Addis Ababa University

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Channel Stability Analysis - The case of Lower Logia River

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ADDIS ABABA UNIVERSTY

SCHOOL OF GRADUATE STUDIES

CHANNEL STABILITY ANALYSIS-THE CASE OF LOWER LOGIA RIVER

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DATE 2015

The undersigned certify that I have read and hereby recommended for the acceptance by the University of Addis Ababa a project entitled channel stability analysis the case of Lower River in partial fulfillment of the requirement for the degree of master of engineering in hydraulic engineering.

…………………………………

Dr.ing Nigussie Teklie

Advisor

I Abayneh shiferaw, declare that this project is my own orginal work and that it has not been presented and will not be presented to any other university for similar or any other degree award.

…………………………..

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Abayneh shiferaw

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LIST OF ACRONYMS

USACE	United State Army Corps of engineers
Em	Engineering manual
HEC-RAS	Hydraulic engineering center –River analysis system
CMS	Meter cube per second
EGL	Energy grade line
Q100	A hundred year return period discharge
WSQ	Water surface elevation at discharge Q
CRTQ	Critical water surface of discharge Q
Banksta	Bank station
LLRIVER	Lower Logia River
RS	River station
WWDSE	Water works design and supervision enterprise
$^{N}/_{m^2}$	Newton per meter square

ABSTRACT

Rivers dynamically respond to changes in the discharge and sediment supply from the catchments. A change of land use and other natural factors in catchments result in changes on sediment supply and discharge. This process of change of River geomorphology seeking for its equilibrium may affect people and property especially in sensitive areas located adjacent to Rivers. Tendaho sugar factory project is found in Afar regional state near Logia River. Logia River is the cause of destruction of structure of the project and private farm due to over flooding of the bank in the vicinity of the main canal of the project. The river also damage properties adjacent to Logia town. To prevent the loss of lands and properties resulting from the changes in the characteristics of this River reach, stabilization measure should be taken. So this thesis deals with analysis of the stability of the channel reach by evaluating their capacity and stability in response to discharge and sediment supplied from the catchments.

For proper design and implementation of any stabilization measures, analysis on stability and channel capacity of this channel reach should be evaluated. According to the study, flow simulated result the 2.5 return period discharge is almost accommodated within the channel section of the whole station. But there are observed in some adjoining areas flooded by the 50 years and 100years return period discharge. From steady flow analysis of lower Logia River a shear induced due to the flow of the design discharge of 50 years and 100years together with the channel forming discharge which is taken as a 2.5years return period is analyzed and compared from the critical shear stress which result show less thus the bank of lower Logia River can generally get easily eroded and have less resistance to shear. According to sediment analysis the model result which is analysis using the sediment function laursen (Copland) and Yang sediment transport formula, deposition is observed in all River station almost 85% of River station. The remaining River station degradation is observed in station at just downstream of the bridge and upstream of the syphon according to the model results. So it is recommended that the stabilization measure should be implemented with engineering, economical and hydraulic analysis for effective and sustainable stabilization of the Rivers.

1 INTRODUCTION

1.1 Back ground

Streams change in response to variations in discharge and sediment supply and they are dynamic by nature. These changes vary specially according to the position within the basin and influenced by local variations in geology, soils, bank characteristics, vegetation, hydraulics and other factors that influence stability such as various types of land use .Besides channel changes are variable in time depending on somewhat on the timings of floods and drought and also land use changes. Especially now a days the variation of climate due to the global warming which is becoming the cause for the change in the frequency of severe floods and drought; and land degradation due to extensive deforestation for fuel wood production and in advance of cultivation in the catchments as a result of rapid population growth, are leading to higher peak discharges, stream sediment loads and unstable Rivers section. The possible link between climate change and River instability is one of the most difficult and certainly the most contentious issues facing the River engineer at the present time.

The debate by concern over the importance of anthropogenic enhancement of 'the green house 'effect on global climate has become one of the central issues in water resources management and catchments planning, and the land degradation resulted in hardship of upland soil resource (by leaching and by accelerated erosion) and adverse hydrological effects such as channel siltation and flooding in the low lands. MACKLIN and LEWIN, 1997 motivated that the consequences affect discharge and sediment indirectly by increasing peak flows and increasing the quantities of sediment considerably. In addition dams and flood plain mining are some activities that have indirect effects on channel form and hydrology. More over activities like channelization and in stream mining have direct impact on River systems. Then the resulting physical impacts may include deposition of the channel bars, transportation of coarser sediments, erosion of channel banks, shifting channel bottoms and change in channel position and pattern. So this in turn causes damage on the adjoining social and developmental activities, especially such activities are intense on River reach which cross towns on flat areas.

For similar reasons the instability of lower Logia River at the reach they cross the main canal are being a threat in flooding the main canal and so far there has been a problem for a cause of canal damaged by the River on the project. The reach of this River where it pass to the side of the town under the bridge and the channel is scoured and gets widened from time to time posing a great threat of flooding for the bridge on Addis to Djibouti highway and adjoining town part. The Logia River is also getting aggraded the bed and eroded the bank continuously. As a result the flood way of this River is also becoming wider and shallower there may be over topping the banks and flooding the adjoining areas. Thus assessment of stability problems of those River reach is help full for implementation of proper stabilization measures.

1.2 Description of the Study area

The town of Logia is located at the low land of Afar regional sate. The River Logia is the tributary of Awash River at downstream of Tendaho dam. The Logia River crosses the main canal by canal siphon just upstream of the confluence of the Logia River and the Awash River at downstream around 7km of the dam .The Logia River passes the Logia town through bridge on the high way of Addis to Djibouti. The distance between the bridge and canal siphon is around1.861km. The River reach between the bridge and the junction of the two River passing over the canal siphon is a bit meandering line and plain which the sediment from the high land aggrades the River bed continuously due to the nature of the River alignment. Because of such reasons the channel is increasing its flood way by eroding the banks side and over flooding the adjoining area. The length of the reach where a problem due to those streams is concentrated is about 1.84kms between bridge and canal siphon.

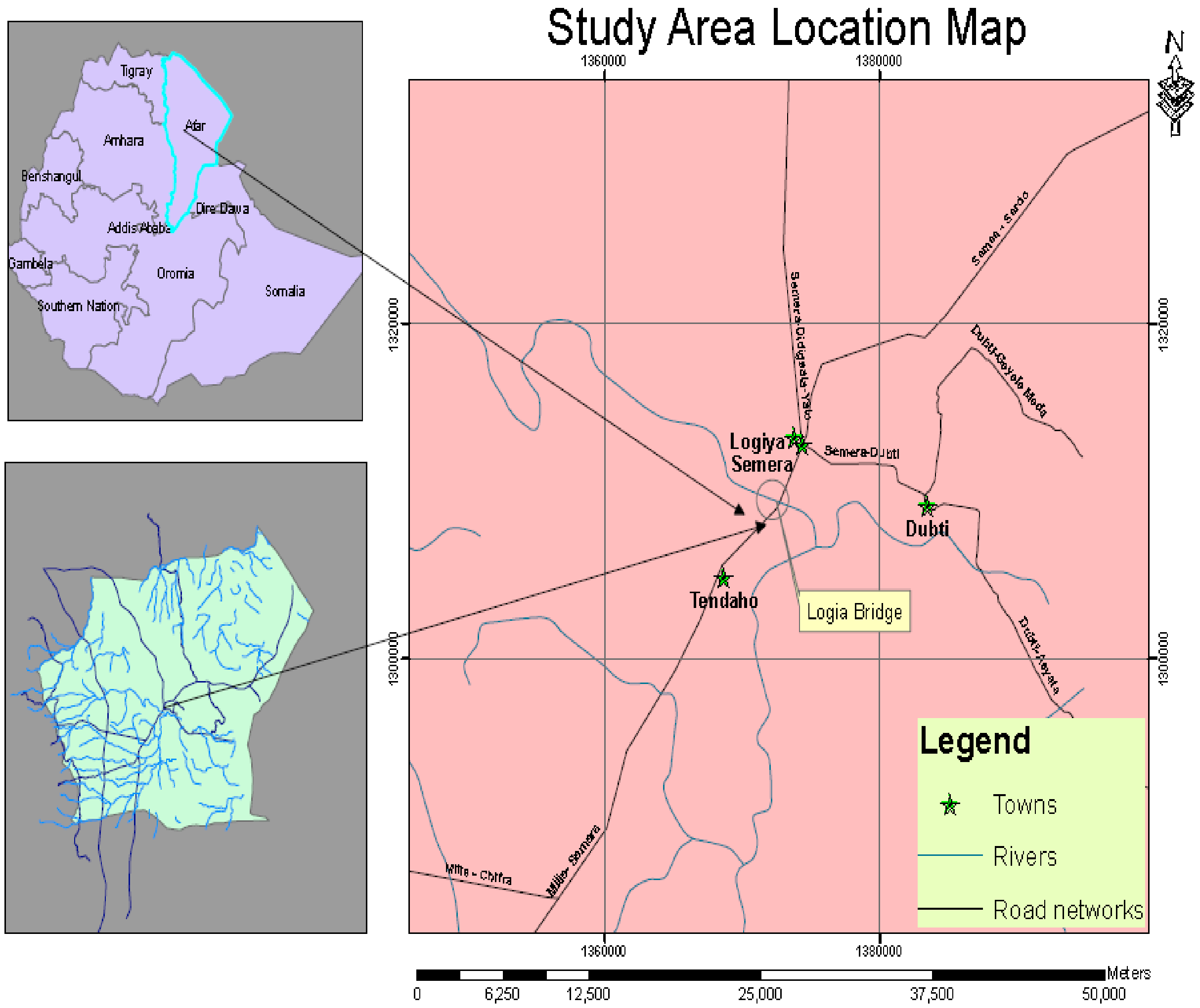


Figure 1-1 study area map

1.3 Location

The geographical study area is situated between latitude 11° 20' to 11° 50' N and Longitude 40° 55' to 41° E and it lies in the deltaic alluvial plains.(*Tendaho dam and irrigation project design report)*

The Logia River is the tributary of Awash River at downstream of the Tendaho dam. The River is the non perennial River which is a flash flood that comes at rain season. The study area mainly concentrated Tendaho sugar factory project. The project area is found at Afar regional state in dupti werda which has high potential of cultivated command area for sugar cane. The catchment area of Logia River situated as part of Awash River catchment.

1.3.1 CLIMATE

The average maximum monthly temperature varies between 46.2°C to 28.30C and the minimum 17.1 °C to 26.1°C. The mean annual rain -fall is about 222mm having two rainy seasons: March-April and July-August. The mean annual sunshine hours are 9.8 hours having small variation among months. Wind speed is in March reaching to 187 Km/day and minimum in September reaching to 95.4 km/day. The mean monthly relative humidity varies 66.8% to 50.5% generally .The climate of the study area according to the traditional classification of climate which is mainly based on altitude variation, the climate is classified as "qolla" (Adopted from Tendaho dam and irrigation Design report)

1.3.2 GEOLOGY OF STUDY AREA

The lower awash valley downstream of the Tendaho dam generally drains in Tendaho garben bounded by block-faulted volcanic and underlain by fluvio-locaustrine sediments and down-faulted Afar stratoid series at depth, as such the bedrock of the lower Awash valley, for most part is alluvial deposits, fluvial-lacustrine sediments and minor volcanic rocks and Aeolian sediments. (Tendaho dam and irrigation Design report)

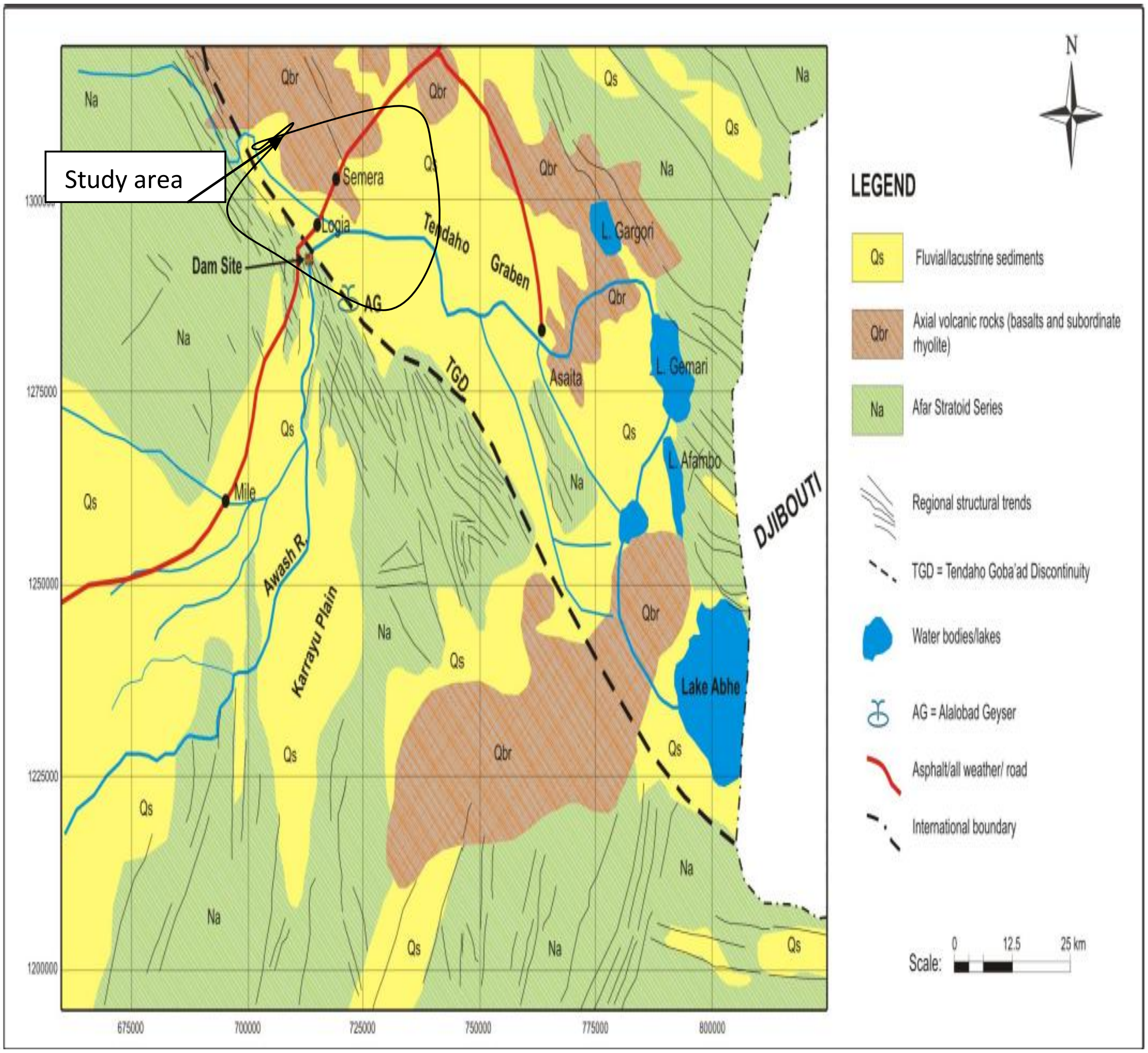


Figure 1-2 Regional geological map of the study area

1.4 Statement of Problem

The town of Logia is located at the flat lands in Afar regional state in the vicinity of Tendaho sugar factory project. The material over the River banks by the side of the town is highly erodible. As a result excessive run off from the catchment accelerates erosion of the banks and consequently the adjoining areas get frequently flooded and damaged main canal of Tendaho dam and irrigation project. It is known that lot of constructed structures in Tendaho project and private farms were lost in a single year in Tendaho dam and irrigation project due to flood from the River. Moreover, structures on the River are at risk due to erosion of the bank, specifically the canal siphon on the main canal. The slope for the Logia River is seen to decrease as it crosses the town. Hence, the transporting capacity of the River channel is likely to decrease as a result of aggradations on the bed and in turn erosion on the bank. Because of such reasons the channel is widened by eroding the banks and over flooding the adjoining area.

The Logia River follows a meandering route with a low speed until it joins Awash River about 2km from bridge. As time goes, the bed silts up and bank materials are easily eroded. The rate of widening and silting of the channel is therefore fast. According to information obtained from the elderly people from the neighboring area, the width of the channel before certain years near to the bridge, which is located around 1.84km up stream of the canal siphon on main canal, was not more than the width of the bridge but by now the channel width at the bridge is more wider than before. The length of the reach where a problem is concentrated is about 1.84kms between the bridge and the canal siphon. The bridge is on the main road of Addis to Djibouti and the siphon is on main canal of Tendaho dam and irrigation project. The study area is in a good pace of infrastructural and socio economical developments especially Tendaho sugar factory.

A problem resulting from such serious bank erosion and consequent flooding can have its own significant influence for the development of Tendaho sugar factory project by damaging the irrigation structure and infrastructures along the River; so it should be controlled and managed properly.

1.5 Objectives of the research

The general objective of this thesis is to analyze the stability of the channel by evaluating its capacity and stability in response to discharge and sediment that are supplied from the catchments.

Specific objectives

The following are the specific objectives:

- To evaluate the capacity and extent of flood corresponding to the less frequent floods.
- To identify possible causes of instability and study its extent.

1.6 Expected out come from the model

- Identified the aggradations section of the reaches

Aggradations are where silt up is observed to happen

- Identified the degradation section of the reaches

Degradation is where erosion is observed to happen

- Identified the flood way and bed stability

2 LITERATURE REVIEW

2.1 Principles and Channel stability Concepts

It is important to understand the relationship of the project length to the stream system and the basin geomorphology. *Geomorphology* here means the relationship of stream channels and flood plains to the geology and physiographic of the region. Factors that have produced the present channel features and will affect the response of the channel to engineering works include sources and supply of sediments, basin materials and vegetation, catastrophic events, earth movements, landslides, eruption and major floods, changes in land use and development, and past interferences including structures, dredging, and diking.

In general terms a drainage basin can be divided into three main zones: an upper erosion zone of sediment production, a middle zone of sediment transport with simultaneous erosion and deposition, and a lower zone of sediment deposition. (USACE, Em 1110-2-1418).

The actual situation is often more complex, because local geological controls or other factors can produce local depositional zones in the upper basin or local erosion zones in the lower basin. But in this thesis the observed situation is the lower depositional and local erosion zones.

And the stream morphology is the expressed form complex interrelation ships between the independent and dependant variables. Independent variables are governed by changes in the water shed that are external to the stream. The driving independent variables are discharge and sediment supply. Geology, soils, land form and climate are independent variables. Channel slope, width, depth and pattern are considered as dependant variables. Changes in any independent or dependant variables initiate adjustment process in one or more of the dependant variables. When discharge and sediment load are not significantly changing, stream adjustment process tend toward stability. Stream channel stability is the ability of a stream, over time in the present climate, to transport the sediment and flows produced by its water shed in such a manner that the stream maintains its dimension, pattern and profile without either aggrading or degrading. *(Fantaw Mengasha 2008)*

The Lanes Balance Diagram was developed in the 1950’s and was one of the early theories of fluvial geomorphology. It shows a scale with sediment load and sediment size on the left side and discharge and stream slope on the right side (Figure 2-1) Changes in one variable tip the balance and must be accounted for by a shift in a combination of the other variables. Streams adjust their width, depth, slope, and pattern through erosion and depositional processes to accommodate changes in discharge and sediment load.

When discharge and sediment load are not significantly changing, stream adjustment processes shift toward stability. Streams that transport sediment loads and convey flows without significant erosion or deposition are in balance and have achieved dynamic equilibrium. Dynamic equilibrium represents a state of natural stability. Streams in dynamic equilibrium maintain a consistent dimension, pattern, and profile in the current environment, although some change may occur in the short term change

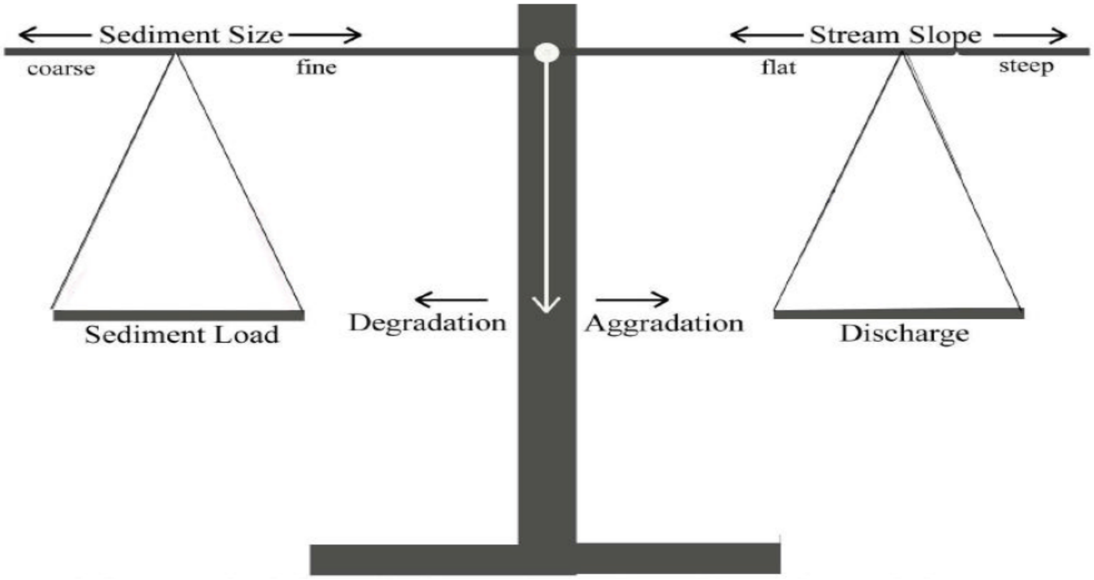


Figure 2-1 sediment load X sediment size is proportional to stream slope X stream slope X slope X stream discharge

in watershed hydrology or sediment supplies (i.e. current environment), may result in changes in the dimension, pattern and/or profile, as the stream adjusts to a new state of equilibrium.

Channels governed by dynamic equilibrium typically have movable gravel or sand beds and erodible banks. Streams with non-mobile beds and banks are not free to adjust and are highly stable. The classic example is a stream formed in bedrock. Bedrock controlled stream morphology is not determined by sediment transport and discharge.

Instead, underlying geology is the determining factor. Dynamic equilibrium theory applies only to systems that are free to adjust their pattern, dimension, and profile.

Dynamically stable channels are often referred to as “in regime” or “graded” and express an average channel morphology that remains relatively constant over time.

Variations in average conditions may occur at particular, short-term time scales and in localized areas of the stream. A stream in dynamic equilibrium responds strongly to these short-term or local variations through feedback mechanisms that return the system to a stable state. Streams have a measure of elasticity that allows the channel to absorb shifts in equilibrium. However, when significant, system wide changes in the independent variables occur, a geomorphic threshold is crossed. A geomorphic threshold represents a point when the channel can no longer adjust to changes in watershed inputs. The stream exhibits abrupt adjustment responses in dimension, pattern, and profile until a new state of dynamic equilibrium is achieved. Degradation occurs when a channel adjusts for excess discharge and/or reduced sediment supply by eroding its bed and banks. This process continues until a stable dimension, pattern, and profile develop. Degradation can be in the form of meander migration or incision. A stream will attempt to add length, and therefore decrease slope, by eroding the outer meander bend and forming a bar along the inner meander bend. The bed is eroded and the base level of the stream is lowered down cutting increases bank height, which can eventually lead to bank failure and channel widening. Widening and down cutting continue until equilibrium is regained. Aggradations occurs when sediment supply exceeds transport capacity and the stream deposits sediment in the channel. Aggradations can be triggered by an increase in sediment supply due to upstream channel erosion or land development, or by a decrease in discharge, which reduces the transport capacity of the system. Deposition continues until a new state of dynamic equilibrium is achieved. *(The Virginia Stream Restoration & Stabilization Best Management Practices Guide, 2004)*

2.2 Channel Characteristics

It is necessary to know the important variables that represent the characteristics of a River in order to analyze the behavior and the stability nature of an alluvial River. The most important ones are water discharge, bed material transport rate, representative size of the bed material, stream slope, width to depth ratio that characterizes the shape of cross section; and the ratio of the stream mileage to valley mileage, which characterizes the shape of the stream in plan i.e. meander pattern. Water discharge and size of the bed material are certainly independent variables. Whereas the variables that represents the shape of the cross section and shape in plan is dependant. But the dependency of the bed material transport rate and stream slope rely on the course of the stream. In the upper course of the stream the slope of the land and hence the slope of stream is determined by the geologic factors and stream slope can be treated as an independent variable thus the bed material transport rate would become a dependant variable and its magnitude is determine by water discharge, representative size of the bed material and stream slope. In the lower course of the stream water discharge , bed material transport rate, and representative size of the bed material become the independent variables and hence slope becomes a dependant variable along with the variables that represent the shape in cross section and the shape in plan(USACE, Em.1110-2-1410 crops of engineer)

2.3 Channel Geometry and Processes

Channel geometry has four main components: plan form, cross section, slope (gradient), and bed topography. The term “channel processes” generally refers to natural changes in plan form, cross-sectional boundaries, longitudinal profiles, and bed topography. (USACE, Em.1110-2-1410)

I) Plan Form:

Stream plan forms can generally be classified as braided, meandering and straight, but a wide variety of natural forms are now recognized. A braided stream can be defined as one which flows in to two or more channels around alluvial islands. Their study shows that braided pattern develops after local deposition of coarser material which can be transported under local conditions existing in the reach. The formation of the bar deflects the stream towards the banks and causes erosion. Whereas a meandering stream is follow sinus path. (Leopold and Wolman) have arbitrarily classified streams with sinuosity, which is thalweg length to valley length, greater than 1.5 as meandering streams.(USACE, Em1110-2-14180)

II) Cross-Section:

The cross section of a natural channel depends on basin run off, sediment input, and boundary soil and vegetation. Usually the average cross section a channel does not change under natural conditions over a period of years. Systematic trends of enlargement or shrinkage usually result from changes in discharge or sediment inputs as a result of basin changes, or on stream works.

The variability of cross section from point to point along the channel depends on many factors; it may be quite small in stable nearly stable channels, and large in highly active channels of complex plan form. (USACE, Em1110-2-14180)

Most of the alluvial stream channels are found to be relatively wide and shallow. If the channel is deep and narrow, the banks become unstable due to higher velocities and the consequent higher shear stresses along the sides. The material that is eroded from the sides drops on the bed and thus a narrow and deep channel tends to widen until the velocities near the side are too low to cause further erosion.

III) Slopes and Profiles:

The longitudinal profile is only partly determined by the landscape. The channel is flatter than the valley slope unless the channel is straight. In many case the channel slope represents a long term equilibrium conditions. When a meandering stream is straightened, a steeper non equilibrium slope is temporarily imposed. Responses in the form of erosion and deposition are then set in motion, in the direction of restoring equilibrium. (USACE, Em.1110-2-1418 crops of engineer)

IV) Bed topography and roughness.

The bed topography and hydraulic roughness of natural channels may vary greatly along the channel and also with stage of flow. The total hydraulic resistance results from a combination of grain roughness and form roughness. Form roughness can arise from bed and bank irregularities and from changes in plan form. In active sand channels, bed forms may range from small ripples a few inches in height, to dunes a few feet in height, to larger waves and bars. These forms depend on flow conditions and mainly control the hydraulic roughness of the bed. Also, the bed topography at any time depends on the preceding flow history as well as on present conditions. Roughness therefore varies with stage and is not always the same at similar stages - one reason for the looped or erratic stage-discharge curves found in many alluvial streams. Other important sources of form roughness are trees and bushes, River bank protection and structures, floodplain obstructions, bedrock outcrops, bends and scour holes and abrupt changes in cross section.

Channels formed in coarser sediments have different and often more stable forms of bed topography than sand-bed channels. In gravel-bed streams, the dominant form of bed topography tends to be an alternation of pools and riffle: the pools are characterized by flatter local slopes and finer bed materials, and the raffles by steeper slopes and coarser materials. Bar characteristics and flow resistance in coarse-bed streams are described by various authors (Hey, Bathurst, and Thorne 1982).

Armoring, whereby the material on the bed surface is coarser than the underlying material, is described in a gravel-bed streams, the dominant form of bed topography tends to be an alternation of pools and riffles: the pools are characterized by flatter local slopes and finer bed materials, and the riffles by steeper slopes and coarser materials related publication (Thorne, Bathurst, and Hey 1987).Some of the features of natural gravel Rivers tend to develop in channelized Rivers and artificial channels. Armoring is common in regulated streams downstream of storage reservoirs. (EM 1110-2-1418 31)

2.4 MATERIAL COMPOSTION

2.4.1 BED MATERIAL

Bed material describes the composition of the channel boundary and sediment characteristics describe how flow events interact with the channel boundary including cohesive scour, armored reaches, and the threshold between wash load and bed material load. Local sources describe sediment supply from features outside of the modeled reaches such as gullies, net bank failure, surface erosion, and augmentation.

The entrainment and transport of sedimentation is governed in large part, by the composition and arrangement of the particles that make up the channel bed. Bed composition and arrangement (i.e. fabric) have been shown to vary systematically in a downstream direction, the coarse sediment of head waters giving way to progressively finer alluvium as base level is approached (James Bathurst)

Sediment in streams can be divided in to the bed material load and wash load. Bed material load consists of grain sizes found in significant quantities on the bed. The channel characteristic most sensitive to bed material size is bed slope. The coarser and steeper channel would also have smaller depths and higher velocities. The influence of bed material size on width is relatively small and difficult to separate from other factors. But generally increased bed material load tends to reduce channel stability, because it forms local deposits that divert flow against banks and so on. (EM 1110-2-1480)

The size of bed material in a natural stream is found to decrease continually along the length of the stream. This reduction in size is partly due to sorting action and partly due to abrasion. As the stream comes down from mountainous regions to the plains the slope decreases and stream width gradually increases. Such a decrease in slope reduce the capacity of the channel to transport the coarser particles brought from upstream and the coarser particles are thus deposited on the stream bottom. (EM 1110-2-1480)

2.4.2 BANK MATERIAL

Bank erodibility primarily reflects bank material composition (% fine or coarse alluvium, colluviums, and bedrock).The bank stability criterion accounts for the increased stability of the channel banks due to consolidation of the bank sediment; cementing by fines and binding of the sediment by root masses." And it is also stated that a sensitivity analysis of the two parameters i.e. the median grain diameter of the bank sediment D_{50} bank and the modified friction angle of the bank sediment can exert a large influence on the channel geometry. (*(Fantaw Mengasha 2008*)

2.4.3 VEGETATION COVER

For fully alluvial streams flowing within an envelope of self-deposited sediments, it is debatable whether bank materials should be considered as independent factors affecting channel characteristics Vegetation, however, is more clearly an independent factor. Instability is often triggered by the clearing of vegetation from stream banks, and sometimes by eroded and deadfall vegetation within the channel. The role of bank vegetation varies greatly with the region and type of vegetation. Vegetation established on bars during low flow periods can have a significant effect on channel capacity and processes. Vegetation has been treated as a variable in some hydraulic geometry relationships. (Em1110-1280)

There is a common sense that bank vegetation does have a significant influence in reducing the channel capacity of natural Rivers and flood control channels. The lack of understanding of the acknowledged beneficial effects of vegetation cover can have in increasing the stability of a bank and reducing erosion, leads to expensive and environmentally unfriendly maintenance work that is carried out to remove the vegetation along the boundary of the channel. According to Richard Masterman and Colin R.Throne the approaches based on the argument that bank vegetation significantly reduces channel capacity is based mostly on the assignment of high manning's n values to streams with in channel vegetation, as indicated in flow resistance guides such as those of Chow (1959, do not properly account for the effects of composite roughness found when a channel has vegetation lined banks but a bed formed in sediment. (Belay Bancha August 2008)

2.5 Application of HEC-RAS 4.1

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The HEC-RAS system contains four one-dimensional River analysis components for:

(1) Steady flow water surface profile computations;

(2) unsteady flow simulation;

(3) Movable boundary sediment transport computations; and

(4) Water quality analysis.

(5) Hydraulic design functions

- ✓ Uniform flow computation
- ✓ Bridge scouring
- ✓ Stable channel design
- ✓ Sediment transport capacity

A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four River analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

HEC-RAS 4.1 can perform mobile bed sediment routing computations with quasi steady (histogram) flow series data. For each flow in the time series a water surface profile is calculated. Hydraulic parameters required for sediment processes are also calculated. The model calculates sediment transport capacity by a number of available methodologies. The sediment continuity equation is then solved in conjunction with sorting and armoring algorithms to solve for the actual volume of deposition or erosion. Additionally, temporal entrainment and deposition functions have been adapted.

I) Steady flow water surface profiles: This component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The steady flow component is capable of modeling sub critical, supercritical, and mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at River confluences (stream junctions). The effects of various obstructions such as bridges, culverts, dams, weirs, and other structures in the flood plain may be considered in the computations.

Equations for Basic Profile Calculations:

Water surface profiles are computed from one cross section to the next by solving the Energy equation with an iterative procedure called the standard step method. The Energy equation is Written as follows:

$y1+z1+\frac{\alpha 1 v1}{2g} = y2+z2+\frac{\alpha 2 v2}{2g}+hl$ ……………………2.1 Where y1, y2 depth of water

z1, z2 elevation of main channel inverts

v1, v2 average velocity

α1, α2 velocity weighing coefficients

g = gravitational acceleration

h = energy head loss

A diagram showing the terms of the energy equation is shown

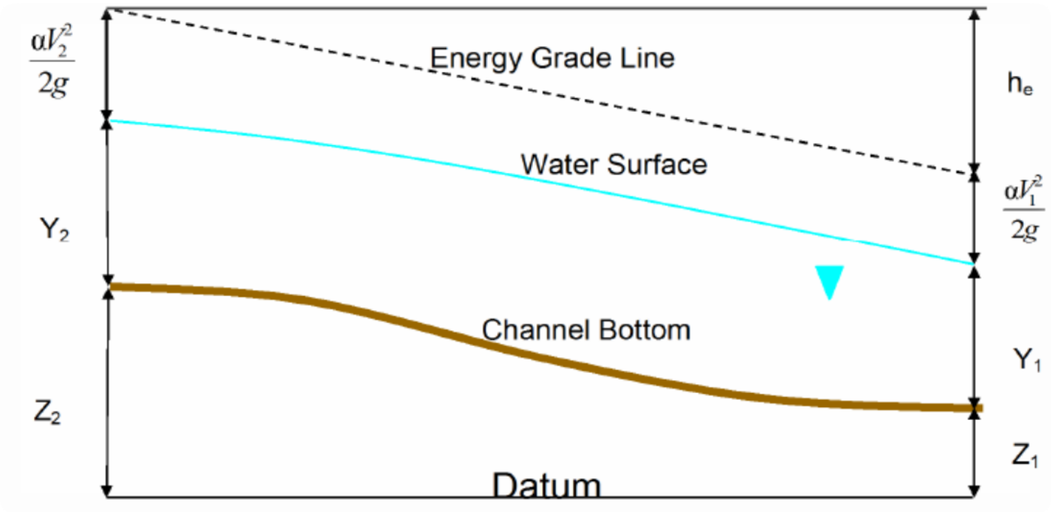


Figure 2-2 Representation of Terms in the Energy Equation

The energy head loss h_e between two cross sections is comprised of friction losses and contraction or expansion losses. The equation for the energy head loss is as follows: $h_e = L\overline{S_f}+C\left|\frac{\alpha 1(v1)^{2}1}{2g}-\frac{\alpha 2(v2)^{2}}{2g}\right|$ ………………………..2.1

Where: L = distance weighted reach length

$\overline{S}_f$ = representative friction slope between two sections

C = expansion or contraction loss coefficient

The distance weighted reach length, L, is calculated as:

$L=\frac{L_{lob}Q_{LOB}+L_{ch}{}^{Q_{Ch}}+L_{rob}Q_{rob}}{Q_{bb}+Q_{ch}+Q_{rob}}$ 2.2

Where: L_{lob} ,L_{rob} ,L_{ch} = cross section reach lengths specified for flow in the left over bank, main channel, and right over bank, respectively.

QQ_{lob} ,Q_{rob} Q_{ch} = arithmetic average of the flows between sections for the left over bank, main channel, and right over bank, respectively

Cross Section Subdivision for Conveyance Calculations:

The determination of total conveyance and the velocity coefficient for a cross section requires that flow be subdivided into units for which the velocity is uniformly distributed. The approach used in HEC-RAS is to subdivide flow in the over bank areas using the input cross section n value break points (locations where n-values change) as the basis for subdivision conveyance. (Conveyance is calculated within each sub division from the following form of Manning's equation (based on English units):

$Q=KS_f^{1/2}$……………………2.3

$K=\frac{1.486AR^{2/3}}{n}$……………………2.4

Where: K = conveyance for subdivision

n = Manning's roughness coefficient for subdivision

A = flow area for subdivision

R = hydraulic radius for subdivision (area / wetted perimeter)

The program sums up all the incremental conveyances in the over banks to obtain a conveyance for the left over bank and the right over bank. The main channel conveyance is normally computed as a single conveyance element. The total conveyance for the cross section is obtained by summing the three subdivision conveyances (left, channel, and right).

Friction Loss Evaluation:

Friction loss is evaluated in HEC-RAS as the product of $\overline{S_f}$ and L (Equation 2-1), where $\overline{S_f}$ the representative friction slopes for a reach, and L is defined by Equation 2-2. The friction slope (slope of the energy grade line) at each cross section is equation as follows:

$S_f=\left(\frac{Q}{K}\right)^2$…………………2.5

Alternative expressions for the representative reach friction slope $\overline{S}_f$ in HEC-RAS are as follows:

Average Conveyance Equation:

$$\overline{S}_f = \left(\frac{Q1+Q2}{K1+K2}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.6$$

Average Friction Slope Equation:

$$\overline{S}_f = \frac{S_{f1}+S_{f2}}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.7$$

Geometric Mean Friction Slope Equation

$$\overline{S}_{f1} = \sqrt{S_{f1}+S_{f2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.8$$

Harmonic Mean Friction Slope Equation:

$$\overline{S}_f = \frac{2(S_{f1}+S_{f2})}{S_{f1}+S_{f2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.9$$

Table 2-1 Criteria utilized in selection of friction slope

Profile Type	Is friction slope at current cross section greater than friction slope at the preceding cross-sections	Equation Used
Sub critical (M_1, S_1)(back water profile	Yes	Average friction slope (2-7)
Sub critical (M_2)(draw dawn profile)	No	Harmonic mean (2-9)
Supercritical(S2)	Yes	Average friction slope(2-7)
Supercritical(M3,S3)	Yes	Geometric mean (2-9)

The criteria given in Table 2-1 for selecting the appropriate energy loss equation are derived based on investigations conducted in order to select the appropriate equation which can approximate the loss for a given type of flow.

The first equation is the default equation.

Contraction and Expansion Loss Evaluation

Contraction and expansion losses in HEC-RAS are evaluated by the following equation:

h_{ce} = $C\left|\frac{a1(v1)^2 1}{2g} - \frac{a2(v2)^2}{2g}\right|$……………………………………………2.10

Where: C = the contraction or expansion coefficient

The program assumes that a contraction is occurring whenever the velocity head downstream is greater than the velocity head upstream. Likewise, when the velocity head upstream is greater than the velocity head downstream, the program assumes that a flow expansion is occurring.

II) Sediment transport for River analysis:

It is possible to analyze the mobile bed sediment transport using HEC-RAS 4.1 and this can be done by specifying transport function, sorting method, fall velocity method, sediment control volume and the bed gradation associated with each cross section.

Transport Potential Functions:

In HEC- RAS 4.1 there are six transport potential functions to select from.

- Ackers-White
- Englund-Hansen
- Laursen (Copeland)
- Myer-Peter-Meuler
- Toffaleti
- Yang (Sand and Gravel)

These functions were selected based on their validity and collective range of applicability. The ranges of input parameters used in the development of each function are shown in Table 2.2

Table 2-2 Range of input values for sediment transport functions (SAM user's manual, 1998

Function	d	d_m	s	V	D	S	W	T
Achers-white(flume)	0.004-0.07	NA	1-2.7	0.07-7.1	0.01-1.4	0.00006 - 0.037	0.23-4	46-49
Englund-hansen(flume)	NA	0.19-0.39	NA	0.65-6.34	0.19-1.33	0.000055-0.019	NA	43-93
Lurasen(field)	NA	0.08-0.7	NA	0.068-7.8	0.67-54	0.0000021-0.0018	63-3640	32-93
Lurasen(flume)	NA	0.011-29	NA	0.7-9.4	0.03-3.6	0.00025-0.025	0.25-6.6	46-83
Meyer-Peter Muller(flume)	0.4-29	NA	1.25-4	1.2-9.4	0.03-3.9	0.0004-0.02	0.5-6.6	NA
Tofaletti (field)	0.062-4.0	0.095-0.76	NA	0.7-7.8	0.07-56.8(R)	0.000002-0.0011	63-3640	32-93
Tofaletti(flume)	0.062-4.0	0.45-0.91	NA	0.7-6.3	0.07-1.1(R)	0.00014-0.019	0.8-8	40-93
Yang (filed sand)	0.15-1.7	NA	NA	0.8-6.4	0.04-50	0.000043-0.028	0.44-1750	32-94
Yang (filed – gravel)	2.5 -7	NA	NA	1.4 - 5.1	0.08-72	0.0012-0.029	0.44-1750	32 - 94

Where: d = Overall particle diameter, mm

d_m = Median particle diameter, mm

s = Sediment specific gravity

V = Average channel velocity, fps

D = Channel depth, ft

S = Energy gradient

W = Channel width, ft

T = Water temperature, $_o$F

(R) = Hydraulic Radius, ft

NA = Data not available

Sorting and Armoring

To compute active layer thickness and vertical bed layer tracking assumptions. Two methods are currently available:

Exner5:- A three layer active bed model that includes the capability of forming a coarse surface layer that will limit erosion of deeper material thereby simulating bed armors (default method).

Active layer: - This is a simplified two layer active bed approach. The active layer thickness is set equal to the d_{90} of the layer. This assumption is only appropriate for gravel beds and is intended for use with the Wilcock transport method in particular.

Fall Velocity:

Several methods are available for computing fall velocity. The options include: Ruby, Toffaleti, Van Rijn, Report 12 (Default method in HEC 6).

3 METHODOLOGY

3.1 Materials

- Surveying instrument (total station and its accessories)
- Soil sample collector and soil sample
- Hydrological data(discharge)
- Eagle point soft ware
- HEC-RAS 4.1 software
- Different books and journals

3.2 METHODS

1. Field investigation

- ✓ Field survey to obtain data for stream and adjacent flood plain cross section and other structures that may affect the hydraulics of the study reach.
- ✓ Collection of representative sample materials from channel bed and banks
- ✓ Laboratory work from the collected data for the determination of gradation size, specific gravity and medium size of bed and banks of the channel

2. Eagle point software

From surveying data using eagle point software developing surface modeling in hec-2 format to export to the geometry data to HEC-RAS 4.1 soft ware.

3. Determine less frequent discharge using frequency analysis method from instantaneous discharge obtained from ministry of water, irrigation and energy.

4. Preparation of geometry and other sediment data for HEC-RAS4.1 software.

3.2.1 COLLECTION AND ANALYSIS OF DATA

3.2.1.1 Geometry of the Channel

- ➢ River system schematic

It is required to define the schematic of the River system that means the geometric structure of several reaches, the reach length as well as a naming convention. This is the first thing that is required to do before any data can be entered in the soft ware (*Behailu tamiru zena September 2006)*

So accordingly it has one reach of length of about 1.84km between the Logia bridge and canal siphon.

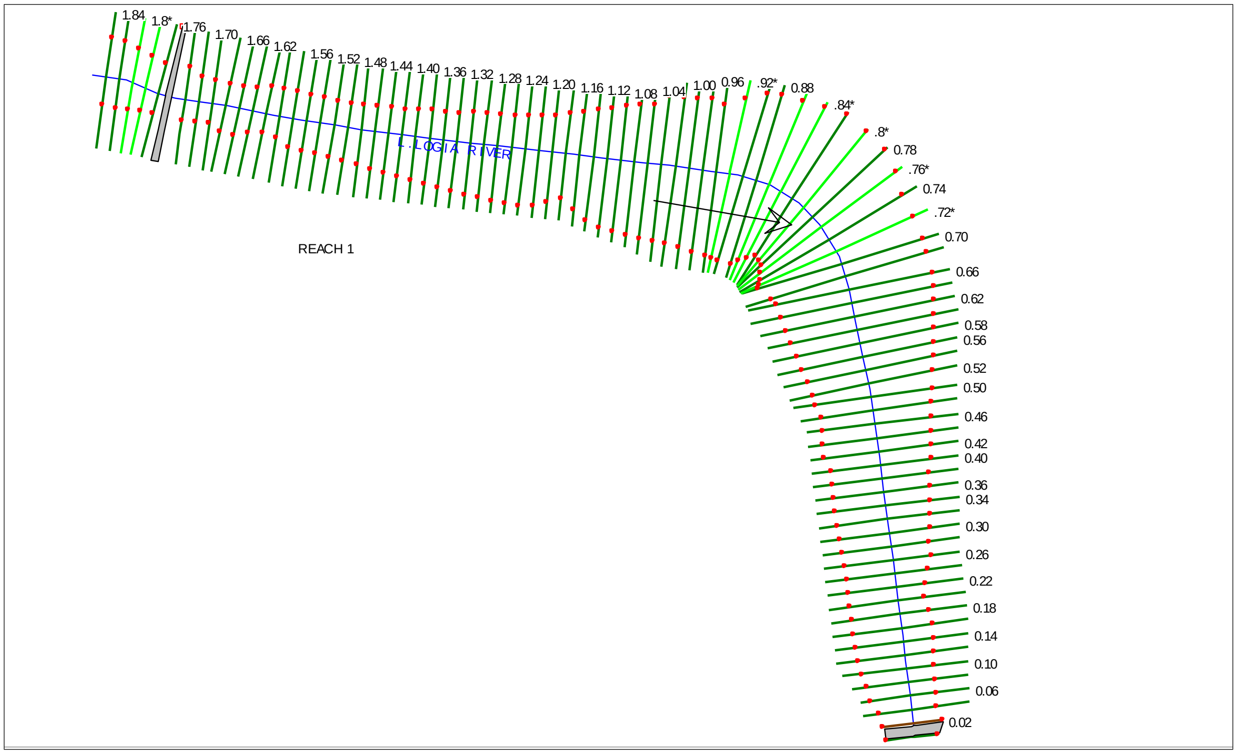


Figure 3-1 schematic layout of River reach

- Cross-Section

The River to be modeled is considered in the single reach in the vicinity of the Tendaho sugar factory project which is the lower part of the Logia River reach that located between Logia Bridge and the canal syphon on the main canal of the Tendaho dam and irrigation project. The distance between the cross section is 20m and the surveying reading is taken on the bed and over the bank of the cross section as shown on the schematic of the HEC-RAS4.1 layout shown on figure 3.1.

This reach considered due to the channel width, depth, alignment and the sensitivity to flood of the River section and it also contain different structures like bridge and siphon. The bank heights at downstream of the bridge in the left side vary from 6.77 to 4.05 m and in the right side it vary from 4.05 to 3.25m along the town. At the middle of the reach the left side of the bank heights' varies from 3.05 to 4.46m and the right bank heights vary from 2.52 to 4.98 m. At the end of the reach of the River along the canal siphon wing wall earthen dike is constructed on the natural River bank which almost similar materials with the bank and bed. The left bank height varies from 5.01m to 7.01m and right bank height varies from 4.27m to 6.96m.

- Channel slopes

Longitudinal channel slope of the lower Logia River is almost flat slope which is 0.1473%. This calculated by considering the average of the elevation of the center of each cross section divide by its respective longitudinal distance between the points.

3.2.1.2 Bed and Bank Materials

Soil samples are taken from the bed, left and right banks of the River.

The bed and bank materials contain a similar range of particle sizes ranging from sands to silt thus sieve analysis is used to determine the particle size analysis and its result is show in Table 3-1.

Table 3-1 typical grain sizes of each of the samples

Sample reaches	station	d16(mm)	d25(mm)	d50(mm)	d65(mm)	d75(mm)	d90(mm)	remark
Bridge area	Left bank	0.195	0.108	1.060	2.400	2.900	6.000	Only the representative sample is considered
	center	0.180	0.250	1.200	2.300	3.400	10.000	
	Right bank	0.060	0.090	0.990	0.240	0.260	0.500	
At the middle of the reach	Left bank	0.190	0.270	1.100	3.800	8.600	13	
	center	0.056	0.110	0.170	0.210	0.240	0.480	
	Right bank	0.050	0.110	0.150	0.180	0.200	0.260	
Siphon area	Left bank	0.046	0.19	1.120	2.912	3.012	5.900	
	center	0.047	0.11	0.164	0.230	0.253	0.640	
	Right bank	0.05	0.11	0.153	0.191	0.200	0.235	

3.2.1.3 Discharge

- Dominant Discharge

The terms dominant discharge are synonymous with bankfull discharge as used according to (stream corridor Restoration principles processes and practice).
A commonly accepted and universally applicable definition of bank full was provided by Dunne and Leopold (1978): "The bank full stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work results in the average morphologic characteristics of channels."

It is the modest flow regimes that transport the greatest quantity of sediment material over time, due to the higher frequency of occurrence for such events (*Wolman and Miller 1960*).The dominant, effective or bank full discharge is associated with the peak of cumulative sediment transport for a given stream flow magnitude and frequency of occurrence. An analysis of return periods related to field-determined bankfull discharge conducted by the (*Wolman and Miller 1960)* over the past 10 years and using data for gage stations located on Rivers throughout North America indicates a range in return interval from 1.05 to 5 years. Exceptions to this finding appear to be associated with highly developed urban watersheds, where the return period of the bankfull discharge is closer to 1.1 year. Often, the U.S. Army Corps of Engineers field interpretation of "ordinary high water" and the bankfull stage are synonymous. Thus, one may conclude that the flow regime associated with bankfull discharge is a relatively frequent event, so according to the above analysis the dominant discharge is considered for this study to be 2.5 years return period.

- Discharge for Steady Flow Profiles

There is a record of 19 years maximum daily instantaneous discharge data at the Bridge of Logia River, (data see appendex-1) from the ministry of Water, Irrigation and Energy. To estimate and examine the carrying capacity of the channels’ reach of the flood way and over banks we considered a 100 years return period and bank full discharges. These helps to know how flood restriction projects affect flood, water elevation and most of the adjacent infrastructures also must be safe at a lower risk of probability by taking this discharge. This can also help to design bank protection structures and this also the design discharge of canal siphon and the Logia Bridge. At a bank full discharge which is taken as a 2.5 years discharge can generally help as a primary design discharge to assess the channel characteristics such as channel width, depth and slope. Generally the strength of the flow due to 2.5, 50, & 100 years discharges must be analyzed against the stability of the banks of the River reach. Therefore these discharges are calculated based on the best fit method which is log Pearson type III distribution methods. Accordingly the result is shown at Table 3-2

Table 3-2 Estimated discharge

Return period	Discharge(m3/sec)
2.5 (channel forming discharge)	142.390
50	524.010
100(design discharge of siphon and bridge)	590.151

- Quasi unsteady flow data

Quasi-unsteady flow is an estimated hydrograph based on a set of measured unsteady flow values collected from the gauge station by the user *(warner et al, 2010)*

These different return periods were determined based on the above hydrological analysis which cause major impact on the River bank and bed, structures and impact on the surrounding area. Due to non linear flow of alluvial sediment transport a hydrograph should be constructed for the River so it is better to estimate roughly the bell shaped hydrograph to develop quasi unsteady flow data for bed sediment transportation based on the measured data. These are done by daily maximum instantaneous flows that are greater than or equal to the minimum discharge that initiate sediment motion are peaked for each month and the average of these maximum flows are taken for each water year to form a single representative water year and quasi unsteady flow is determined. Accordingly the nineteen years data from ministry of water, irrigation and energy is collected and from that the average of the monthly flow that can initiate sediment transport which is greater than or equal to the critical shear force are consider . Quasi unsteady flows assumption approximates the continuous flow hydrograph with series of discrete steady flow for each record in the flow series; flow remains constant over specified time window for transportation. *(HEC-RAS Reference manual)*

Each discrete steady flow profiles divided and further sub divided in to shorter blocks of time for sediment transport computation –HEC-RAS utilize three different time step each sub division. These are flow duration, the computation incremental and the mixing time step.

Flow duration is the length of time over which flow, stage, temperature and sediment load assume to be constant

Computation increment time is the subdivided flow of flow duration at which the bed geometry and hydrodynamics are updated after each computational increment.

Mixing time step in each computation increment the bathy meter, hydraulic parameter and transport potential for each grain size remain constant. According to the above assumption and available data the flowing hydrograph is developed.

$u_* = \sqrt{\frac{\tau_b}{\rho}}$ --4.3.3.1

Where $\cup_*$ shear velocity

τ_b Shear stress

ρ_s Density of the particles

But from critical shields parameter $\theta_{cr} = \frac{\tau_{b\,cr}}{(\rho_s - \rho) g d_{50}}$--------------4.3.3.2

Where θ_{cr} critical shield parameter

D_* Median particle diameter

$\theta_{cr} = 0.14 * D_*^{-0.64}$ for $4 < D_* < 10$

$\theta_{cr} = 0.14 * (0.6785 * 10^{-3})^{-1}$

$\theta_{cr} = 0.03349$

$\tau_{b\,cr} = \theta_{cr} * ((\rho_s - \rho) g d_{50}$

= 0.0349*(1.749-1)*0.6785

= 0.00017

But the bed shear stress shall be equal to the critical bed shear stress at initiation of bed load motion; so, $\tau_{bc} = \gamma h S$

From this, h can be expressed in terms of the critical shear stress as,

h = $\tau_{bcr} / \gamma s$

From manning formula $Q = (B * h) \frac{S^{1/2} R^{2/3}}{n}$

For wide channel $R = h = \frac{\tau_{b\,cr}}{\gamma s}$ =0.115m

Q_{min} = (B*$\frac{S^{1/2}R^{5/3}}{n}$)

Where average width at gauging station B = 45m

S=0.1473%

n= 0.035

Q_{min} =14.72m3/sec

so we considered the discharge above minimum discharge for formation of quasi unsteady flow hydrograph and the result shown in Table 3-3 quasi unsteady flow hydrograph

Table 3-3 quasi unsteady flow hydrograph

S.No	month	flow duration	average flow (cms)
1	January	720	15
2	February	720	21
3	March	720	26
4	April	720	32
5	May	720	39
6	June	720	46
7	July	500	55
8	July	220	70
9	August	180	83
10	August	6	172.12
11	August	1	185.2
12	August	12	164
13	August	220	102.2
14	September	480	100
15	October	720	70
16	November	720	65
17	December	520	53
18	December	520	23

3.2.2.4 Other Hydraulic Input data

- Roughness coefficients

The selection of manning coefficient (n) values involves judgment, skill, and subjectivity if not perform practical investigation.
Manning coefficient vary based on channel terrain, Size and type of the bed and bank materials, shape of the cross section, longitudinal variation in cross-sectional shapes, the distribution of roughness materials along the wetted perimeter, longitudinal bed profile (form resistance), state of the flow motion such as unsteadiness, viscous friction, and free surface as published in most hydraulic engineering books. (U.S. Geological Survey in case of Manning's Roughness Coefficients for Illinois Stream data series 668).

The adjustment factors organized by Cowan (1956) are examples for organizing the roughness characteristics. Therefore the n value for each of the segments; the main channel and left & right flood plains are estimated as per the following equation (Chow, 1958).

$$n = (n_0 + n_1 + n_2 + n_3 + n_{4)})n_5 \ldots\ldots 3.1$$

Where
n_0 = a basic value for a straight, uniform, smooth channel in a natural material involved
n_1 = a value added to no to account for the effect of surface irregularities
n_2 = a value for variations in shape and size of the channel x-section
n_3 = a value for obstruction
n_4 = a value for vegetation and flow condition
n_5= correction factor for meandering of a channel
Because of similarity in channel characteristics within the concerned reach, a uniform n value is taken as an average for all the cross sections in the reach. That is an average Manning's n for the main channel and an average n for the right and left over banks is taken for all the cross sections in a reach.

Table 3-4 manning roughness channel characteristics (chow1959)

Channel condition		Some n Values	
Degree of irregularity	smooth	n1	0.000
	minor		0.005
	moderate		0.01
	sever		0.02
Variations of channel cross section	Gradual	n2	0.000
	Alternating occasional		0.005
	Alternating frequent		0.01 -0.015
Relative of effective obstructions	negligible	n3	0.000
	minor		0.010 -0.015
	appreciable		0.02 -0.030
	sever		0.04 -0.06
vegetations	Low	n4	0.005-0.01
	medium		0.01 -0.025
	high		0025 -0.05
	Very high		0.05-.1
Degree of meandering	minor	n5	1
	appreciable		0.15
	sever		1.3

The basic value $n_0$is estimated by the following empirical relations (French, 1986):

n_0 =0.039$d_{50}^{1/6}$ (d, m) ………………………………………………….3.2

Where, d_i is a grain size in which i percentage of the particles finer than d.

So according to the bed and bank material laboratory result the average roughness is calculated in the respective channel section.

These are:

From the above table the values of different roughness factors are:

Degree of irregularity minor n1 values =0.010

Variation of channel cross section n2 values =0.005

Relative of effective obstruction minor n3 values n3= 0.005

Vegetation low n4 values= 0.01

Degree of meandering m minor n5 values 1

Therefore $n = (n_0 + n_1 + n_2 + n_3 + n_4)n_5$

For left part of the channel = (0.0002+0.010+0.005+0.005+0.01)*1=0.035

For the right part of the channel = (0.0002+0.010+0.005+0.005+.01)*1=0.035

For the center part of the channel = (0.0002+0.010+0.005+0.005+0.01)*1=0.035

Table 3-5 value of n_o and particles diameter

stations	Average d_{50} (m)	Average d_{50}(ft)	Average d_{90}(m)	Average n_o	Adopted formula
Left bank	0.0011	0.0003	0.0083	0.0002	Equation (3.2)
Main channel	0.0005	0.0002	0.0037	0.0002	
Right bank	0.0004	0.0001	0.0033	0.0002	

Equation 3.2, Garde and Raju, (Cited in Michael, 2003)

- The coefficients of contraction and expansion

Contraction and expansion consider as by HEC-RAS are evaluated in the following equation

$$h_{ce} = C\left|\frac{a1(v1)^2}{2g} - \frac{a2(v2)^2}{2g}\right|$$

Where c is the contraction or expansion coefficients

The program assume that the contraction occurring when the velocity head at downstream greater than the velocity at the upstream likewise velocity head at upstream greater than at downstream the program assume that the expansion flow is occurring.

The contraction and expansion of different channel is stated on table 3.6

Contraction and expansion for various channel condition is given in chow (1959)

Table 3-6 contraction and expansion

Channel condition	Coefficients	
	contraction	expansion
Gradual change	0.2	0.1
Abrupt change	0.3	0.5

Based on the above table and by evaluating the change in channel cross section variations and the plan form variations values for the contraction and expansion coefficient estimated for each cross section.

- Bridge loss

There is bridge at the upstream end of the reach with a span width of 75m with average clear water way of 60m and four piers with average water depth 4m.Depending on the flow situation the HEC-RAS automatically select the suitable flow equations as a result a weir coefficient 1.44 and maximum submergence of 0.95 are used from the default values.

- Canal siphon loss

The siphon also found at the downstream end of the channel reach which seem as concrete lined trapezoidal open channel for flow but it has no significant flow resistance comparing with earthen channel except the transition zone of contraction and expansion loss.

- Roughness coefficients of concrete lining and culvert

The roughness coefficients of different concrete lining structure are adopted from chow (1959) as shown the table below.

Table 3-7 roughness coefficients of different concrete lining adopted from chow 1959

Type of materials Concrete lining of	minimum	normal	maximum
Culvert straight and free of debris	0.010	0.011	0.013
culvert with bends contains some debris	0.011	0.013	0.014
Finished culvert	0.011	0.012	0.014
Sewer with manhole inlet etc ,straight	0.013	0.015	0.017
Unfinished smooth wood form	0.012	0.014	0.016
Unfinished steel form	0.012	0.013	0.014
Unfinished rough wood form	0.015	0.017	0.020

4 MODEL APPLICATION AND DISCUSSIONS OF RESULTS

4.1 Water surface profile

The water profile for predetermine return period of 2.5,50 and 100 years discharge is calculated using manning method. According to the simulated result the 2.5 discharges is accommodated within the channel section of the whole station. But there is observed in some adjoining areas flooded by the 50years and 100years return period discharges.

For example, on River stations from 1.84 to 1.82 at left bank of the channel a flood of about 0.5m depth of water flows, and at station 1.66 and 1.64 on both bank it flooded the surrounding area at a height of 0.23m and almost from station 1.70 to 1.28 the water over top the bank in both side at different elevations from 0.2 to 0.72m height of water. A plot of water surface profile for selected cross sections is shown in figures below.

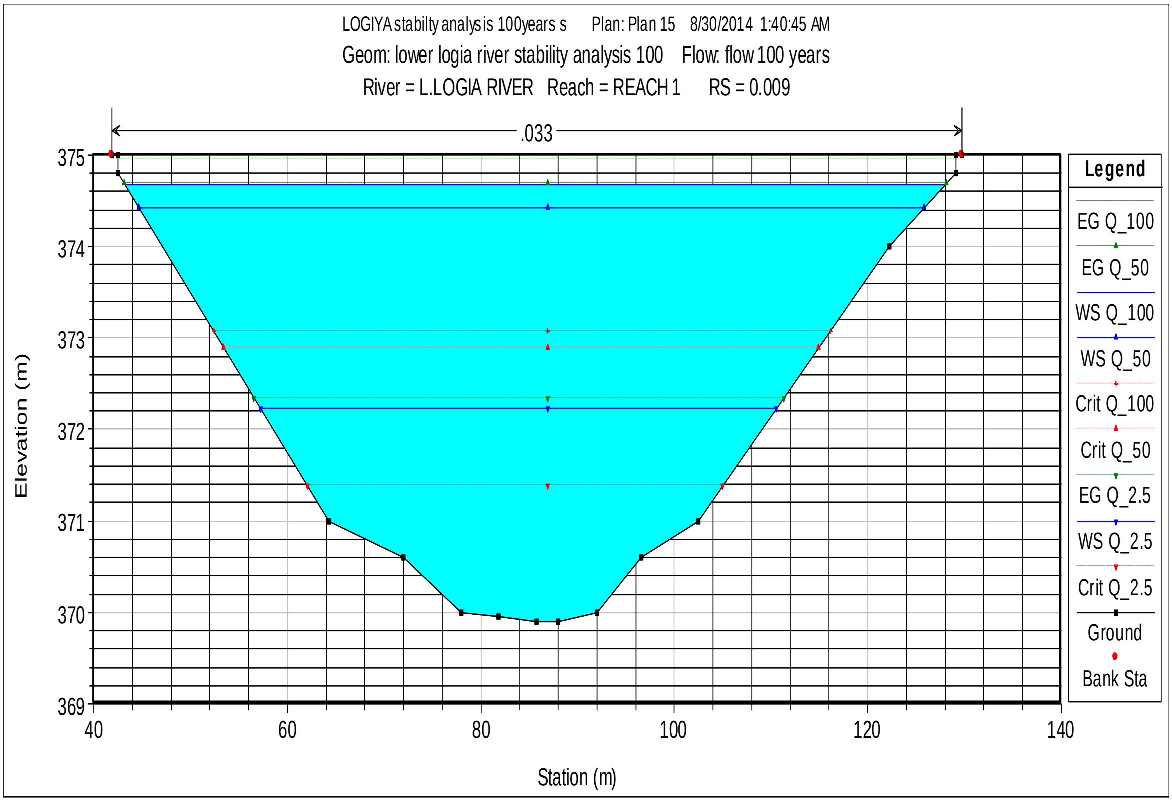


Figure 4-1 water profiles at siphon

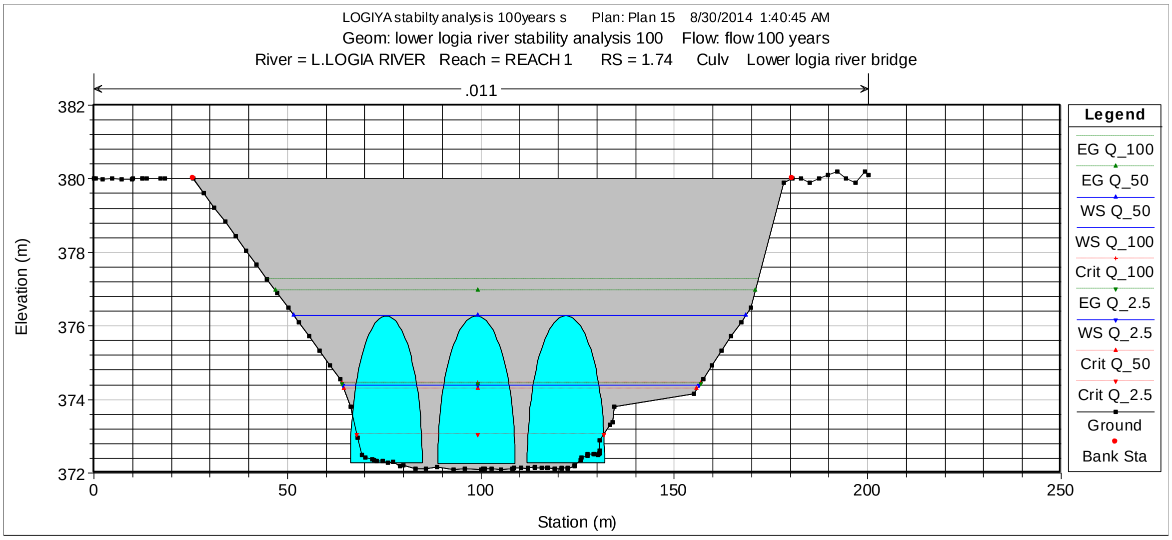


Figure 4-2 water profiles at Logia Bridge

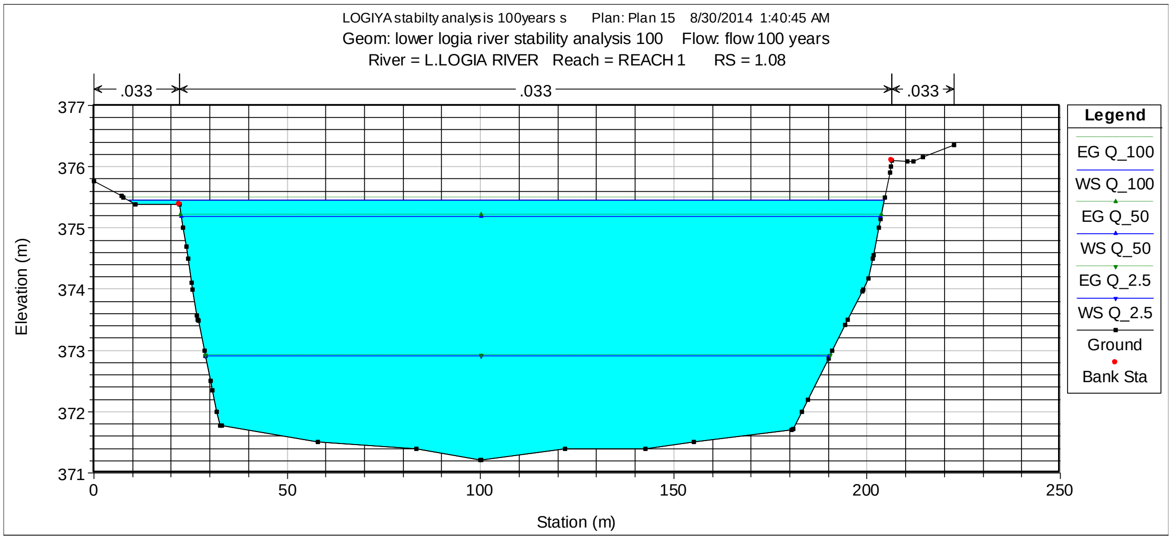


Figure 4-3 water profiles at Rivers station1.08

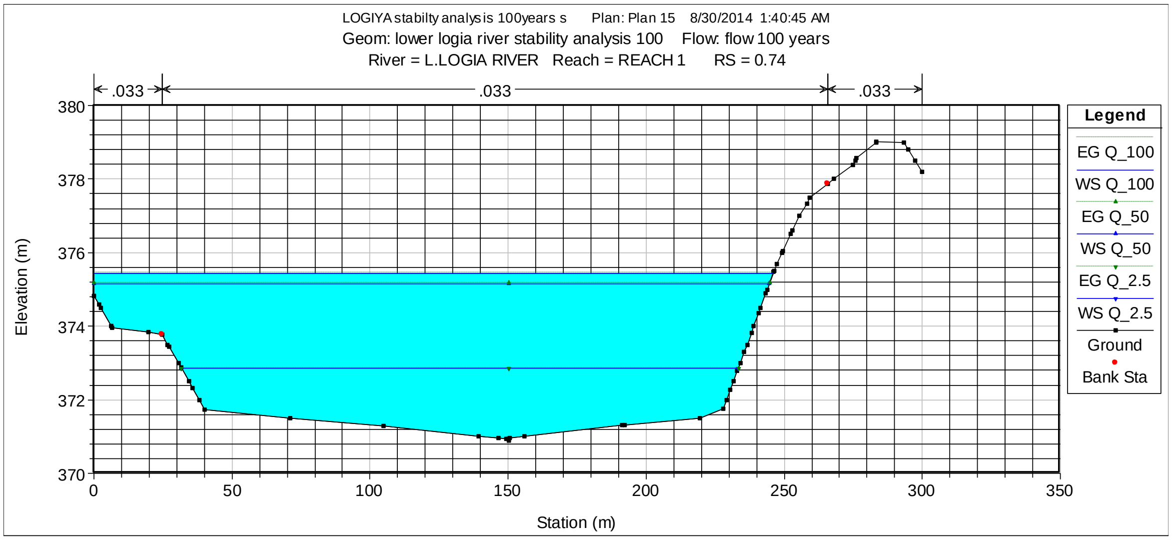


Figure 4-4 water profiles at River station 0.74

In the lower River station almost the channel accommodate the water surface of 100years discharge. And a little over top near the canal siphon.

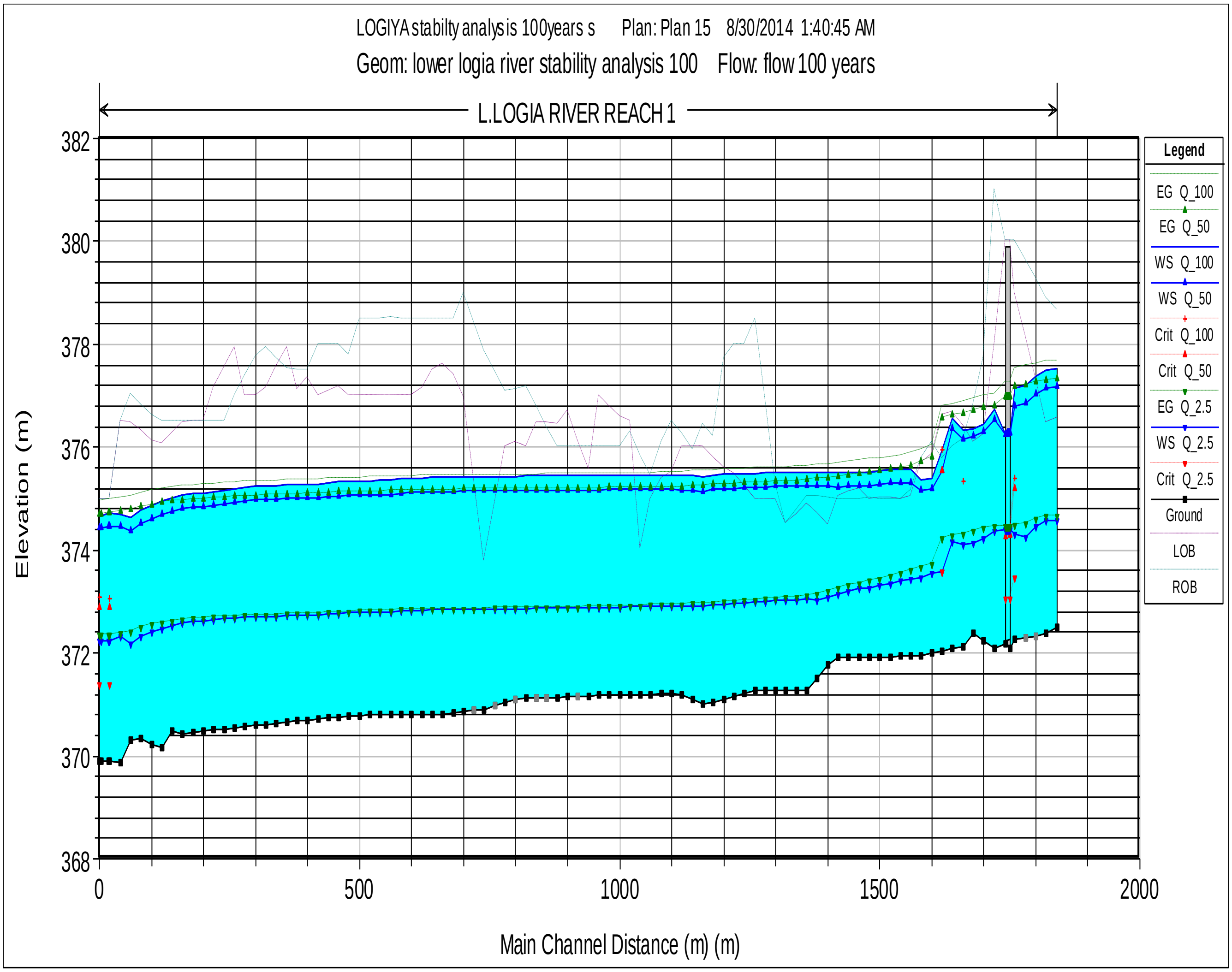


Figure 4-5 water surface profiles along the longitudinal River station

Plot of X-Y-Z perspective plot of 2.5,50 and 100years

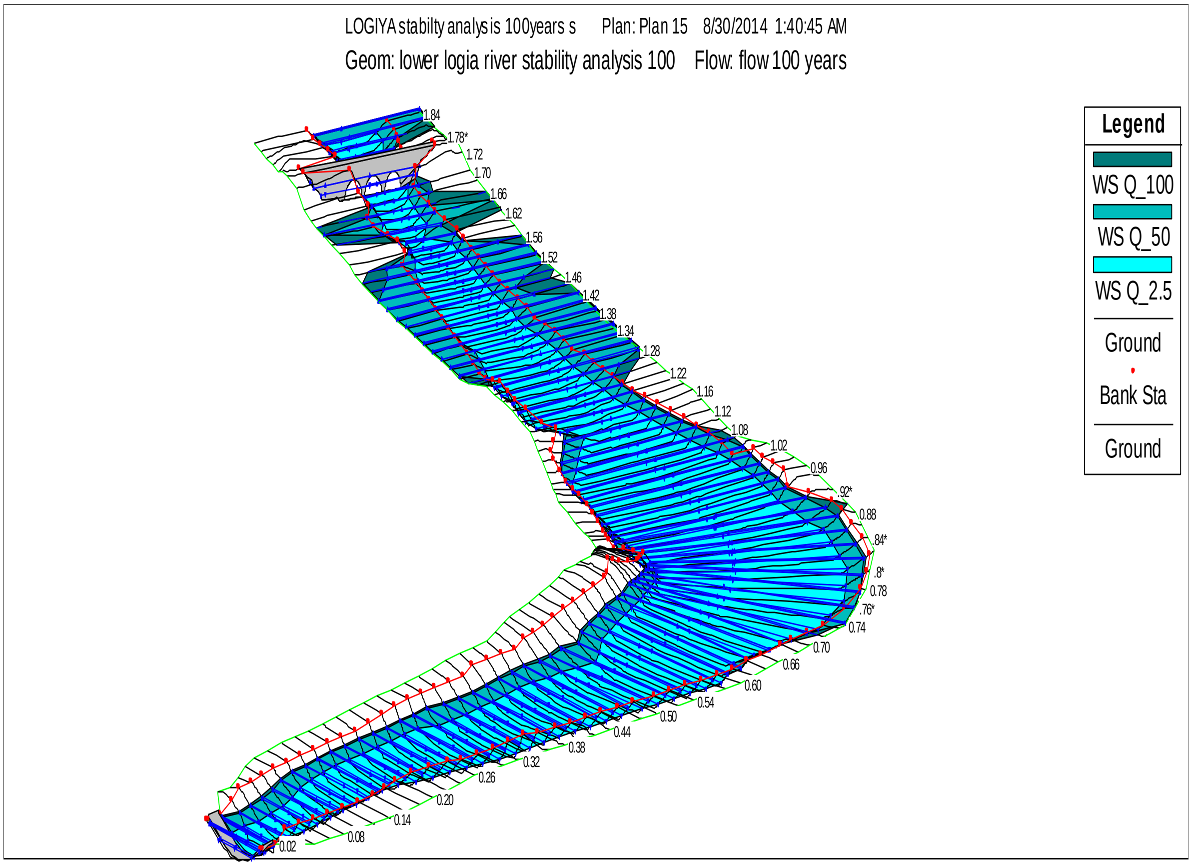


Figure 4-6 plot x-y-z perspective plot of 2.5,50 and 100years return period

4.2 Bank stability

The stability of the banks is evaluated by the resistance for erosion of the banks against the maximum and minimum shear stresses induced by the flow on the boundary and resistance by the vegetation cover and other factor from the geometry of the banks.

From steady flow analysis of lower Logia River a shear induced due to the flow of the design discharge of 50 years and 100years together with the channel forming discharge which is taken as 2.5years return period is analyzed.

The maximum shear stress ($^{N}/_{m^2}$) on channel bed of the lower Logia River reach is observed on station 1.62 and values 130.77 for 2.5 years return period ,135.32 for return period 50years and 172.96 for 100years return period in $^{N}/_{m^2}$and the minimum shear stress observed at station 0.88 and the values are 1.87 for 2.5 years 3.28 for 50 years and 3.49 for 100years return period discharge taking 75%of the above values as the shears on the banks and this is compared with critical shear stress ,$\tau_c$for non cohesive bed material which is described by shields

τ_c= μ_sγ(G_S-1)d_s

G_S =Specific gravity of particles (taken as 2.65)

d_s =Particle size (median size is taken)

μ_s= varies from 0.3 to 0.03 for sand and has an approximately constant value of 0.02 particles such silt and sand.

γ unit weight of water (9.81KN/m^2)

Then for the lower Logia River d_{50}on the right bank is about 1.04mm and critical shear stress from the steady flow stimulation is

4N/m^2.

$$\tau_c = 0.02 * 9.81 * (2.65 - 1) * 1.04$$

=0.34N/m^2

This is much more less than the minimum shear stress induced by any of the predetermined discharges. Thus the rest of the banks have similar materials which does not has significant impact on the result of critical shear stress .The vegetation cover on the banks are rarely placed shrubs and short height bushes whose roots are shallow that there is not hinder erosion of the bank due to their existence except near upstream of the siphon. Thus the bank of lower Logia River can generally get easily eroded and have less resistance to shear.

4.3 Bed stability

According to the model result which is analyze using the sediment function laursen (Copland) and Yang (filed sand) sediment transport formula, deposition is observed in all River station almost 85% of River station.

The remaining River station degradation is observed in station at just downstream of the bridge according to the model results.

According to the luarsen (Copland) and Yang (filed sand) sediment transport formula a maximum degradation depth is 1.818 m at station 0.86* and a deposition of 3.524m at a station 1.08 is observed.

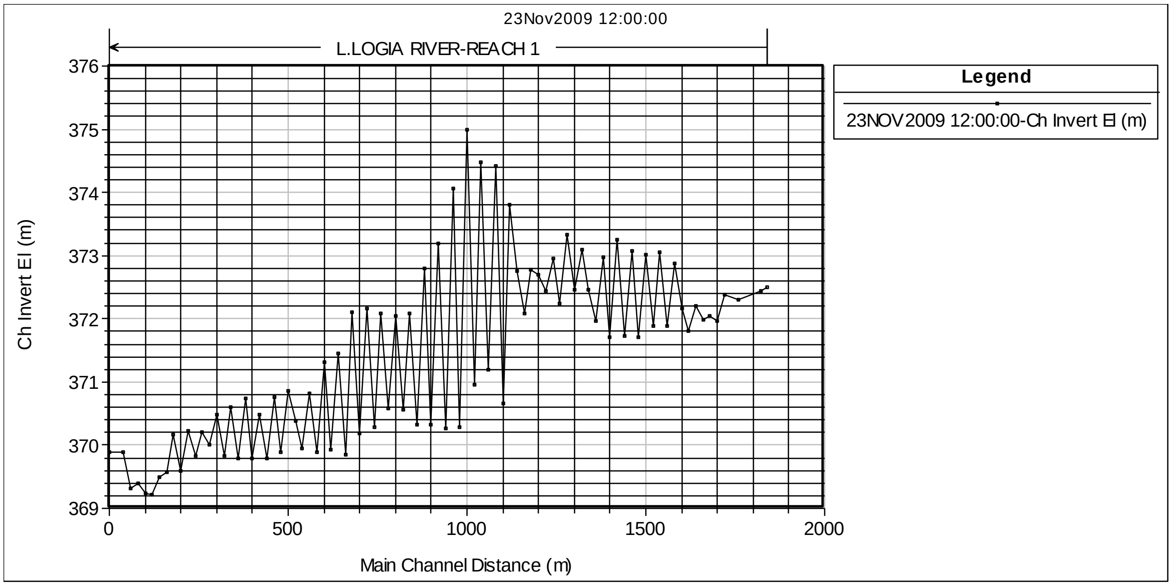


Figure 4-7 channel invert elevation for each month of stimulation period

Bed profile plot of Lower Logia River at start and end of simulation time And the tabular form results and time series plots for considered cross section of the reach based on the considered transport formula.

Table 4-1 Bed profile at start simulation and end of simulation

S.No	River	Reach	RS	Elevation		Difference
				At Start of Simulation	At End of simulation	
1	L.LOGIA RIVER	REACH 1	1.840	372.500	372.500	0.000
2	L.LOGIA RIVER	REACH 1	1.820	372.37	372.458	-0.078
3	L.LOGIA RIVER	REACH 1	1.760	372.269	372.296	-0.026
4	L.LOGIA RIVER	REACH 1	1.720	372.100	372.481	-0.380
5	L.LOGIA RIVER	REACH 1	1.700	372.250	371.550	0.699
6	L.LOGIA RIVER	REACH 1	1.680	372.369	372.054	0.315
7	L.LOGIA RIVER	REACH 1	1.660	372.130	371.990	0.140
9	L.LOGIA RIVER	REACH 1	1.620	372.040	371.813	0.226
11	L.LOGIA RIVER	REACH 1	1.580	371.959	372.969	0.009
12	L.LOGIA RIVER	REACH 1	1.560	371.940	371.884	0.055
13	L.LOGIA RIVER	REACH 1	1.540	371.940	373.043	0.102
14	L.LOGIA RIVER	REACH 1	1.520	371.930	371.896	0.033
15	L.LOGIA RIVER	REACH 1	1.500	371.930	373.044	0.114
16	L.LOGIA RIVER	REACH 1	1.480	371.930	371.633	0.296
17	L.LOGIA RIVER	REACH 1	1.460	371.920	373.262	0.342
18	L.LOGIA RIVER	REACH 1	1.440	371.920	371.842	0.077
19	L.LOGIA RIVER	REACH 1	1.420	371.920	373.044	0.124
20	L.LOGIA RIVER	REACH 1	1.400	371.780	371.718	0.061

21	L.LOGIA RIVER	REACH 1	1.380	371.520	372.865	0.005
22	L.LOGIA RIVER	REACH 1	1.360	371.269	372.197	-0.927
23	L.LOGIA RIVER	REACH 1	1.340	371.269	372.683	-1.413
24	L.LOGIA RIVER	REACH 1	1.320	371.269	372.761	-1.491
25	L.LOGIA RIVER	REACH 1	1.300	371.269	372.865	-1.595
26	L.LOGIA RIVER	REACH 1	1.280	371.260	372.988	-1.728
27	L.LOGIA RIVER	REACH 1	1.260	371.260	372.558	-1.298
28	L.LOGIA RIVER	REACH 1	1.240	371.209	372.788	-1.578
29	L.LOGIA RIVER	REACH 1	1.220	371.150	372.372	-1.222
30	L.LOGIA RIVER	REACH 1	1.200	371.100	372.814	-1.713
31	L.LOGIA RIVER	REACH 1	1.180	371.050	372.285	-1.235
32	L.LOGIA RIVER	REACH 1	1.160	371.000	373.058	-2.058
33	L.LOGIA RIVER	REACH 1	1.140	371.090	371.634	-0.544
34	L.LOGIA RIVER	REACH 1	1.120	371.180	374.093	-2.913
35	L.LOGIA RIVER	REACH 1	1.100	371.219	370.100	-1.119
36	L.LOGIA RIVER	REACH 1	1.080	371.209	374.734	-3.524
37	L.LOGIA RIVER	REACH 1	1.060	371.200	370.238	-0.961
38	L.LOGIA RIVER	REACH 1	1.040	371.200	374.959	-3.759
39	L.LOGIA RIVER	REACH 1	1.020	371.190	369.871	-1.318
40	L.LOGIA RIVER	REACH 1	1.000	371.19	374.551	-3.361
41	L.LOGIA RIVER	REACH 1	0.980	371.180	369.880	-1.299
42	L.LOGIA RIVER	REACH 1	0.960	371.180	374.214	-3.034
43	L.LOGIA	REACH 1	0.940	371.169	369.883	-1.286

	RIVER					
44	L.LOGIA RIVER	REACH 1	.92*	371.160	373.854	-2.694
45	L.LOGIA RIVER	REACH 1	0.900	371.1501	369.967	-1.182
46	L.LOGIA RIVER	REACH 1	0.880	371.130	373.678	-2.548
47	L.LOGIA RIVER	REACH 1	.86*	371.130	369.311	-1.818
48	L.LOGIA RIVER	REACH 1	.84*	371.130	372.170	-1.040
49	L.LOGIA RIVER	REACH 1	0.8200	371.130	370.008	-1.121
50	L.LOGIA RIVER	REACH 1	.8*	371.084	371.768	-0.683
51	L.LOGIA RIVER	REACH 1	0.780	371.040	371.628	-0.588
52	L.LOGIA RIVER	REACH 1	.76*	370.969	370.107	0.862
53	L.LOGIA RIVER	REACH 1	0.740	370.900	371.837	-0.937
54	L.LOGIA RIVER	REACH 1	.72*	370.880	370.054	-0.825
55	L.LOGIA RIVER	REACH 1	0.700	370.859	371.883	-1.024
56	L.LOGIA RIVER	REACH 1	0.680	370.840	370.61	-0.230
57	L.LOGIA RIVER	REACH 1	0.660	370.820	371.634	-0.814
58	L.LOGIA RIVER	REACH 1	0.640	370.820	371.126	-0.306
59	L.LOGIA RIVER	REACH 1	0.620	370.820	370.831	-0.011
60	L.LOGIA RIVER	REACH 1	0.600	370.820	371.045	-0.225
61	L.LOGIA RIVER	REACH 1	0.580	370.809	370.989	-0.180
62	L.LOGIA RIVER	REACH 1	0.560	370.809	369.487	-0.322
63	L.LOGIA RIVER	REACH 1	0.540	370.809	371.089	-0.279
64	L.LOGIA RIVER	REACH 1	0.520	370.799	369.282	1.517
65	L.LOGIA RIVER	REACH 1	0.500	370.790	371.313	-0.52
66	L.LOGIA RIVER	REACH 1	0.480	370.780	369.053	1.727

67	L.LOGIA RIVER	REACH 1	0.460	370.759	371.235	-0.475
68	L.LOGIA R	REACH 1	0.440	370.740	368.934	-0.805
69	L.LOGIA RIVER	REACH 1	0.420	370.720	371.076	-0.356
70	L.LOGIA RIVER	REACH 1	0.400	370.699	368.913	-0.786
71	L.LOGIA RIVER	REACH 1	0.380	370.680	371.134	-0.454
72	L.LOGIA RIVER	REACH 1	0.360	370.649	368.857	-0.792
73	L.LOGIA RIVER	REACH 1	0.340	370.630	371.020	-0.390
74	L.LOGIA RIVER	REACH 1	0.320	370.610	368.826	-0.783
75	L.LOGIA RIVER	REACH 1	0.300	370.589	370.878	-0.288
76	L.LOGIA RIVER	REACH 1	0.280	370.570	368.763	-0.806
77	L.LOGIA RIVER	REACH 1	0.260	370.549	370.752	-0.202
78	L.LOGIA RIVER	REACH 1	0.240	370.520	368.626	1.893
79	L.LOGIA RIVER	REACH 1	0.220	370.499	370.371	0.128
80	L.LOGIA RIVER	REACH 1	0.200	370.489	368.703	1.786
81	L.LOGIA RIVER	REACH 1	0.180	370.460	370.284	0.175
82	L.LOGIA RIVER	REACH 1	0.160	370.439	368.725	1.714
83	L.LOGIA RIVER	REACH 1	0.140	370.470	369.545	0.925
84	L.LOGIA RIVER	REACH 1	0.120	370.170	368.997	1.172
85	L.LOGIA RIVER	REACH 1	0.100	370.220	369.053	1.166
86	L.LOGIA RIVER	REACH 1	0.080	370.339	368.890	1.449
87	L.LOGIA RIVER	REACH 1	0.060	370.310	368.728	1.581
88	L.LOGIA RIVER	REACH 1	0.040	369.880	369.228	0.651
89	L.LOGIA RIVER	REACH 1	0.000	369.880	369.880	0.000

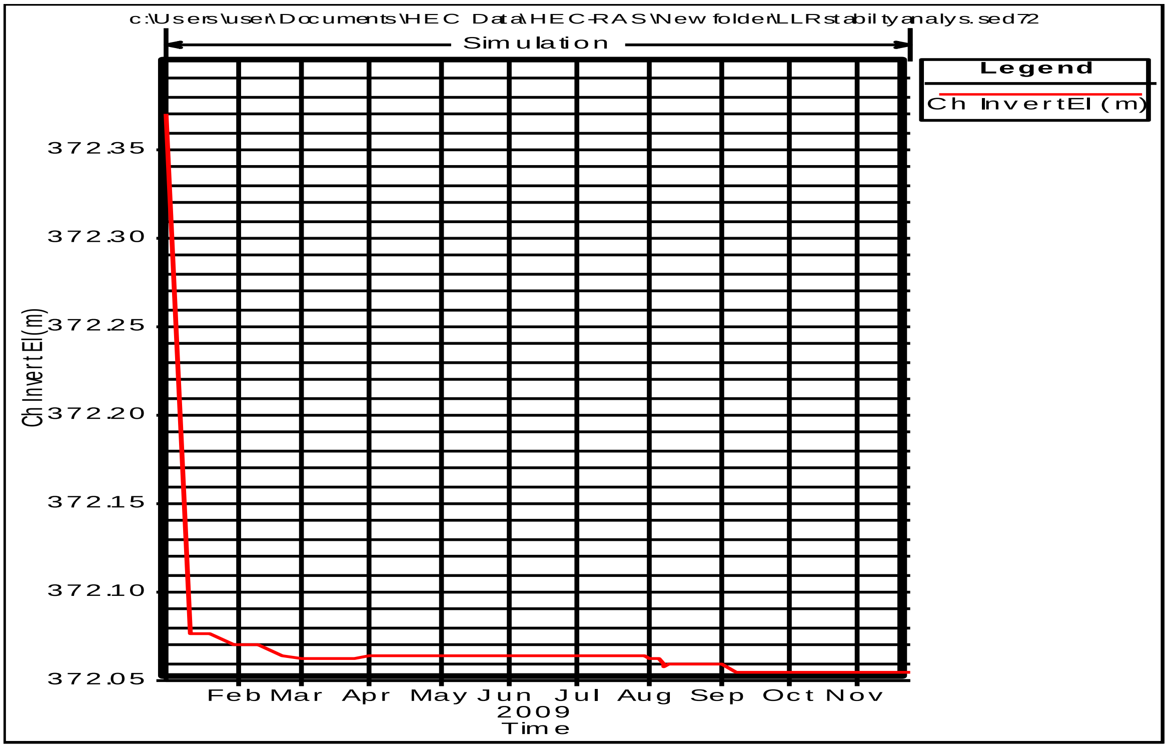


Figure 4-8 time series for the cross section station of 1.68

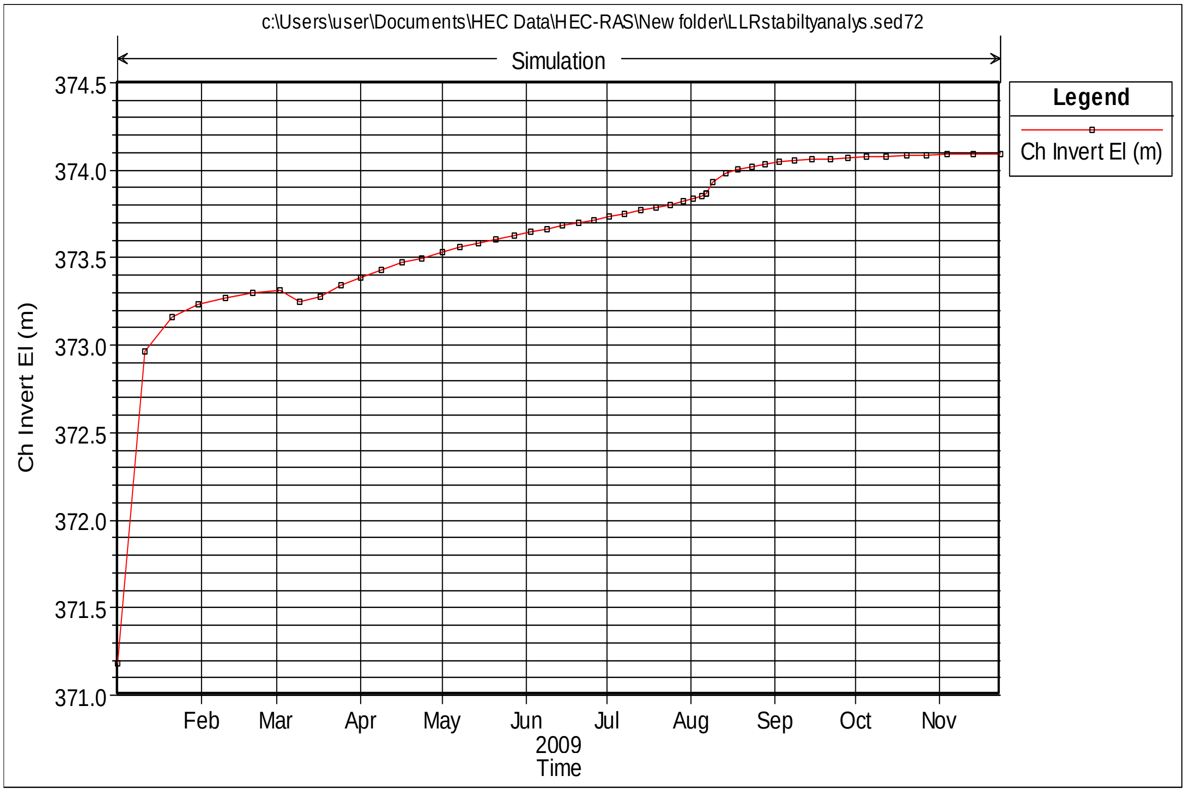


Figure 4-9 Time series for the cross section station of 1.12

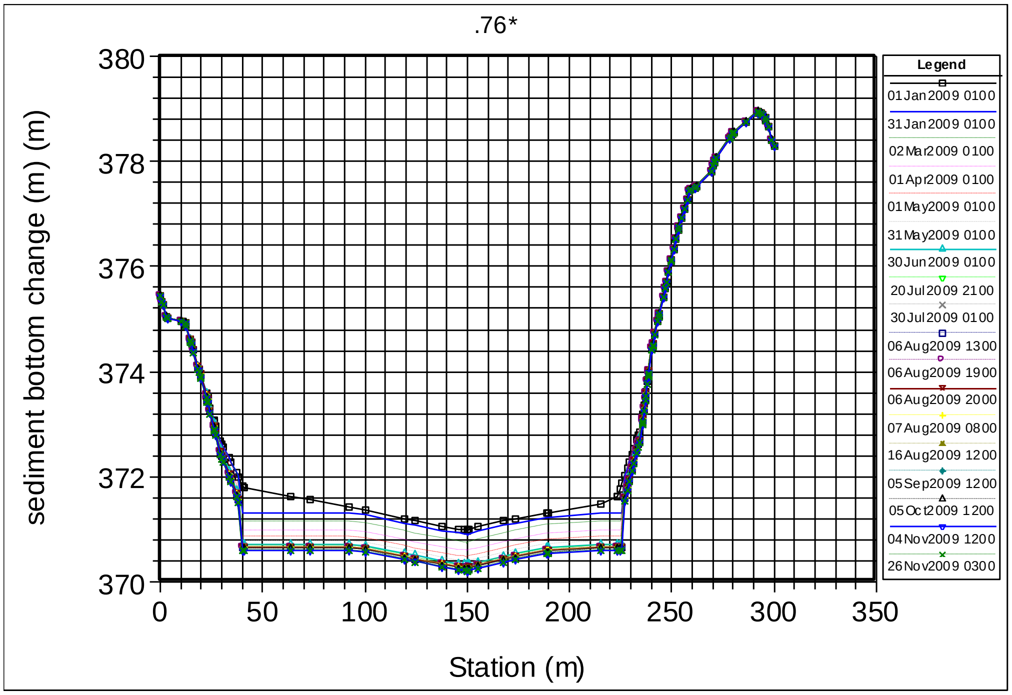


Figure 4-10 Bed elevations for the stimulation of period at station 0.76

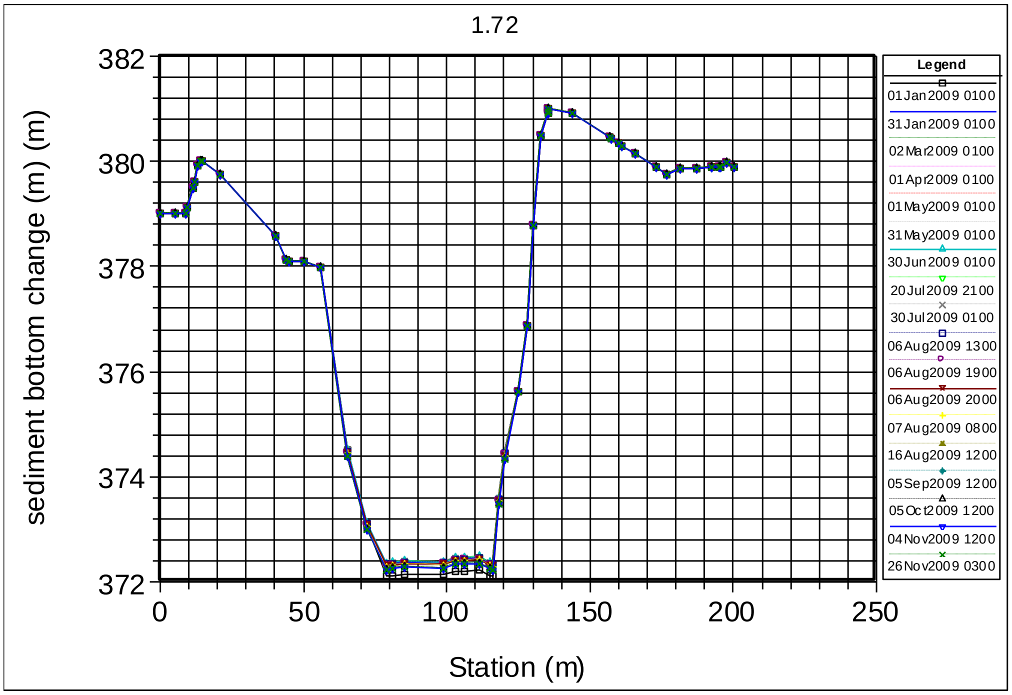


Figure 4.11 Bed elevations for the stimulation of period at station

4.4 Model Calibrating

HEC-RAS requires several inputs, the most important are: channel roughness and channel geometry which includes, river profiles and river cross section at different station in this thesis all the above inputs are measured data and physical observed data such as, longitudinal uniformity of cross sectional shape, channel linearity, degree of channel meander, longitudinal slope and uniformity of slope which are the governing value of channel roughness are obtained throughout the study reach. The water profile from the steady flow simulation result at some defined cross section and the measured rating curve water profile should align parallel, if this is achieved, it may suggest that the river channel is adequately defined and roughness coefficients appropriately estimated .so according to our result from steady flow simulation and the rating curve of the river at Logia Bridge from Ministry of irrigation, water and energy are shown in Figure 4-11 and Table 4-2 which are defined appropriately and acceptable to conclude the result.

Table 4-3 Rating curve calibration data

Simulation Data at station bridge		Measured Data at bridge	
Discharge	Water Surface Elevation	Discharge	Water Surface Elevation
Discharge	Elevation at respective discharge	Gauge discharge	Elevation Gauge
0	372.465	163.35	375.42
15	373.437	28.56	374.74
21	373.729	28.54	374.66
26	373.93	27.79	374.56
32	374.106	13.66	374.06
39	374.268	11.69	374
46	374.427	5.9	373.91
53	374.75	5.84	373.82
55	374.558	4.67	373.78
65	374.841	4.65	373.72
70	374.912	4.38	373.7
70	374.728	3.64	373.6
83	374.861	3.15	373.5
100	375.26	2.64	373.43
102.2	375.108	2.27	373.43
164	375.122	1.6	373.3
172.12	375.108	1.36	373.095
185.2	375.25	1.01	373.29

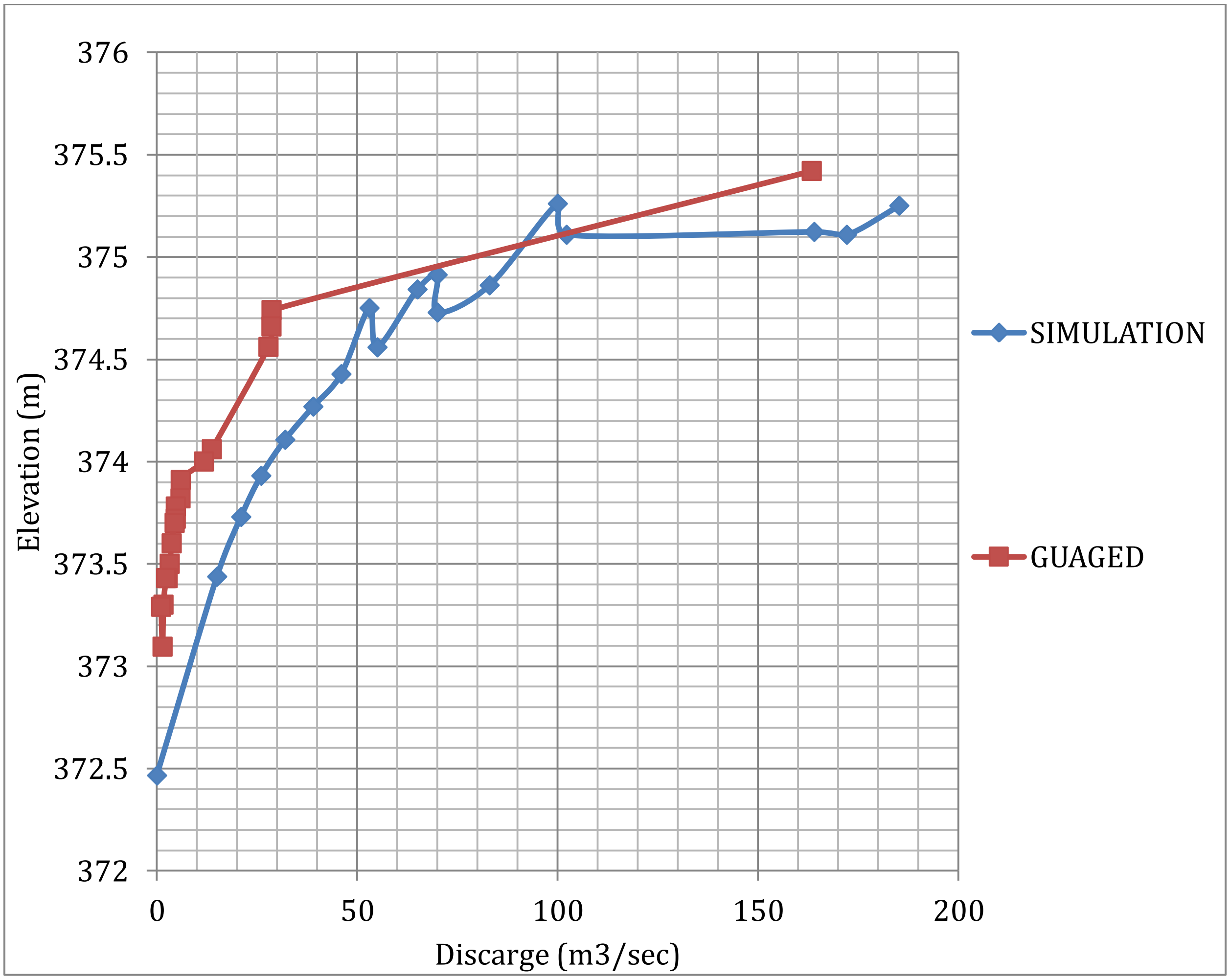


Figure 4-12 Rating curve calibration

4.5 Discussion on Results

4.5.1 AGGRADATIONS

Model result as shown on the table 4.1 those aggradations stations are observed almost 85% of the River stations. These show that an excess of sediment load come to the River compare to the available sediment transport capacity. This is in turn lead to formation of mid channel bars, loss of channel cross section, cause over bank flooding, increase lateral migration River bank and increase bed slope of the River.

The cause of aggradations problem for lower Logia River:

- ✓ Increased sediment yields from the upstream which is due to deforestation of the catchments.
- ✓ Loss of bank stability due to reduced vegetation cover, as bank of River poorly vegetated because of uncontrolled continual man made deforestation, low vegetation cover due to weather condition of the area and global warming. Thus while the channel trying to stabilize through these process ,it may affects the adjacent town and private farm along the River reach, if further it may propagate the problem to affect Tendaho sugar factory project command area and irrigation structure so this process of aggradations should have to be taken some stabilizing measures.

These are:

- ➢ To control bed aggradations, we have to provide a vegetation at upstream of the River.
- ➢ Providing a bank control structures that increase the River bank stability namely guide wall using masonry, gabion wall and providing River training structures to control local channel width that can increase the sediment transport capacity of the channel and reduce aggradations.
- ➢ Provide a small dam at upstream to control high flood and sediment and release as per the capacity of the channel.
- ➢ Increasing the whole channel bank stability either in natural or manmade structure.

4.5.2 DEGRADATION

Simulation show that 0.0055 to 1.812m depth of erosion observed at different stations of channel namely at stations 1.72 to 1.38 and 0.42m to 0.00.These eroded part specially observed just at downstream of the bridge and near upstream of the siphon. The down cutting of the bed at downstream of the bridge due to the increase of flow energy by contraction of bridge water way due to debris on the pier and constructed gabion guide wall along the abutment of the bridge. Whereas down cutting of the bed upstream near the siphon is because of the bank of the channel relatively stable due to naturally vegetated over these stations of the channel.

4.5.3 BANK STABILITY AND WATER SURFACE PROFILE.

Bank at downstream of the bridge especially at stations 1.58 to 1.38 erode since the channel bed highly wash out and the bank would be vertical the station lead to failure of the banks.

Moreover the 100years flood over top the bank in these stations which the surrounding geomorphologies almost soft no vegetation cover so it is easily erode.

The left bank of the lower River almost flat it has similar elevation with the bank of the River along the high way Addis to Djibouti and Tendaho dam and irrigation project main canal which is easily flooded, if any protection barrier is not provide more over the left part of the surrounding area almost flat and similar elevation up to Semera high land which is around 3km far from the River bank and the over topped flood can flooded the area up to the extent of Semera high land.

The right bank of the River where the 100years flood over top is near Logia town so to overcome these problem and safe the society over these station protection of the River bank should need hard formation to protect bank failure and over topping of the floods. However it is overtops the bank, the surrounding area elevation increasing as it far from the bank it is not a great risk for the society in this discharge.

The bank and bed near upstream of the siphon structure is eroded so to safe the structure both at upstream and downstream transition wall and approach channel bed should be built in hard formation like concrete or stone pitching. Otherwise the siphon guide wall and the intersection of the channel bank form weak zone and the channel near the structure relatively narrow and the flow energy relatively high due to this the bank and bed of the channel have no withstand the flow energy as much as the guide wall of the structure.

5 CONCLUSION AND RECOMMENDATION

By considering the channel condition, dimension, flow condition, sediment characteristic, and hydraulic calculation that are performed on lower Logia River, based on the simulation of the model the sloped channel bank and River bed are changed for the whole channel reach due to:

- ✓ excess of sediment load come to the River compare to the available sediment transport capacity, this is in turn lead to formation of mid channel bars which increase bed slope of the River.
- ✓ The channel bed slope increase the water profile also increase which are cause of loss of channel cross section, over bank flooding and lateral migration River bank.
- ✓ Less flood resistance of the soil characteristics of the channel bank and the adjacent areas of the channel.
- ✓ Rapid change of the channel cross section because of the sediment deposition and the surrounding small depth of the channel have a great contribution to decrease the capacity of the channel at different station.
- ✓ on River stations from 1.84 to 1.82 at left bank of the channel water flow about 0.5m depth of flood extent and stations 1.70 to 1.28 the extent of water depth up to 0.72m in both side of the bank. So we can conclude according to HEC-RAS 4.1 version simulation results that the channel beds and banks are not stable more over the channel has less capacity for less frequent discharges.

The channel reach is considered at lower part of just upstream of the junction of lower Awash River. The widening of the River channel from aggradations and continuous bank failure due to scouring can cause loss of areas in both sides that may lead displacement of the society in the near future. It may also cause of destruction of irrigation structure on main canal and command area of Tendaho dam and irrigation project, so it is recommended that the stabilization measure should be implemented with engineering, economical and hydraulic analysis for effective and sustainable stabilization of the River.

Among these

- ✓ Increasing the bank stability and decreasing the inflow sediment by covering the area with vegetation and provide sediment trap structure at upstream.
- ✓ Increasing the channel capacity of the River especially at Logia bridge by removing debris and increasing the bank height at small depth of River banks and making transition section by hard formation both at upstream and downstream of the siphon.
- ✓ Since lower Logia River is non perennial and also tributary of Awash River near the main canal of Tendaho sugar factory project, to assess the stability and instability of the River effectively further assessment of the River should carried out by evaluation of channel geomorphic and sediment transport dynamics by analyzing its problem based on measured data of hydrological, hydraulics, geomorphic and sediment characteristics of the River.

REFERENCES

1. Macklin,M.G and Lewin.J, 1997), Channel ,flood plain and drainage basin responsive to environmental change chichester; Wiley
2. Tendho dam and irrigation design report (WWDSE in association with WAPCOS (INDIA)Ltd Ethiopia.
3. U.S. Army Corps of Engineers (USACE). 1994. ‘‘Engineering and Design—channel stability assessment for flood control projects.’’ Rep No. EM *1110-2-1418,* Washington, D.C
4. Fantawu Mengash, 2008 channel stability analysis in case of BORKENA River (Ethiopia)
5. The Virginia Stream Restoration & Stabilization Best Management Practices Guide. Virginia Department of Conservation and Recreation (DCR). http://www.dcr.state.va.us.Accessed on oct20, 2014
6. U.S. Army Corps of Engineers, USACE (1991). Hydraulic design of flood control channels. Rep. No. EM 1110-2-14180, Washington, D.C.)
7. Hey,Bathurst,and thone ,1982 Colin R. Thorne, RichardD. Hey, MalcoleD . Newson, Chister (Editors);Applied fluvial geomorphology for River engineering and management/; New York: John
8. Hey, R.D. 1997. Stable River Morphology. Applied fluvial geomorphology for River Engineering and Management. Ed., C.T. Thorne, R.D. Hey and M.D.Newson, . John Wiley and Sons.
9. USACE,Em 1110-2-141831) Hydraulic design of flood control channels. Rep. No. EM 1110-2-141831, Washington, D.C.)
10. Belay Banch august 2008, investigation of flood hazarded and mitigation measures in Lante area of Gamo Gofa zone.
11. Peter wilcok P.R and Crowe j.c 2004;surface based transport model for mixed size sediment ; Journal of hydraulic engineering 129(2)
12. Davies T.R.H 1987; Problem of bed load transport in braided gravel Rivers IN GBR
13. U.S. Army Corps of Engineers (USACE). (1995). “Sedimentation Investigations of Rivers and Reservoirs”. *Rep No. EM 1110-2-4000,* Washington, D.C

14. U.S. Army Corps of Engineers, USACE (2012). HEC-RAS River Analysis System. Users Manual. v. 4.0 (beta). U.S. Army Corps of Engineers Institute for Water Resources. Hydrologic Engineering Center, Davis, CA
15. Chow,V.T 1959 open channel hydraulics. McGraw. Hill ,New York
16. Behailu tamiru sep ,2006 flood mapping and mitigation measures for lower Kulfo reach
17. Garde R.J and Ranja Raju,K.G(1985) Mechanics of sediment transport and alluvial stream problem
18. French R.H. (1986). Open channel hydraulics, McGraw Hill Book co,New York.
19. Dunne,T and L B.leopold. 1978' water in Enviromental planning.W.H freeman and company, New York),
20. Wolman and Miller (1960) Andrews, E.D., 1980, Effective and bankfull discharges of streams in the Yampa River basin, Colorado and Wyoming: J. Hydrol., v. 46, p. 311-330.

Appendix 1

Surface Water Hydrology MoWR

Annual Report of Daily Data: Instantaneous Daily Flow

Station Number : 033027
Latitude : 11:44: 0 N

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.8	0	0	0	0	0	0	0	0
	0	0	0	0.2	0	0	0	0	0	0	0	0
	0	5.6	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.3	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	15	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.2	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	30	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.5	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	5.6	0	30	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0.1	0	0	0	0	0	0	0	0
	0	0	0	0.8	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	1.8	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	64	0	0	0	0	0	0	0	0
	0	0	0	0.1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0.8	0	0	0	0	0	0	0	0	0
	0	0	0	0.8	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0.5	0	0	0	0	0	0	0	0	0
	0	0	2	0	0	0	0	0	0	0	0	0
	0	0	0.1		0	0	0	0	0	0	0	0
												0
Maximum	0	1.8	2	64	0	0	0	0	0	0	0	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.2	0	0	0	0	0	0	0	0
	0	0	0	3.7	0	0	0	0	0	0	0	0
	0	0	0	1.7	0	0	0	0	0	0	0	0
	0	0	0	2.9	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0.1	0	0	0	0
	0	0	0	0	0	0	0	10	0	0	0	0
	0	0	0	0	0	0	0	0.5	0	0	0	0
	0	0	0	0	0	0	0	0.1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	4.8	0	0	0	0
	0	0	0	0	0	0	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	40	0	0	1.4	0	0	0	0	0
	0	0	0	0	0	0	0.1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
												0
Maximum	0	0	0	40	0	0	1.4	10	0	0	0	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0.8	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0.9	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	4.3	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	4.6	0	0	0	0	0	0	0	0	0
	0	0	0.1	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	5.1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	617	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	12	0	0	0	0	0	0	0	0	0
	0	0	2.2	0	0	0	5.6	0	0	0	0	0
	0	0	0	0	0		0	0	0	0	0	0
Maximum	0	0	12	0	0.9	0	5.6	5.1	617	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	8.4	0	0	0	0
	0	0	0	0	0	0	0	7	2.3	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	159	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0.5	0	0.2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	4.3	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0.8	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	2.9	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0.2	0	0	0	0	56	0	0	0	0
	0	0	0	0	0	0	0	4	0	0	0	0
	0	0	0	0	0	0	0	2.9	0	0	0	0
	0	0	0	0	0	0	0	72	0	0	0	0
	0	0	0	0	0	0	0	107	0	0	0	0
	0	0	0	0	0	0	0	1.3	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	3.7	0	0	0	0	6
	0	0	0	0	0	0	1.1	0	0	0	0	1.1
	0	0	0	0	0	0	8.1	0	0	0	0	0.6
	0	0	0	0	0	0	5.1	0	0	0	0	0
	0	0	0	0	0	0	4.8	14	0	0	0	0
	0		0	0	0	0	7.5	68	0	0	0	0
	0		0		0		8.1	4.3		0		0
Maximum	0	0	0.2	159	0	0	8.1	107	2.3	0.2	0	6

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	3.5	0	0	0.9	0	0	0	0	0	0	0
	0	25	0	0	3.7	0	0	0	0	0	0	0
	0	29	0	0	0.6	0	0	0	0	0	0	0
	0	6.4	0	0	3.1	0	0	0	0	0	0	0
	0	0.8	0	0	2.1	0	0	0	64	0	0	0
	0	0	0	0	0	0	0	0	13	0	0	0
	0	57	0	0	0	0	0	0	5.1	0	0	0
	0	11	0	0	0	0	0	0	0.8	0	0	0
	0	2.8	0	0	0.2	0	0	0	0	0	0	0
	0	0.8	0	0	0	0	0	0	0	0	0	0
	0	2.8	0	0	0	0	0	0	0	0	0	0
	0	31	0	0	0	0	0	0	0	0	0	0
	0	125	0	0	0	0	0	0	0	0	0	0
	0	33	0	2.1	0	0	0	0	0	0	0	0
	0	4.6	0	7.7	0	0	0	0	0	0	0	0
	0	7.7	0	0.4	0	0	0	0	0	0	0	0
	0	4.3	0	1	0	0	0	0	0	0	0	0
	0	0	0	2	0	0	0	0	0	0	0	0
	0	0	0	23	0	0	0	0	0	0	0	0
	0	0	0	3.1	0	0	0	0	0	0	0	0
	0	0	0	0.1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	5.1	0	0	0	2.9	0	8.1	0	0
	0	0	0	0.2	0	0	0	1	0	1.2	0	0
	0	0	0	0.5	0	0	0	2.7	0	0	0	0
	0	0	0	0	0	0	0	0.1	0	0	0	0
	0	0	0	0	0	0	0	15	0	0	0	0
	0	0	0	4	0	0	0	1.4	0	0	0	0
	0	0	0		0		0	0	0	0	0	0
Maximum	0	125	0	23	3.7	0	0	15	64	8.1	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0.5	4	0	0	0
	0	0	0	0	0	0	0	9.6	2	0	0	0
	0	0	0	0	0	0	0	18	1	0	0	0
	0	0	0	0	0	0	0	39	0.9	0	0	0
	0	0	0	0	0	0	0	1.8	7	0	0	0
	0	0	0	0	0	0	0	14	4	0	0	0
	0	0	0	0	0	0	0	1.9	1.5	0	0	0
	0	0	0	0	0	0	0	0.5	0.5	0	0	0
	0	0	0	0	0	0	0	0.2	9.3	0	0	0
	0	0	0	0	0	0	0	0.2	2.9	0	0	0
	0	0	0	0	0	0	0	0	1.8	0	0	0
	0	0	0	0	0	0	0	0	1.4	0	0	0
	0	0	0	0	0	0	0	22	14	0	0	0
	0	0	0	0	0	0	0	42	5.1	0	0	0
	0	0	0	0	0	0	0	8.8	4.3	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	1	0	0	0	5.6	0	0	0	0
	0	0	0	0	0	0	0	62	0	0	0	0
	0	0	0	0	0	0	0	46	0	0	0	0
	0	0	0	0	0	0	0	2.9	11	0	0	0
	0	0	0	0	0	0	0	0.2	35	0	0	0
	0	0	0	23	0	0	0	0	9.1	0	0	0
	0	0	0	0	0	0	0	0	4.3	0	0	0
	0	0	1.4	0	0	0	0	8.6	37	0	0	0
	0	0	7.5	0	0	0	0	0.6	2.3	0	0	0
	0	0	0	0	0	0	0	0	1.8	0	0	0
	0	0	0	0	0	0	0	52	0	0	0	0
	0	0	0	0	0	0	28	37	0	0	0	0
	0	0	0	0	0	0	37	10	0	0	0	0
	0	0	0	0	0	0	152	1	0	0	0	0
	0	0	0	0	0		5.6	14		0	0	0
Maximum	0	0	7.5	23	0	0	152	62	37	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	2.4	3.1	0	0	0
	0	0	0	0	0	0	0	8.6	2.3	0	0	0
	0	0	0	0	0	0	0	8.6	2.2	0	0	0
	0	0	0	0	0	0	0	4.9	1.9	0	0	0
	0	0	0	0	0	0	0	0.5	1.7	0	0	0
	0	0	0	5.1	0	0	0	0	1.2	0	0	0
	0	0	0	0.5	0	0	0	0	1	0	0	0
	0	0	0	7	0	0	0	19	0.5	0	0	0
	0	5.6	0	4.6	0	0	1	12	3.8	0	0	0
	0	0	0	0.5	0	0	0	3.8	4.3	0	0	0
	0	0	0	4.1	0	0	182	28	2.9	0	0	0
	0	0	0	0.7	0	0	4.1	34	2.3	0	0	0
	0	0	0	0.1	0	0	0	0	0.2	0	0	0
	0	0	0	0	0	0	28	17	0	0	0	0
	0	0	0	0	0	0	8.6	11	0	0	0	0
	0	0	0	7	0	0	8.1	4.6	0	0	0	0
	0	0	0	2.3	0	0	28	14	0	0	0	0
	0	0	0	12	0	0	0.6	14	0	0	0	0
	0	0	0	0.5	0	0	14	34	0	0	0	0
	0	0	0	0	0	0	4.6	21	0	0	0	0
	0	0	0	0	0	0	6.4	20	0	0	0	0
	0	0	1.4	0	0	0	4.9	4.4	0	0	0	0
	0	0	3.7	0	0	0	12	46	0	0	0	0
	0	0	5.3	9.8	0	0	11	14	0	0	0	0
	0	0	5.3	11	0	0	1.8	2.8	0	0	0	0
	0	0	0.1	7	0	0	1	2.3	0	0	0	0
	0	0	0	2	0	0	11	0.3	0	0	0	0
	0	0	0	7.5	0	0	113	0	0	0	0	0
	0	0	0	1.2	0	0	17	4.3	0	0	0	0
	0	0	0	0.2	0	0	4.3	2.5	0	0	0	0
	0	0	0		0		4.3	8.6	0	0	0	0
Maximum	0	5.6	5.3	12	0	0	182	46	4.3	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	1.9	1.2	0.3	0	0	43	0	0	0
	0	0	0	0.1	0.6	0.3	0	0	15	0	0	0
	0	0	0	0	0.3	0.1	0	0	25	0	0	0
	0.9	0	0	0	0.2	0	0	0	11	0	0	0
	0.3	0	0	0	0	0	0	0	6.1	3.8	0	0
	0	0	0	0	0	0	0	0	5.9	0	0	0
	0	0	0	0	0	0	0	0	21	0	0	0
	0	0	0	0	0	0	0	0	6.8	0	0	0
	0	0	0	0	0	3.7	0	0	3.7	0	0	0
	13	0	0	0	0	2.2	0	0	3.8	0	0	0
	3.5	0	0	0	0	0.7	0	0	4	0	0	0
	0.3	0	0	0	0	0	0	0	1.9	0	0	0
	0	0	0	0	0	0	35	7.1	4.3	0	0	0
	0	0	0	0	0	0	2.2	0	4.5	0	0	0
	0	0	0	0	4.9	0	1.4	3.7	3.7	0	0	0
	0	0	0	0	0.7	0	0	0	2.8	0	0	0
	0	0	0	0	12	0	0	0	1.1	0	0	0
	0	0	0	6.4	30	0	0	0	0.8	0	0	0
	11	0	0	4.5	3.8	0	0	0.1	0	0	0	0
	14	0	0	1	15	0	0	0.6	0	0	0	0
	0.3	0	0	50	2.8	0	0	23	0	0	0	0
	0.2	0	0	50	1.4	0	0	28	0	0	0	0
	0	0	0	7.1	0.8	0	0	259	0	0	0	0
	0	0	0	4.2	30	0	0	15	0	0	0	0
	5.8	0	0	0.8	8.8	0	34	35	0	0	0.8	0
	0.5	0	0	0.2	4.2	0	22	11	0	0	0	0
	0.1	0	0	0	18	0	2.6	38	0	0	0	0
	0.2	0	6.6	0	15	0	0.1	9.4	0	0	0	0
	0.1	0	2.2	16	3.5	0	0	6.4	0	0	0	0
	0	0	1	2.4	2.4	0	0	6.4	0	0	0	0
	0	0	0.7		0.7	0	0	49	0	0	0	0
Maximum	14	0	6.6	50	30	3.7	35	259	43	3.8	0.8	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	135	0	2.8	0	0	0	0	1.8	0.2
	0	0	0	8	4.2	0	0	14	0	0	0.9	0
	0	0	0	103	0	0.4	0	1.5	0	0	0	0
	0	0	0	1.4	0	0.4	0	0.2	0	0	0	0
	0	0	0	0.4	0	0	0	0	0	0	0	0
	0	0	0	0	0	50	0	0	0	0	0	0
	0	0	0	0	0	2.5	0	2.4	0	0	0	0
	0	0	0	0	0	2.2	13	0.3	0	0	0	0
	0	0	0	0	14	2.2	14	0.1	0	0	0	0
	0	0	0	12	0	0	2.8	0	0	0	0	0
	0	0	0	0.8	0	0	1.2	0.2	0	0	0	0
	0	0	0	0	0	0	7.1	0.1	0	0	0	0
	0	0	0	0	0	0	8	0	0	0	91	0
	0	0	0	0	0	0	2.9	4	0	0	6.4	0
	0	0	0	0	0	0	0.2	6.6	0	0	4.2	0
	0	0	0	0	0	0	0	2.9	0	0	3.2	0
	0	0	0	0	0	0	0	3	0	0	0	0
	0	0	0	0	0	0	0	2.2	0	0	0	0
	0	0	3.2	0	0	0	26	3.3	0	0	0	0
	0	0	24	0	0	0	13	3	0	0	0	0
	0	0	4.3	0	0	0	0.6	1.6	0	5.5	0	0
	24	0	0	0	0	0	0.4	1.8	0	66	0	0
	6.4	0	0	0	0	0	0.1	0	0	8.3	1	0
	16	0	21	0	0	0	0	3.2	0	19	0.3	0
	1.9	0	0	0	0	0	0	0	0	67	0.8	0
	0.1	0	0	0	0	0	0	0	0	13	0.9	0
	0	0	0	0	0	0	10	0	0	12	13	0
	0	0	0	0	0	0	1.4	11	0	5.5	14	0
	0		0	0	0	0	0.1	24	0	16	3	0
	0		157	0	0	0	0	7.1	0	3.7	3.5	0
	0		4.2		10		0	1.2		0		0
Maximum	24	0	157	135	14	50	26	24	0	67	91	0.2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	1.2	0	0	0	0	94	93	0.5	0	0
	0	0	82	0	0	0	0	56	50	7.1	0	0
	0	0	20	0	0	0	0	23	31	18	0	0
	16	0	3.5	0	0	0	0	14	45	7.1	0	0
	6.1	0	89	0	0	0	0	3.8	15	17	0	0
	1.3	0	74	0	0	0	0	7.1	7.5	21	0	0
	0.3	0	14	0	0	0	0	6.6	19	15	0	0
	0.1	0	3.5	0	0	0	0	7.1	61	6.4	0	0
	0	0	13	0	0	0	0	4.9	147	12	0	0
	0	0	8	0	0	0	3.8	52	50	61	0	0
	0	0	8	0	0	0	0.8	225	10	30	0	0
	16	0	5.5	0	0	0	0	140	9.1	39	0	0
	1	0	4	0	0	0	0	39	6.8	11	0	0
	0.1	0	0.7	0	0	0	4.5	10	3.8	6.1	0	0
	0	0	0.5	0	0	0	2.4	6.6	2.2	1.7	0	0
	0	0	0.3	0	0	0	1.1	19	0	0	0	0
	0	0	0.1	0	0	0	1.2	31	0	0	0	0
	0	0	0	0	0	0	34	127	0	0	0	0
	0	0	0	0	0	0	23	27	0	0	0	0
	0	0	0	0	0	0	67	72	0.7	0	0	0
	0	0	6.1	0	0	0	32	130	6.6	0	0	0
	0	0	3.8	0	0	0	13	132	4.2	0	0	0
	4.2	6.8	1.5	0	0	0	82	52	16	0	0	0
	0.4	4.9	0.2	0.9	0	0	34	19	16	0	0	0
	0.3	1.9	0	8.3	0	0	27	53	11	0	0	0
	0	5.1	0	1.9	0	0	11	22	3.3	0	0	0
	0	1.7	0	0.8	0	0	7.5	20	15	0	0	0
	0	3.5	0	80	0	0	16	47	11	0	0	0
	0		0	1.4	0	0	24	191	21	0	0	0
	0		0	0	0	0	27	143	6.6	0	0	0
	0		0		0		49	87		0		0
Maximum	16	6.8	89	80	0	0	82	225	147	61	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	2.5	0	0	82	18	0	0	0
	0	0	0	0	0.5	0	0	18	11	0	0	0
	0	0	0	0	0	0	0	3.2	4.5	0	0	0
	0	0	0	0	0	0	0	1.2	3.2	0	0	0
	0	0	0	0	0	0	15	2.8	25	0	0	0
	0	0	0	0	0	0	7.1	46	15	0	0	0
	0	0	0	0	0	0	3.8	40	28	0	0	0
	0	0	0	0	0	0	2.9	2.9	172	16	0	0
	0	0	0	0	0	0	2.1	2.4	42	94	0	0
	0	0	0	0	0	0	1.7	13	20	49	0	0
	0	0	76	0	0	0	0.8	5.3	57	7.3	0	0
	0	0	9.7	0	0	0	0	0.8	4.9	0	0	0
	0	0	3.7	0	0	0	0	1.8	0	0	0	0
	0	0	53	0	0	0	0	5.3	0	0	0	0
	0	0	15	0	0	0	2.5	1.6	19	0	0	0
	0	0	1.3	0	0	0	39	1.9	15	0	0	0
	0	0	0.3	0	0	0	22	1.3	9.4	0	0	0
	0	0	0	0	0	0	57	38	0	0	0	0
	0	0	0	0	0	0	27	105	0	31	0	0
	0	0	0	0	0	0	4.2	72	0	26	0	0
	0	0	0	0	0	0	22	20	0	16	0	0
	0	0	0	0	0	0	92	4.3	0	0	0	0
	0	0	0	0	0	0	9.7	2.8	0	0	0	0
	0	0	0	0	0	0	20	13	0	0	0	0
	0	0	0	0	0	0	4.7	4.9	0	0	0	0
	0	0	0	0	0	0	13	1.7	0	0	0	0
	0	0	0	0	0	0	4.9	81	0	0	0	0
	0	0	14	0	0	0	13	11	0	0	0	0
	0		1.2	0	0	0	3.2	6.6	16	0	0	0
	0		0.3	12	0	0	1.5	34	0	0	0	0
	0		3.2		0		61	137		0		0
Maximum	0	0	76	12	2.5	0	92	137	172	94	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	19	0	0	30	15	21	6.6	0
	0	0	0	0	4.5	0	0	22	27	12	0	0
	0	0	0	0	32	0	0	35	63	7.1	0	0
	0	0	0	0	81	0	0	67	57	6.1	0	0
	0	0	0	0	11	0	0	103	15	0	0	0
	0	0	0	0	2.9	0	0	72	12	0	0	0
	0	0	0	0	2.9	0	0	240	11	0	0	0
	0	0	0	0	2.9	0	0	49	9.1	0	0	0
	0	0	0	0	0.8	0	0	32	13	0	14	0
	0	0	0	0	0.5	0	0	39	10	0	82	0
	0	0	0	0	0.3	0	0	259	6.6	0	18	0
	0	0	0	0	0	0	0	177	4.9	0	12	0
	0	0	0	0	0	0	0	99	4.5	0	9.1	0
	0	0	0	0	0	0	0	172	20	0	3.8	0
	0	0	0	0	0	0	0	32	11	0	2.2	0
	0	0	0	0	0	0	0	81	5.3	0	1.7	0
	0	0	0	0	0	0	0	136	1.9	0	1	0
	0	0	0	0	0	0	0	39	1.8	0	0.8	0
	0	0	0	0	0	0	0	9.1	1.7	0.4	0.8	0
	0	0	0	0	0	0	0	15	1.7	14	0.7	0
	0	0	0	0	0	0	6.6	4.9	1.7	6.8	0.4	0
	0	0	0	0	0	0	0	189	1.4	6.6	0	0
	0	0	0	0	0	0	0	42	1.7	4.3	0	0
	0	0	0	0	0	0	0	15	0.8	2.2	0	0
	0	0	0	0	0	0	6.6	7.5	0	1.2	0	0
	0	0	0	0	0	0	0.9	61	0	0	0	0
	0	0	0	0	0	0	7.1	20	0	0	0	0
	0	0	0	0	0	0	14	18	0	0	0	0
	0	0	0	13	0	0	14	12	0	6.6	0	0
	0	0	0	111	0	0	25	11	0	34	0	0
	0	0	0		0		39	11		11		0
Maximum	0	0	0	111	81	0	39	259	63	34	82	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	166	240	0	0	0
	0	0	0	0	0	0	0	65	65	0	0	0
	0	0	0	0	0	0	0	76	34	0	0	0
	0	0	0	0	8.6	0	0	184	28	0	0	0
	0	0	0	0	55	0	0	42	16	0	0	0
	0	0	0	0	19	0	0	74	0	0	0	0
	0	0	0	0	39	0	0	43	21	0	0	0
	0	0	0	0	6.1	0	0	15	49	0	0	0
	0	0	0	0	0	0	0	23	32	0	0	0
	0	0	0	0	0	0	0	16	7.8	0	0	0
	0	0	15	0	0	0	0	6.6	0	0	0	0
	0	0	6.1	0	0	0	0	11	0	0	0	0
	0	0	0	0	0	0	0	65	0	0	0	0
	0	0	0	0	0	0	0	84	0	0	0	0
	0	0	42	0	0	0	0	37	0	0	0	0
	0	0	7.1	0	0	0	0	46	0	0	0	0
	0	0	4.2	0	0	0	0	26	0	0	0	0
	0	0	4.3	0	0	0	0	23	0	0	0	0
	0	0	58	0	0	0	0	35	0	0	0	0
	0	0	7.1	0	0	0	0	12	0	0	0	0
	0	0	2.6	0	0	0	0	14	12	0	0	0
	0	0	9.7	0	0	0	12	17	41	0	0	0
	0	0	14	0	0	0	4	14	0.4	0	0	0
	0	0	43	0	0	0	44	113	0	0	0	0
	0	0	45	0	0	0	53	19	0	0	0	0
	0	0	18	0	0	0	8	6.6	0	0	0	0
	0	0	82	0	0	0	5.9	20	0	0	0	0
	0	0	14	0	0	0	4.9	30	0	0	0	0
	0		0	0	0	0	55	27	0	0	0	0
	0		0	0	0	0	67	46	0	0	0	0
	0		0		0		23	62		0		0
Maximum	0	0	82	0	55	0	67	184	240	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	1.5	0	0	0	0	0	0	0	0	0
	0	0	39	0	0	0	0	0	3.2	0	0	0
	0	0	0	0	0	0	0	0	0.1	0	0	0
	0	0	0	0	0	0	0	0	6.1	0	0	0
	0	0	0	0	0	0	0	0	69	0	0	0
	0	0	0	0	0	0	0	0	0.5	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.1	0	0	0	0	0	0	0	0
	0	0	0	259	0	0	0	0	0	0	0	0
	0	0	0	53	0	0	18	0	0	0	0	0
	0	0	0	6.6	0	0	8	0	0	0	0	0
	0	0	0	4	0	0	4.9	0	0	0	0	0
	0	0	0	1.7	0	0	4.2	0	0	0	0	0
	0	0	50	0	0	0	0	79	0	0	0	0
	0	0	0	0	0	0	0	106	0	0	0	0
	0	0	0	0	0	0	0	0.2	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	164
	0	0	0	0	0	0	148	0	0	0	0	133
	0	0	0	0	0	0	0	0	0	0	0	35
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	50	259	0	0	148	106	69	0	0	164

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	79	0	0	0
	0	0	0	4.5	0	0	0	0	54	0	0	0
	0	0	0	1.2	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	43	0	0	0	247
	0	0	0	0	0	0	0	312	78	0	0	46
	0	0	0	0	0	0	0	44	31	0	0	63
	0	0	0	0	0	0	0	0	22	0	0	16
	0	0	0	0	0	0	0	0	18	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	34	0	0	0
	0	0	0	0.3	0	0	0	0	0	0	0	0
	0	0	0	142	0	0	0	0	0	0	0	0
	0	0	0	40	0	0	0	0	0	0	0	0
	0	0	0	23	0	0	0	169	0	0	0	0
	0	0	0	92	0	0	0	-	0	0	0	0
	0	0	0	204	0	0	0	98	0	0	0	0
	0	0	0	45	0	0	2.8	86	0	0	0	0
	0	0	0	16	0	0	0	0	0	0	0	0
	0	0	0	105	0	0	0	13	31	0	0	0
	0	0	0	97	0	0	0	24	0	0	0	0
	0	0	0	98	0	0	0	0	7.1	0	0	0
	0	0	0	42	0	0	0	49	37	0	0	0
	0	0	0	31	0	0	0	57	0.7	0	0	0
	0	0	0	12	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	74	0	0	0	0
	0	0	0	0	0	0	4.7	2.6	0	0	0	0
	0	0	0		0		0	0		0		0
Maximum	0	0	0	204	0	0	4.7	0	79	0	0	247

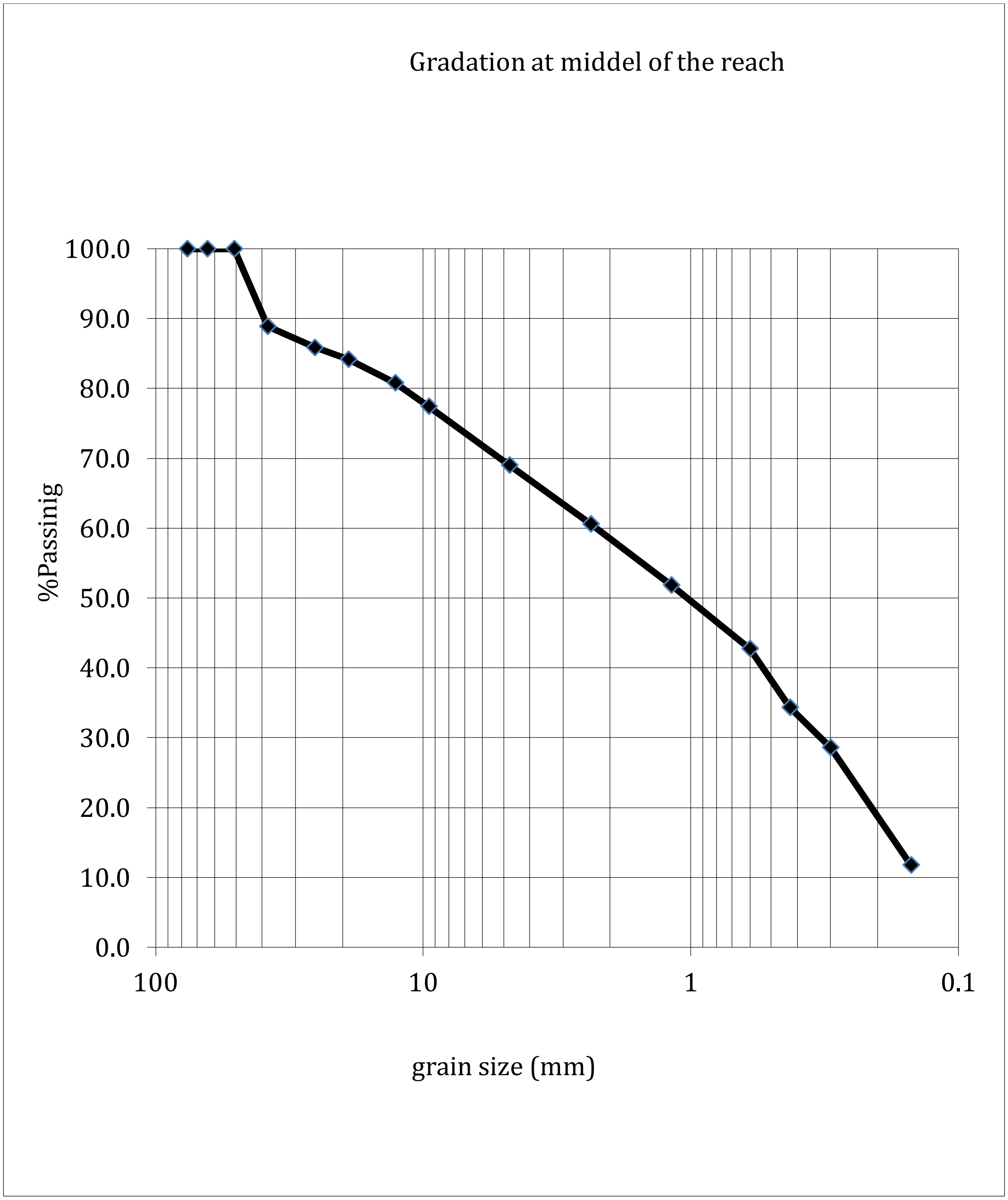
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	8.6	0	0	0	0	0	0	0	0
	0	0	0	16	0	0	0	0	0	0	0	0
	0	0	0	42	0	0	0	0	0	0	0	0
	0	0	0	35	0	0	0	0	0	0	0	0
	0	0	0	3.5	0	0	0	0	0	0	0	0
	0	0	0	90	0	0	0	0	0	0.3	0	0
	0	0	0	42	0	0	0	0	0	40	0	0
	0	0	0	146	0	0	0	0	0	40	0	0
	0	0	0	76	0	0	0	0	0	0	0	0
	0	0	0	84	0	0	0	0	0	0	0	0
	0	0	0	154	0	0	0	0	0	0	0	0
	0	0	0	303	0	0	0	0	0	0	0	0
	0	0	0	-	0	0	0	0	0	0	0	0
	0	0	0	123	0	0	0	0	0	0	0	0
	229	0	0	199	0	0	0	0	0	0	0	0
	23	0	0	103	0	0	0	0	0	0	0	0
	9.1	0	0	37	0	0	0	0	0	0	0	0
	4.5	0	0	30	0	0	0	0	0	0	0	0
	3.2	0	0	25	0	0	0	0	0	0	0	0
	0	0	0	18	0	0	0	0	77	0	0	0
	0	0	0	47	0	0	0	0	79	0	0	0
	0	0	0	84	0	0	0	0	24	0	0	0
	0	0	0	103	0	0	0	0	0	0	0	0
	0	0	0	21	0	0	0	0	0	0	0	0
	0	0	0	0.5	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	49	0	0	0	0	0	0	0	0
	0	0	0	38	0	0	0	0	0	0	0	0
	0	0	0	28	0	0	0	0	0	0	0	0
	0		0.4	1.2	0	0	0	0	0	0	0	0
	0		20	0	0	0	0	0	0	0	0	0
Maximum	229	0	20	0	0	0	0	0	79	40	0	0

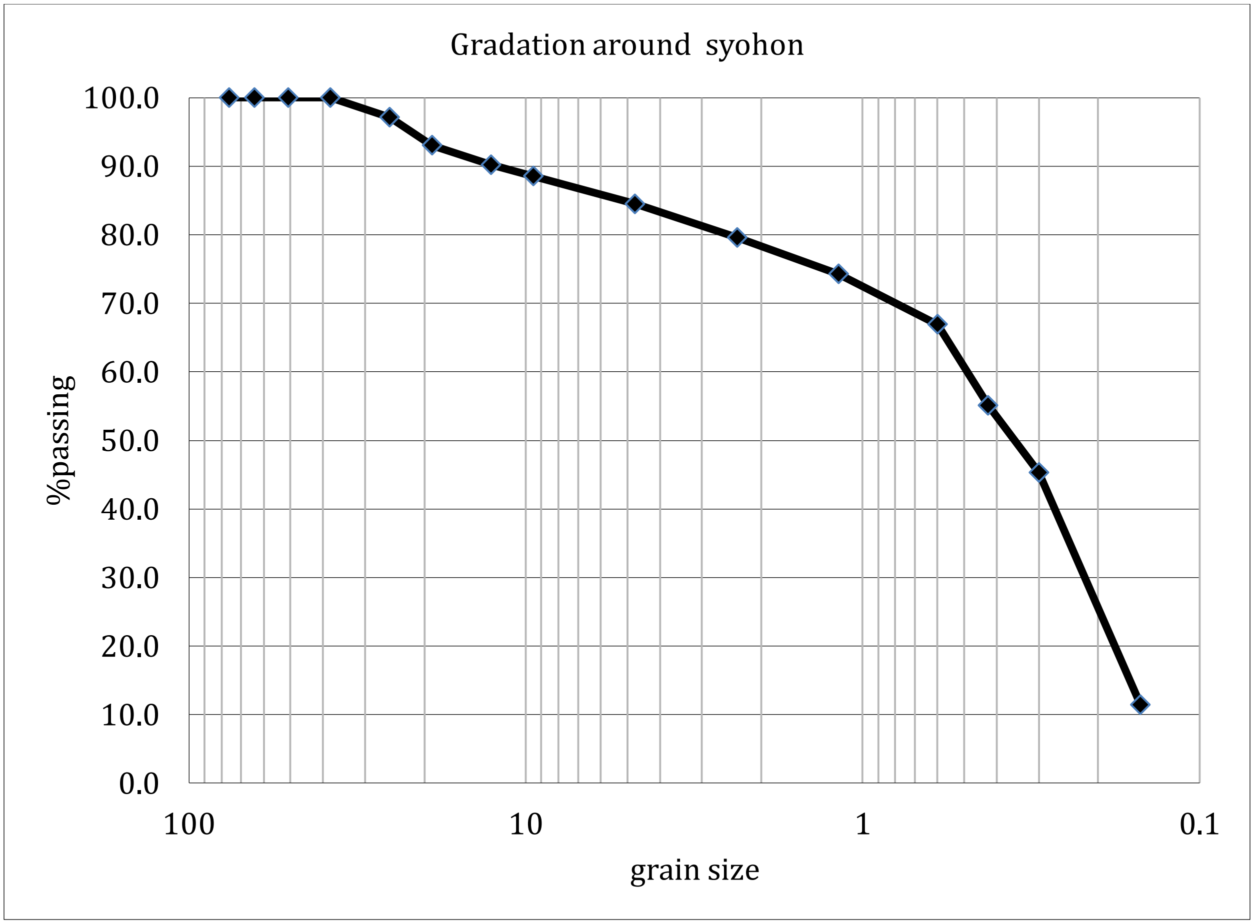
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	28	3.7	0	9.1	225	18	0	0
	0	0	0	0	15	0	0	0.7	225	0	0	0
	0	0	0	0	0.8	0	0	0	72	0	0	0
	0	0	0	0	0	0	0	0	77	0	0	0
	0	0	0	0	0	0	0	0	30	0	0	0
	0	0	0	0	0.4	0	0	0	20	0	0	0
	0	0	0	0	72	0	65	39	3.7	0	0	0
	0	0	0	0	34	0	-	47	0	0	0	0
	0	0	0	0	0.8	0	123	3.2	0	0	0	0
	0	0	0	0	0	0	21	42	0	0	0	0
	0	0	0	0	0	0	1.3	58	0	0	0	0
	0	0	0	0	0	0	0	157	0	0	0	0
	0	0	0	0	0	0	0	111	0	0	0	0
	0	0	0	0	0	0	0	40	0	0	0	0
	0	0	0.1	0	0	0	0	22	0	0	0	0
	0	0	0	0	0	0	0	13	0	0	0	0
	0	0	7.8	0	0	0	0	0.5	0	0	0	0
	0	0	148	0	0	0	0	0	0	0	0	0
	0	0	166	21	0	0	14	0	0	0	0	0
	0	0	180	27	0	0	213	0	0	0	0	0
	1.6	0	127	16	37	0	0	218	123	0	0	0
	3.7	0	96	9.1	1.2	0	0	105	24	0	0	0
	0	0	3	0	0	0	0	74	9.1	0	0	0
	0	0	0	27	31	18	312	21	0	0	0	0
	0	0	0	21	23	2.6	184	50	0	0	0	0
	0	0	0	194	78	0.3	49	115	0	0	0	0
	0	0	0	31	31	0	2.9	188	0	0	0	0
	0	0	0	47	0	0	0	221	3.7	0	0	0
	0	0	0	76	0.3	0	0	146	21	0	0	0
	0	0	0	32	27	0	0	80	92	0	0	0
	0	0	0		14	0	12	169	0	0		0
Maximum	3.7	0	180	194	78	18	184	221	225	18	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	16	0	0	0	9.1	225	0	0	0
	0	0	0	11	0	0	0	0.7	225	0	0	0
	0	0	0	99	0	0	0	0	72	0	0	0
	0	0	0	316	0	0	0	0	77	0	0	0
	0	0	0	316	22	0	0	0	30	0	0	0
	0	0	0	103	40	0	0	0	20	0	0	0
	0	0	0	79	0	0	65	39	3.7	0	0	0
	0	0	0	172	0	0	0	47	0	0	0	0
	0	0	0	0	0	0	123	3.2	0	0	0	0
	0	0	0	1.9	0	0	21	42	0	0	0	0
	0	0	0	65	0	0	1.3	58	0	0	0	0
	0	0	0	32	0	0	0	157	0	0	0	0
	0	0	0	22	0	0	0	111	0	0	0	0
	0	0	0	9.1	0	0	0	40	0	0	0	0
	0	0	0	0	0	0	0	22	0	0	0	0
	0	0	0	0	0	0	0	13	0	0	0	0
	0	0	0	0	0	0	0	0.5	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	28	0	0	0	14	0	0	0	0	0
	0	0	12	0	0	0	213	0	0	0	0	0
	0	0	22	0	0	0	0	218	123	0	0	0
	0	0	23	0	0	0	0	105	24	0	0	0
	0	0	23	0	0	0	0	74	9.1	0	0	0
	0	0	12	42	0	0	312	21	0	0	0	0
	0	0	9.1	84	0	0	184	50	0	0	0	0
	0	0	9.1	19	0	0	49	115	0	0	0	0
	0	0	0	3.7	0	0	2.9	188	0	0	0	0
	0	0	3.7	0	0	0	0	221	3.7	0	0	0
	0	0	24	0	0	0	0	146	21	0	0	0
	0	0	55	0	0	0	0	80	92	0	0	0
	0	0	98	0	0		12	169		0	0	0
Maximum	0	0	98	316	40	0	184	221	225	18	0	0

APPENDIX 2

Sediment grain size graph


Gradation at middel of the reach
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
%Passinig
100
10
1
0.1
grain size (mm)


Gradation around syohon
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
%passing
100
10
1
0.1
grain size

APPENDIX 3

Normal probability plot

Steps

1. Rank the data from largest (m = 1) to smallest (m = n)
2. Assign plotting position to the data
3. Plotting position – an estimate of exccedance probability
4. Use p = (m-3/8)/(n + 0.25)
5. Find the standard normal variable z corresponding to the plotting position (use - NORMSINV (.) in Excel)
6. Plot the data against z
7. If the data falls on a straight line, the data comes from a normal distribution.

Since the data is not fall in the straight line ,it is not fit the normal distribution.

Mean …………………………… 186.423

St .dev ………………………….. 82.640

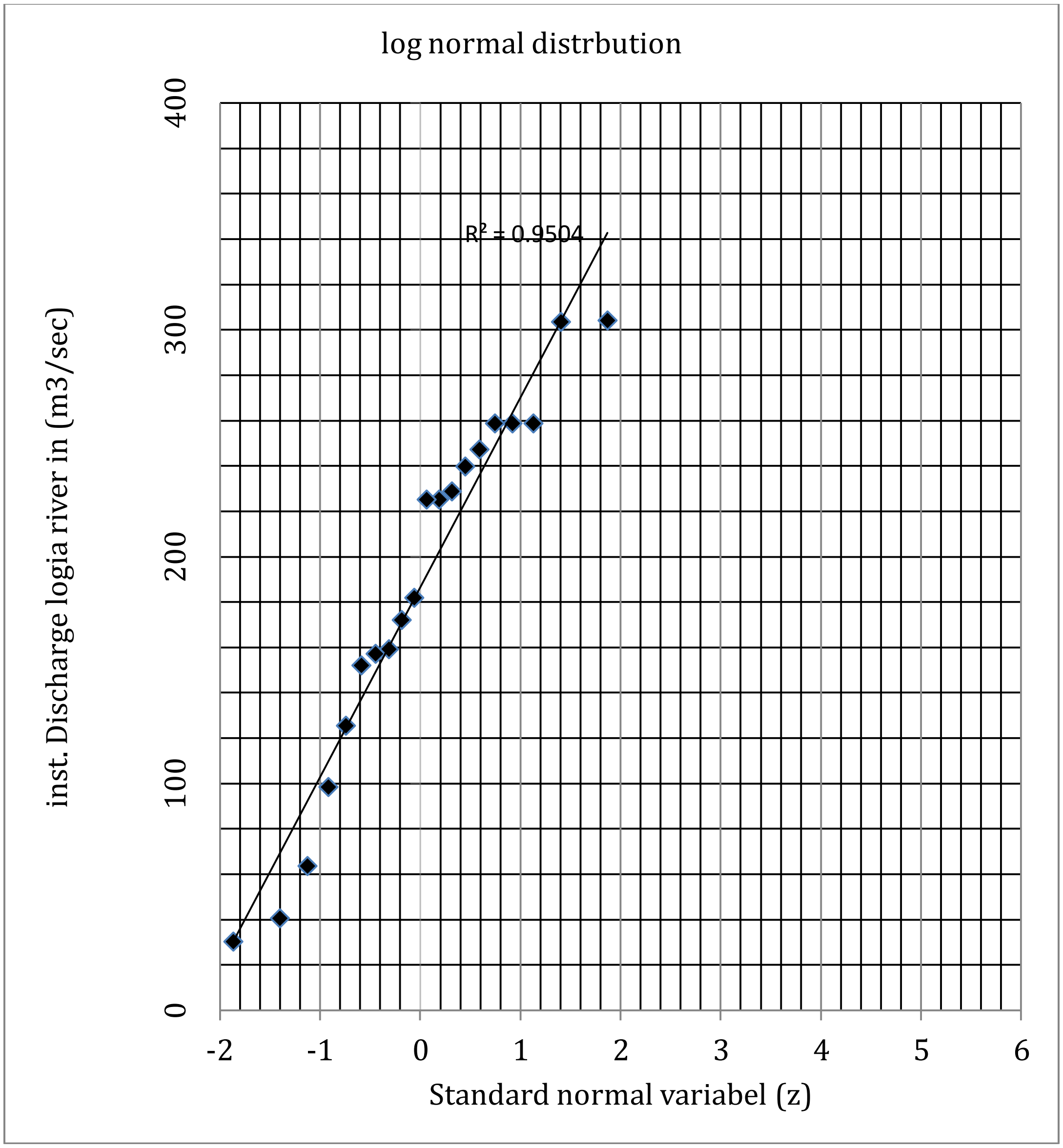
kt...................................... 2.450

ε =……………………………….. 64.463

μ…………………………………… 149.220

f(x)=-1/s√2πexp(-(x-u)2^2/2s^2)

log normal						
year	recorded data	RankData	Rank	Return priod	P	standard z
1988	30.206	304	1	21.000	0.031	1.868
1989	63.524	303.368	2	10.500	0.080	1.403
1990	40.471	258.616	3	7.000	0.130	1.128
1991	304	258.616	4	5.250	0.179	0.919
1992	159.094	258.616	5	4.200	0.228	0.744
1993	125.369	247.127	6	3.500	0.278	0.589
1994	151.951	239.636	7	3.000	0.327	0.448
1995	181.756	228.65	8	2.625	0.377	0.315
1996	258.616	225.054	9	2.333	0.426	0.187
1997	157.059	225.054	10	2.100	0.475	0.062
1998	225.054	181.756	11	1.909	0.525	-0.062
1999	171.968	171.968	12	1.750	0.574	-0.187
2000	258.616	159.094	13	1.615	0.623	-0.315
2001	239.636	157.059	14	1.500	0.673	-0.448
2002	258.616	151.951	15	1.400	0.722	-0.589
2003	247.127	125.369	16	1.313	0.772	-0.744
2004	228.65	98.343	17	1.235	0.821	-0.919
2005	225.054	63.524	18	1.167	0.870	-1.128
2006	98.343	40.471	19	1.105	0.920	-1.403
2007	303.368	30.206	20	1.050	0.969	-1.868


log normal distrbution
inst. Discharge logia river in (m3/sec)
0
100
200
300
400
-2
-1
0
1
2
3
4
5
6
Standard normal variabel (z)
R² = 0.9504

Extreme value type one probability

Steps

1. Sort the data from largest to smallest
2. Assign plotting position using Gringorten formula pi= (m – 0.44)/(n + 0.12
3. . Calculate reduced variant yi = -ln(-ln(1-pi))
4. Plot sorted data against yi
5. If the data falls on a straight line, the data comes from an EV1 distribution.

As we see on the plotted, the data more fit in the extreme value type I (Gumbel distribution).

From the record data mean …………………186.424

From the record data standard deviation………82.640

Sample size ……………………………………………………19

Y_n=0.5442

S_n =1.1436

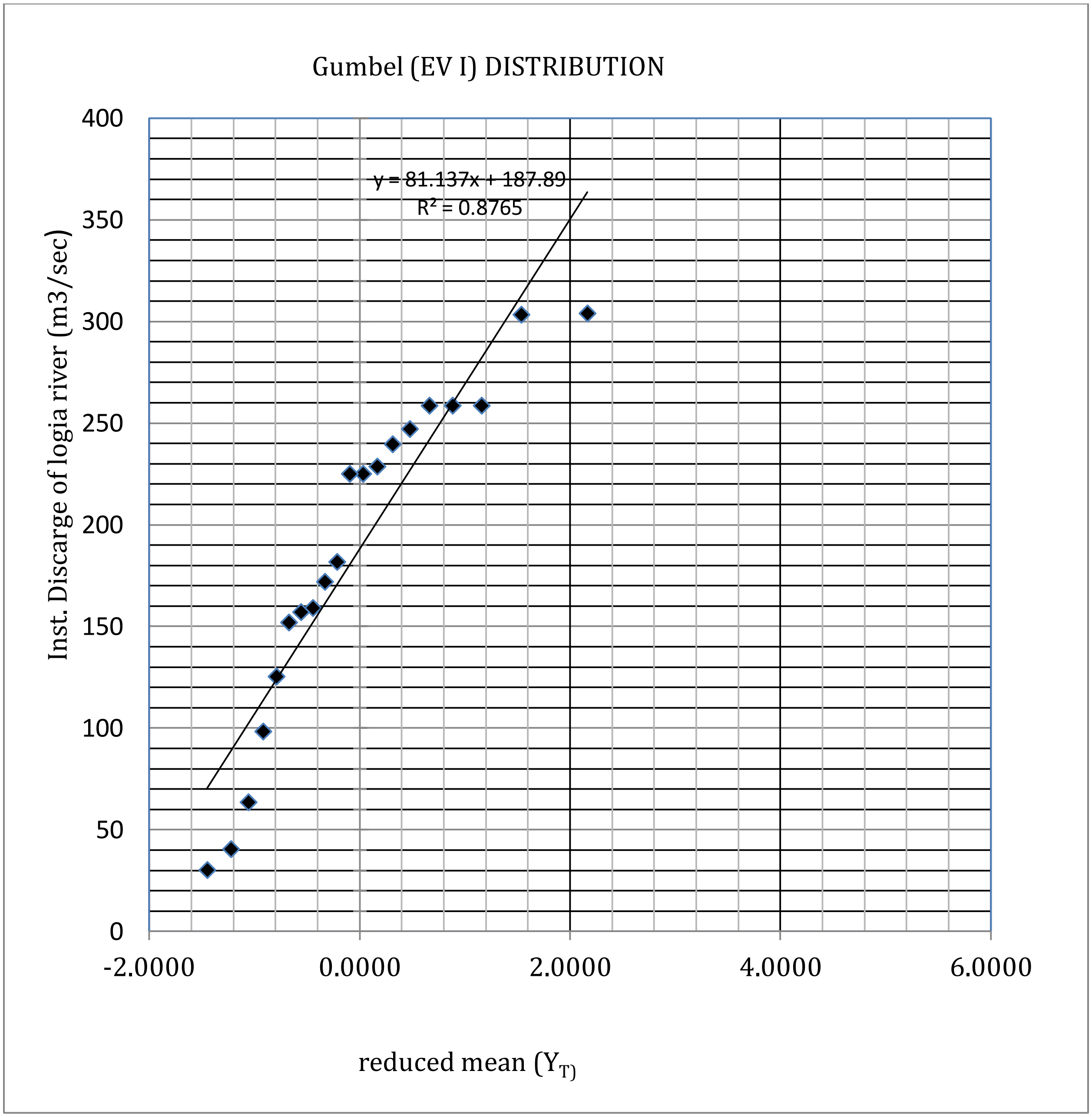
Y_T=-[Ln-Ln(T/(T-1)]

Y_T=-[Ln-Ln(10000/9999)] = =-[Ln-Ln(10000/9999)]= 9.2103

k =(Y_T-y_n/s_n)

Ȳ+k*s_n

Gumbel							
year	sample data	Inst. Discharge descending order	Rank	T	pi	y_t	$k=Y_t-Y_n/S_n$
1988	30.206	304	1	21.000	0.02783	3.020227	2.1651
1989	63.524	303.368	2	10.500	0.07753	2.301751	1.5369
1990	40.471	258.616	3	7.000	0.12724	1.869825	1.1592
1991	304	258.616	4	5.250	0.17694	1.554433	0.8834
1992	159.094	258.616	5	4.200	0.22664	1.302197	0.6628
1993	125.369	247.127	6	3.500	0.27634	1.08924	0.4766
1994	151.951	239.636	7	3.000	0.32604	0.90272	0.3135
1995	181.756	228.65	8	2.625	0.37575	0.734859	0.1667
1996	258.616	225.054	9	2.333	0.42545	0.580505	0.0317
1997	157.059	225.054	10	2.100	0.47515	0.435985	-0.0946
1998	225.054	181.756	11	1.909	0.52485	0.29849	-0.2149
1999	171.968	171.968	12	1.750	0.57455	0.165703	-0.3310
2000	258.616	159.094	13	1.615	0.62425	0.035543	-0.4448
2001	239.636	157.059	14	1.500	0.67396	-0.09405	-0.5581
2002	258.616	151.951	15	1.400	0.72366	-0.22535	-0.6729
2003	247.127	125.369	16	1.313	0.77336	-0.36122	-0.7917
2004	228.65	98.343	17	1.235	0.82306	-0.50575	-0.9181
2005	225.054	63.524	18	1.167	0.87276	-0.66573	-1.0580
2006	98.343	40.471	19	1.105	0.92247	-0.855	-1.2235
2007	303.368	30.206	20	1.050	0.97217	-1.11334	-1.4494


Gumbel (EV I) DISTRIBUTION
y = 81.137x + 187.89
R² = 0.8765
Inst. Discarge of logia river (m3/sec)
400
350
300
250
200
150
100
50
0
-2.0000
0.0000
2.0000
4.0000
6.0000
reduced mean (YT)

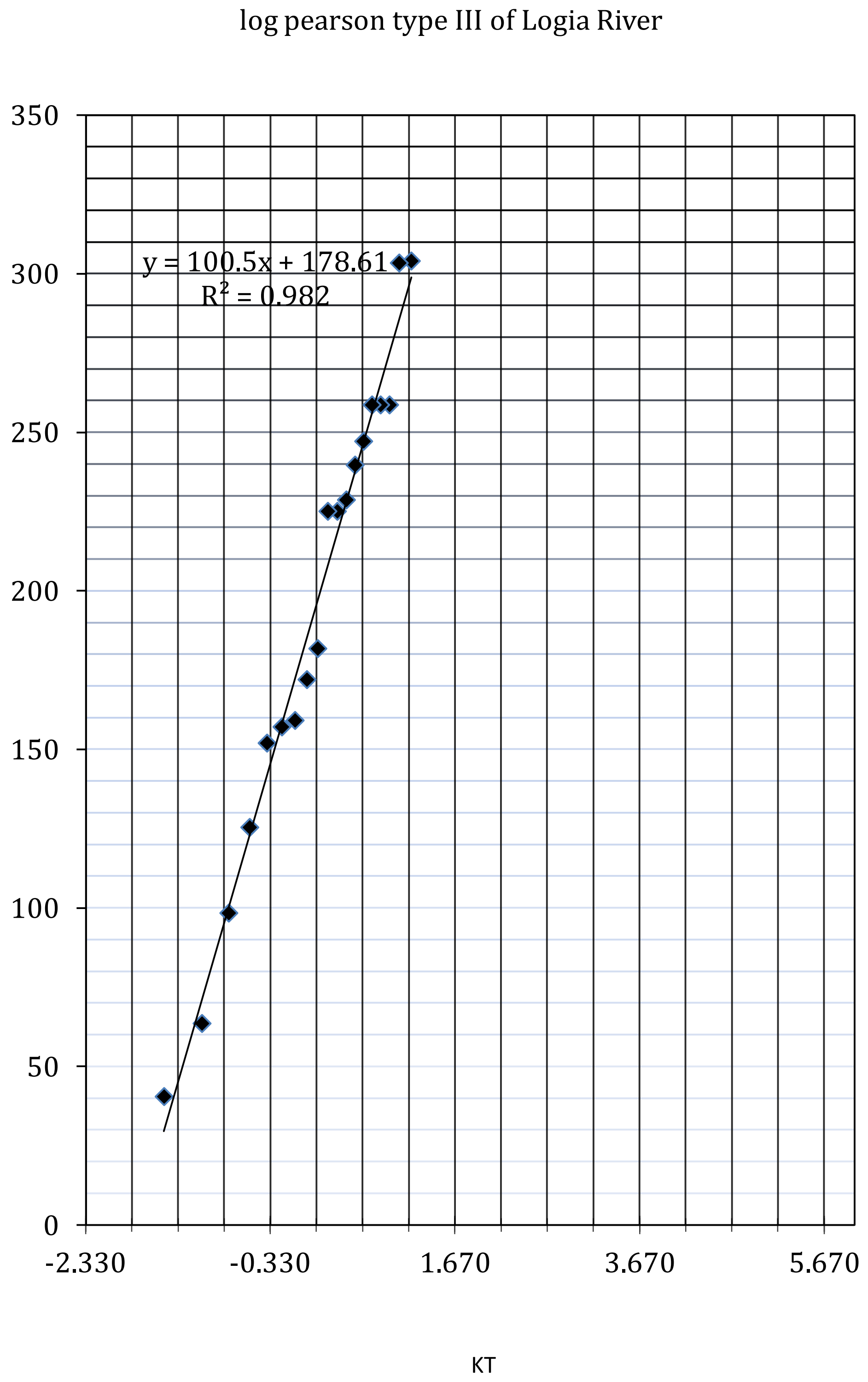
Exponential distribution

1. Probability density function and distribution function
2. parameter are determined by MOM
3. Describes events that occur instantaneously and independently along a time horizon
4. λ is the mean rate of occurrence of events
5. time intervals between major precipitation events, etc
6. K_T for log pearson III Distribution (log pearson) is given by
7. $K_{'t}$ = ($Z-(Z^2-1)K+1/3(Z^3-6Z)K^2-(Z^2-1)K^3-ZK^4-1/3K^5$
8. $Z=w-((2.515517+0.80285w+0.010328w^2)/1+1.43178860+0.189269w^2+0.001308w^3)$
9. $w=[\ln(t/(t-1))^2]^{0.5}$
10. $K=CS/6$

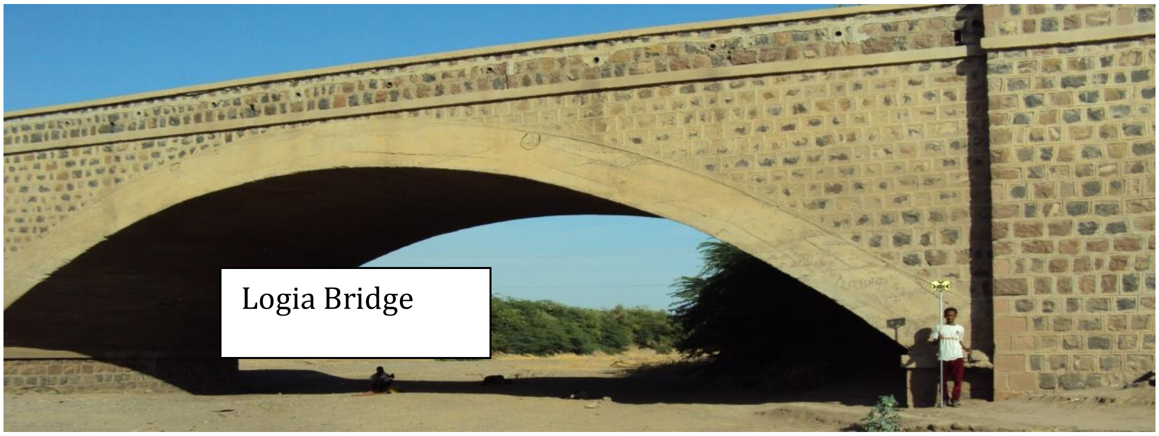
MEAN……………………………………………………………….. 186.423

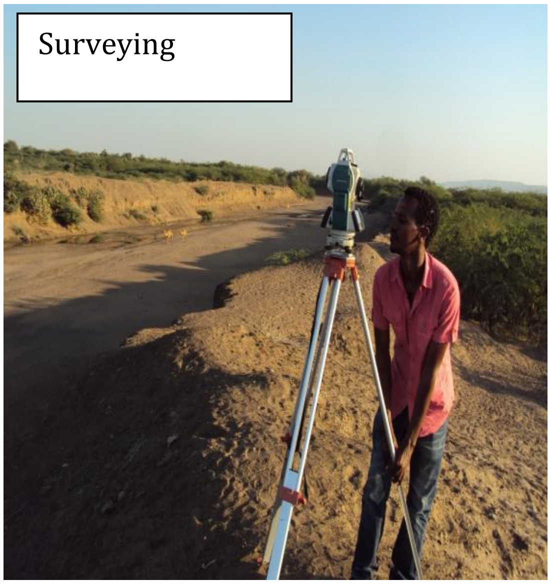
STADV……………………………………………………………82.640

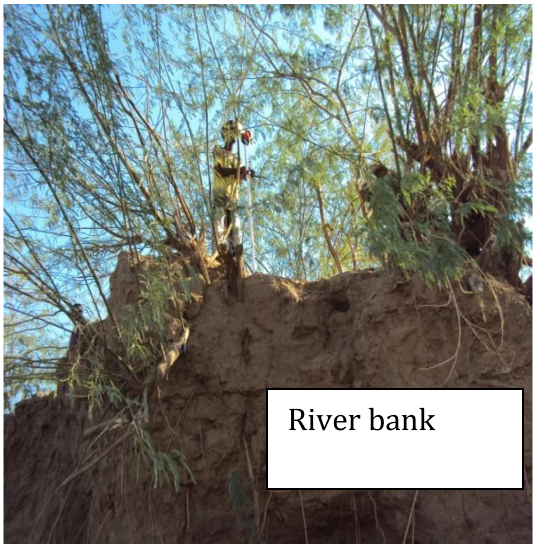
year	discharge	72hr	Rank Data	Rank	Pi=(m-.375)/(n+0.25)	LOG (XI)	w	Z	k_T
1988	30.206	30.206	304	1.000	0.025	2.483	2.716	1.960	1.196
1989	63.524	63.524	303.368	2.000	0.075	2.482	2.276	1.440	1.066
1990	40.471	40.471	258.616	3.000	0.125	2.413	2.039	1.150	0.960
1991	304	304.000	258.616	4.000	0.175	2.413	1.867	0.935	0.864
1992	159.094	159.094	258.616	5.000	0.225	2.413	1.727	0.755	0.771
1993	125.369	125.369	247.127	6.000	0.275	2.393	1.607	0.597	0.680
1994	151.951	151.951	239.636	7.000	0.325	2.380	1.499	0.453	0.588
1995	181.756	181.756	228.65	8.000	0.375	2.359	1.401	0.318	0.493
1996	258.616	258.616	225.054	9.000	0.425	2.352	1.308	0.189	0.395
1997	157.059	157.059	225.054	10.000	0.475	2.352	1.220	0.063	0.292
1998	225.054	225.054	181.756	11.000	0.525	2.259	1.135	-0.062	0.183
1999	171.968	171.968	171.968	12.000	0.575	2.235	1.052	-0.188	0.066
2000	258.616	258.616	159.094	13.000	0.625	2.202	0.970	-0.317	-0.063
2001	239.636	239.636	157.059	14.000	0.675	2.196	0.887	-0.450	-0.205
2002	258.616	258.616	151.951	15.000	0.725	2.182	0.802	-0.592	-0.366
2003	247.127	247.127	125.369	16.000	0.775	2.098	0.714	-0.745	-0.554
2004	228.65	228.650	98.343	17.000	0.825	1.993	0.620	-0.918	-0.781
2005	225.054	225.054	63.524	18.000	0.875	1.803	0.517	-1.121	-1.071
2006	98.343	98.343	40.471	19.000	0.925	1.607	0.395	-1.382	-1.482

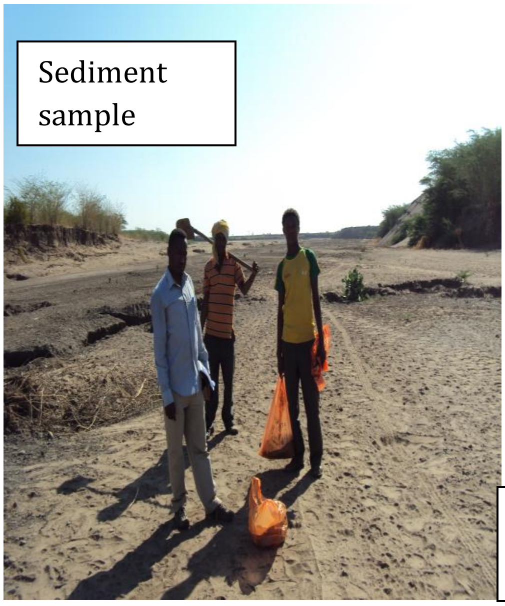

log pearson type III of Logia River
y = 100.5x + 178.61
R² = 0.982
logia river discharge(m3/sec)
350
300
250
200
150
100
50
0
-2.330
-0.330
1.670
3.670
5.670
KT

APPENDIX 4


Logia Bridge


Surveying


River bank


Sediment sample


Soil laboratory