control point, establish a new maximum D_{15} size by multiplying the minimum D_{15} size by 5, and locate a new maximum D_{15} size. Label the maximum D_{15} size Control point 1 and the minimum D_{15} size Control point 2.

Additionally, coarse and fine limits of the filter band should each have a coefficient of uniformity of 6 or less. Here, the maximum D_{10} is determined by dividing the maximum D_{15} by

1.2 by assuming the slope of the line connecting D_{10} and D_{15} should be on a uniformity coefficient of about 6. Hence, the value of maximum D_{10} is 0.42mm. This value enables to determine the maximum allowable D_{60} by multiplying 0.42 with 6, and equals to 2.52mm. In turn, the minimum allowable D_{60} for the fine side of the filter band can be calculated by dividing 2.52 with 5, and equals to 0.5mm.

Then determine the minimum D_5 and maximum D_{100} sizes of the filter. These maximum and minimum particle size criteria are defined, for all base soil categories, as D_5 greater or equal to 0.075mm, and D_{100} less than or equal to 75mm. Following this step, criteria for filter segregation during construction is considered. To minimize segregation during construction the relationship between the maximum D_{90} and the minimum D_{10} of the filter is important. In this step a preliminary minimum D_{10} size is calculated by dividing the minimum D_{15} size by 1.2, and the maximum D_{90} is determined based on range of this calculated D_{10} below (Appendix 2). Accordingly, the values of the D_{10} and D_{90} are 0.08 mm and 20mm, respectively.

Then connect Control points $\mathbf{D_{60Fmin}}$, $\mathbf{D_{15FMin}}$, and $\mathbf{D_{5FMin}}$ to form a partial design for the fine side of the filter band. Connect Control points $\mathbf{D_{100F}}$, $\mathbf{D_{90FMax}}$, $\mathbf{D_{60FMax}}$, and $\mathbf{D_{15FMax}}$ to form a design for the coarse side of the filter band. This results in a preliminary design for a filter band. The value completed the design by extrapolating the coarse and fine curves to the 100 percent finer value.

3.3.5.2 Sherard's Recommendations

Experiments conducted at the Soil Mechanics Laboratory, in USDA-SCS on different soils revealed the following criteria (Baharat Singh, 1995);

I. The filter is successful in its function of arresting particles migration if;

$$\frac{D_{15}\ of\ Filter}{d_{85}\ of\ Protacted\ layer} < 9 \text{..} \textbf{(3.2)}$$

This shows that Terzaghi's criterion includes a factor of safety of 2 and conservative.

II. The size of the pore channel, which governs permeability is determined by the size of finer filter particles and will be represented by D15 size.

III. The coefficient of permeability (K) of dense filters is generally in the range of K = 0.2 to 0.6 $D15^2$ with average 0.35 $D15^2$ (K in cm/s and D15 in mm)

IV. The filter gradation curve need not necessarily be parallel to the base material.

- **From Principal Findings of Sherard et a.l (1984b)**

Numerous filter tests were performed (Sherard et al. 1984a), and based on the slot test data (Sherard at el 1984b) four soil categories with **four individual filter criteria** were identified:

1 For sandy silts and clays: $D_{15}/d_{85} \leq 5$ is conservative and reasonable for silts and clays with a significant sand component (d_{85} of 0.1-0.5 mm) (safe).

2 For fine grained clays (d_{85} of 0.03-0.10 mm), sand of gravelly sand filters with D_{15} less than or equal to 0.5 mm are reasonable and conservative (safe).

3 For fine grained silts of low cohesion and without significant sand content (d_{85} of 0.03-0.10mm) and low plasticity, sand or gravelly sand filters with average D_{15} less than or equal to 0.3 mm are conservative (safe).

4 For exceptionally fine soils such as clays and silts with d_{85} less than or equal to about 0.02 mm (not very common in nature), filters with an average D_{15} of 0.2 mm or smaller are conservative (safe).

Because of using the sherard recommendations indicated that the effective pore diameter of a filter (the minimum diameter of pores that will allow soil particles to pass) is about 0.11 times the D_{15}. If the d_{85} of the soil is the same size as the effective pore diameter of the filter ($d_{85}=0.11*D_{15}$), then the filter D15 =9*d_{85} of the soil. According to this finding, the early practice of using $D_{15} \leq 5*d_{85}$ for sandy soils provided a filter with a factor safety nearly 2. Additionally this study showed that for silt and clay soil, progressive clogging occurs where the first colloidal particles pass through the filter and fine sand and silt size particles are caught. Subsequent colloidal particles are then caught forming “a filter cake” with a very low permeability. The filter cake basically seals the filter face over the width of the crack and some distance on each side of the crack, stopping any flow through the crack. The crack then fills with soft soil from slaking of the soil on the sides of the crack. The remainder of the filter (between cracks or openings) is open for receiving seepage water through the pores of the soil. Because progressive clogging occurs with silt and clay soils, the D_{15} is allowed to be up to 9*d_{85}.

3.3.6 Clogging Criteria Analysis

Indraratna et al. (1990) reported a relationship between the coefficient of uniformity and clogging. Several series of tests were ducted, and in fine to medium sand filters, a clogging filter was detected with uniformity coefficient. The uniformity coefficient (Uc) is a numeric estimate of how sand is graded, and is a dimensionless number or in other words it has no units. The term graded relates to where the concentrations of sand particles are located by size.

According to DOH Staff Researcher at Sand/Media specification (Eliasson, 2002), filter with small grain size slow the water movement and increase the chance of clogging. The effective size (D10) and uniformity coefficient (Uc) are the principal characteristics of granular media treatment systems. And also Eliasson cited Crites and Tchobanoglous, (1998), the primary sand characteristics affecting filtration performance are the effective grain size and uniformity coefficient. These characteristics tend to affect the retention time of liquid passing through the filter and the potential for clogging.

From Eliasson citation, a uniformity coefficient of 4 or less is recommended for all filters (National Small Flows Clearinghouse, 1997; Crites and Tchobanoglous, 1998; EPA, 2002). This recommendation is intended to avoid clogging at higher loading rates (Darby et al., 1996). Sands from most natural sources are widely graded containing a variety of grain sizes, which results in a high Uc.

$$\mathbf{CU} = \frac{\boldsymbol{D60}}{\boldsymbol{D10}} \qquad (3.3)$$

3.3.7 Considered aspects during design of filter material

Some considered aspects necessary for filter shown by Messerklinger S (2013), was self healing, Drainage capacity and Material durability are some used for this research

I. Drainage capacity

According to Terzaghi criterion and Sherard recommendation stated on Messerklinger S. (2013) D15f/d85b ≥ 4 and D15f ≥ 0.2 mm respectively still applies.

II. Self healing Performance

According to Messerklinger S (2013), the filter material must not have cohesion. This is assured by limiting the content of non-plastic fines to less than 5% at particle size 0.075mm.

III. Material durability

The durability of filter materials is typically investigated with standard tests such as the Los Angeles abrasion test (ASTM C535) or the wet and dry strength variation (typical limit ≤35%). However, for important dam structures a mineralogical and chemical investigation of the dam material is recommended. This can highlight if the material has inclusions of (i) swelling clay minerals or (ii) minerals which dissolve in water, e.g. gypsum or carbonate rocks. Latter materials cannot just dissolve but also re-cement at the particle contacts and create true cohesion. Materials with carbonate and sulphide content should be used with care for dam filter materials. Although naturally occurring gravel and sands sometimes can be used for filters and drains with little or no processing, drainage aggregates usually need to be treated. Most natural sand and gravel deposits are highly variable in grading from point to point in a borrow area, or they are covered or interbeded with silt and clay which is difficult to remove (Cendergren, 1977).

3.3.8 Filter Material Contamination

Contamination of filters during construction is a common problem. Crossing the filters and drains with construction equipment can contaminate or move the filter or drain material causing serious damage and disruption of the filter width.

Also contamination with dust can occur when dumping adjacent filter material without water sluicing or at an excessively dusty location such as adjacent to a haul road with little dust control.

Protection with a geo-textile or geo-membrane is a technique that is often used during prolonged periods of inactivity, during persistent rainy periods, or when the filter is otherwise vulnerable to contamination

For the case of Aguat-wuha dam contamination occurs during periods of rainfall when muddy runoff carries fines to partially constructed filter zones and also to the stocked filter material. This can occur from erosion of a partially constructed fill surface or from erosion of the abutment areas. Contamination of the coarse filter or of drain material with eroded fines can and often does occur. In this case, fines will penetrate the material because of very fines of eroded soil than the size of the stocked filter material and partially constructed filter zone. Therefore the Aguat-wuha dam's partially constructed filter was contaminated as shown below fig 8 and causes destruction of the constructed filter zone it also shown at fig 9.

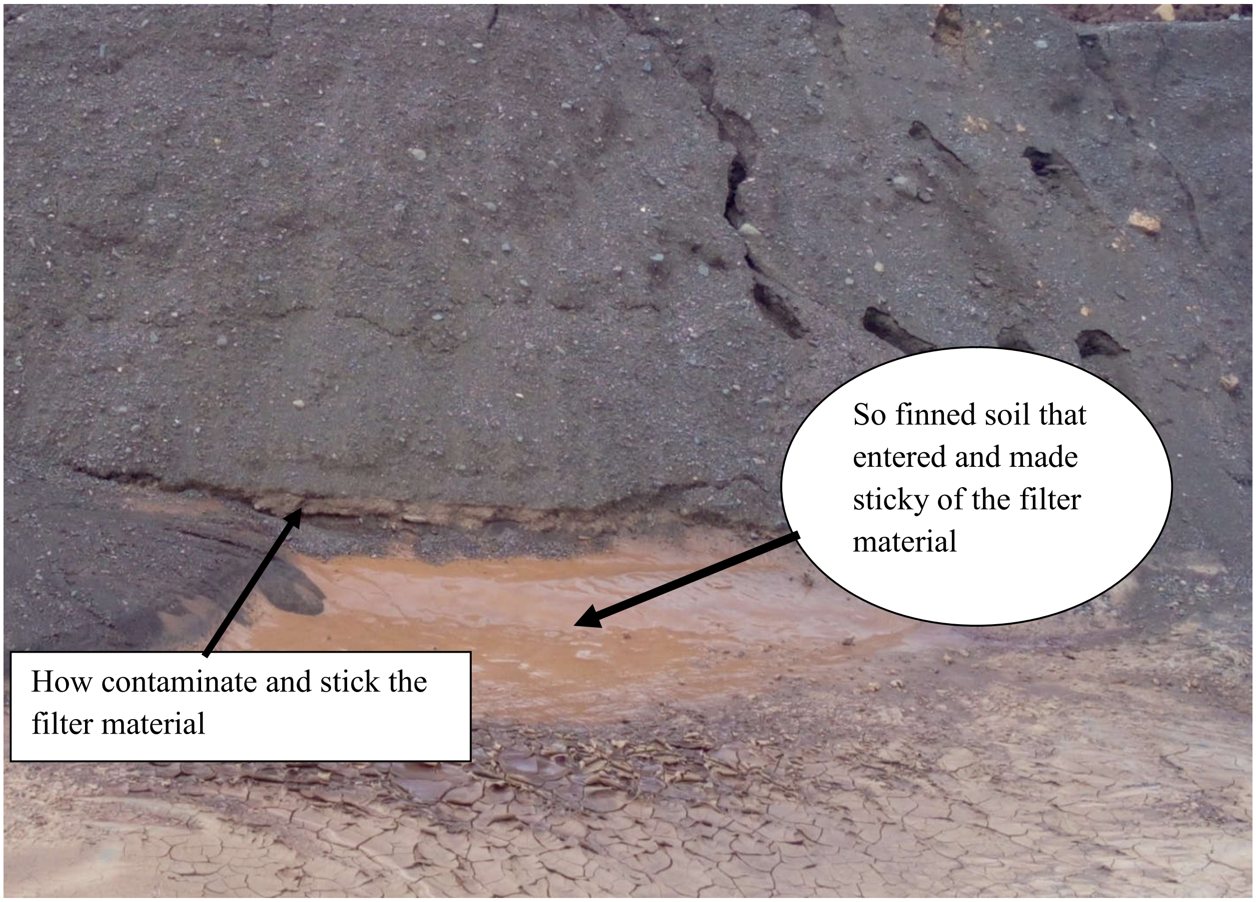

Figure 8: contaminated stock filter material of Aguat-wuha dam

Due to contamination of partially constructed filter zone that comes from fill material by unwanted flood and unexpected rain, costly repair can result. It is common practice to restrict the crossing of filter zones to specific locations, thus reducing the exposure of filters to damage. Where crossings occur, the filter/drain system should be protected; geotextiles, geomembranes, and/or a protective fill, are commonly used. Crossings should be moved horizontally from lift to lift, especially adjacent to abutments, to avoid a vertical zone of material that has a higher probability of contamination.

3.3.8.1 Inadequate Construction Surveillance/Inspection

Inadequate specifications and inadequate field surveillance can leave many critical decisions improperly made. The result is that the intended quality and function of the filters are easily compromised. Filters that are constructed under inadequate specifications and surveillance should not likely perform as intended and the long-term safety of the embankment dam containing such filters may be in doubt. Therefore on Aguat-wuha dam, destruction or fall of partially constructed filter was due to improper inspection and inadequate construction measurements along the abutment as shown below fig 9. From figure the constructed filter totally dismissed near to the abutment. Because did not have sufficient inspection for constructed drainage to control the coming high flood or runoff on the side of the abutment. Additionally lack of supportive protection for constructed drainage like changing some of the flood source direction out of the site and minimize the volume of flood that entered to the construction area.

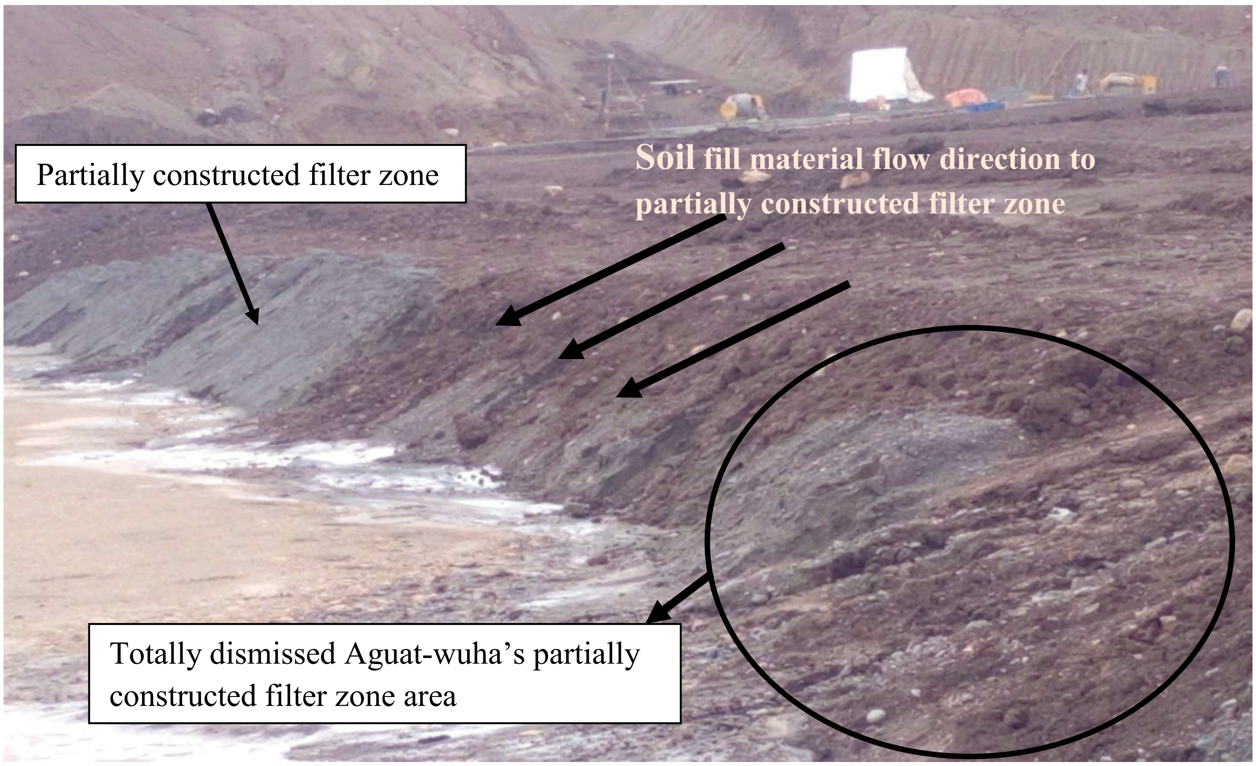

Figure 9: contamination of partially constructed filter zone

Commonly, the owner with professional material inspector organizes a field team to perform the tasks of quality control and quality assurance to enforce the specifications and to provide surveillance during construction. The field staff must maintain close contact with the designers for decisions related to the design intent. In addition, the design team makes frequent trips to the site to provide additional input as needed and for routine inspection. The combined effort of these activities is to increase the success rate of translating the design intent to the actual constructed product.

Due to the result of runoff the partial constructed filter damaged as shown below figure. But not only the abutment area even due to the runoff discharge increment the filter zone damage extended up to 5m horizontally from the abutment as shown below fig 10.

Figure 10: contaminated by fill soil and loose serviceable partially constructed filter zone

In otherwise the construction bonds on Aguat-wuha dam especially the filter and the core was improper as shown fig 11. Keeping the elevation of the filters higher than the adjacent fill can minimize such problems. Slopping the embankment surface away from the filters will force runoff toward the outer slopes of the embankment and away from the filters. But the actual construction method was one aspect for contamination of the filter. Because protect the filter material from contamination by core, made the filter more elevation than the core and also should use like spreader box as shown below fig 12 in order to made proper bondage and also to get accurately inspected width of filter zone. Additionally the spread box as the research seas from related area around Debremarkos at Lumame area dam namely Taba earth dam constructed on this way using spreader box. But it shows not only the width perfection and contamination protection it also uses for material saving. But not carried out at the Aguat-wuha dam or not use other related remedial measures for proper placement as shown below fig 11.

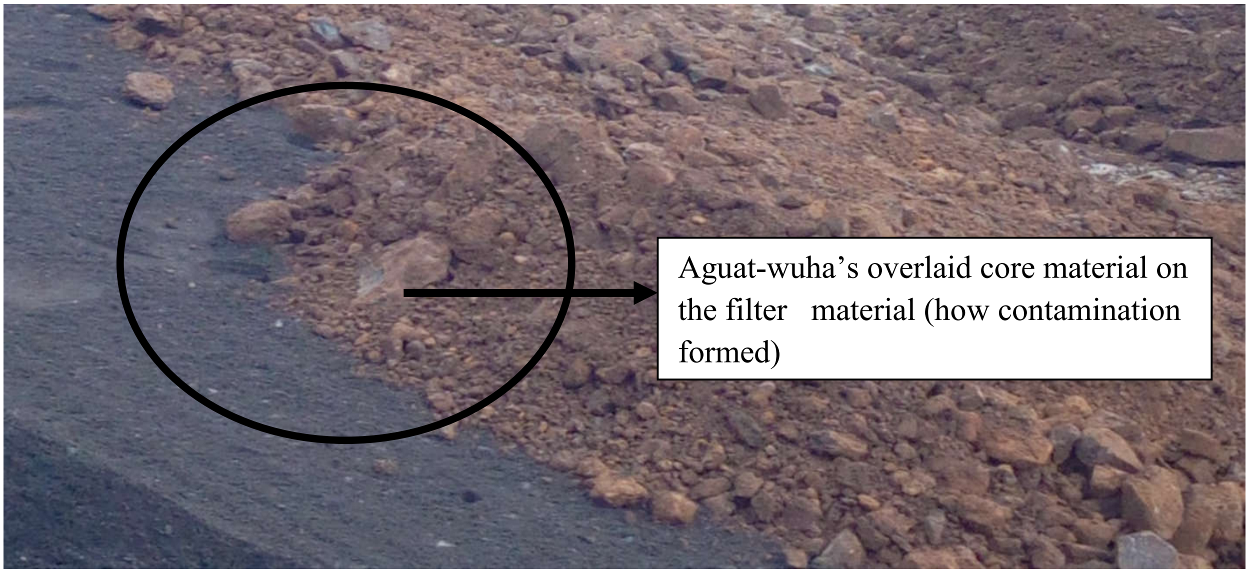

Figure 11: Contamination of partially constructed filter zone

Figure 12: Filter material spreader box

Material is dumped into the spreader box bin, which is then pulled or pushed (depending on the particular operation) along the axis of the filter/drain zone. As the spreader box moves, material feeds out the rear of the box, releasing material at the specified loose lift thickness and width. Use of this device can be somewhat cumbersome, but is usually worth the extra effort as no blading or trafficking by equipment (other than by the prime mover for the box) is required to place the filter/drain material in the exact loose lift thickness and zone width.

3.4 Input Parameter for Assessing Filter Criteria

Table 6: Actual site (before wash) sample on dam site Data

S/N	Required Parameter	Sample Numbers Before Wash						Re-mark
		AGWDF 1	AGWDF 2	AGWDF 3	AGWDF 4	Aver-age	Re-graded	
1	**D15(mm)**	0.2	0.2	0.2	0.2	0.2	**- - -**	
2	**D10(mm)**	0.1	0.1	0.1	0.1	0.1	**- - -**	
3	**D60(mm)**	0.8	0.8	0.8	0.8	0.8	**- - -**	
4	**D30(mm)**	0.4	0.4	0.4	0.4	0.4	**- - -**	
5	**d15B(m)**	- - -	- - -	- - -	- - -	- - -	**- - -**	
6	**d85B(m)**	0.07	0.07	0.07	0.07	0.07	**- - -**	
7	**D15FMax (mm)**	0.63	0.63	0.63	0.63	0.63	**- - -**	
8	**D15FMin (mm)**	0.1	0.1	0.1	0.1	0.1	**- - -**	
9	**Cu**	6.3	6.5	6.4	5.5	6.2	**- - -**	
10	**Cc**	1.6	1.6	1.5	1.3	1.5	**- - -**	
11	**Percent fines (%)**	5.7	5.8	5.8	5.5	5.7	**- - -**	**> 5%**

Table 7: After wash sample Data

S/N	Required Parameter	Sample Numbers Before Wash						Remark
		AGWDF1 washed	**AGWD F2wash ed**	**AGWDF 3 washed**	**AGWDF 4 washed**	**Av-erage**	**Re-grade d**	
1	**D15(mm)**	0.3	0.3	0.3	0.3	0.3	0.3	***The value tak-en from the washed Aguat wuha dam filter material***
2	**D10(mm)**	0.2	0.2	0.2	0.2	0.2	0.2	
3	**D60(mm)**	0.9	0.9	0.9	0.9	0.9	0.8	
4	**D30(mm)**	0.5	0.5	0.5	0.5	0.5	0.4	
5	**d15B(m)**	- - -	- - -	- - -	- - -	- - -	**- - -**	***This values taken from the fill material core (base)***
6	**d85B(m)**	0.07	0.07	0.07	0.07	0.07	**- - -**	
7	**D15FMax (mm)**	0.5	0.5	0.5	0.5	0.5	0.5	
8	**D15FMin (mm)**	0.1	0.1	0.1	0.1	0.1	0.1	
9	**Cu**	3.9	4.0	3.9	3.8	3.8	3.8	**< 6**
10	**Cc**	1.0	1.0	1.0	0.9	1.0	1.0	
11	**Percent fines (%)**	1.8	2.0	2.5	2.4	2.2	2.2	**< 5 even < 3**

4 RESULTS AND DISCUSSION

4.1 Material in Soils Finer Than 75 µm (No. 200)

The research takes 1540gm sample of filter material from the dam and then washed properly and then dried the sample. Therefore the results are shown below (table 8).

Table 8: Results for Material in filter finer than 75µm

Silt and clay content test by washing method						
A	**before washing weight (gm)**	1540	1540	1540	1540
B	**After washing weight (gm)**	1453	1439	1441	1465
C	**A-B**	87	101	98.9	75.3
silt and clay content (%) =C/A*100		**5.62**	**6.56**	**6.42**	**4.89**
		Average	**5.873 > 5%**		

According to ASTM the filter material finer than the 75-µm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than with dry sieving. Therefore, when accurate determinations of material finer than 75-µm sieve in soil are desired, this test method is used on the test specimen prior to dry sieving. Usually the additional amount of material finer than 75-µm sieve obtained in the dry sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked, as it could be an indication of degradation of the soil.

The present research carried out wash and determined the sample is dry sieved after washing as shown above table 8; because some material will pass the 75-µm (No. 200) sieve that did not pass during washing operations. This can be a significant amount for samples with a high percent of very fine sand or coarse silt.

From the result out put the sample that used for construction of Aguat-wuha dam has an effect due to entrance of fine or silty that passes on sieve size 200 or -0.075 has more than 5%. Therefore it needs treatment from this the economical one was wash. Therefore the result shows the filter material has an error and it has negative effects on the dam due to filter much fines and leads to silt or clay.

So that, ASTM standard stated quality of the result produced by wash is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Generally considered capable of competent and objective testing/sampling/inspection/etc are the best ways to get reliable results. It generalized that a specimen of the soil is washed over a 75-µm (No. 200) sieve. Clay and other particles that are dispersed by the wash water, as well as water-soluble materials, are removed from the soil during the test. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-µm (No. 200) sieve by washing.

4.2 Geometrical and Empirical Results

4.2.1 USDA-SCS

The geometrical suitability of the filter that suggested and placed on Aguat wuha dam is analyzed using USDASCS, Engineering Division 1986 design procedures. It is based on the type of base soil in terms of its grain size or gradation. This showed that the basic requirements could best be met by designing the particle size of the granular filters in relation to the particle size of the soil being protected. Therefore based on USDASCS 12 steps the following (table 9) result detected.

Table 9: Results of USDA-SCS Method

Control points	Result
D5FMin	0.075mm
D10FMin	0.08mm
D10FMax	0.42mm
D15FMin	0.1mm
D15FMax	0.5mm
D60FMin	0.5mm
D60FMax	2.52mm
D90FMax	20mm
D100F	10mm

Table 10: Control points for coarser

Particle size	Coarser Filter
75	100
20	90
2.52	60
0.5	15

Table 11: Control points for Finer

Particle size	Finer Filter
2	100
0.5	60
0.1	15
0.075	5

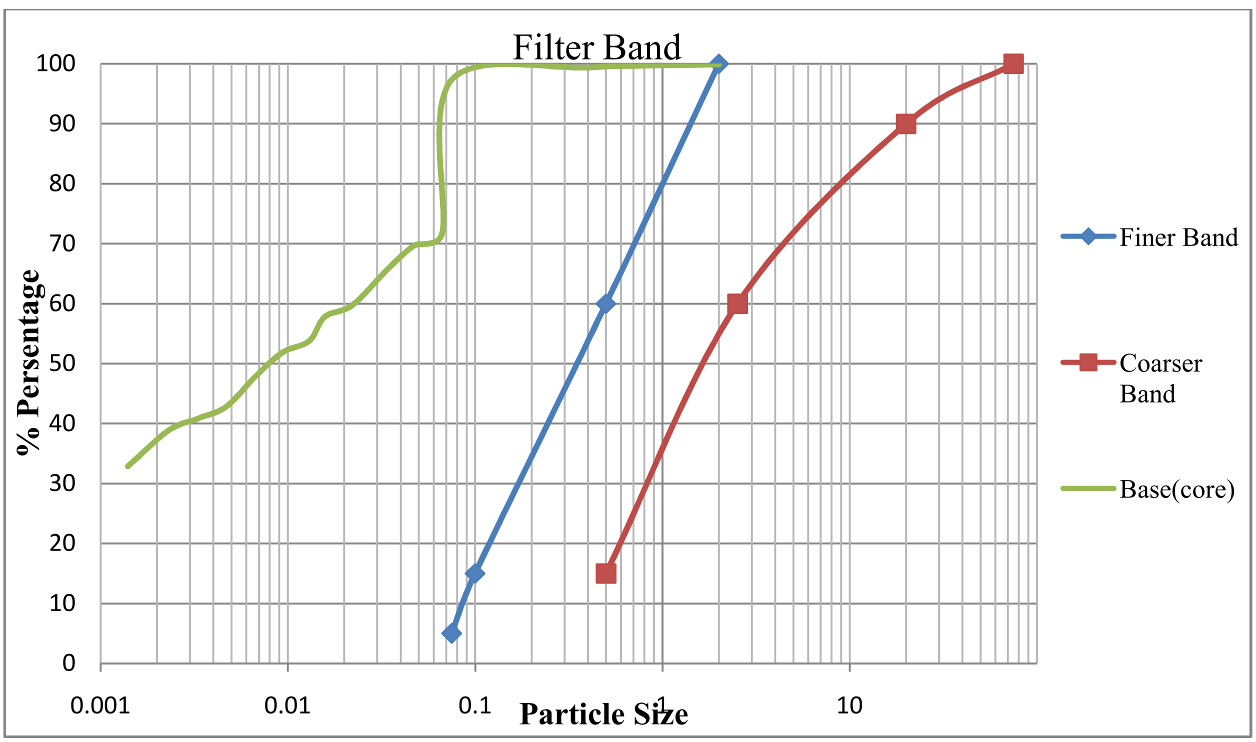

Figure 13: Filter Band after connecting the extrapolated control point

The above graph shown at figure 8 was the connected value of finner part that displayed in blue color, those points are **D_{60Fmin}**, **D_{15FMin}**, and **D_{5FMin}** to form a partial design for the fine side of the filter band and also the red color was control points for the coarser part those points are **D_{100F}, D_{90FMax}**, **D_{60FMax}**, and **D_{15FMax}**. Both bands are the boundary of filter gradation for protracting the core material. The fine limits of the resulting filter sand were then used to develop the drain gradation because drain gradation needs to meet filter criteria for the transition/filter materials, so the fine limits restricts the over fineness of filter for improving draining ability of the filter material.

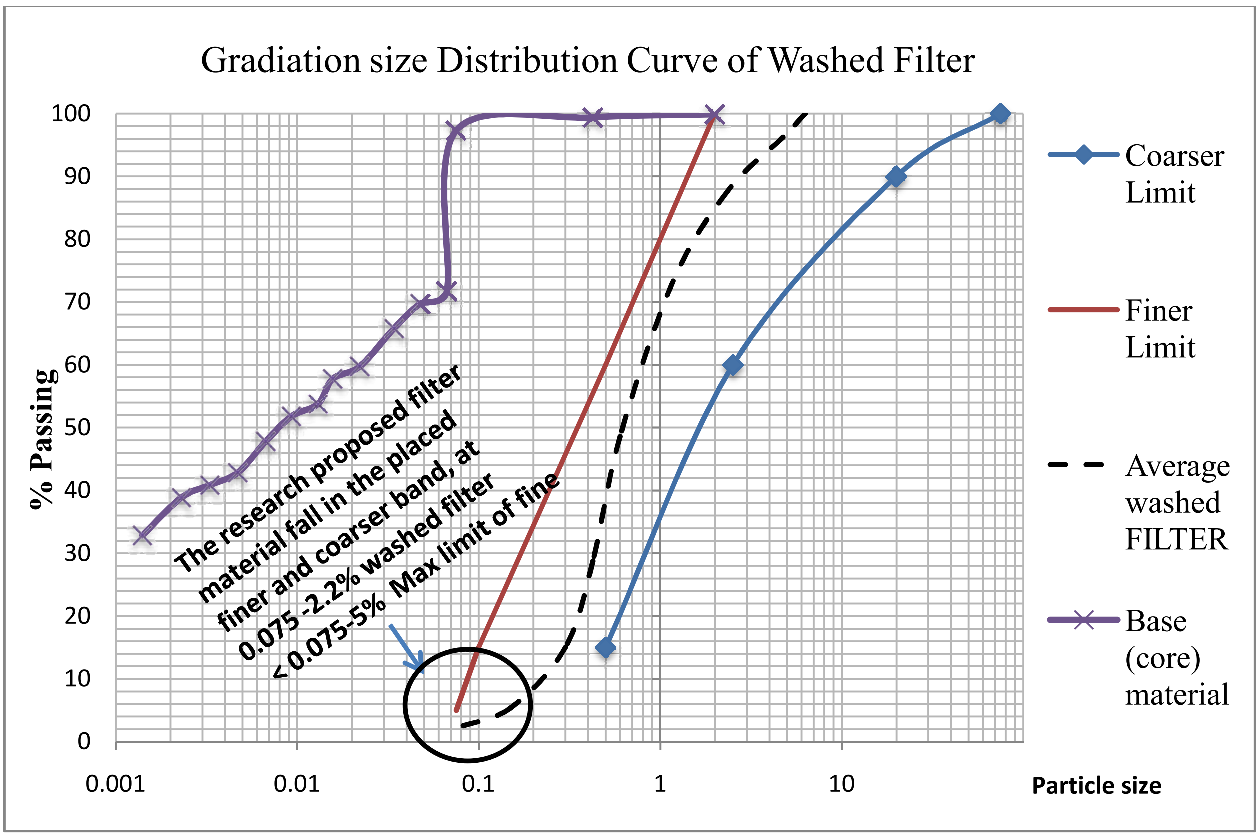

Figure 14: Grain Size Distribution Curve for the Average Washed Filter Material

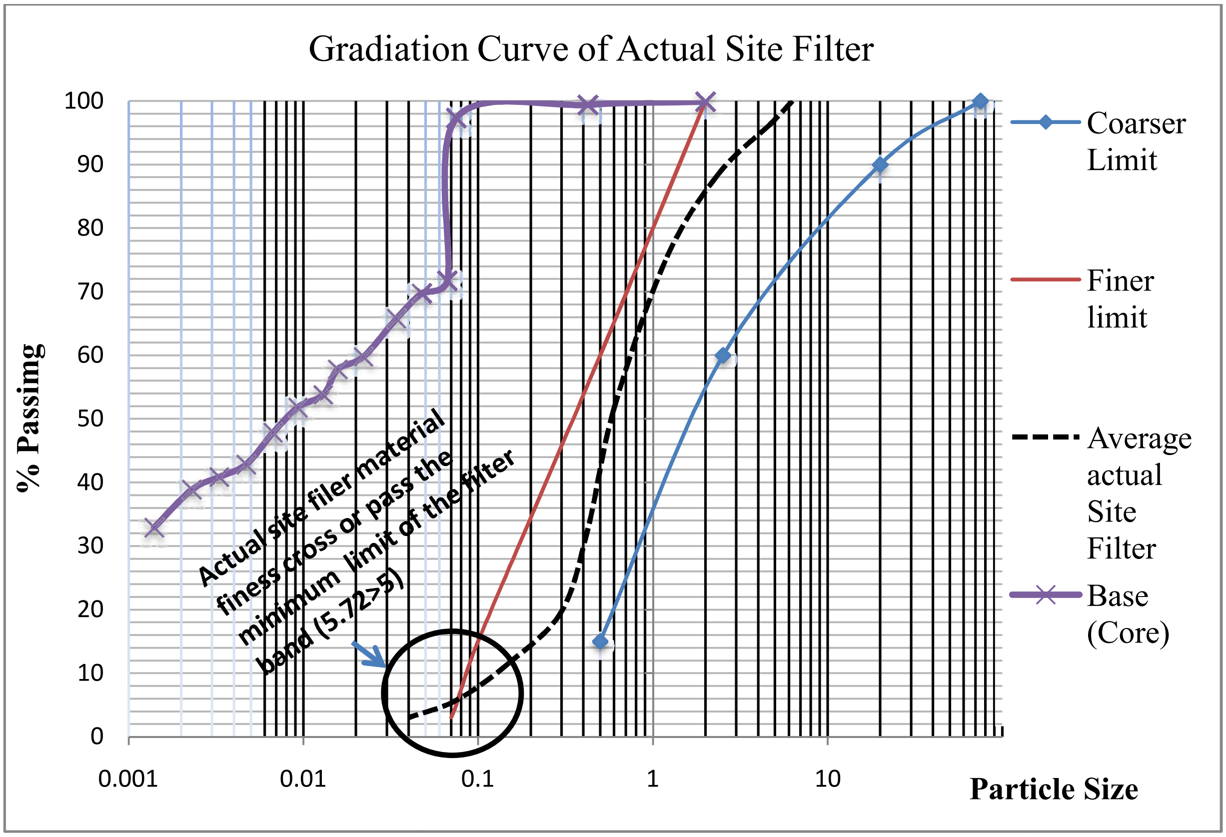

Figure 15: Grain Size Distribution Curve for the Average Actual site Filter Material

The gradation distribution of washed Aguat-wuha dam can be specified as suitable filter material for the protection of the base soil and also as appropriate drainage, both as chimney and horizontal filters. Because the research applied the adjustment of the treated or washed sample was used as filter.

Therefore, according to the above figure (fig 10) of the actual site data assessment and the research data and taken treatment like proper wash of actual site filter material comparison the present study indicated (figure 9) an attempt has been made to highlight some of the facts with following reasons;

The actual site have not correct adjustment because according to NEH, (1994) the filter material should prevent gap graded and this are checked by taking the ratio of maximum $D_{15}F$ and minimum $D_{15}F$ value was less than or equal to five (5). So the result of actual site filter material parameter ratio equal to 6.3. Therefore it shows greater than 5, that does not satisfy the criteria for prevention of gap grade. Additionally as it is demonstrated in figure 16 below, the filter band at the finer side some intersection occurred between the two curves, that the proposed filter passes the ultimate limit of finer band 5% passes at particle size 0.075mm to prevent crack and cohesiveness. As it was shown in figure 16, the actual site filter material average passed 5.72% at particle size 0.075mm.

But filter which was treated properly from through washing was effective to remove fine material and the prevention of gap graded criteria also staisfied, where the ratio of maximum to minimum D_{15} equal to 5. As shown the above figure of washed filter the recommended treated filter not pass the the finner limit band and also the value of silt content minimized and prevention of crack more available than the actual site regarding perviousness has higher than the autherity provided and constructed filter.

4.2.2 Sherard Recommendations

Different scholars identify their own criteria for filter from them the research refers and use justification based on Sherard d_{15B} has no significant influence on the retention properties of the filter. In many design situations it is necessary to ensure that the permeability of the filter is sufficiently greater than the base soil permeability to drain the soil and prevent a buildup of high pore pressure. Hence, the use of d_{15B} is not recommended to represent filter performance. But as basic filter criteria it is required that the gradation curve of the filter material must be parallel to the gradation curve of the core material. However, Sherard's criterion is relaxed from this condition as aback failler.

Table 12: Criteria Checking Result as Per Sherard Recommendations

Criteria	Sampled Filters		Remarks
	AGWDF 1	AGWDF **1"washed**	
I.	2.86	4.28	
II.	0.2	0.3	
III.	0.014	0.0315	K values
IV.	Not Parallel	Parallel	
	Nearly satisfied	Fully satisfied	

Therefore based on Sherard's recommendation and principal finding the actual site filter result shows nearly satisfied the criteria but the pervious result shows poor because the value shows too small and the case for this are the occurrence of finer or silt particle more than the percentage passing of 5%.

But the result of the treated or the washed sample shows fully satisfied the criteria with more pervious value than the actual site.

Depending on the principal findings of Sherard the actual site sample or before washed sample not fulfilled either of the listed finding because the value of d85=0.07 (Core) and the value of D_{15} = 0.2 (Filter), therefore the range on the above list of this value not identified

The treated filter lies in between the soils indicated in the criteria of Sherard's principal finding (1984b). Because, it satisfy the criteria identified on the principal finding. So that it is fine grained silts of low cohesion and without significant sand content, have d_{85} that 0.07mm with high plasticity and sand filter with D_{15} equal to 0.3mm for the washed filter. This almost satisfied the requirements. Since the recommendations have some degree of conservatism or safety factor, the proposed filter can be used safely for the intended purposes according to these Sherard's recommendations.

4.3 Clogging

The relationship between the coefficient of uniformity and clogging several series of tests were ducted by different scholars like Indraratna et al. in 1990, and in fine to medium sand filters, a clogging filter was detected with uniformity coefficient. The uniformity coefficient (Uc) is a numeric estimate of how sand is graded, and is a dimensionless number or in other words it has no units. The term graded relates to where the concentrations of sand particles are located by size.

Table 13: Filter Clogging Check for at site and treated Filter Materials

Sample Name	**Actual site filter**	**Treated filter**	**Standard value was Less than (<)**
AGWDF 1	6.3	3.9	4
AGWDF 2	6.5	4.0	4
AGWDF 3	6.4	3.9	4
AGWDF 4	5.5	3.8	4
Average	6.2	3.8	4

Totally actual site filter material was not satisfied because the CU value greater than 4 and it was near to clog. Therefore the constructed filter of Aguat-wuha was lead to clog for coming serviceability and not easy for maintenance. But the treated was almost satisfied the standard. Except sample 2 all was satisfied far from clogging nearly because they was less than 4 but sample 2 was equal to the maximum criteria value of CU. So those, the average value satisfy the criteria recommendation.

It’s important that the sand grains all be about the same size; i.e. relatively uniform for uniformity coefficient of 4 or less. This recommendation is intended to avoid clogging at higher loading rates (Darby et al., 1996). Sands from most natural sources are widely graded containing a variety of grain sizes, which results in a high Uc. If the grain sizes vary greatly, the smaller ones will fill the spaces between the larger particles, making it easier for the filter to clog (National Small Flows Clearinghouse, 1997).

From the result data of constructed and the research proposed filter namely washed filter coefficient of uniformity value the authority constructed filter are totally vulnerable to clogging because the value greater than 4(four) but the washed one was invulnerable to clogging in all sample of treated sample except sample 2 was equal to the ultimate value to control clogging but not less so this sample was included and guided by average value because the average of all sample are satisfy the criteria to protect the clogging of filter material.

4.4 Considered Aspects (Criteria) During Design of Filter Material

From the design state of the art filter materials, the following aspects are considered: (a) Self healing (b) Drainage capacity (c) Material durability. From this the research identifies self healing performance and draining capacity the filter material.

4.4.1 Self healing Performance

ASTM C 33 specifications to satisfy the function of a filter, sands should be “self-healing.” This refers to the ability of a sand to adjust and fill any cracks that may form in the surrounding earthfill. A filter zone should not be able to sustain a crack through itself if it is to function satisfactorily. According to Messerklinger S (2013), the filter material must not have cohesion. This is assured by limiting the content of non-plastic fines to less than 5% at particle size 0.075mm.

The result value of fine content for the actual site or constructed and treated filter sample was tabulated below

Table 14: Fineness Content of Constructed and treated Filter Material Samples

Particle name	AGWDF1 % Passing	AGWDF2 % Passing	AGWDF3 % Passing	AGWDF4 % Passing	Average Value
Site material	5.7	5.8	5.8	5.5	5.72
Treated material	1.8	2.0	2.5	2.4	2.2

In addition to grain size criteria that ensure restraint of the base soil while allowing free passage of water, a filter must also be graded so that the filter itself will no crack. To ensure that filters will not support cracks and replacing the crack by healing itself, most current filter gradation criteria require that no more than 5% of the filter material should be finer than the #200 sieve, and that the fines within the filter should be non-plastic.

Therefore according to the justifications of different investigations shown above (table 14) the actual site filter sample of Aguat-wuha dam not satisfy self healing performance because the fineness of the sample averagely 5.72% was greater than 5% and this lead the filter into sticky and clog the filter material due to this the filter vulnerable to crack loss the base material and it has poor self-healing characteristics has excessive fines or chemical cementation that causes it not to collapse when saturated. But the treated material shows averagely fineness content was 2.2%, this shows less than the limit of fineness 5% at sieve #200. Therefore the treated one was more suitable and has self healing performance regarding ability to sustain a crack and also cohesiveness was small and not leads to sticky and vulnerable to crack than that of the authority constructed filter.

Filter fine content increasing more than 5%, do not improve filter performance, also cause increasing pore water pressure and improper filter performance in the embankment dams must be expected Sakamoto et al. (2002).

The ability of the base material to be self-healing is partly dependent on the cohesion of the soil or its ability to flocculate.

4.4.2 Drainage capacity

It was found that the value of constructed filter and treated filter shown below table. Additionally the samples have the same input parameter for comparing the drainage capacity for actual material and treated sample. Therefore the research takes one sample name from constructed filer samples and also taken one sample from treated samples as shown below (table 16).

Table 15: Result of drainage capacity for constructed and the treated filter sample

Sample name	**D15f/d85B**	**D15f**
AGWDF 1**washed**	4.28	0.3
AGWDF 1	2.86	0.2

Therefore the sample of constructed actual site filter material not satisfied because the value 2.86 < 4 on Terzaghi criteria even at Sherard recommendation the value was 0.2 = 0.2 but the research proposed filter satisfied fully the Terzaghi criteria and the Sherard recommendation the value was 4.28 >4 and 0.3 >0.2 respectively. From the above stated value of criteria and recommendation the washed sample satisfied drainage capacity.

4.5 Contamination Formation of Filter Material

The study determined two formed contaminations on Aguat-wuha's filter material those are on stock and on partially constructed filter zone. Therefore the stock filter contaminated due to

- Poor Placement and spreading techniques
- Insufficient and lack of well sized drainage in all working area and also lack of special drainage design around the abutments of the dam to control unexpected runoff
- Poor spreading requirements
- Poor locations and measures to protect crossings of filter and drain systems like haul road crossings.

Also partially constructed filter of this dam contamination formed due to the following causes

- Poor selection of slope for stocking filter material

- Lack of material requirements for protection runoff entry like concrete at the underneath of the stock, geomembrane and the same like protective materials.

Generally, keeping the elevation of the filters higher than the adjacent fill can minimize such problems. Slopping the embankment surface away from the filters will force runoff toward the outer slopes of the embankment and away from the filters. Therefore from the research determination below results fig 16, the stocked filter material contaminated from 60-80cm due to runoff from the ground and also the over fined and unwanted material entry shown at fig 17. This ranges shows contamination increment or declination area of stocked filter material.

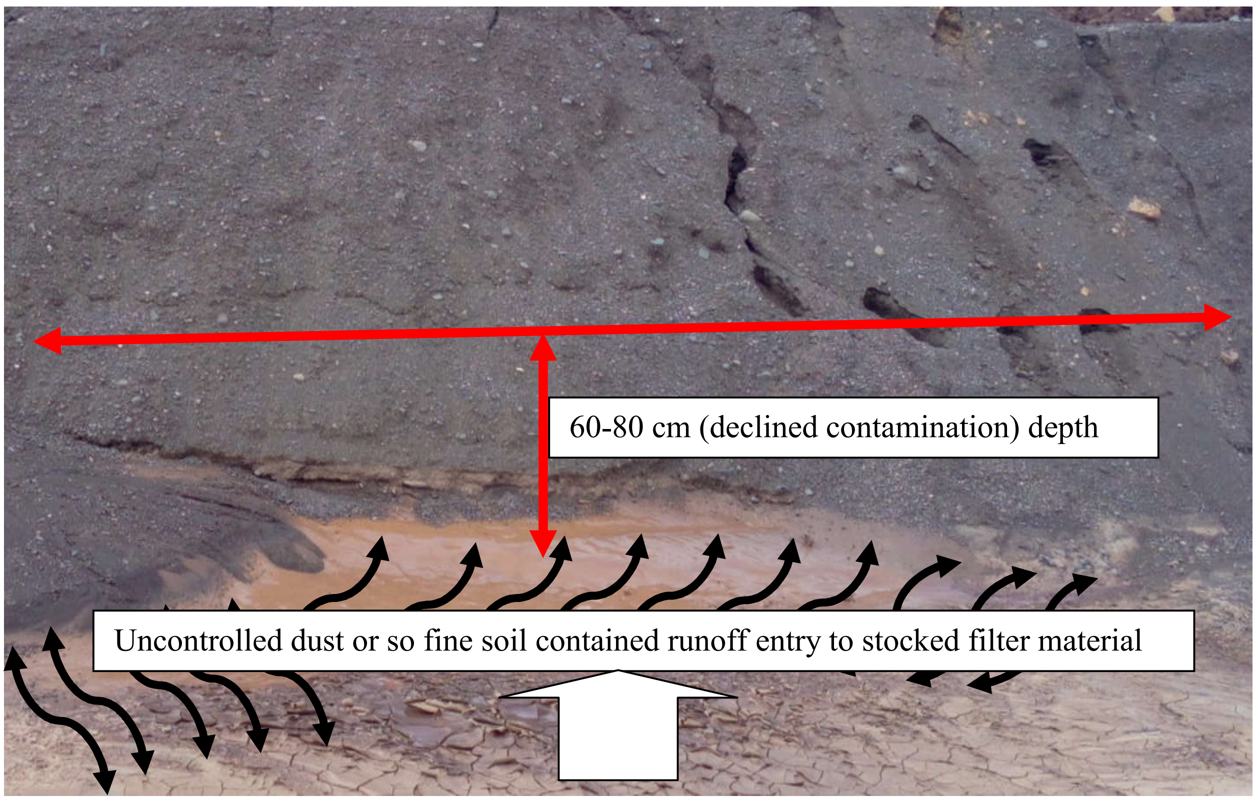

Figure 16: excessive contamination area of the stocked filter material

From the above figure (fig 16) the black zigzagged arrow shows the runoff entry face to the filter material stocking area and sticky and made filter cake forms for Aguat-wuha dam filter. Also fixed arrow forms at the upper side of the stock or runoff entry arrows (red color) are for showing the depth and area of stocked filter that are mostly contaminated area of Aguat-wuha dam. From this the contamination ranges and effect of that dust runoff entry was shown below. Additionally, due to rainy season, the rain fall has positive effects at the top of stocked filter material. Because it makes cleaning of the stocked than before what it had. Therefore the ranges are shown below figure based on their depth regarding the unwanted fine contaminating material value that passes at sieve size of 0.075mm. Therefore the result shown below (fig 17) shows the percentage of fine material that entered to the filter material. So the pyramidal diagram from 2.9% - 4% the upper stocked filter material (from 80cm-the upper end) shows cleaned and well performed material because it is not susceptible (harmed) by runoff and also additional wash appeared by the coming rain. But from ground to 80cm depth result was easily contaminated by runoff and its percentage passing of fineness at sieve 0.075(#200) was 4%-8.4% because the runoff easily entered to the stock due to sufficient protective measures was not carried out. This was already contaminated and poor suitability for construction of the filter.

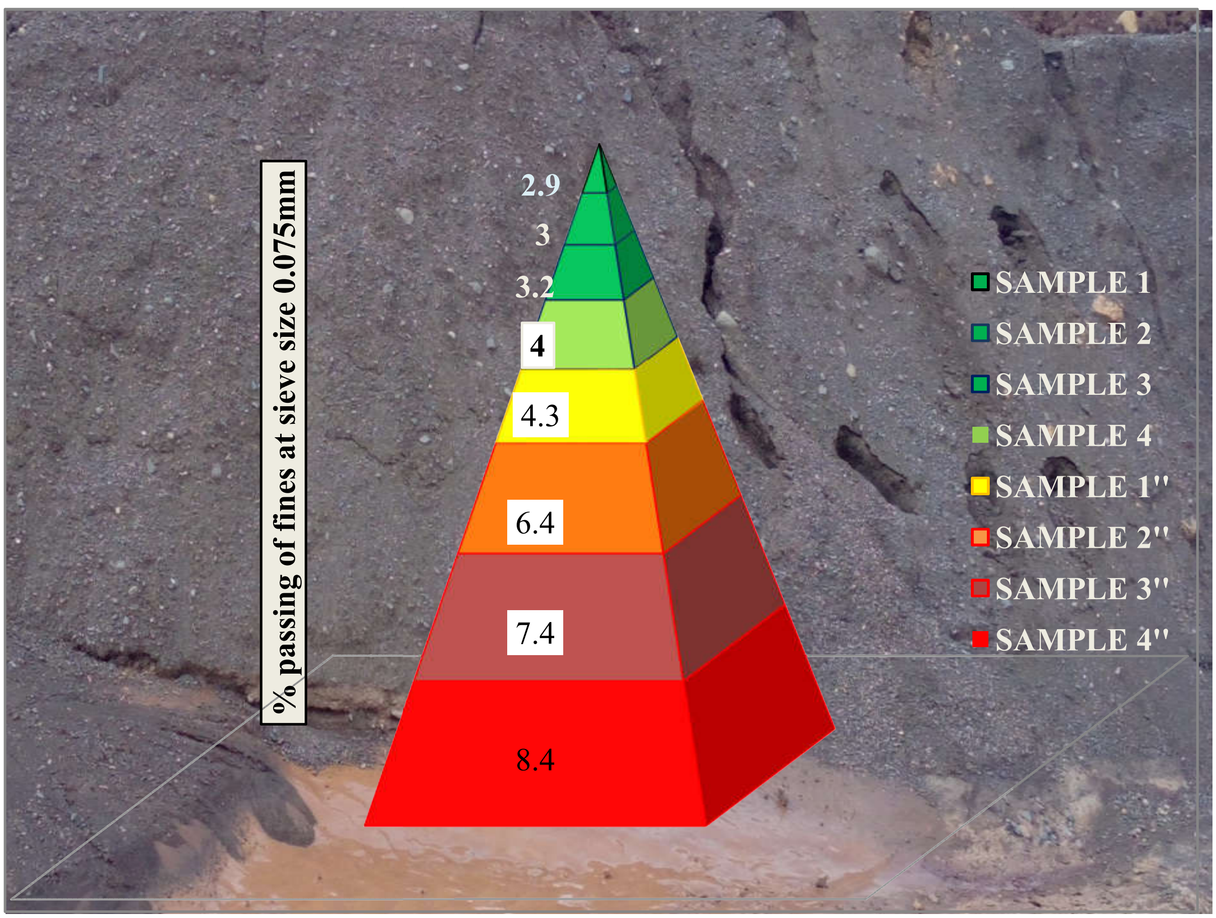

Figure 17: over fined contaminator ranges of stocked filter material

Therefore the above mentioned contamination occurred due to malfunction and poor placement of stocked filter material. Also not placed possible remedial measures and solutions to protect the contamination for partially constructed and also for stocked filter material. For example :-

1 For Constructed filter

a) **Haul road crossings: -** In order to construct a zoned embankment, equipment used to construct other zones must inevitably cross the filter/drain/transition zone. Equipment crossings are fraught with potential for contamination of the filter/drain, for reduction in filter/drain width, and for the filter/drain to be partially or completely cut off vertically. Therefore, special measures must be taken to ensure that the crossings do not adversely affect the design cross section or the desired properties of the filter/drain. Equipment crossings must be controlled; they must be kept to the absolute minimum necessary and must be in definite and confined locations. All personnel working on the dam must be instructed as to crossing locations and the importance of utilizing them. All personnel working on the dam must be instructed as to crossing locations and the importance of utilizing them. Crossings are kept to a minimum and are at specified, confined, and well-marked locations, one method to protect the filter/drain is to place a sacrificial pad of drain material at each crossing. This pad should be wide enough to accommodate equipment. When the crossing is no longer needed, the pad and drain material below the crossing and well beyond its width are excavated and the drain brought back to desired grade with clean, well compacted filter/drain material.

Another method requires the placement of a heavy geomembrane or steel plates over the drain at the crossing to help protect the material from effects of vehicle traffic. Even with the use of a geomembrane or steel plates, some undercutting and backfilling of the filter/drain material will still be required, but usually not to the extent required without the covering.

b) Surface grade: - The surface grade of the embankment should be maintained in a manner that the filter is protected at all times from contamination by surface runoff. To accomplish this, the filter/drain should be maintained at the crown of the embankment surface and protected by whatever means necessary (grading, windrows, etc.) at the end of a shift or when impending storms are forecast. In addition, the embankment surface should not contain low areas, especially those that involve filter/drain zones. Inspectors should watch for contamination resulting from overzealous water truck operators on adjacent zones. Whenever contamination of filter/drains occurs, all contaminated material must be removed prior to resumption of normal placement operations.

2 For Stocked filter material

a. **Use stocking pad: -** to minimize contamination between the stockpile and ground surface. Stocking pads can consist of concrete, geomembrane, or an over-excavation backfilled stockpile material.

Generally the constructed material was almost not fulfill filter efficiency because due to the entrance of over fined filter material its permeability was minimized and almost not able to made filtration for the coming servicing time. Regarding that it was vulnerable to clogging and also do not have sufficient draining capacity.

Additionally the research determined general ensuring of a quality product. Therefore proper control during construction must be treated as an important and integral part of the process by which a project grows from inception to reality. The importance of effective control of construction cannot be overemphasized. No matter how thorough and complete a design, without proper control during construction, there cannot be any great degree of confidence that the desired end product has been attained. So the contamination occurred due to the lack of below the research determined two basic quality control activities:

1) Quality control and,
2) Quality assurance

1) **Quality Control (QC):-** Quality control is generally a planned system of activities or processes that ensure the intended product quality is attained. Specifically for construction of filter/drain/transition zones in embankments, the purpose of QC is to ensure the specification requirements are met and to provide as-built documentation of the constructed product. Normally, QC consists of field inspections, field measurements, surveying, and laboratory testing. Quality control may be exercised by the contractor or by the owner. Based on experience with larger projects, QC is most effectively administered by the owner, independent of the contractor. Regardless of who is responsible for implementation, a QC program cannot be effectively carried out without a full staff of experienced inspectors and

laboratory personnel. This is relatively expensive, but is just as much a part of project cost as is design. The old adage that states quality costs least is certainly true in the case of embankment dam construction and particularly construction of filter/drain and transition zones. The contractor will be performing construction activities as fast as possible, and schedules and milestones must be met in accordance with the contract documents.

Although time is of secondary importance to quality, QC staff must be capable of performing their work in a timely manner that does not slow down construction unless problems are encountered.

A. Inspection:-"There are few things of more importance in ensuring quality on a construction job than to have a set of eyes attached to a calibrated brain observing the construction operations" (Peck 1973). Regardless of the number of tests performed, they represent only a minute fraction of material that has been placed. Therefore, continuous inspection, or observations of field operations and conditions, is the backbone of the QC program and is vitally important to ensuring quality. Typical items an inspector should observe with respect to filter/drain/transition zone construction include the hauling, dumping, spreading and compaction operations; condition of the in-place material; and protection of completed work. In addition to observation, the inspector must call for testing to be performed at the locations he determines. All of these operations should be observed and monitored with respect to specification compliance and proper construction practice.

Inspection personnel must be experienced, knowledgeable of the plans and specifications, and exhibit good communication skills. Early in the job, inspectors must make every effort to become calibrated to material characteristics and behavior in the construction process. This is necessary to lend credibility to the observations and to operate efficiently. By observing construction processes and material conditions, a properly calibrated inspector should be able to have a very good idea whether placed material meets the specifications even before testing is performed. Inspectors must communicate well, especially with contractor personnel. Experience has repeatedly shown that inspectors should get to know the people who do the work and explain to them why things such as removing contaminated material or maintaining specified minimum drain width are important. When properly motivated by knowing the reasons for and importance of the work they are performing, laborers and equipment operators usually will take more pride in their work, resulting in an additional, though informal, QC force. To be most effective, inspectors must establish a reputation for being strict but fair. Documentation of inspection operations is in the form of inspection reports, which are prepared daily by the inspector and reviewed by supervisory personnel.

2) **Quality assurance (QA):-** Quality assurance is considered an oversight program of QC to ensure that verification and documentation procedures of the QC program are being accomplished correctly and to provide additional data for documentation of filter. As such, QA will consist of essentially the same items as QC. The owner should have, and should administer, the QA program, whether with in-house personnel or with contract personnel.

4.5 Impact of Filter on Seepage by Geo studio Analysis

This analysis carried out to check the efficiency of filter for the way of performing well permeable material. But the analysis was taken for additional comparison of the treated and actual site sample filter material seepage performance shown below figure.

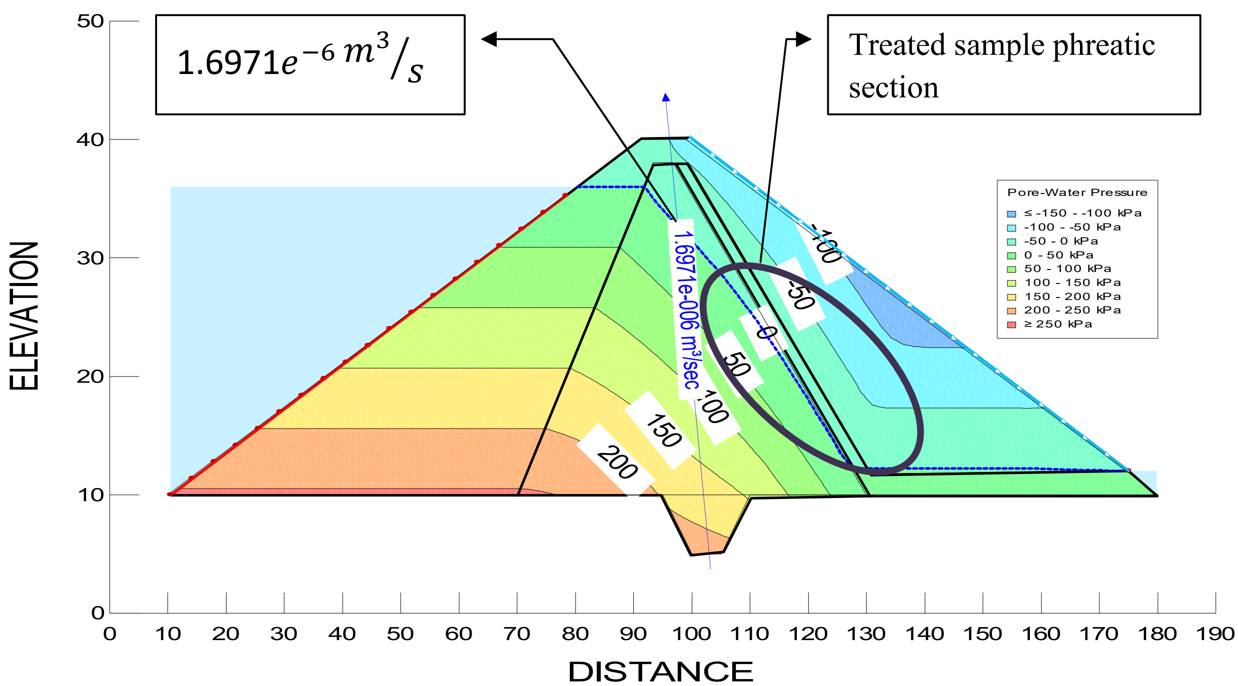

Figure 18: Treated filter material seepage efficiency

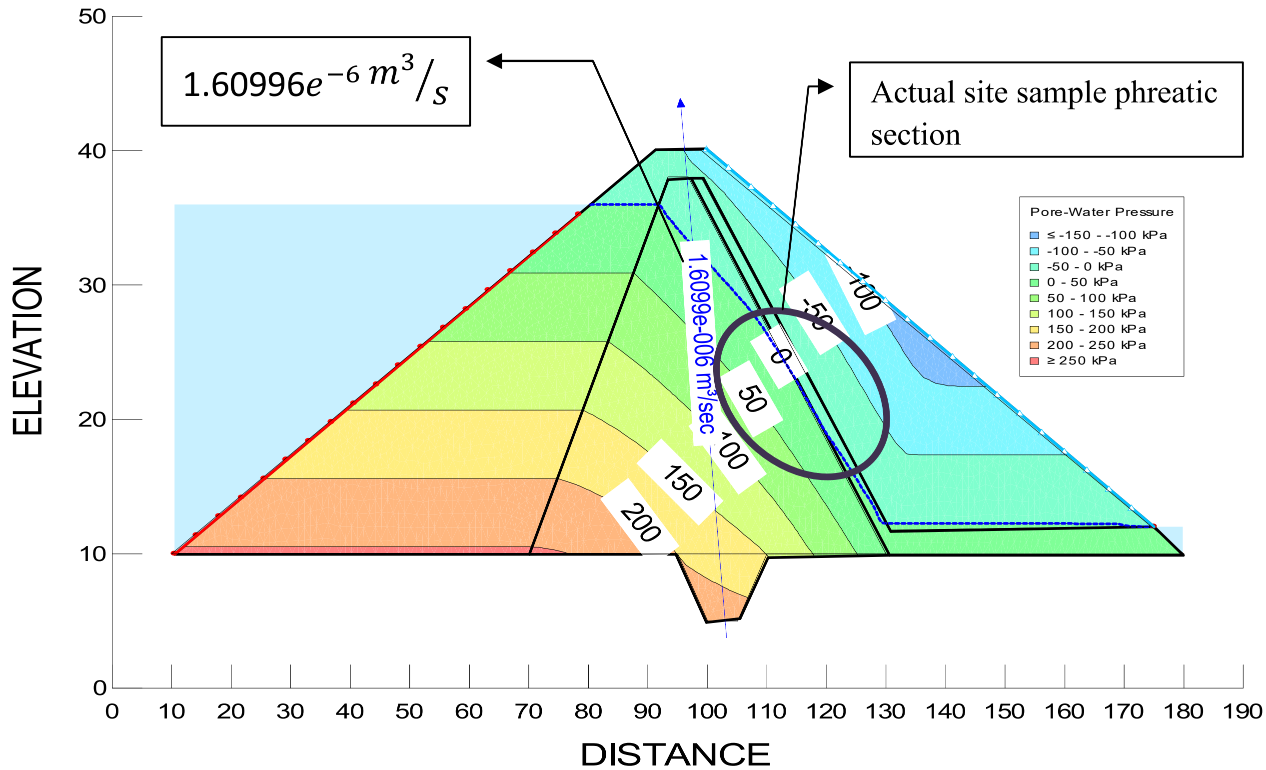

Figure 19: actual site filter material seepage efficiency

Therefore from the analysis result the treated/washed was more permeable. And it has more seepage efficiency because the seepage value shown from the above figure (fig18) $1.6971e\hat{}(-6)\ m\hat{}3\,/\,s$ was grater seepage efficiency than the actual site seepage value ($1.60996e\hat{}(-6)\ m\hat{}3\,/\,s$) shown (fig 19). So this seepage difference shows the performance of treated filter was more effective on the way of emitting unwanted water that enters to the core zone than the actual site filter. Moreover the treated material increases the life expectancy and suitability of the dam.

Additionally the treated sample was safer for pore, than the actual site because the treated material used figure shows less saturated zone, less saturation rise up (referred from the phreatic line) and properly emit the water than the actual. The negative variation occurred due to material proper gradation difference known as over fine graded filter material entry (at actual site filter material), this lead to minimize the permeability and formal filtering ability. Then the dam come to saturated and pored, so it minimize the dam suitability but the reverse is true for treated comparatively.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The present research work mainly aims at assessing and characterizing the filter material for its suitability as filter for base or core material. The suitability analysis is based on or considers mainly geometrical empirical criteria, which are developed using comparison results of the grain size distribution of the filter of the actual site and the research proposed or washed filter sample of Aguat-wuha constructed filter regarding their protected base soils.

- The various well known criteria have been applied to check the suitability of the filter material derived from the dam site in comparison to the constructed actual site sand and the present study namely washed sand after collecting sample from the constructed dam with different depth sample selected and then washed. Almost each empirical criterion has their own condition of application, and the filter materials are examined accordingly. Selection of criteria, which considers base soil type, is found reasonable and so the analysis results from such criteria is used to conclude and recommend final design of the filter. Most of design rules or criteria used for this research do not entirely allow selection of the particle distribution of filters. The emphasis in those rules is on 'spot' limitations within the grading curve. In this regard the criterion developed by USCS, which is reported by Sherard and Dunnigan (1985), is basically implemented.
- The available empirical criteria implemented for this research work have been compared to each other to differentiate which one of them are more applicable and practical for the suitability analysis of a filter material for a given base soil. Most of them depend or considers the relationship of spot grain size ratios of the two types of soils; the filter and the base. The USCS method and Sherard et.al. recommendations, on the contrary, considers or aims to design the whole gradation limits, in which a filter need to be bounded based on a give type of base soil category. The proposed filter materials for this particular research project have been analyzed using the filter gradation design procedures of USCS, and their relative suitability in protecting or filtering the base soil safely have been evaluated. Based on this evaluation the following conclusions have been drawn;

- The washed filter sample or the research proposed sample mostly satisfied the suggested recommendation and criteria than the authority constructed or actual site filter therefore the research treatment and use quality development was more useful.
- On the design procedure of the research the lower or finer, and upper or coarser gradation limits of the filter material suitable for this particular core (silts and clays) soil have been drawn. Then each proposed filter materials of the washed one filter soils gradation curves are examined with respect to the limits. And then an average filter soil for the constructed material has been prepared theoretically and its suitability was also checked in the same manner. The result indicates that almost all selected and tested filter materials fall generally within the limits, so the general justification displayed using average filter material soils fall in the limit but the actual site constructed filter material lied in the limit but on the finer limit side have more fines than the limited band and crosses the fine containing limit so the authority constructed filter shows extra finer.
- The soil constructed for filter and used for relative suitability checking as filter totally falls within the grading limits. It is a suitable material as a filter for this particular soil type. The problem associated to this material is that the source area is located at relatively very distant place during construction of filter. Besides to this the source is now under over exploitation that there may be some shortage of the material in the coming times and also the treatment was not implemented during exploring and also before stockpile and also not checked after construction.
- Breakdown of particles occurs during placement and compaction. Specifications should apply to the filter after placement in the dam. This means that the contractor may have to manufacture the filters coarser than the specifications over-compaction of filters and drains, breaks down particles, causing loss of permeability. Therefore the researcher shouldn't analyze only the performance criteria and then performing ability and quality before construction even should analyze during placement and compaction to know the variation and to take remedial measurements because more times filter material gradation size changed during placement and compaction changed to fine and silty so that it reduces permeability. Washing on-site can be problematic for fall construction and Keep fines content down: < 3% in stockpile, < 5% in place.

- The criteria used for this research fine material passage limit at the particle size 0.075mm, other than the gradation limits /geometrical factors, considered in the design of the filter was also well satisfied by the research proposed type of filter soils. The percentage of fines in the materials of washed filter averagely less than 3% because the value was 2.2% therefore the value shows in the fine limit called 5%. But the actual site value was averagely 5.72% > 5%, these shows more fine than the ultimate limit of filters fine content shown by different author like Terzagi and sherard to ensure that filter remains adequately pervious and does not sustain a crack. Therefore the research proposed filter relatively more qualified and satisfy the author recommended and proposed criteria.
- The final output of the design procedure is to define or specify the grain size distribution ranges for the filter material which successfully protect the base soil. It is; hence, specification in respect to the limit of gradation of the filter based on the American Standard for Testing of Materials (ASTM) standard sieve sizes has been prepared. This specification indicates that the research filter materials can be washed but not on site or during placement or construction; especially wash can be carried out during exploration and then wash at stocking place around the constructed dam area to remove unwanted deposited silt or made fine layer under stocked material that washed during exploration and other ones will improve the soils (become coarser) and change the finer filters as successful filter for the base soil.
- According to Ramos and Locke, (2000) except in the case where real filter materials are sourced from the proposed stockpile or deposit, it is necessary to produce a filter material to a particular grading. The required grading is usually determined from the D15 size and coefficient of uniformity, although other factors such as maximum and minimum particle size may also control the grading. In order to prepare such a sample, the material should be split into distinct fractions by sieving and washed on a 75µm sieve to remove any cohesive fines.

5.2 Recommendations

The present work has some limitations, especially financial. It is therefore the work focuses mainly on one single issue in the design of filter procedures or considerations, i.e. on the geometrical suitability checking using existing empirical approaches developed for other country cases. The design of filter in embankment needs assessment of several parameters of both the filter and base or protected soil. Considering the limitation, the following recommendations are proposed for further study;

- To remove or minimize the fineness of filter material should conduct proper technical wash during construction
- Design of QC/QA programs Because of intimate knowledge of the design and its intent, the project designer should have major input into development of QC/QA programs. The designer knows best which items must be monitored and at what intensity and frequency. If the contractor is to perform the QC program, the designer should review and approve the plan. If the owner is to perform the QC program, the project designer should design the plan with input from field personnel who will be responsible for contract administration. The designer should develop the QA program in either case since the QA program is administered by the owner.
- Compaction of the filter material can lead to breakdown of particles, which produces finer particles than the original grading. This is very dangerous as it produces false results, predicting success whereas the real filter will fail. To control this particle size distribution (PSD) of a filter sample after compaction should be measured and compared with the original sample. After completion of a test, the filter material can be recovered, washed and separated into size fractions again, to provide material for another filter test. The filter particles should be examined to ensure they have not broken down during this process to different sizes and shapes, as particle shape has been shown to effect filtration efficiency.
- The filter material clog with time, resulting in diminished effectiveness. A routine schedule of cleaning and pump testing should be part of the filter operations and maintenance requirements.

The recommendations made through the present study must be considered as indicative only as the study was conducted under the constraints of limited time, restricted resources and financial deficiency. These limitations might have affected the quality of the results marginally. Thus, it is strongly recommended to perform elaborate tests on various aspects before implementing results or findings of the present study.

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Appendices

Appendix 1: Base Soil Category

Base Soil Category	% finer than No. 200 Sieve (0.075mm)	Base Soil Description
1	**>85**	**Fine silt and clays**
2	**40 – 85**	**Silty and clayey sands**
3	**15 – 39**	**Silty and Clayey Sand and gravel**
4	**<14**	**Sand and Gravel**

Appendix 2: Segregation Criteria

Base Soil Category	If D10 (mm) is:	Then Maximum D90 (mm) is:
All Categories	**< 0.5**	**20**
	0.5 – 1.0	**25**
	1.0 – 2.0	**30**
	2.0 – 5.0	**40**
	5.0 - 10	**50**
	> 10	**60**

Appendix 3: USBR Filter Criteria Checking Result

Sample	**Required Particle Sizes (mm)**			**Criteria**				**Remark**
	D85	D15	D15F	(i)	(ii)	(iii)	(iv)	
AGCOTP1	0.07	0.1	-	-	-	-	-	
AGWDF 1			0.2	2	2.86 but **not parallel?**	7	Yes	Almost not Satisfy
AGWDF 1”**washed**			0.3	3	4.28 parallel	7	yes	satisfy except criteria i

Appendix 4: Results of Filter Checking Using Terzaghi's Criteria

Cri te- ria	**Sampled Filters**						**Re- marks**
	AGWDF 1	AGWDF **1"washed**	AGWDF **2"washed**	AGWDF **3"washed**	AGWDF **4"washed**	Average of **washed 1"- 4"**	
1	2.86	4.28	4.28	4.28	4.28	4.28	
2	2	3	3	3	3	3	
(i)	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
(ii)	5.7 > 5 **Not Ok**!	1.8 < 5 **Ok!**	2 < 5 **Ok!**	2.5 < 5 **Ok!**	2.4 < 5 **Ok!**	2.2 < 5 **Ok!**	
(iii)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
(iv)	**clay silt**	**clay silt**	**clay silt**	**clay silt**	**clay silt**	**clay silt**	Okay
	almost not satisfy	All are fully satisfied except criteria 2 almost satisfied					

Appendix 5: The actual site Gradation of all filter samples

S/S	Wt . Rt 1	cum re-tained	% Pass-ing	Wt . Rt 2	cum re-tained	% Pass-ing	Wt . Rt 3	Cum retained	% Pass-ing	Wt . Rt 4	cum re-tained	% Pass-ing	Average % Passing
37.5	0	0	100	0	0	100	0	0	100	0	0	100	100.00
25	0	0	100	0	0	100	0	0	100	0	0	100	100.00
20	0	0	100	0	0	100	0	0	100	0	0	100	100.00
12.5	0	0	100	0	0	100	0	0	100	0	0	100	100.00
9.5	0	0	100	0	0	100	0	0	100	0	0	100	100.00
6.3	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	100.00
4.75	55	3.5	96.5	55	3.5	96.5	55	3.5	96.5	55	3.5	96.5	96.46
2.36	123.6	8.0	88.4	123.7	8.0	88.4	123.6	8.0	88.4	123.6	8.0	88.4	88.43
1.18	208.5	13.5	74.9	207.8	13.5	74.9	207.7	13.5	74.9	208.4	13.5	74.9	74.92
0.6	359.4	23.3	51.5	366.3	23.8	51.1	349.6	22.7	52.2	358.6	23.3	51.6	51.63
0.425	294.5	19.1	32.4	289.6	18.8	32.3	287.7	18.7	33.6	287.5	18.7	32.9	32.81
0.3	195.6	12.7	19.7	187.6	12.2	20.1	198.6	12.9	20.7	224.3	14.6	18.4	19.72
0.15	121.7	7.9	11.8	124.7	8.1	12.0	129.7	8.4	12.2	125.5	8.1	10.2	11.58
0.075	94.4	6.1	5.7	95.6	6.2	5.8	98.7	6.4	5.8	*72.2*	4.7	5.5	5.72
pan	87.3	5.7	0.0	89.8	5.8	0.0	89.8	5.8	0.0	85.3	5.5	0.0	0.00
total	**1540**			**1540**			**1540**			**1540**			

Appendix 5: The gradation of all filter samples after wash

S/S	Wt . Rt 1	cum retained	% Passing	Wt . Rt 2	cum retained	% Passing	Wt . Rt 3	cum retained	% Passing	Wt . Rt 4	cum retained	% Passing	Average % Passing
37.5	0	0	100	0	0	100	0	0	100	0	0	100	100.0
25	0	0	100	0	0	100	0	0	100	0	0	100	100.0
20	0	0	100	0	0	100	0	0	100	0	0	100	100.0
12.5	0	0	100	0	0	100	0	0	100	0	0	100	100.0
9.5	0	0	100	0	0	100	0	0	100	0	0	100	100.0
6.3	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	100.0
4.75	55	3.7	96.3	55	3.8	96.2	55	3.8	96.2	55	3.7	96.3	96.2
2.36	123.6	8.5	87.7	123.7	8.6	87.6	123.6	8.6	87.6	123.6	8.4	87.8	87.7
1.18	208.4	14.3	73.4	207.8	14.4	73.2	207.7	14.4	73.2	208.6	14.2	73.6	73.4
0.6	359.2	24.7	48.7	366.3	25.5	47.7	349.6	24.3	49.0	358.6	24.5	49.1	48.6
0.425	294.5	20.3	28.4	281.6	19.6	28.1	287.7	20.0	29.0	286.8	19.6	29.5	28.8
0.3	193.6	13.3	15.1	184.6	12.8	15.3	198.6	13.8	15.2	222.3	15.2	14.4	15.0
0.15	140.7	9.7	5.4	142.3	9.9	5.4	139.5	9.7	5.5	133.4	9.1	5.3	5.4
0.075	53.4	3.7	1.8	49.2	3.4	2.0	44.4	3.1	2.5	41.4	2.8	2.4	2.2
pan	25.5	1.8	0.0	28.5	2.0	0.0	35.5	2.5	0.0	35.5	2.4	0.0	0.0
total	**1453**			**1439**			**1441**			**1465**			

Appendix 6: Tabulated Contamination result of 8 samples under sample A and B

Cleaned and well treated sample zone
Sample A

Contaminated sample zone
Sample B

Samples	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE **1''**	SAMPLE **2''**	SAMPLE **3''**	SAMPLE **4''**
% passing at 0.075	2.9	3	3.2	4	**4.3**	**6.4**	**7.4**	**8.4**
Sample depth	**(220cm)TOP-180cm**	**180cm-140cm**	**140cm-100cm**	**100cm-80cm**	**80cm-60cm**	**60cm-40cm**	**40cm-20cm**	**20cm-ground**

Appendix 7: average contamination result of section A and B with sectional diagram

sample depth	Sample A (Avg)	Sample B (Avg)
% passing at 0.075	3.3	6.6
Sample depth	**(220cm)TOP-80cm**	**80cm-Ground**