ROUTING BLACK FLOOD HYDROGRAPH OF RIVER NIGER INTO KAINJI RESERVOIR

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ABSTRACT

Flood routing and hydrograph generation form key elements of Flood plain management. Flood routing reveals the magnitude of peak discharge, the time of the peak discharge and depth. Flooding along the river plain, especially river Niger and Benue is annual event. This attributed to both inflows within the country and transboundary flow. This study routed the inflow during the dry season at Jiderebode to Kainji reservoir. The study was carried out using kinematic wave model approach for flow between Jiderebode and Kainji on River Niger. The period of data gaps in flow record (2002-2012) was filled using recession equation. Advection equation and Kinematic wave model were coded in Microsoft excel. The length between Jiderebode and Kainji was divided into 21 sub reaches, each sub reach is 10 km. The catchment characteristics such as vegetation, topography and soil (manning's roughness coefficient) were captured. The study revealed that kinematic wave model could be used to route the flow in river Niger. The Nash-Sutcliffe Efficiency (NSE) is 0.009, indicating that it is closely match with the observed inflow record at Kainji. The findings of these work would give better understand of the contribution of flow from upper and middle Niger Basins into Nigeria, during the dry season (black flood).

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

DCP	Data Collection Platform
DEMs	Digital Elevation Models
GIS	Geographic Information System
NEST	Nigerian Environmental Study Team
NIHSA	Nigerian Hydrological Services Agency
NSE	Nash-Sutcliffe Efficiency
NFIP	National Flood Insurance Program

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

River flooding in Nigeria is no exception to countries that experienced flooding in recent time. Flood occur in rivers when the flow rate exceeds the capacity of the river channel. Flooding occurs when excess rainfall cannot be absorbed by the receiving soils or discharged fast enough by the stream network. Flooding is an overflowing of water into land that normally dry. Flood is one of the most important water-related natural disaster causing damages of properties and loss of lives.

Flood routing and hydrograph generation form the key elements of floodplain management. A hydrograph of a stream is a graphical representation of its fluctuations in flow arranged in chronological order or a graph of the time distribution of runoff from a watershed. A flood-routing model is used to estimate the outflow hydrograph by routing a flood event from an upstream flow-gauging station to a downstream location (Blackburn and Hicks, 2001). Flood routing in a river is important to trace the movement of flood peaks along the channel length and thereby determine the flood hydrograph at any downstream section (Wilson, 1990). Runoff routing is a procedure to calculate a surface runoff hydrograph from rainfall and transboundary inflow (Laurenson, 1964 and Mein *et al*., 1974). Flood routing is a procedure to determine the time and magnitude of flow (that is the flow hydrograph) at a point on a watercourse from known or assumed hydrographs at one or more points upstream (Chow *et al.*, 1988 and Akan, 2006).

There are different approaches to flood routing, they fall broadly into the categories of hydrologic routing and hydraulic routing. Hydrologic routing depends upon the equation of continuity. On the other hand, hydraulic routing combines both the continuity equation and the equation of motion for unsteady flow. In order to determine the change in shape of a hydrograph of a flood as it travels through a natural river or artificial channel, different flood simulation techniques can be used. Traditionally, the hydraulic (that is kinematic, dynamic and diffusion wave models) and hydrologic (that is linear and nonlinear Muskingum models) routing procedures that are well known as distributed and lumped ways to hydraulic and hydrologic practitioners, respectively, can be utilized. The hydrologic models need to estimate hydrologic parameters using recorded data in both upstream and downstream sections of rivers and by applying robust optimization techniques to solve the one-dimensional conservation of mass and storage-continuity equation (Barati, 2011). The difference is that in a lumped system, the flow is calculated as a function of time alone at a particular location, while in a distributed system the flow is calculated as a function of space and time throughout the system. Hydrologic models use the continuity equation and mathematical relationships between discharge and storage, and usually have a closed-form solution equation. Hydraulic models use both the continuity and momentum equations, and usually require some form of numerical integration (EI-Bahrawy, 1999).

1.2 Statement of the Research Problem

Many communities have suffered losses due to flood problems. Floods have their greatest impacts at local level especially in the lives of ordinary people. These problems cause considerable hardship. Flood have several socio-economic and political implications which caused a wide range of complex issues. Some of the immediate consequences include the displacement of people, the destruction of infrastructure such as houses and roads, damage to farms and crops and loss of cattle and livestock. The 2012 flood in Nigeria was the worst, claiming 363 lives, displacing 2.1 million, affecting 7.7 million and injuring 18,282 people between July 1 and October 31. It was reported to be the worst flood disaster in half a century (NEMA, 2012a). The Red Cross reports that over 150 people have died and 25,000 are displaced as a result of flooding in Nigeria that began in September to October 2020. The destruction of roads and other infrastructure delayed on-going development initiatives and political processes (Theron, 2007).

Communities along the banks of a river cultivate in the flood plain and surrounding land. They are affected by regular flood, which annually cause considerable damage to their crops and houses. Erosion of the river banks is also a significant problem to those communities. Despite these problems, farmers continued to cultivate in the flood plain. Shifting has affected our farmlands. We are now short of land to farm because we shift and erect houses on the farmlands (Adelye and Rustum, 2011). Flood management include flood warning. Flood warning is the linked to the task of forecast time-profiles of a channel flows or river levels at various locations, the steps to do flood warning is flood routing which is essential for flood management. By the time you get the information, it is always too late. Floods come at different times, it can come in the morning, afternoon or night (Goulden and Few, 2011).

1.3 Aim and Objectives of the Study

The aim of this research is to route black flood hydrograph of River Niger from Jiderebode into Kainji reservoir.

The objectives of this research work are to:

i. assess flow record at Jiderebode,
ii. route flow from Jiderebode to Kainji using kinematic wave model, and
iii. determine the travel time and attenuation of runoff from Jiderebode to Kainji.

1.4 Justification of the Study

The need to protect the environment is of great concern to man. Flood management is currently a key focus of many national and international research programmed with flooding from rivers, estuaries and the sea posing a serious threat to millions of people around the world during a period of extreme climate variability. Flood warning and flood mitigation depend on understanding how quickly a flood crest travels downstream and how the height of the crest changes as it does so. The prediction of the downstream hydrograph requires an estimate of how fast the flood wave is moving; it will enhance power generation in Kainji.

1.5 Scope of the Study

The study focuses on transboundary flow into Nigeria without considering rainfall and the tributaries within the reach, the records data (2002-2012) at Jiderebode and Kainji were available, and to investigate the movement of flood peaks and predict the travel time of runoff of River Niger, using kinematic wave model, from Jiderebode in Kebbi State to Kainji in Niger state, Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Flood

A flood is an overflow of water that submerges land that is usually dry. In the sense of "flowing water", the word may also be applied to the inflow. Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries (GM, 2000) or it may occur due to an accumulation of rainwater on saturated ground in an area flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals.

Flood can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Flood often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry (WHO, 2021).

When it rains or snows, some of the water generated is retained by the soil depending on the degree of dryness of the soil, some are absorbed by vegetation, some evaporate and the remainder, which reaches stream channels, is called runoff. Flood is an unusual accumulation of water above the ground, cannot be carried in stream channels or retained in natural ponds and constructed reservoirs. Periodic flood occurs naturally on many rivers, forming an area known as the flood plain (Ogbonna *et al.,* 2017). These river floods often result from heavy rain, sometimes combined with melting snow, which causes the rivers to over flow their banks; a flood that rises and falls rapidly with little or no advance warning is called a flash flood. Flash floods usually results from intense rainfall over a relatively small area. Coastal areas are occasionally flooded by unusually high tides induced by severe winds over ocean surfaces.

2.1.1 Upslope factors

The amount, location, and timing of water reaching a drainage channel from natural precipitation and controlled or uncontrolled reservoir releases determines the flow at downstream locations. Some precipitation evaporates, some slowly percolates through soil, some may be temporarily sequestered as snow or ice, and some may produce rapid runoff from surfaces including rock, pavement, roofs, and saturated or frozen ground. The fraction of incident precipitation promptly reaching a drainage channel has been observed from nil for light rain on dry, level ground to as high as 170 percent for warm rain on accumulated snow (Babbitt *et al.*, 1949). Most precipitation records are based on a measured depth of water received within a fixed time interval. Frequency of a precipitation threshold of interest may be determined from the number of measurements exceeding that threshold value within the total time period for which observations are available. Individual data points are converted to intensity by dividing each measured depth by the period of time between observations. This intensity will be less than the actual peak intensity if the duration of the rainfall event was less than the fixed time interval for which measurements are reported (Simon *et al.*, 1981).

2.1.2 Downslope factors

Water flowing downhill ultimately encounters downstream conditions slowing movement. The final limitation in coastal flooding lands is often the ocean or some coastal flooding bars which form natural lakes. In flooding low lands, elevation changes such as tidal fluctuations are significant determinants of coastal and estuarine flooding. Less predictable events like tsunamis and storm surges may also cause elevation changes in large bodies of water. Elevation off lowing water is controlled by the geometry of the flow channel and, especially, by depth of channel, speed of flow and amount of sediments in it (Simon *et al.*, 1981). Flow channel restrictions like bridges and canyons tend to control water elevation above the restriction. The actual control point for any given reach of the drainage may change with changing water elevation, so a closer point may control for lower water levels until a more distant point controls at higher water levels. Effective flood channel geometry may be changed by growth of vegetation, accumulation of ice or debris, or construction of bridges, buildings, or levees within the flood channel.

2.1.3 Impact of flood

In Nigeria alone, it is estimated that approximately 12% of the land area is within the 100-year floodplain (NEST, 1991). However, the percentage of urban and rural areas within the flood plain is much higher (about 20%). The total property value within the flood plain already exceeds hundreds of millions of Naira and is growing at a rate of about 5% per annum. Flood disasters have increased tremendously everywhere in Nigeria in recent times, resulting to loss of lives and properties, rendering, thousands homeless, and disruption of economic activities. Without flood control and adequate drainage structures, the extent of destruction and damage would increase at an even faster pace. There were over 200 floods affecting over 180 million people, 8,000 deaths and over £40 billion is damages in 2007 (Pitt, 2007). It is in fact the most common of all environmental hazards and it regularly claims over 20,000 lives per year and affects around 75 million people worldwide (Smith, 2006). The result or implication of human development is the evolution of serious environmental problems such as flooding, deforestation, erosion and so on. These environmental problems have prevailed more in the developed and developing nations of the world and urban centers in general. Flooding particularly has caused a lot of the world. Floods cause about one third of all damages from natural disaster (Akin, 2009). Flood is a body of water which rises to over- flow land, which is normally submerge red (NEST, 1991). They are environmental hazards that occur regularly every year in different parts of the country especially during the rainy season. Floodwater overflow expanse of land, submerging the land. Flood occurrence is usually due to the increase in the volume of water within the water body such as rivers and lakes. This causes water to exceed the drainage channel capacity and overflow its bounds. Flooding occurs also when excess runoff is created owing to the inability of the soil to infiltrate water or when the soil has reached its field capacity or saturation. The result is excess runoff which submerges the landscape. This form of flooding is particularly the case in most urban centers of the world and Nigeria in particular, where urbanization has disturbed or altered the natural process of infiltration.

2.1.4 Analysis of flood information

Concerns for flooding has increased in recent times due to climate change (especially in more frequent and severe rainfall events), sea level rise, rapid population growth and urbanization, and the level of awareness of flood risk. In Nigeria, flooding and solutions to its impacts are critical issues (Obeta, 2014). With history of devastating floods which affected millions of human populations and caused fiscal losses amounting to billions of Naira, the importance of exploring more realistic flood risk mitigation measures for Nigeria should be paramount (OCHA, 2012). Flooding in Nigeria are fluvial (resulting from rivers overtopping their natural and manmade defenses), coastal (affecting mainly the coastal areas) and pluvial (flash, arriving unannounced following a heavy storm) in nature and have been a major cause of concern for rural areas and cities within the country (Bashir *et al.*, 2012). Whilst stake holders' efforts towards tackling the hazard have not yielded satisfactory results, they have been criticized as ad-hoc, poorly coordinated, non-generalizable and not well established (Obeta, 2014).

The efforts are limited due to lack of quality data, which are needed to systematically tackle flooding, poor perception of flooding among the general populace, lack of funds and improved technology as well as poor political will power. The growing number of flood victims and the constrained sustainable development caused by flooding within the country suggest that much of what is known regarding flooding in the country is deficient on remedies. The widespread flooding in Nigeria along with how to deal with associated challenges has received considerable attention, although more discussions focused on local communities, geopolitical regions and states within the country (Agbonkhese *et al.*, 2014). Although the lack of definite measures and capacity to radically tackle the hazard within the country has been arguably overwhelming, concerted efforts in the form of environmental and infrastructural planning, policy directives, social responses, physical intervention and enhanced public enlightenment programmes have been extensively considered (Agbola *et al.,* 2012). Other measures considered are community based early warning systems.

Flooding along with its severe impacts on human lives, properties and economic activities is globally acknowledged. Conceptually, flooding is the result of water overtopping its natural and manmade defenses and overflowing places not typically submerged (Smith and Ward, 1998). It is also a result of sudden arrival of heavy storms, which overwhelms soil infiltration capacity and urban drainage systems. Flood modelling generally predicts flood hazard characteristics such as water flow depth, flow velocity and inundation extent which are required for estimating the likelihood of flood hazard and its impacts required for flood risk/hazard mapping.

Although, existing flood models are rife with limitations which may constrain their applications in Nigeria, however, developing bespoke flood models for Nigeria can be a priority. This need for flood models was emphasized by the Director General (DG) of Nigerian Hydrological Services Agency (NIHSA, 2013) in a recent mission statement: in view of flooding in Nigeria, governments at all levels should create awareness on the need for communities to relocate to safer terrain. Figure 2.1 show the Spatial distribution of areas affected by extreme floods in Nigeria in 2012 (NIHSA, 2012). Moreover, while the current trends in climate variations prevails, the need to develop flood modelling and early warning systems cannot be overemphasized. There is also need to carry out a comprehensive flood hazard mapping for all areas considered at risk of flooding in the country.

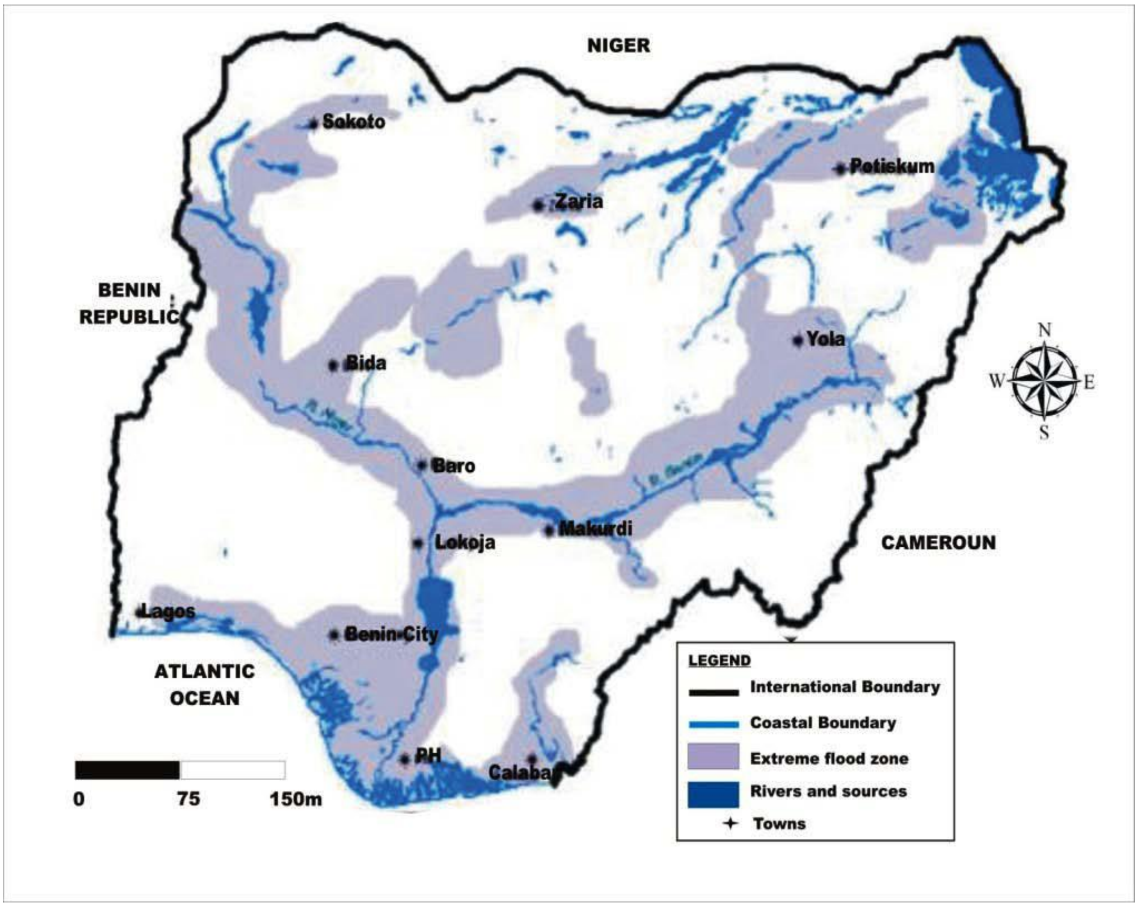


Figure 2.1: Spatial distribution of areas affected by extreme floods in Nigeria between (Source: NIHSA, 2012)

The flood risk/hazard assessment, flood modelling plays considerable roles. Under the European Union (EU) commission directive on flood, the United States flood control policy, National Flood Insurance Program (NFIP) and other regionally based flood risk management policies, the relevance of flood information to both flood risk/hazard mapping and flood risk reduction highlights the significance of flood modelling techniques (Nkwunonwo, 2016). The Key roles of flood modelling techniques can be summarized as follows:

1. The roles of flood modelling technique can assist in description of flow behaviour around groups of buildings and other complex geomorphological features especially in assessment of urban flooding (Bates *et al.,* 2010).

2. The technique can assist in provide critical information for strategic planning of flood defence measures and effective flood risk management such as temporal inundation information about the onset, duration and passing of flood event (Zerger, 2004).
3. The technique can assist in improved understanding of the flood phenomena, provides insight into the causes of flooding and guide through more appropriate measures to be taken to reduce flood damage (Chow *et al.,* 1988).
4. The technique can serve as the basis for flood forecasting, flood early warning system and flood damage estimation, as well as provides the basis for the decision making of flood risk management (EA, 2007).
5. The technique can serve as the basis for producing flood risk/hazard maps that community officials or the general public can use to evaluate their flood risk and analyze possible evacuation procedures (De Moel, 2009).

2.2 Hydrologic Flood Routing

Lumped (hydrologic) flow is calculated as a function of time alone at a particular location represented in Figure 2.2 and governed by continuity equation and flow and storage relationship. Hydrological models are simpler than hydraulic models. Generally, they are limited in application because they need observed inflow and outflow hydrographs from a reach to determine the routing coefficients. Back-water effects from tides, significant tributary inflow, dams or bridges are not considered.

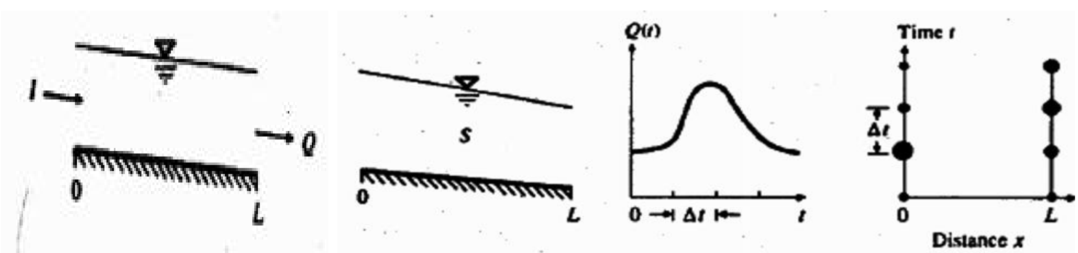


Figure 2.2: Deterministic lumped unsteady-flow model

2.3 Hydraulic Flood Routing

Distributed (hydraulic) flow is calculated as a function of space and time throughout the system and governed by continuity and momentum equations. According to (France, 1985), hydraulic flow routing methods are more complex and often difficult to implement. Hydraulic flow routing methods involve the numerical solutions of either the convective diffusion equations or the one-dimensional Saint-Venant equations of varied unsteady flow in open channels (France, 1985 and Sameer, 2008). With the advancements in technology, the advent of high speed computers, and increasing availability and affordability of data for setting-up and running more complex models, the complete solution of Saint Venant equations is becoming more feasible for addressing various unsteady flow problems (Patowary and Sarma, 2013). The flow of water through the soil and stream channels of a watershed is a distributed process because the flow rate, velocity, and depth vary in space throughout the watershed. Estimates of the flow rate or water level at important locations in the channel system can be obtained using a distributed flow routing model (Figure 2.3). This type of model is based on partial differential equations, i.e. the Saint-Venant equations for one-dimensional flow, that allow the flow rate and water level to be computed as functions of space and time, rather than of time alone in the lumped models.

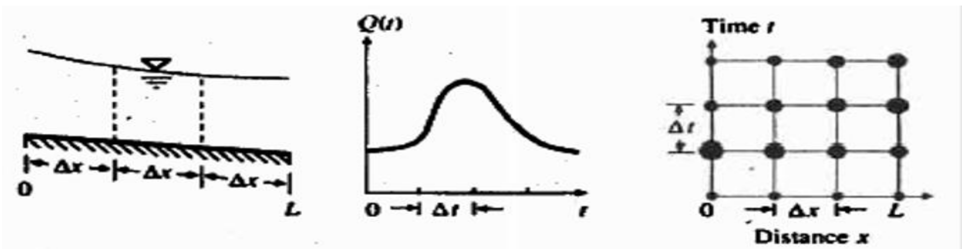


Figure 2.3: Deterministic distributed unsteady-flow model

Continuity Equation: apply both in hydrologic and hydraulic flow Equation (2.1).

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

(2.1)

where: $\frac{\delta Q}{\delta x}$ is the rate of discharge(Q) with space(x), $\frac{\delta A}{\delta t}$ is the Area(A) with time(t)

Momentum Equation: only applicable to hydraulic flow routing Equation (2.2 and 2.3).

$$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0 \quad (2.2)$$

Local acceleration term	Convective acceleration term	Pressure force term	Gravity force term	Friction force term

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

(2.3)

Kinematic Wave

Diffusion Wave

Dynamic Wave

where: Q = discharge [m3.s-1], A = cross sectional area [m2], Q = discharge [m3.s-1], x = distance along longitudinal axes of the channel or flood plain [m], t = time [s], and

q_l = lateral inflow per unit length [m3.s-1/m]. S_0 = bed slope [m/m], Sf = friction slope [m/m], V = velocity [m/s],

y = hydraulic depth [m], and g = acceleration due to gravity = 9.81 [m/s2].

Kinematic wave: when gravity forces and friction forces balance each other (steep slope channels with no back water effects)

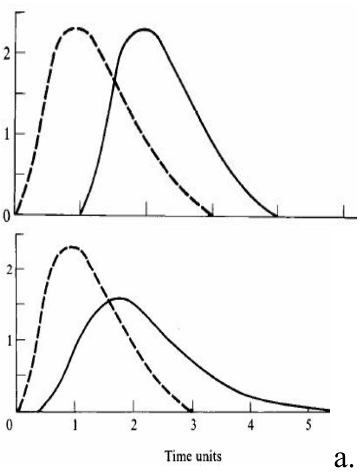
Diffusion wave: when pressure forces are important in addition to gravity and frictional forces

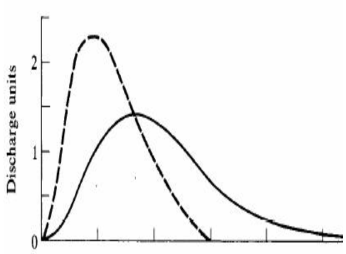
Dynamic wave: when both inertial and pressure forces are important and backwater effects are not negligible (mild slope channels with downstream control, backwater effects).

Simple Translation: The flood wave moves without changing its shape. This tendency is dominant in steep, straight streams. Flow velocities are high and relatively constant (Figure 2.4a).

Attenuation: The wave is attenuated by storage within the channel and the valley floor. A reservoir is a good example (Figure 2.4b).

Combination: Most natural rivers have both tendencies of translation and attenuation (Figure 2.4c).





a. Translation b. Attenuation c. Combination

Figure 2.4: Flow Hydrograph

2.4 Comparison of Hydraulic and Hydrological Techniques

Flood routing is used to simulate flood wave movement through river reaches and reservoirs. Routing can be applied using either hydrologic or hydraulic approaches. In a hydrologic approach, the spatially lumped form of the continuity equation is applied, a water budget (or water balance) is determined, and the flux relation of inflow, and outflow is evaluated (Singh, 2004). Hydraulic approaches require both continuity and dynamic equations, which requires mass and momentum conservation, channel geometry (cross section shape, bed slope, etc.). The hydraulic methods generally describe the flood-wave profile adequately when compared to hydrological techniques, but practical application of hydraulic methods is restricted because of their high demand on computing technology, as well as on quantity and quality of input data (Singh, 1988). Even when simplifying assumptions and approximations are introduced, the hydraulic techniques are complex and often difficult to implement (France, 1985). Studies have shown that the simulated outflow hydrographs from the hydrological routing methods always have peak discharges higher than those of the hydraulic routing methods (Haktanir and Ozmen, 1997). However, in practical applications, the hydrological routing methods are relatively simple to implement and reasonably accurate (Haktanir and Ozmen, 1997). An example of a simple hydrological flood-routing technique used in natural channels is the Muskingum flood-routing method (Shaw, 1994).

Among the many models used for flood routing in rivers, the Muskingum model has been one of the most frequently used tools, because of its simplicity (Tung, 1985). As noted by Kundzewics and Strupczewski (1982), the Muskingum method of flood routing has been extensively applied in river engineering practices since its introduction in the 1930s. The modification and the interpretation of the Muskingum model parameters in terms of the physical characteristics, extends the applicability of the method to ungauged rivers (Kundzewicz and Strupczewski, 1982). Most catchments are ungauged and thus a methodology to compute the flood-wave propagation down a river reach or through a reservoir is required. One option is to calibrate flood-routing models on gauged catchments and relate their parameters to physical characteristics (Kundzewicz, 2002). The flood-routing models with derived parameters can then be applied to ungauged catchments in the region (Kundzewicz, 2002).

2.5 Application of Flood Routing Models

Classical, explicit finite differences in the hydraulic models and simple Muskingum model were used to investigate the flood routing (Schubert *et al.,* 2018). It has been reported that the applied numerical methods had numerical instability, for some case studies. As a result, the Muskingum model showed superior performance compared to the same applied hydraulic models (Schubert *et al*., 2018). It has been reported that the 2-D models could be developed, based on the availability of enough information about topography and topology. Fassoni-Andrade *et al.* (2018), considered the development of a one dimensional model based on the equation of hydrological models, which include the continuity equation and mass equation, such as the equation of the Muskingum models (Fassoni-Andrade *et al*., 2018). It was observed that one-dimensional flow routing inertial models, based on the explicit solution were superior to the other models. These models simplified the Saint-Venant equation, and the main advantages of these models were good simulated results with a simple structure. The hydraulic models need to measure the flow depth and discharge based on applying stream gauging. These models are known as complex models and difficult to use, while the hydrologic models need only to use the discharge data. In addition, the hydrologic models can be effective for the initial planning level, where the measuring system is undeveloped for accurate measurement (Costabile *et al*., 2017).

For example, Chatila (2003), simulated flood routing based on the Muskingum model and EXTRAN hydraulic model. The hydraulic model, developed was based on finite difference. Both hydrologic models and hydraulic models, were applied on simple and compound channels for flood routing. The results revealed that the Muskingum model had achieved higher accuracy compared with the hydraulic model because of its flexibility in calibration, where even the river bed geometry was not considered for this model. It has been demonstrated that the Muskingum model could simulate the peak discharge, achieving a close fit with the actual one, compared to the hydraulic model. Furthermore, it has been reported that hydraulic models are dependent too many assumptions, such as reach geometry, channel slope, and flow velocity, which causes the application of some hydraulic models to be limited to the specific case studies. The Muskingum model is a useful and important hydrological model, due to its high accuracy and simplicity. Hydrological models could be accomplished after estimating the value of parameters, on the other hand, hydraulic models are required to simulate the complex boundary hydraulic conditions that causes an increase in the computational time (Chatila, 2003). The application of Flood Routing Models for Flood Mitigation in Orashi River, South-East Nigeria. Flood data were collected for the study area and subjected to statistical analysis. Three flood Routing models were comparatively applied including Muskingum model, Level Pool model and Modified Pul's model. Though, flood models of the Muskingum method and Level Pool method exhibited good correlation (Ogbonna *et al*., 2017).

2.6 Kinematic Wave Routing

The kinematic wave routing scheme does not assume that flow changes instantaneously throughout the system. This routing option uses the Continuity and Momentum equations often called the Saint Venant equations when used together (Miller, 1984).

The kinematic wave method adopts the idea that the natural movement of flood waves is governed mostly by the friction and bed slopes. Kinematic wave models assume the pressure term, the convective acceleration, and the local acceleration terms of the Momentum Equation to be insignificant, thus only gravity and friction forces are included (Miller, 1984). Some general assumptions for using the kinematic wave flow routing technique are that the flows are one-dimensional with no backwater effects, and the velocity is constant during the model time step. The changing flow wave propagates downstream, allowing an increased flow at the boundary to travel down the stream network with a lag in time (Miller, 1984).

According to Miller (1984), kinematic wave hydraulic routing methods are used mainly for channel and overland-flow routing where lateral inflow is continuously added as a large part of the total flow. The model is usually applied in precipitation-runoff modelling system and in the distributed routing rainfall-runoff models such as Hydrologic Engineering Centre's (HEC-1) (City of Springfield, 2007 and Li *et al.*, 2010). The kinematic wave routing method is based on the solution of the continuity equation and uniform flow equation such as Chezy or Manning's equations. Miller (1984), states that kinematic-wave models ignore a number of terms in the equation of motion and assume that the friction slope is equal to bed slope and also assumes uniform steady flows conditions (Henderson, 1966). Miller (1984), noted that kinematic wave-models always predict a steeper wave with less dispersion and attenuation than actually occurs. Li *et al.* (1976), concluded that the applicability of the kinematic wave model to river flood routing is limited because of shock formation, a discontinuity representing a sudden rise in the flow depth. The approximations made in the development of the kinematic-wave equations are not generally justified for most channel-routing applications (Li *et al.*, 1976).

In general, the steeper the channel bed slope, the shorter the wave period needed to satisfy the kinematic wave assumption: (Hromadka, 1988) said that the selection of Δx and Δt values may have significant impact on the kinematic wave modelling result. Internal checks for selecting Δx and Δt values are needed in order to achieve an accurate solution. Internal checks should notify program users when inappropriate values of Δx and Δt cause computation error due to channel storage effects. Meanwhile kinematic wave models should be used properly, especially in choosing the values of Δx and Δt. With the kinematic wave approach, the leading edge of the flood wave becomes steep with distance downstream (Hunt, 1987). Kinematic wave can also be discussed in term of the method of characteristics. Unlike the dynamic wave method, in the case of the kinematic wave method, there is only one kind of characteristic line in the x-t plane (Figure 2.5), corresponding to a single direction of wave motion.

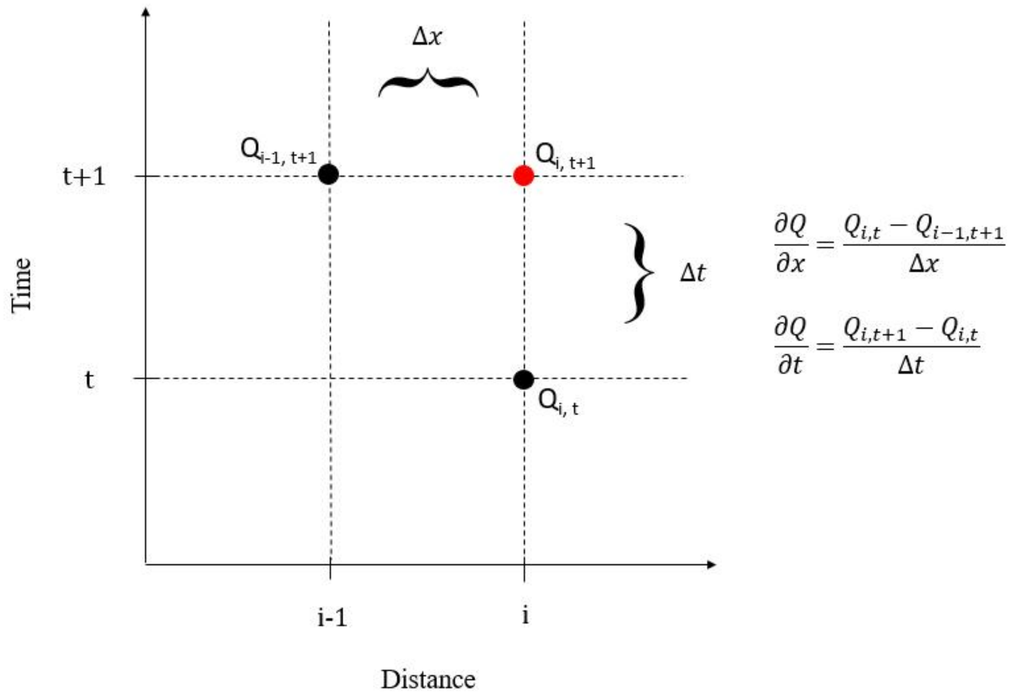


Figure 2.5: The computational grid for solving the finite difference numerical approximation

2.7 Digital Elevation Models (DEMs) in Geographic Information System (GIS)

Digital Elevation Models (DEMs) are used in water resources projects to identify drainage features such as ridges, valley bottoms, River networks, surface drainage patterns, and to quantify sub catchment and river properties such as size, length, and slope. The accuracy of this topographic information is a function both of the quality and resolution of the DEM, and of the DEM processing algorithms used to extract this information. Watershed delineation is one of the most commonly performed activities in hydrologic analyses. DEMs provide good terrain representation from which watersheds can be derived automatically using Geographic Information System (GIS) technology. The techniques for automated watershed delineation have been implemented in various GIS systems and custom applications (Garbrecht and Martz, 1996). The automated derivation of topography watershed data from DEMs is faster, less subjective, and provides more reproducible measurements than traditional manual techniques applied to topographic maps.

2.8 Applications of Hydraulic Model

Calculation of rainfall, calculating surface runoff and precipitation, determining the water balance of a region, determining the agricultural water balance, designing riparian restoration projects, mitigating and predicting flood, landslide and drought risk, real-time flood forecasting and flood warning, designing irrigation schemes and managing agricultural productivity, part of the hazard module in catastrophe modeling, providing drinking water, designing dams for water supply or hydroelectric power generation, designing bridges, designing sewers and urban drainage system, analyzing the impacts of antecedent moisture on sanitary sewer systems, predicting geomorphologic changes, such as erosion or sedimentation, assessing the impacts of natural environmental change on water resources.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study Area

River Niger extending 4,180 km and basin size of 2,117,700 km^2 and is the third largest river in Africa, after the Nile and the Congo Rivers. Rising in Guinea, the river flows northeast into Mali. East of Timbuktu, it bends to the southeast, flowing across western Niger and forming part of the international boundary between Niger and Benin. From there, the Niger River enters Nigeria and flows predominantly southwards, finally entering the Atlantic Ocean through an extensive delta (Figure 3.1).

Figure 3.1: River Niger Across West Africa

The latitudes 11^0 00’N and longitudes 4^0 00’E at Jiderebode to latitudes 10^0 03’N and longitudes 4^0 60’E at Kainji, hydrological gauged stations of river Niger in Nigeria (Figure 3.2).

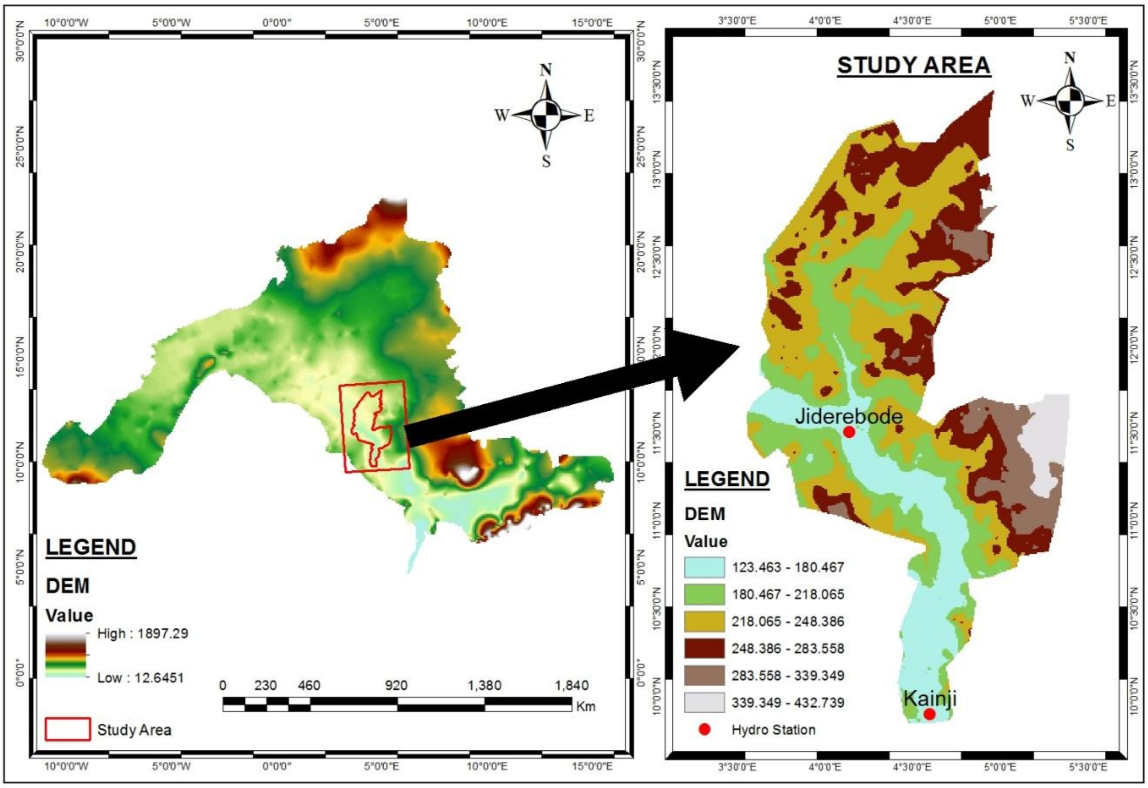


Figure 3.2: DEM of Niger Basins and study Area

3.2 Hydrology of Niger River

The climatic change of annual river flood does not occur at the same time in different parts of the River Niger Basin in Nigeria. The white flood (so called because of the light sediment content of the water) occurs soon after the rainy season between July and October; a second rise the black flood (so called because of the greater sediment content) begins in December with the arrival of floodwaters from upstream. In January a slight rise occurs due to the arrival of floodwaters from the upper Niger.

River Niger at Jiderebode: The station is in Kebbi state, close to the border of Nigeria and Benin/Niger Republics. The station monitors the flow of River Niger into the country from Niger Republic. The station is equipped with a Data Collection Platform (DCP) and Staff Gauge.

River Niger at Kainji: Kainji Dam is the first Dam on river Niger within the Nigerian portion of the River Niger, with Jebba Dam 100km downstream. The station is on the Dam crest equipped with DCP to measure the inflow to the Dam and Staff Gauge to measure the tail raise (outflow).

3.3 Data Source

Historical inflow data of River Niger at Jiderebode and Kainji hydrological gauge station, from 2002 to 2012 were collected from Nigerian Hydrological Services Agency (NIHSA).

3.3.1 Missing data gaps using recession techniques

During periods of recession when the flow is dependent on surface and sub-surface storage rather than rainfall, the flow exhibits a pattern of exponential decay, interpolation between the logarithmically transformed points before and after the gap will result in a more realistic recession than simple linear interpolation. It is possible to make this interpolation as stage rather than as discharge but, as the principle is based on depletion of a storage volume, it is conceptually simpler to apply the interpolation to discharge rather than to stage. The slope of the logarithmically transformed flow recession α (also called a reaction factor) is represented in Equation (3.1).

$$\alpha = \frac{InQ_{t0-InQ_{t1}}}{t_{1-t_0}}$$

(3.1)

where: $Q_{t\,0}$ is the last value before the gap at time t_0; $Q_{t\,1}$ is the first value after the gap at time t_1.

$$k = \frac{1}{\alpha}$$

(3.2)

where: k, is a reservoir coefficient. Hence at time t within the gap, Q_t is:

$$Q_t = Q_{t_0} \ \exp\left(-\frac{t - t_0}{k}\right)$$

(3.3)

3.4 Methods of Routing

Geographic Information System (GIS) and Digital Elevation models (DEMs) were used for catchment delineation. A hydraulic model was applied to solve the unsteady flow equations in flood routing models. The method was carried out by applies the Advection Equation and kinematic wave model approach for river flow in a watershed. Interpolating Gaps using Recessions to fill in the missing discharge data; Advection Equation and Kinematic wave model were coded in Microsoft excel.

3.4.1 Advection equation

The linear advection for Q(x,t).

Consider the advection equation in its non – conservative form Equation (3.4).

$$\frac{\delta Q}{\delta t} + C\frac{\delta Q}{\delta x} = 0 \qquad (3.4)$$

Discretize Equation (3.4) as follows:

Choose the scheme: forward in time and forward in space (forward in difference scheme).

$$(\frac{\delta Q}{\delta t})_i^j = \frac{Q_i^{j+1} - Q_i^j}{(\Delta t)}$$

$$(\frac{\delta Q}{\delta x})_i^j = \frac{Q_{i+1}^j - Q_i^j}{(\Delta x)}$$

$$\frac{Q_i^{j+1} - Q_i^j}{(\Delta t)} + C\left[\frac{Q_{i+1}^j - Q_i^j}{(\Delta x)}\right] = 0 \qquad (3.5)$$

$$\frac{Q_i^{j+1} - Q_i^j}{(\Delta t)} =- C\left(\frac{Q_{i+1}^j - Q_i^j}{(\Delta x)}\right)$$

$$(Q_i^{j+1} - Q_i^j)(\Delta x) =- C\Delta t(Q_{i+1}^j - Q_i^j) \qquad (3.6)$$

$$\frac{Q_i^{j+1}(\Delta x)}{(\Delta x)} - \frac{Q_i^j(\Delta x)}{(\Delta x)} =- \left(\frac{C\Delta t}{\Delta x}\right) Q_{i+1}^j + \left(\frac{C\Delta t}{\Delta x}\right) Q_i^j$$

$$Q_i^{j+1} - Q_i^j =- \left(\frac{C\Delta t}{\Delta x}\right)(Q_{i+1}^j - Q_i^j)$$

$$Q_{i+1}^j = Q_i^j - \frac{\Delta x}{C\Delta t}(Q_i^{j+1} - Q_i^j) \qquad (3.7)$$

where; Q_i^j = discharge at point i and time step j, Q_i^{j+1} = discharge at point i and time step j + 1, Q_{i+1}^j= discharge at point i+1 and time step j, Δx = length of sub reach, Δt = time interval, C = wave celerity.

$$C= \sqrt{gh} \qquad (3.8)$$

The Equation (3.7) represent the linear advection equation and was coded in excel for routing. Example, Cell: D4= C4+(0.003386*C4) - (0.003386*C5).

3.4.2 Routing model

The kinematic wave method was used to solve the unsteady flow equations in many flood routing models. Some of reasons for using this method are because it is simple, it does not require downstream boundary conditions for solving the below equations, and it was believed that its approach approximates the natural condition of flood flow. The method assumes that the effects of the inertia and depth slope terms in natural flood flow are small compared with the bed slope term, so that they can be neglected. The friction term in momentum equation mainly depends on bed slope.

$$1/A \frac{\partial Q}{\partial t} + 1/A \frac{\partial (\frac{Q^2}{A})}{\partial x} + g \frac{\partial y}{\partial x} - g\,(S_0 - S_f) = 0$$

(3.9)

For a kinematic wave, the momentum equation reduces to Equation (3.10):

$$S_0 = S_f$$

(3.10)

Implying that the energy grade line is parallel to the channel bottom, and that the flow is steady and uniform. The above momentum equation can be shown to be equivalent to the following relationship between discharge, Q, and area of flow, A;

$$A = \alpha\, Q^{\beta}$$

(3.11)

which, can be satisfied by Manning equation:

$$Q = \frac{1.49\sqrt{S_f}}{n} R^{\frac{2}{3}} A$$

(3.12)

which can be rearranged as: $A = \left[\frac{np^{\frac{2}{3}}}{1.49\sqrt{S_f}}\right]^{\frac{3}{5}} Q^{\frac{3}{5}}$

$$\alpha = \left[\frac{np^{\frac{2}{3}}}{1.49\sqrt{S_f}}\right]^{\frac{3}{5}} \quad \text{and} \quad \beta = \frac{3}{5} \qquad (3.13)$$

where α is a function of roughness n, perimeter P, and bed slope S_f, while β = 0.6.

Together with the continuity equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \qquad (3.14)$$

If an observer moves with the kinematic wave at a speed equal to the kinematic wave celerity, the observer would see the flow rate increase at a rate equal to the lateral inflow rate, q, as shown in Equation (3.15);

$$\frac{dQ}{dx} = \frac{\partial Q}{\partial x} + \frac{\partial Q}{\partial t}\frac{dt}{dx} = \frac{\partial Q}{\partial x} + \frac{1}{C_k}\frac{\partial Q}{\partial t} = q \qquad (3.15)$$

when, $q = 0, \quad \frac{dQ}{dx} = 0$

Thus, kinematic waves do not attenuate; they simply translate downstream without dissipation. Given that at any cross section Q and A are functionally related as:

$A = \alpha Q^{\beta}$, the continuity Equation (3.9) can be rewritten as:

$$\frac{\partial Q}{\partial x} + \frac{dA}{dQ}\frac{\partial Q}{\partial t} = q \qquad (3.16)$$

$$\frac{\partial A}{\partial t} = \frac{dA}{dQ}\frac{\partial Q}{\partial t} = \alpha\,\beta Q^{\beta-1}\left(\frac{\partial Q}{\partial t}\right)$$

OR

$$\frac{\partial Q}{\partial x} + \alpha\beta Q^{\beta-1}\left(\frac{\partial Q}{\partial t}\right) = q \qquad (3.17)$$

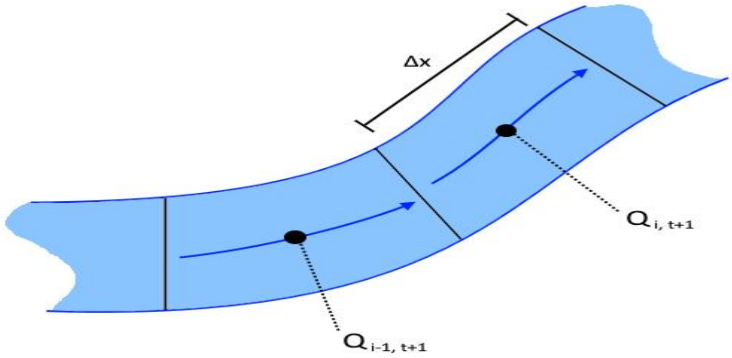


Figure 3.3: Stream location visualization

For the linear solution, Equation (3.17) is linearized by substituting an average of known solutions for the coefficient of the nonlinear term. This leads to the following solution;

$$\frac{Q_{i+1}^{j+1}-Q_{i}^{j+1}}{\Delta x}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_{i}^{j+1}}{2}\right)^{\beta-1}\left(\frac{Q_{i+1}^{j+1}-Q_{i+1}^{j}}{\Delta t}\right)=\left(\frac{q_{i+1}^{j+1}-q_{i+1}^{j}}{2}\right) \qquad (3.18)$$

$$Q_{i+1}^{j+1}=\frac{\left[\frac{\Delta t}{\Delta x}Q_{i}^{j+1}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_{i}^{j+1}}{2}\right)^{\beta-1}Q_{i+1}^{j}+\Delta t\left(\frac{q_{i+1}^{j+1}+q_{i+1}^{j}}{2}\right)\right]}{\left[\frac{\Delta t}{\Delta x}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_{i}^{j+1}}{2}\right)^{\beta-1}\right]} \qquad (3.19)$$

when, $q_{i+1}^{j+1}=0, \quad q_{i+1}^{j}=0$

Equation (3.20) represents the kinematic wave flow routing approach

$$Q_{i+1}^{j+1}=\frac{\left[\frac{\Delta t}{\Delta x}Q_{i}^{j+1}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_{i}^{j+1}}{2}\right)^{\beta-1}Q_{i+1}^{j}\right]}{\left[\frac{\Delta t}{\Delta x}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_{i}^{j+1}}{2}\right)^{\beta-1}\right]}$$

(3.20)

where; Q_{i+1}^{j+1} = discharge at point i + 1 and time step j + 1,

Q_{i}^{j+1} = discharge at point i and time step j + 1,

Q_{i+1}^{j}= discharge at point i+1 and time step j, Δx = length of sub reach,

Δt = time interval

Equation (3.20) was coded in excel for flood hydrograph routing. Example: Cell D6=(0.36*C6+10.404*D5*((D5+C6)/2)^(-0.4))/(0.36+10.404*((D5+C6)/2)^(-0.4))

3.5 Manning Roughness Coefficient (n)

Roughness coefficients represent the resistance to flood flows in channels and flood plains. It has a great effect on flood route (Table 3.1), flow resistance is a fundamental control of flow hydraulics in streams and rivers, not only determining the amount of water, a channel can convey through its influence on velocity (and thus flow depth), but also controlling the distribution of shear stress around the channel boundary and the magnitude and distribution of bed and bank erosion.

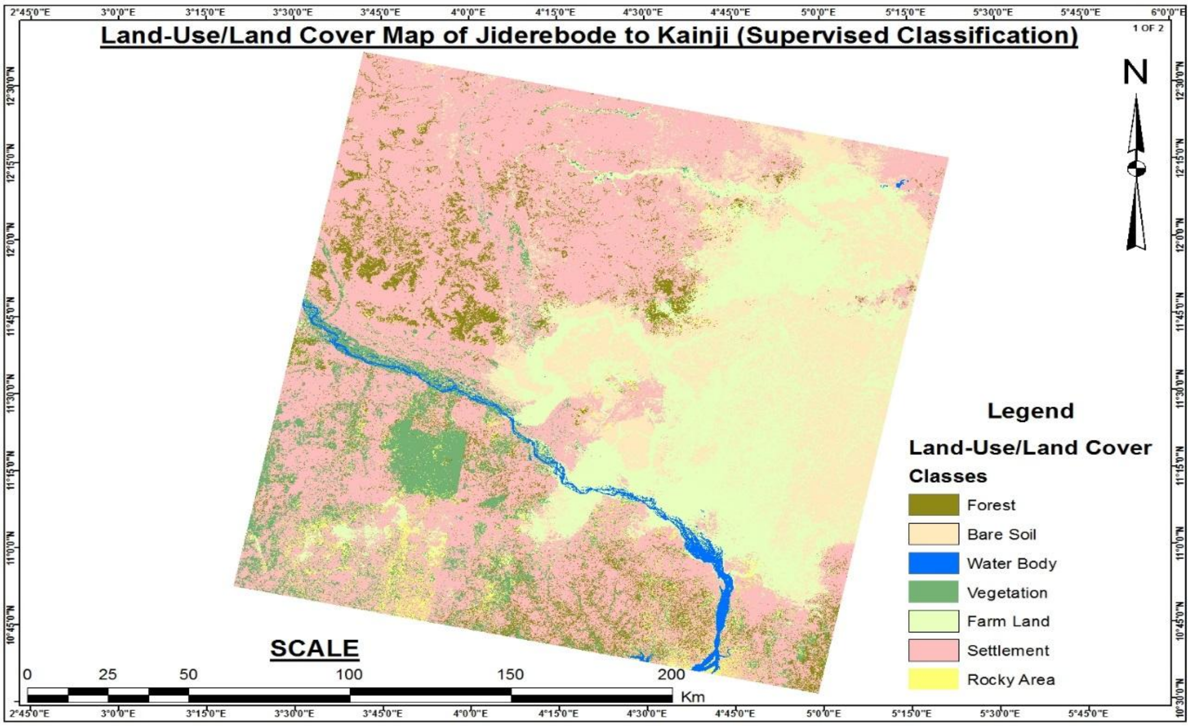
Table 3.1: Manning's n values for Floodplains (Chow, 1959)

Floodplains Conditions	**Manning's n Values**		
	Minimum	**Normal**	**Maximum**
Pasture, no brush			
short grass	0.025	0.030	0.035
high grass	0.030	0.035	0.050
Cultivated areas			
no crop	0.020	0.030	0.040
mature row crops	0.025	0.035	0.045
mature field crops	0.030	0.040	0.050
Brush (Land covered by small trees)			
scattered brush, heavy weeds	0.035	0.050	0.070
light brush and trees, in summer	0.035	0.050	0.060
light brush and trees, in summer	0.040	0.060	0.080
medium to dense brush, in winter	0.045	0.070	0.110
medium to dense brush, in summer	0.070	0.100	0.160
Trees			
dense willows, summer, straight	0.110	0.150	0.200
cleared land with tree stumps, no sprouts	0.030	0.040	0.050
with heavy growth of sprout	0.050	0.060	0.080
heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
with flood stage reaching branches	0.100	0.120	0.160

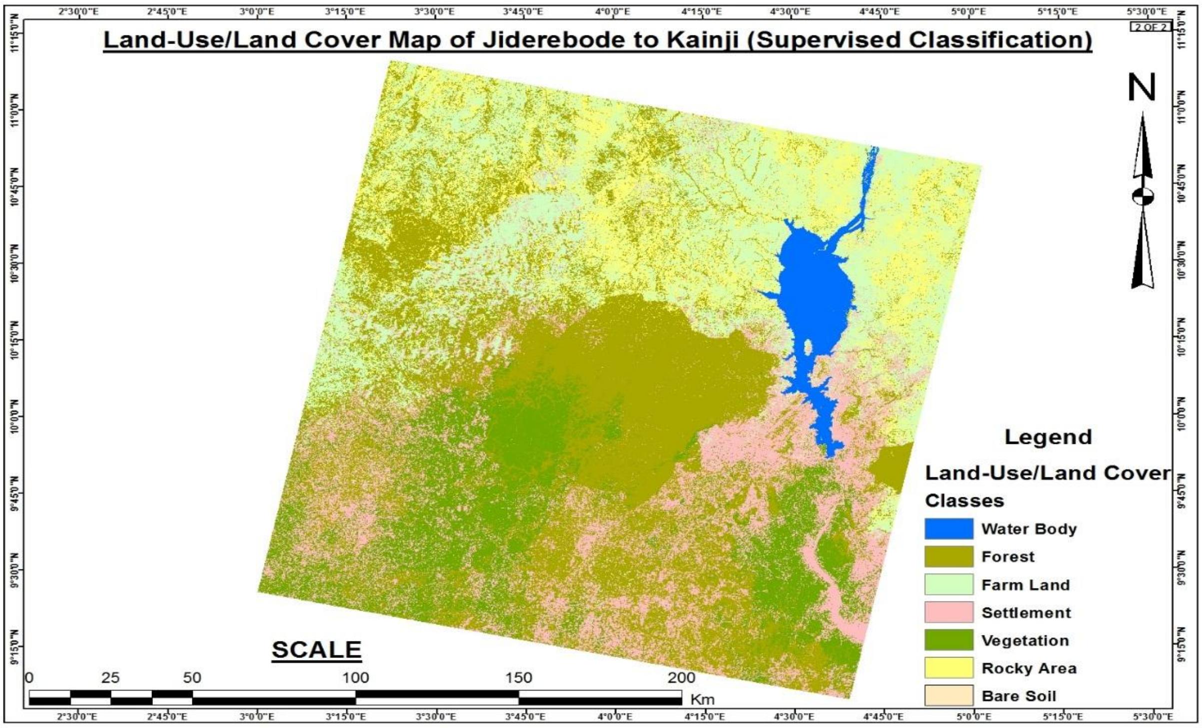
Table 3.2: Parameters Used in Routing Hydrograph

Parameter	Description	Value
NSE	Nash-Sutcliffe Efficiency	-∞ to 1
Δt	Time interval	1-day (24hrs)
Δx	Increment distance	10km (10000m)
N	Floodplain Manning's Roughness	0.020 to 0.200
d	Depth varies	39m to 53.2m
S_f	Slope varies	0.001 to 0.002
B	Width of the water surface varies	2.8km to 3.1km

The land use and land cover map along river Niger from Jiderebode to Kainji reservoir represented in Figure 3.4.



(a)



(b)

Figure 3.4: Digital Image of the Study Area

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Flow at Jiderebode

The inflow hydrograph at Jiderebode is presented in Figure 4.1. August, September and October, have the peak flow, while April, May and June have the minimum flow see Figure (4.3, 4.4a and 4.4b). No rainfall between November to April, the flow comes from upper Niger (Guinea). Peak flow in August and September in Guinea arrives Jiderebode between November to February. This is why river Niger has high peak at Kainji every year. The first peak is black flood, due to transboundary flow. While the second peak in August and September (white flood) due to flood in Nigeria. Figure 4.2 shows the minimum, average and maximum inflow at Jiderebode; 2012 has the maximum inflow, while 2007 has average inflow and 2004 has the minimum inflow. Table 4.1 shows the minimum, average and maximum annual inflow at Jiderebode. The minimum, average and maximum white and black flood at Jiderebode (Table 4.2 and 4.3).

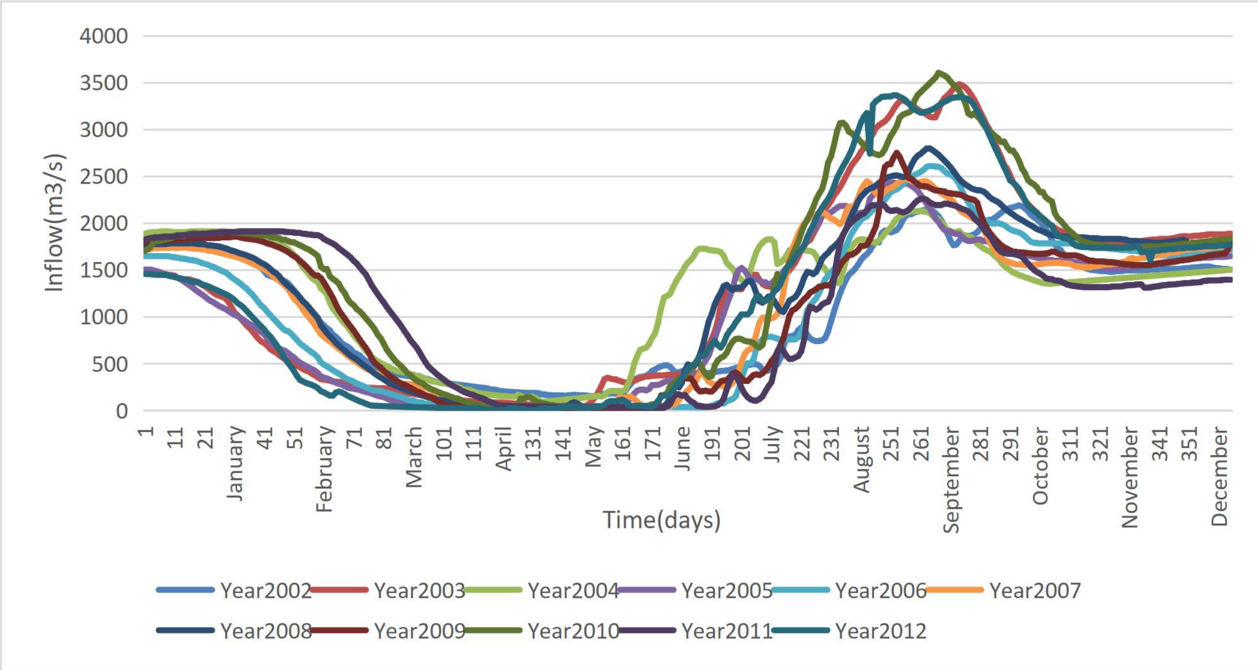


Figure 4.1: Flow Hydrograph at Jiderebode

Table 4.1: The minimum, average and maximum annual inflow at Jiderebode

Year	Minimum(m^3/s)	Maximum(m^3/s)	Average(m^3/s)
2002	5357.8	62669.6	34013.7
2003	1813.0	96080.5	48946.7
2004	2058.4	57877.3	29967.9
2005	1109.2	66997.1	34053.1
2006	1109.2	66997.1	34053.1
2007	1280.0	71099.9	36189.9
2008	1403.0	77545.9	39474.5
2009	791.1	71752.9	36272.0
2010	1940.1	87016.4	44478.3
2011	1224.3	65529.3	33376.8
2012	653.1	97951.2	49302.1

Table 4.2: The minimum, average and maximum white flood at Jiderebode

Year	Minimum(m^3/s)	Maximum(m^3/s)	Average(m^3/s)
2002	31696.7	62669.6	47183.1
2003	32403.6	96080.5	64242.0
2004	47130.5	57877.3	52503.9
2005	31762.1	66997.1	49379.9
2006	31762.1	66997.1	49379.9

2007	15461.5	71099.9	43280.7
2008	33024.7	77545.9	55285.3
2009	22198.9	71752.9	46975.9
2010	29798.6	87016.4	58407.5
2011	39234.6	65529.3	52381.9
2012	53149.3	97951.1	75550.2

Table 4.3: The minimum, average and maximum black flood at Jiderebode

Year	Minimum(m^3/s)	Maximum(m^3/s)	Average(m^3/s)
2002	17762.3	53885.5	35823.9
2003	17765.0	55537.3	36651.2
2004	22369.5	57179.3	39774.4
2005	19419.6	49794.9	34607.3
2006	19419.6	40409.8	29914.7
2007	15069.4	53078.0	34073.7
2008	15182.3	55442.3	35312.3
2009	10393.8	56643.3	33518.5
2010	20065.3	57504.7	38785.0
2011	15182.3	56225.8	35704.0
2012	18697.7	53581.0	36139.4

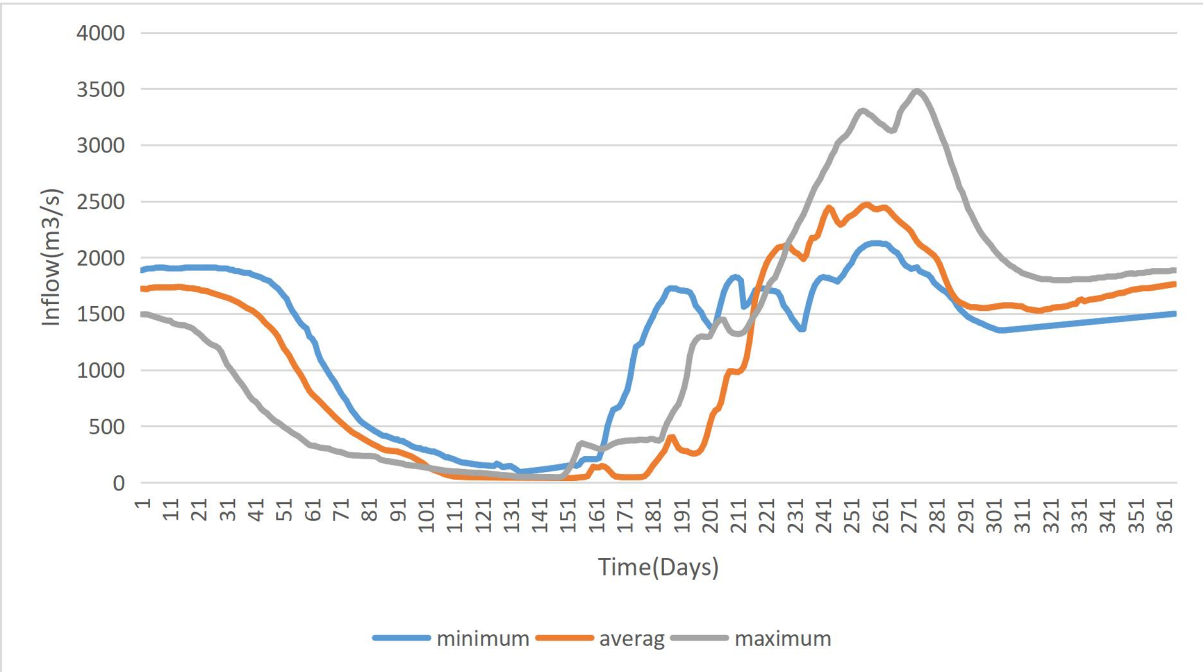


Figure 4.2: Minimum, Average and Maximum Inflow at Jiderebode

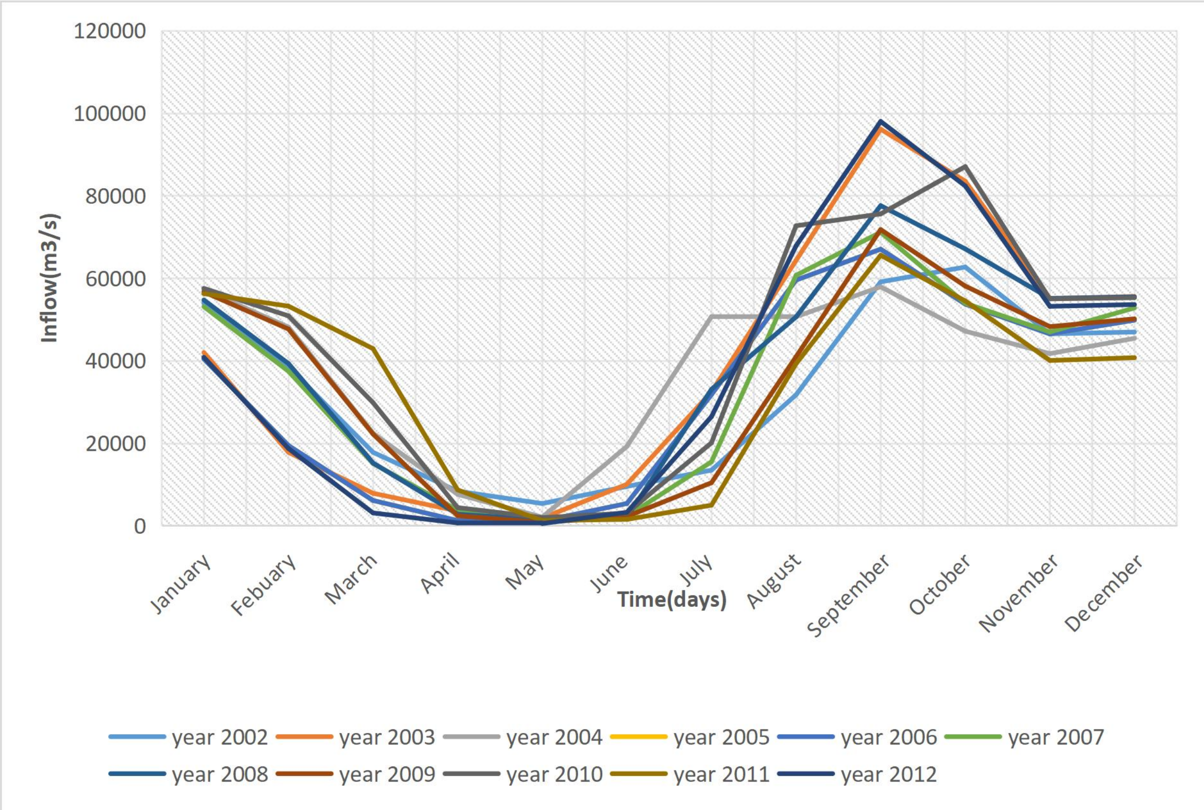
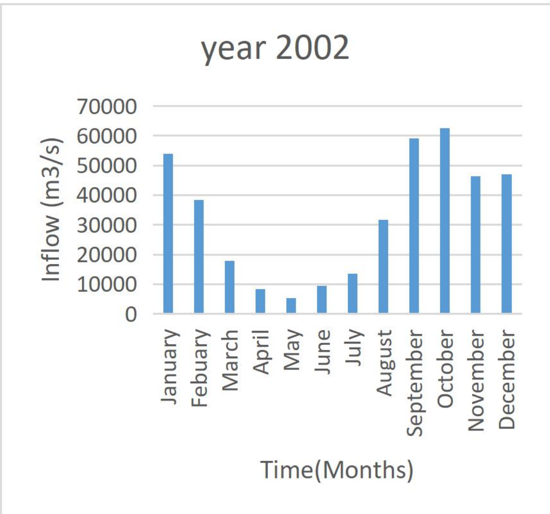
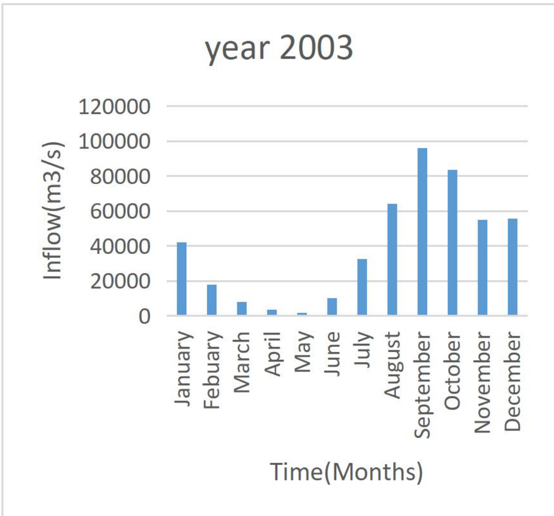


Figure 4.3: Monthly Hydrograph at Jiderebode





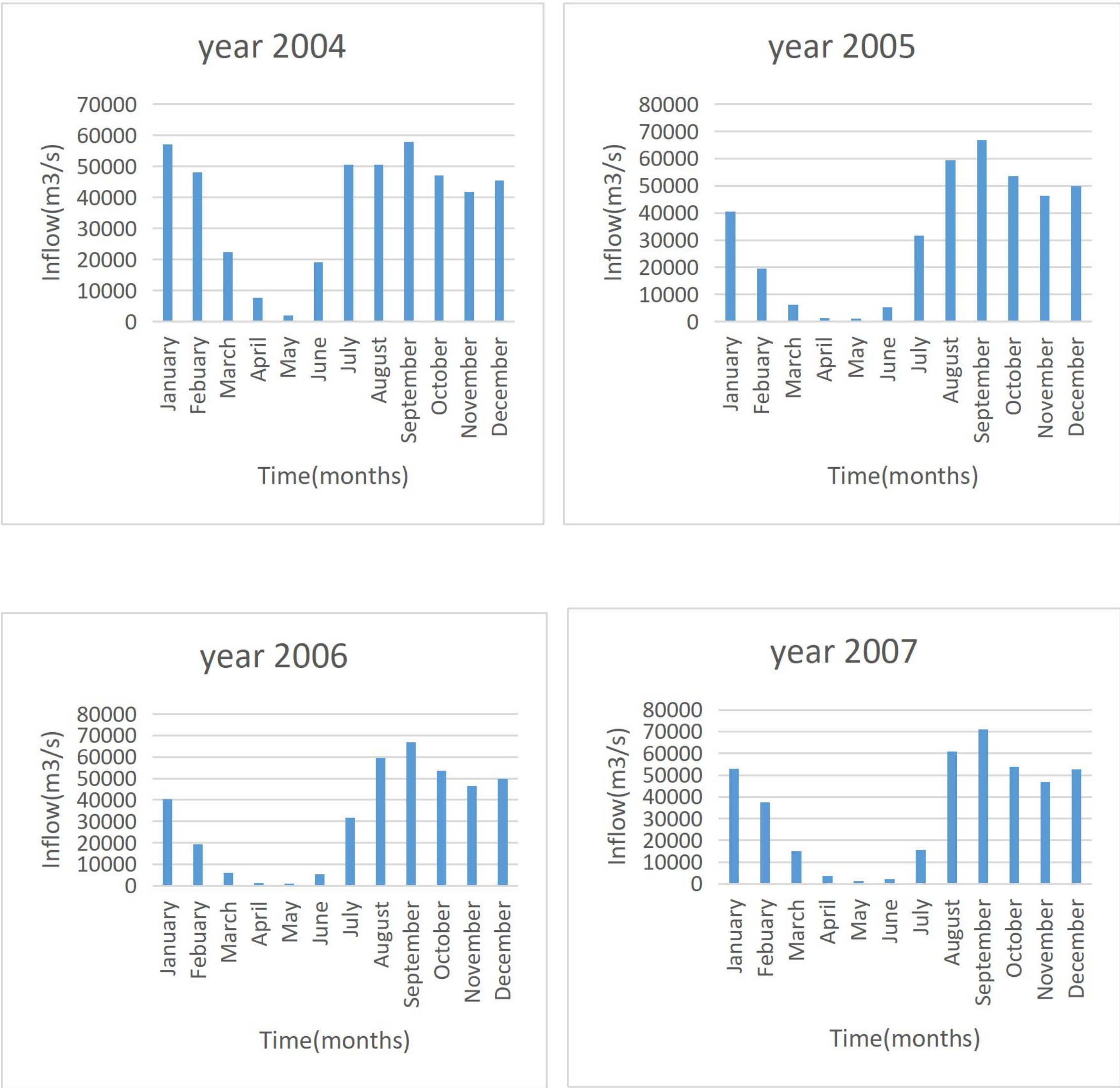
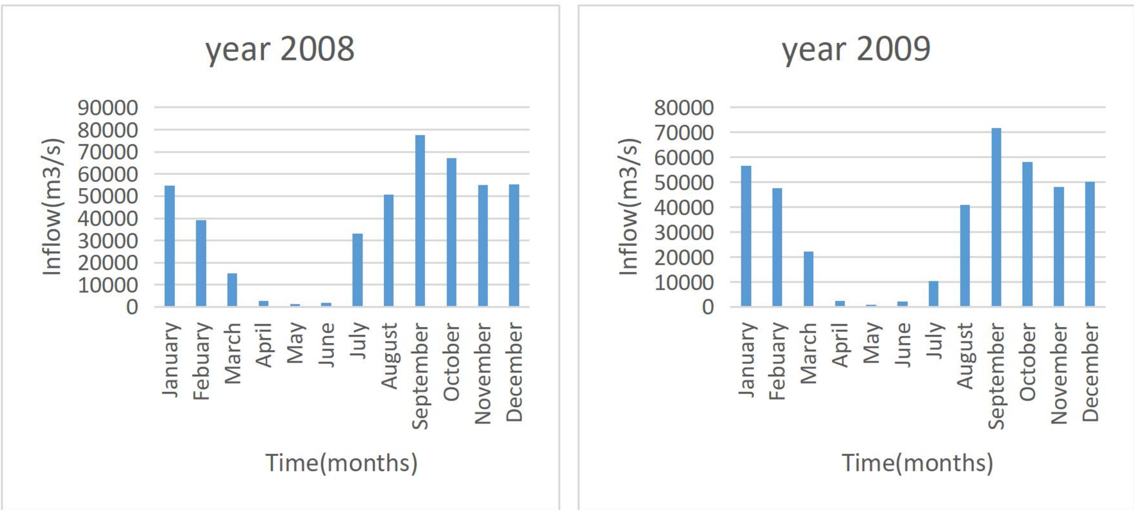


Figure 4.4a: Monthly Inflow at Jiderebode, 2002 to 2007



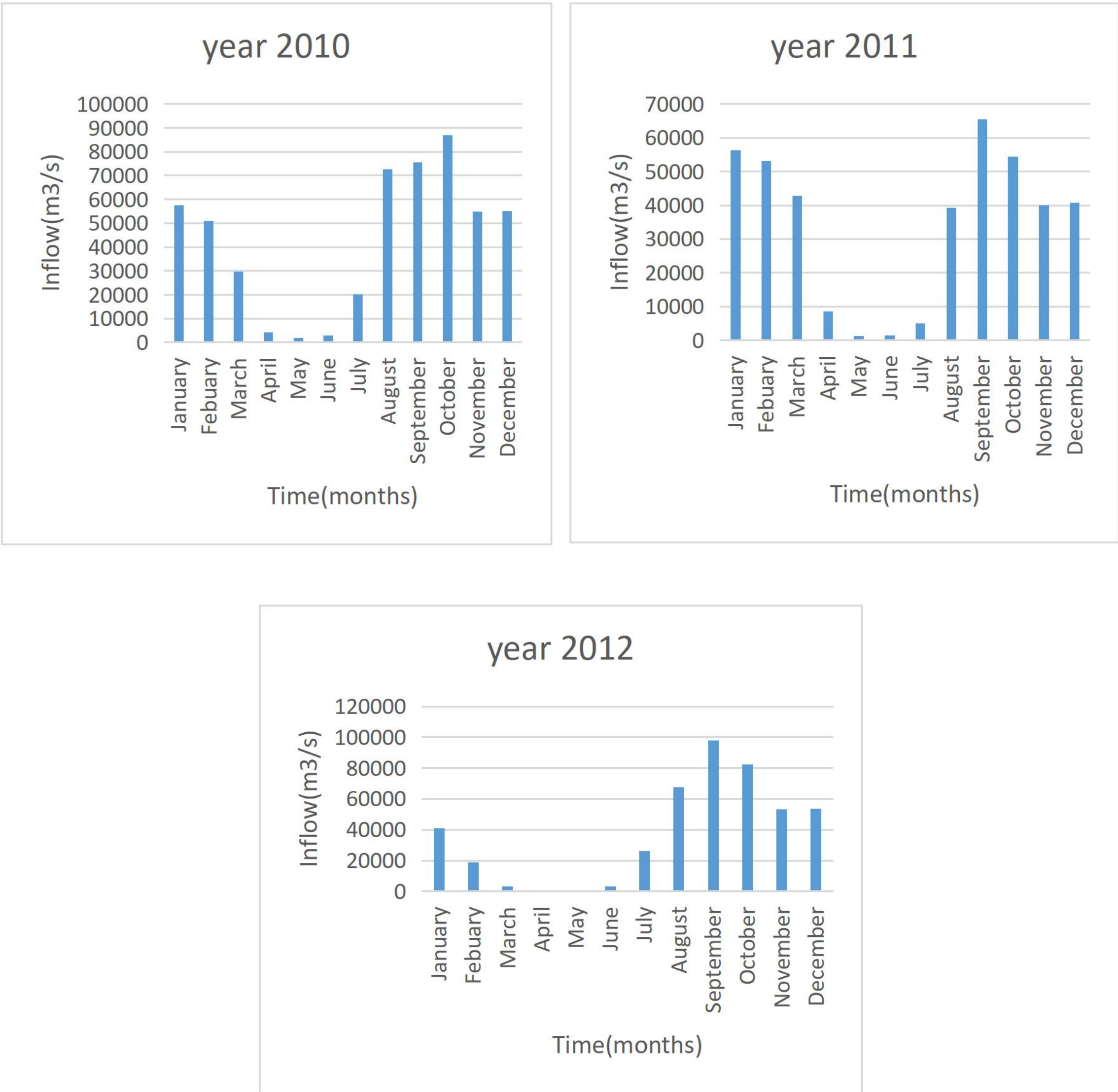


Figure 4.4b: Monthly Inflow at Jiderebode, 2008 to 2012

4.2 Routed Hydrograph

The routed hydrograph from Jiderebode to Kainji is presented in Figure 4.5. The routed inflow (simulated outputs) from Jiderebode (at 215 km) and observed record at Kainji during dry season (black flood) into Kainji reservoir is presented in Figure 4.6, it Shows the observed inflow at Kainji are less than routed inflow from Jiderebode. The calibration produced model outputs that closely match with the observed inflow record at Kainji. The comparison between simulated output and observed inflow were considered during dry season (December to April). The analysis is only for transboundary inflow into Nigeria without considering rainfall within the reach (Figure 4.6).

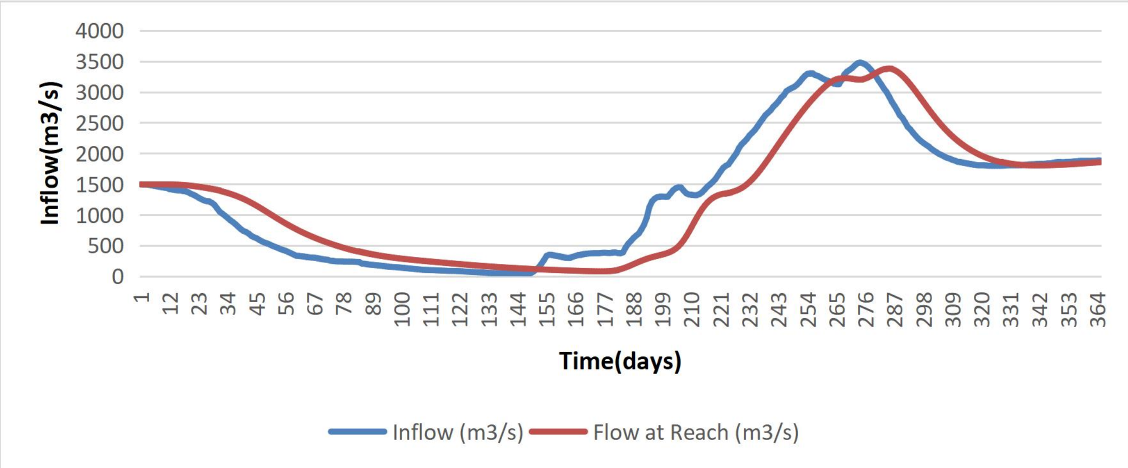


Figure 4.5: Routed Hydrograph of the Reach

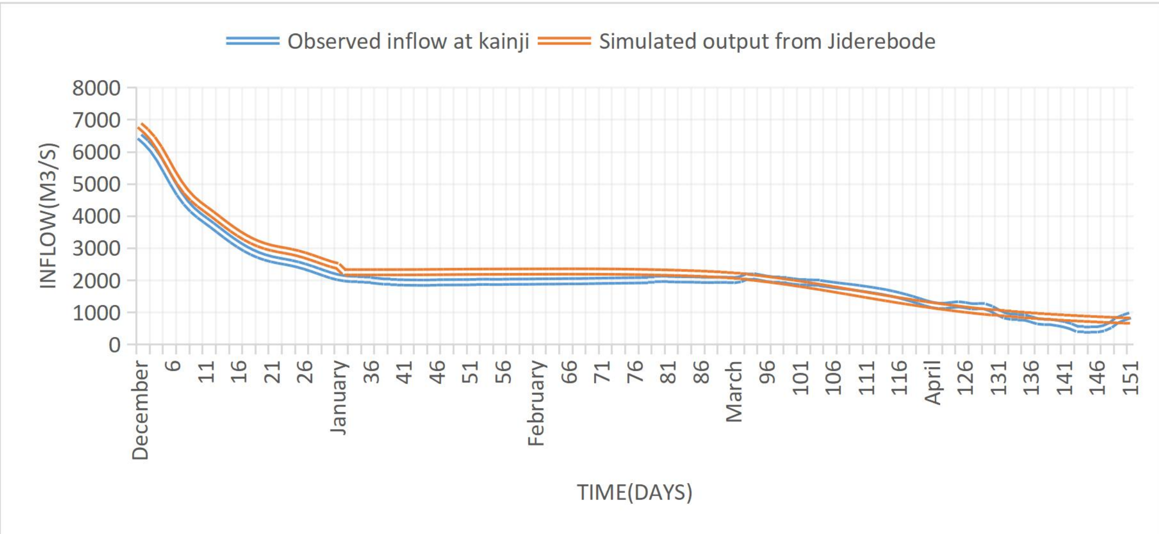


Figure 4.6: Simulated output and Observed inflow in dry season

4.2.1 Nash-Sutcliffe efficiency (NSE)

The manual model calibration was performed and the model predictions were examined to identify optimal values of NSE sensitive stream flow parameters. Calibration were performed manually with trial-and-error procedure useing equation (4.1).

$$NSE = 1- \frac{\sum_{t=1}^{T}(Q_s^t - Q_o^t)^2}{\sum_{t=1}^{T}(Q_o^t - Q_{mean})^2} \quad (4.1)$$

where Q_s^t = model simulated output at time t, Q_o^t = observed discharge at time t, Q_{mean} = mean of observed discharges and T = total number of observations.

The data and model are fully accounted for, identifying the parameters values through calibration, the parameter values were significantly divergent from predetermined values produced model simulations that considered near good model. Consequently, models must be calibrated to ensure that simulation results are sound and defensible. The Nash-Sutcliffe Efficiency (NSE) is 0.009, indicating that is closely match with the observed inflow record at Kainji (Figure 4.6).

NSE values range from negative infinity to 1, where NSE is 1 shows a perfect model. NSE is zero, implies the observed mean is as good a predictor as the model, and if NSE is less than zero, then the model is worse predictor than Q_{mean}.

4.3 Time to Peak and Attenuation

The output of a flood forecast is typically a maximum expected water level and the likely time of its arrival at key locations along the river. Floods can come at different times, it can come in the morning, afternoon or night. The travelling Time of Peak from Jiderebode to Kainji is 166 hours (6 days, 22 hours, 4 minutes and 8 seconds) Table 4.4.

Table 4.4: Time of Peak per Sub Reach

Sub-reach (km)	Travelling Time of Peak(hours) from Jiderebode to Kainji
10	6.9
20	7.3
30	7.7
40	7.8
50	7.6
60	7.9
70	7.8

80	7.5
90	7.3
100	7.4
110	7.6
120	7.7
130	7.8
140	7.7
150	7.6
160	7.4
170	7.5
180	7.8
190	7.4
200	7.5
210	7.6
215	7.2

From the results obtained, it was observed that kinematic wave-models predict a steeper wave with less dispersion and attenuation than it actually occurs, attenuation per sub reach (Table 4.5).

Table 4.5: Attenuation per sub reach

Sub-reach (km)	ATTENUATION (m^3/s)										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
10	10.222	13.222	0.544	11.389	1.366	16.4	20.161	43.011	29.556	12.711	4.619
20	10.222	21.519	6.2	0.911	5.922	16.4	24.193	73.239	39.073	27.555	12.614
30	29.333	34.889	1.655	0	2.278	4.1	24.194	69.625	59.297	16.923	15.424
40	41.334	46.157	15.667	0	13.211	8.2	32.258	80.178	71.045	12.444	23.006
50	23.555	51.091	29.488	5.467	31.434	8.2	32.258	13.211	109.866	0.889	30.329
60	20	60.597	20.712	21.411	27.333	4.1	32.461	29.155	19.205	3.556	41.325
70	31.111	68.953	13.966	18.678	11.389	16.4	36.833	25.056	24.32	11.555	23.897
80	33.778	61.678	34.622	29.611	19.589	28.7	41	20.956	34.354	0.889	19.817
90	39.556	67.12	47.078	46.011	33.711	28.7	45.1	5.466	31.293	7.555	15.324
100	48.889	55.782	31.622	43.189	49.655	24.6	41	1.822	52.211	8	3.521
110	70.666	75.628	14.134	48.189	76.078	24.6	32.8	15.033	41.666	9.778	9.014
120	48	82.915	15.289	49.822	64.645	20.5	24.6	16.4	34.354	15.556	9.354
130	35.111	65.893	6.973	57.333	53.844	20.5	20.5	12.756	21.428	14.222	13.263
140	24.445	71.744	7.005	54.667	42.733	20.5	20.5	2.733	29.858	10.222	17.954
150	44.444	80.962	34.855	33.333	44	28.4	12.3	5.922	24.221	17.333	22.811
160	38.667	43.658	11.123	50.667	32.889	44.2	8.2	4.1	38.455	28.889	20.35
170	30.667	69.244	11.622	35.555	32	40	4.1	13.667	5.987	43.111	19.615
180	22.666	76.078	9.467	13.778	24.889	28	8.2	6.833	59.247	31.112	15.067
190	16.445	41.455	27.288	4.445	10.667	20	24.6	2.278	37.663	29.777	19.563
200	12.444	54.211	41.156	15.111	30.667	16	32.8	5.922	6.743	46.667	9.595
210	4.445	49.656	23.722	10.666	6.222	20	24.6	2.278	41.065	42.667	5.283
215	15.111	47.244	22.034	2.223	5.334	20	16.4	9.567	61.616	30.666	0.803

4.4 Discussion of Results

Figure 4.5 shows the flow hydrograph of a reach, the flow was routed into 21-subreach at the distance of 10 km each and it has different time delay. The kinematic wave route scheme does not assume that flow changes instantaneously throughout the system (Jan *et al*., 2018). The kinematic wave routing option is a non-instantaneous flow model. The model output where the flow wave is translated through the stream system at different times. In the middle Niger (at Jiderebode, Nigeria), a first high-water discharge the white flood occurs soon after the rainy season between July and October; a second rise the black flood begins in December to March with the arrival of floodwater from upstream (transboundary inflow into Nigeria). April, May and June are the low-water months in the middle stretch.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is observed that August, September and October, have the peak flow, while April, May and June have the minimum flow. The Nash-Sutcliffe Efficiency (NSE) is 0.009, indicating that it is closely match with the observed inflow record at Kainji. Kinematic wave-models predict a steeper wave with less dispersion and attenuation than it actually occurs. The travelling time of Peak from Jiderebode to Kainji is 166 hours (6 days, 22 hours, 4 minutes and 8 seconds). Flood warning and flood mitigation depend on understanding how quickly a flood crest travels downstream.

5.2 Recommendations

Based on this study the following recommendations were made:

i. The length of sub reaches should be reduced (less than 10 km) to capture variation in catchment characteristics in the model.
ii. Should consider both the tributaries and their reservoirs at the upstream to give a better understand of the contribution of flow from upper and middle Niger Basin into Nigeria, during the dry season (black flood).

5.3 Contribution to Knowledge

This study routed the inflow during the dry season from Jiderebode into Kainji reservoir. The Advection equation and Kinematic wave model were coded in Microsoft excel. The length between Jiderebode and Kainji was divided into 21 sub reaches, each sub reach is 10 km. The travelling Time of Peak from Jiderebode to Kainji was 166 hours (6 days, 22 hours, 4 minutes and 8 seconds).

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APPENDICES

Appendix A: Peak Values per Sub Reach

sub reach(km)	Peak (m³/s) 2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
10	2180.943	3469.075	2124.931	2426.194	2597.566	2462.22	2789.821	2718.205	3493.105	2253.435	3358.39
20	2178.598	3467.473	2125.251	2422.037	2602.477	2452.922	2781.747	2709.83	3462.004	2249.976	3358.253
30	2163.559	3452.832	2121.598	2419.9	2600.578	2439.209	2763.454	2660.54	3425.732	2231.718	3349.981
40	2139.82	3424.961	2121.179	2419.092	2598.441	2431.486	2741.443	2598.623	3374.497	2214.301	3337.052
50	2105.423	3385.189	2111.474	2418.786	2589.348	2433.673	2712.98	2525.522	3310.491	2199.951	3317.571
60	2077.688	3338.113	2089.753	2415.272	2566.246	2439.604	2682.167	2490.027	3216.966	2193.855	3291.055
70	2054.695	3282.349	2068.679	2400.642	2540.526	2439.29	2650.368	2458.555	3171.774	2193.672	3254.958
80	2026.836	3218.178	2051.943	2383.516	2523.805	2428.967	2615.462	2431.131	3171.573	2200.682	3226.822
90	1995.471	3155.798	2024.417	2358.68	2505.309	2407.234	2576.804	2407.769	3149.294	2202.852	3204.106
100	1959.263	3090.542	1985.174	2320.81	2477.343	2381.213	2534.205	2395.541	3121.222	2199.062	3186.195
110	1915.572	3031.563	1950.629	2279.763	2435.936	2356.114	2492.71	2392.039	3077.645	2192.694	3182.162
120	1855.987	2962.097	1928.408	2234.45	2373.169	2331.365	2456.73	2381.385	3035.383	2184.242	3186.574
130	1803.567	2884.3	1910.378	2186.524	2309.499	2309.276	2427.9	2367.179	2998.275	2171.452	3194.188
140	1761.601	2814.361	1907.339	2133.038	2252.127	2288.199	2404.29	2353.883	2971.272	2157.799	3205.465
150	1730.104	2743.536	1910.319	2079.047	2203.932	2267.506	2382.643	2347.133	2942.478	2146.253	3221.077
160	1691.109	2666.599	1890.649	2037.751	2158.459	2242.11	2366.814	2340.898	2916.646	2131.189	3241.373
170	1652.455	2610.865	1876.114	1990.946	2120.787	2205.241	2355.722	2335.985	2882.796	2107.731	3261.722
180	1618.598	2546.859	1863.335	1951.065	2086.661	2166.557	2348.965	2325.664	2874.384	2072.393	3281.611
190	1591.352	2475.578	1852.544	1926.944	2058.216	2134.485	2341.318	2317.504	2833.612	2039.705	3298.379
200	1570.44	2423.106	1831.947	1914.65	2040.583	2109.827	2323.199	2312.979	2794.898	2008.856	3316.979
210	1554.473	2369.731	1799.197	1900.684	2015.102	2090.472	2296.051	2307.593	2776.526	1968.57	3329.725
215	1545.194	2318.832	1771.879	1888.706	2001.284	2070.754	2270.52	2304.127	2743.799	1926.991	3337.614

Appendix B: Daily inflow (m^3/s) data at Jiderebode from 2002 to 2012

S/No	Year2002	Year2003	Year2004	Year2005	Year2006	Year2007	Year2008	Year2009	Year2010	Year2011	Year2012
1	1772.636	1494.444	1885.342	1501.864	1646	1722	1766	1798	1701.652	1823.11	1454.785
2	1758	1494	1894.544	1502	1646	1718	1770	1798	1719.778	1831.778	1454
3	1759.778	1492.222	1901.289	1500.222	1646	1722	1774	1799.778	1747.333	1839.333	1452.222
4	1765.556	1484.667	1902	1492.667	1646	1730	1774	1805.556	1796.222	1845.556	1446.444
5	1767.778	1476.667	1902.544	1484.667	1646	1734	1774	1806	1805.556	1846	1446
6	1773.556	1468.667	1909.289	1474.889	1646	1734	1774	1806	1807.778	1847.778	1446
7	1774	1460.667	1910	1461.111	1646	1734	1774	1807.778	1815.333	1853.556	1446
8	1775.778	1452.667	1910	1452.667	1646	1734	1778	1813.556	1823.333	1854	1444.222
9	1781.556	1444.667	1906.167	1444.667	1644.222	1734	1782	1814	1831.333	1854	1436.667
10	1783.778	1438.444	1902	1436.667	1636.667	1734	1782	1815.778	1839.333	1855.778	1428.844
11	1786	1433.022	1902	1427.244	1630.444	1734	1782	1821.556	1852.667	1861.556	1421.6
12	1774.889	1415.244	1902	1413.2	1628.222	1734	1782	1822	1872.667	1863.778	1414.4
13	1772.222	1407.2	1902	1397.2	1620.667	1738	1782	1822	1861.111	1869.556	1407.2
14	1761.111	1400	1902	1376	1614.444	1738	1782	1823.778	1859.778	1870	1400
15	1743.333	1396	1905.833	1354.4	1612.222	1734	1782	1829.556	1878.444	1871.778	1392.8

16	1742	1397.6	1910	1332.8	1604.667	1730	1782	1830	1887.333	1877.556	1384
17	1742	1386	1910	1309.6	1598.444	1726	1782	1831.778	1892.301	1878	1371.6
18	1742	1378.4	1910	1282.8	1596.222	1726	1778	1837.556	1886.588	1878	1365.6
19	1740.222	1366.4	1910	1260.8	1586.889	1722	1774	1838	1881.833	1879.778	1362
20	1734.444	1342	1910	1239.2	1573.111	1718	1774	1838	1886	1885.556	1348.4
21	1732.222	1325.2	1910	1216	1564.667	1714	1770	1838	1886.167	1886	1335.6
22	1724.667	1302.4	1910	1189.2	1554.889	1706	1762	1838	1887.833	1886	1326.4
23	1716.667	1275.6	1910	1168.8	1541.111	1702	1758	1838	1896.167	1887.778	1312.4
24	1708.667	1253.6	1910	1152.4	1530.889	1698	1754	1838	1895.333	1893.556	1298
25	1700.667	1233.6	1910	1131.2	1515.333	1690	1750	1839.778	1895.167	1895.778	1283.6
26	1694.444	1220.4	1910	1111.2	1499.333	1682	1746	1845.556	1897	1901.556	1269.2
27	1692.222	1211.2	1909.456	1096.4	1485.111	1674	1738	1846	1897.333	1902	1254.8
28	1684.667	1194	1902.711	1080.484	1473.111	1666	1730	1846	1904.667	1902	1240.4
29	1673.111	1159.6	1902	1059.812	1448.4	1658	1718	1847.778	1902.333	1902	1224.4
30	1655.333	1102.253	1902	1039.31	1419.733	1650	1706	1853.556	1899.833	1902	1203.2
31	1652.222	1047.014	1901.456	1020.366	1397.6	1642	1698	1854	1896.5	1903.778	1178.4
32	1642.889	1016.198	1890.878	1006.347	1376	1634	1686	1852.222	1900.667	1909.556	1146.4
33	1629.111	982.477	1885.456	989.676	1352.8	1622	1674	1844.667	1892.667	1910	1124
34	1622.444	946.861	1878.711	964.669	1326	1610	1666	1836.667	1895.5	1910	1099.2

35	1618.444	909.351	1877.456	943.83	1300.8	1598	1654	1830.444	1888.833	1910	1064.422
36	1599.778	879.798	1870.167	923.37	1267.2	1582	1642	1828.222	1882.667	1910	1030.217
37	1572.222	844.561	1862.711	902.91	1236.4	1566	1630	1822.444	1882.167	1910	996.117
38	1557.111	804.02	1862	882.45	1199.2	1550	1614	1820.222	1876.5	1910	962.017
39	1545.111	764.616	1857.622	860.474	1156.4	1538	1594	1812.667	1882.333	1910	927.917
40	1520.222	734.877	1846.167	835.089	1118	1526	1574	1804.667	1866.5	1910	895.332
41	1485.111	718.471	1838.167	811.219	1090.569	1506	1558	1794.889	1867.667	1910	863.127
42	1446.889	691.317	1830.167	772.008	1051.14	1486	1538	1781.111	1863.333	1910	821.07
43	1435.067	654.625	1821.622	722.445	1016.577	1462	1510	1772.667	1849.833	1910	789.622
44	1422.044	632.478	1806.878	702.225	982.477	1430.8	1482	1762.889	1844.667	1910	748.524
45	1414.4	616.083	1798.167	683.053	948.377	1404.8	1462	1749.111	1840.667	1910	703.079
46	1405.6	589.258	1789.078	660.906	914.277	1383.2	1431.2	1738.889	1834.5	1910	654.294
47	1391.6	565.917	1763.211	645.369	880.177	1358	1390.4	1723.333	1820.667	1908.222	600.197
48	1377.2	545.472	1742.333	634.792	853.654	1329.2	1358	1707.333	1819.167	1902.444	546.75
49	1356.4	532.056	1721.956	610.839	845.698	1293.2	1329.2	1689.556	1805.167	1902	505.986
50	1318	513.847	1690.667	584.775	818.418	1242.8	1300.4	1666	1794.5	1900.222	465.625
51	1282	492.778	1659.211	563.042	784.697	1192.4	1271.6	1643.778	1791.833	1894.444	417.975
52	1230.8	476.625	1631.778	532.056	749.468	1160	1242.8	1623.778	1776	1894	366.444
53	1192	459.708	1572.422	509.694	713.988	1124	1203.2	1594.444	1761	1892.222	322.908

54	1152.4	440.167	1524.089	491.292	689.333	1074.17	1163.6	1568.222	1745.167	1884.667	308.628
55	1122.8	425.292	1490.122	471.667	665.533	1029.08	1134.8	1536.667	1728	1878.444	292.256
56	1089.453	412.167	1447.653	455.625	641.733	991.57	1098.8	1502.889	1714.333	1876.222	282.522
57	1043.183	392.017	1412.181	439.875	618.022	954.06	1059.96	1465.111	1693.167	1870.444	270.45
58	1003.316	372.239	1388.08	422.958	594.689	909.73	1022.26	1439.778	1671.833	1870	256.328
59	968.837	351.739	1369.06	396.95	562.722	858.58	984.75	1434.622	1645.09	1868.222	236.283
60	936.252	332.069	1298.53	361.236	510.764	814.25	906.32	1412.444	1533.244	1855.333	204.689
61	907.078	326.142	1276.14	349.583	487.5	783.56	865.4	1364	1506.385	1828.222	191.167
62	877.903	321.292	1235.48	339.883	470.208	759.69	824.48	1312	1509.788	1811.333	174.6
63	854.033	315.364	1148.53	328.028	449.5	736.255	790.38	1256.4	1430.878	1795.333	157.8
64	809.324	307.011	1085.352	310.244	428.5	711.15	756.28	1200.8	1402.55	1779.333	155
65	785.454	302.969	1046.376	295.758	408.667	684.375	720.51	1131.6	1380.662	1759.778	190.233
66	754.393	301.622	1003.259	283.703	391.725	657.6	690.325	1070.107	1351.158	1730.444	200.033
67	715.689	296.131	961.732	273.411	371.161	633.8	663.55	1022.66	1291.204	1706	190.933
68	696.275	287.575	924.08	257.467	348.236	607.325	636.775	979.824	1250.808	1682	173.667
69	678.425	279.333	889.516	242.889	330.722	581.25	607.325	933.979	1183.942	1658	154.767
70	653.964	272.044	843.131	235.144	319.406	558.25	581.25	892.68	1144.827	1630.444	140.767
71	615.994	267.717	798.052	229.906	304.214	535.25	561.125	850.244	1120.885	1594.889	125.113
72	602.344	261.794	760.4	222.844	287.203	512.25	541	802.883	1080.796	1566.444	111.255

73	585.722	250.861	728.889	216.672	274.55	490	515.125	755.53	1057.131	1527.333	96.449
74	553.778	243.344	680.474	205.622	261.339	468.75	490	710.4	1024.118	1489.111	85.889
75	527.264	239.928	637.924	197	246.989	447.75	466.125	668.508	984.171	1451.867	71.44
76	509.375	239.7	607.472	188.6	235.6	432	442.5	619.325	949.098	1396.978	59.638
77	491.292	238.789	573.735	179.267	218.517	418.875	418.875	552.225	908.878	1336	50.426
78	467	235.828	544.865	166.9	211.456	403.125	393.025	508.639	867.138	1286.4	48.753
79	438.125	235.6	524.109	155.233	210.067	387.775	370.6	481.375	808.949	1241.2	47.425
80	429.958	235.6	506.859	147.533	205.167	373.025	351.2	456.5	771.063	1194.4	46.314
81	420.917	234.689	490.123	141.233	197	358.475	331.8	422.958	714.555	1154.4	44.878
82	414.208	231.728	473.971	128.147	188.6	343.925	309.975	395.314	650.752	1106.4	43.523
83	405.167	230.589	456.31	113.368	179.267	331.8	291.325	367.95	606.889	1063.307	42.52
84	397.381	222.117	442.828	103.5	167.833	319.675	276.6	346.889	566.516	1022.26	41.436
85	384.925	203.044	427.078	91.984	159.2	305.125	262.25	323.986	526.726	981.34	40.108
86	379.492	196.767	414.201	83.455	150.8	293.375	249.95	303.572	496.897	940.42	38.997
87	374.642	189.533	410.643	75.703	141.467	284.8	235.6	284.242	469.97	896.469	37.669
88	369.792	185.1	403.344	67.135	129.087	280.7	223.3	273.411	434.297	845.698	36.558
89	364.942	180.9	392.871	56.64	116.423	278.65	210.9	257.467	398.226	800.989	35.339
90	361.169	176.7	383.257	50.32	105.615	276.6	198.4	241.067	376.121	750.604	34.58
91	358.744	172.5	377.646	49.214	99.974	272.5	192.1	223.733	344.01	711.343	33.74

92	350.661	168.3	368.707	48.022	91.749	266.35	183.7	205.144	318.96	672.806	33.09
93	345.542	163.167	363.096	47.48	84.312	258.15	171.1	192.1	299.317	623.489	32.276
94	340.692	155.933	351.503	46.883	78.488	247.9	158.5	178.567	288.412	567.239	31.788
95	335.842	151.5	338.947	45.935	69.063	239.7	148	162.933	262.907	515.569	31.301
96	329.914	148.233	323.164	45.068	63.923	229.45	137.5	150.1	244.661	469.764	30.813
97	320.483	147.067	312.602	44.553	57.282	215.05	129.1	135.62	225.074	438.417	29.825
98	310.783	143.1	305.226	44.173	52.996	200.5	122.77	115.95	215.272	410.797	28
99	302.161	138.9	300.046	43.929	49.076	185.8	114.31	98.799	199.608	381.489	26.5
100	297.042	134.7	291.467	43.117	47.778	171.1	107.965	83.069	186.588	356.858	25.5
101	292.358	130.5	286.656	42.493	46.558	150.1	103.735	71.205	174.156	332.608	25.5
102	288.217	126.293	280.785	41.653	45.908	131.2	97.389	59.53	165.157	308.525	25.5
103	284.117	122.065	275	41.139	44.959	120.655	91.044	49.965	152.988	285.65	25.5
104	280.017	117.835	270.256	40.759	44.092	107.965	86.814	48.266	140.388	265.894	25.5
105	275.917	113.605	262.421	40.515	43.578	99.504	80.844	46.829	128.123	249.267	25
106	271.817	109.375	252.256	39.702	42.981	91.044	75.061	45.474	122.695	231.956	23.5
107	267.717	105.145	237.713	39.187	42.033	78.916	73.133	44.58	110.873	212.528	22
108	263.617	101.854	223.75	38.699	41.166	69.278	71.205	43.848	98.182	196.528	21.5
109	259.517	100.679	219.285	38.103	40.651	63.494	67.35	42.547	85.692	183.7	23.5
110	255.417	97.624	213.214	37.263	40.163	57.711	63.494	41.219	77.47	172.967	26

111	251.317	97.389	204.589	36.856	39.675	51.684	59.639	39.295	69.759	165.5	26
112	247.217	96.449	192.648	36.829	39.187	49.268	53.856	38.59	62.048	150.333	22.5
113	243.117	93.394	183.875	36.721	38.699	48.537	49.756	37.534	54.646	138.433	19
114	239.017	92.219	175.761	36.26	38.212	47.561	49.268	36.206	53.681	128.853	13.25
115	234.917	89.164	171.187	35.881	37.832	46.586	48.781	35.312	49.918	115.483	9
116	229.906	87.989	168.714	35.746	37.805	45.854	48.537	34.797	48.598	99.739	5.5
117	222.844	84.934	163.161	35.176	37.697	45.366	48.049	34.2	47.602	86.98	4
118	218.517	84.699	160.314	34.336	37.127	44.878	47.317	33.361	46.209	74.224	3.75
119	213.483	84.699	156.487	33.821	36.287	45.366	46.829	32.737	45.183	60.709	2.25
120	206.328	83.842	152.573	33.442	35.664	45.122	46.342	31.789	44.145	53.21	1.5
121	201.9	81.058	152.2	33.415	34.824	43.903	45.854	31.03	43.008	49.184	0.5
122	198.633	79.987	150.187	33.523	34.309	43.659	45.122	31.084	42.52	48.347	1.5
123	197.467	76.346	148	33.875	33.821	43.415	44.39	31.328	41.87	47.182	2.23
124	194.433	73.347	145.987	33.902	33.334	43.171	43.903	30.453	40.895	45.501	3
125	193.267	72.276	145.515	34.01	32.846	42.927	43.415	28.304	40.081	44.58	4.3
126	190.233	68.635	165.903	34.363	32.358	42.683	42.683	27.083	70.237	43.848	5
127	189.067	65.636	154.364	34.498	31.978	42.439	41.951	26.667	125.57	42.873	7
128	186.033	64.565	137.179	34.959	31.843	42.195	41.464	25.917	122.74	43.035	22
129	185.8	61.78	141.525	35.556	31.382	42.195	40.732	27.8	141	42.385	21

130	185.8	60.709	145.614	37.046	31.328	42.195	40.488	31.947	139.6	40.976	21
131	185.8	57.068	141.502	39.675	32.358	42.195	40.488	36.043	121.34	39.512	2
132	184.867	53.213	129.434	39.566	32.331	41.951	40.976	35.365	97.389	39.241	1.667
133	179.967	50.106	112.26	37.371	31.978	41.707	40.976	33.712	86.234	41.87	9.083
134	171.8	49.431	93.212	36.531	31.843	41.707	40.244	38.943	78.274	41.301	17
135	165.267	48.943	95.485	35.339	31.599	41.464	40.732	41.193	70.563	39.647	21.083
136	163.867	48.672	98.182	35.014	31.815	41.22	41.708	41.138	62.852	38.509	20.417
137	160.833	48.997	100.97	35.772	31.599	41.22	42.195	38.645	54.815	37.29	14
138	160.6	48.916	103.837	37.426	31.815	41.22	41.464	35.285	48.374	37.073	14.167
139	160.6	48.564	106.786	38.239	31.165	40.976	40.244	32.087	46.423	37.425	19
140	159.667	48.429	109.752	38.293	29.081	40.732	42.439	28.802	44.634	36.097	29.468
141	156.633	48.076	112.852	38.185	25.417	40.732	45.61	23.333	43.008	34.742	35.987
142	157.333	48.049	116.057	37.724	24.417	40.488	46.83	19.083	41.382	33.848	37.29
143	161.3	47.941	119.352	37.236	26.083	40.244	54.564	16	40.081	33.442	34.173
144	164.567	47.48	122.741	36.639	28.333	40.244	77.363	13.333	38.13	33.307	32.33
145	163.867	46.883	126.226	35.8	28.167	40	87.002	11.75	36.992	32.629	31.301
146	160.833	45.935	129.107	35.176	27.967	39.756	71.205	10.583	36.992	31.544	30.434
147	160.6	45.176	133.497	34.336	30.863	39.512	52.613	10.167	36.179	33.089	30.027
148	159.667	45.881	137.287	33.821	31.328	39.268	34.58	9.083	36.016	38.374	28.667

149	154.767	52.1	141.186	33.334	31.87	39.024	25.5	9	36.666	38.672	25.992
150	149.4	72.528	145.195	33.605	34.77	38.78	28.482	8.667	37.642	38.645	31.807
151	152.9	106.182	149.318	34.932	34.797	38.78	37.805	7.25	38.618	40.108	35.23
152	157.1	142.623	153.558	32.52	33.279	38.537	44.39	5.083	37.723	41.273	36.965
153	162.233	198.689	157.642	31.978	33.956	39.513	41.951	1.417	36.531	39.892	38.238
154	170.4	260.367	147.306	32.276	34.58	42.927	36.342	0.083	37.127	38.401	45.149
155	176.933	331.222	158.634	34.418	35.095	44.878	32.196	0.333	39.621	38.835	56.708
156	178.333	347.967	192.182	38.889	34.336	46.586	30.488	1.417	44.824	40.163	86.477
157	181.367	339.883	206.8	42.52	33.712	49.269	28.5	1.5	47.046	38.563	99.739
158	180.667	331.261	206.8	45.041	32.764	55.783	24	1.167	46.775	37.181	97.624
159	176.7	325.064	206.8	53.585	31.897	98.483	24.75	0.417	43.252	36.179	99.269
160	172.5	315.633	206.8	77.98	31.49	139.6	27.75	1.75	39.214	35.637	108.2
161	175.767	305.933	206.8	89.206	31.897	133.285	28.988	2.25	38.211	36.721	115.015
162	206.856	297.311	216.09	94.804	33.632	133.285	30.488	0.167	39.837	37.859	97.571
163	248.567	295.425	286.76	104.909	34.255	145.9	27	1.2	41.382	36.585	63.482
164	285.967	304.317	370.806	129.747	32.141	139.6	22.5	3.33	39.647	36.423	47.523
165	327.386	315.094	498.189	178.563	30.596	120.64	21	4.667	40.407	40.054	46.992
166	343.925	329.375	580.046	210.722	30.596	93.534	24	19.833	40.949	40.108	49.675
167	356.319	342.847	645.272	220.567	31.274	65.422	29.964	23	40.407	31.811	48.564

168	361.708	352.817	657.476	223.3	32.249	50.952	34.147	29.717	40.705	22.856	44.499
169	368.714	361.439	669.938	212.822	32.303	47.074	35.854	30.705	42.141	16.583	41.111
170	388.647	366.558	708.23	227.628	33.659	45.61	36.098	31.463	51.655	16.083	39.946
171	421.544	370.331	770.594	269.311	35.339	45.366	34.147	37.94	65.473	19.917	41.951
172	436.083	371.678	822.86	271.589	37.615	45.366	34.39	47.432	66.231	22	57.64
173	455.333	374.103	934.955	271.361	39.268	45.122	37.317	80.809	101.51	22.083	100.973
174	470.208	371.947	1088.252	283.828	40.054	45.366	41.22	158.851	142.62	26.358	143.553
175	479.833	376.258	1204.04	300.131	41.139	45.854	46.829	164.8	162.467	31.512	162.7
176	481.875	380.031	1222.33	312.669	40.461	46.586	75.566	169.467	182.056	38.834	152.9
177	466.417	379.222	1241.05	319.136	37.561	47.561	131.11	191.144	254.439	64.707	172.267
178	431.125	375.719	1312.02	317.956	35.745	54.808	224.75	229.872	279.378	130.813	212.389
179	403.708	377.606	1374.46	290.103	35.041	77.363	270.45	296.489	312.069	173.432	262.406
180	407.792	385.689	1425.586	294.394	35.556	112.18	245.85	340.733	337.189	167.833	305.231
181	418	386.497	1474.256	346.786	36.287	150.1	295.45	348.506	350.122	155.933	347.697
182	418	375.181	1532.122	424.706	36.124	181.6	428.85	340.961	373.561	164.567	390.8
183	392.042	369.792	1576.789	433.458	35.095	212.85	490.25	339.075	410.528	123.22	441.086
184	390	386.575	1605.878	403.214	33.658	247.9	474	338.267	444.833	97.154	469.333
185	391.167	467.667	1650.089	385.217	32.195	278.65	490.25	298.131	482.972	80.531	478.667
186	393.792	529.056	1706.656	383.892	31.165	334.225	518	234.561	504.986	50.157	503.194

187	390.292	573.308	1725.289	414.253	31.653	398.475	593.55	202.561	492.278	43.441	578.458
188	391.167	622.319	1722.711	489.542	32.927	403.325	690.325	208.178	434.389	39.675	579.972
189	396.125	660.575	1724.744	535.944	36.043	351.2	821.505	211.861	386.45	38.157	603.558
190	401.375	695.202	1711.589	588.358	41.924	305.125	950.65	201.428	356.05	38.022	654.658
191	406.625	762.35	1705.456	677.43	49.437	286.85	1029.27	201.133	365.017	40.515	708.948
192	411.875	840.014	1702	765.905	61.431	278.65	1131.2	230.794	478.433	43.604	741.761
193	417.125	952.672	1698.167	859.338	76.774	274.55	1199.6	271.633	532.806	54.002	697.46
194	421.208	1124.486	1689.622	946.861	76.346	264.3	1257.2	308.381	559.208	78.124	669.5
195	422.667	1218	1649.156	1032.618	70.598	256.1	1325.6	319.136	575.5	124.343	717.187
196	427.625	1261.2	1574.056	1126.969	97.279	258.15	1340	320.483	614.003	224.223	797.442
197	432.875	1287.6	1542.122	1210.8	108.2	266.35	1307.6	354.164	683.075	309.192	847.971
198	440.458	1298	1512.156	1299.6	121.582	292.45	1286	392.242	733.603	369.792	884.344
199	453.292	1293.6	1458.222	1425.022	150.33	341.5	1307.6	405.167	762.721	372.486	937.768
200	459.125	1291.6	1425.307	1496.756	226.3	417.05	1311.2	381.467	768.026	316.119	979.446
201	465.542	1297.6	1390.36	1518.889	330.778	516.625	1311.2	342.308	758.932	238.761	1024.154
202	475.75	1346.4	1361.2	1492.667	435.606	598.8	1343.6	315.633	742.261	179.917	1022.639
203	485.083	1398.8	1399.6	1446.533	502.208	639.75	1376	312.131	734.683	140.52	1023.776
204	491.903	1431.556	1501.967	1407.733	497.278	654.625	1383.2	346.889	729.379	117.123	1053.794
205	497.694	1446.889	1600	1396.4	546.131	710.35	1332.8	376.797	719.744	104.675	1153.327

206	490.361	1441.822	1693.278	1397.6	660.092	824.48	1242.8	384.881	685.697	102.559	1218.4
207	475.75	1392.933	1751.744	1382.8	726.468	937.01	1163.6	375.989	670.492	121.112	1215.2
208	430.25	1348.8	1789.333	1368	758.981	988.16	1149.2	394.756	697.878	147.53	1170.509
209	424.417	1328.8	1816.411	1365.6	777.119	984.75	1181.6	424.125	834.057	204.689	1167.884
210	426.167	1320.8	1825.289	1345.2	784.697	981.34	1214	470.472	1016.663	257.217	1187.9
211	457.083	1316.8	1818.878	1353.2	786.97	981.34	1210.4	526.5	1174.491	299.583	1219.333
212	467.875	1323.2	1793.856	1387.6	775.982	994.98	1163.6	563.681	1342.625	433.053	1270.52
213	493.333	1335.2	1561.278	1405.2	765.752	1029.08	1109.6	623.994	1454.667	628.911	1296.039
214	556.789	1366	1576.789	1433.867	750.597	1110.17	1063.56	695.339	1390.65	679.086	1347.993
215	678.225	1410.533	1605.878	1483.822	750.976	1253.6	1049.54	766.848	1421.467	635.3	1431.191
216	763.632	1458.178	1650.089	1521.111	755.901	1447.2	1106.38	888.891	1491.333	581.317	1516.744
217	790.38	1493.111	1706.656	1551.333	756.28	1626	1170.8	1009.378	1576.667	548.986	1551.167
218	795.306	1532.667	1725.289	1603.333	756.28	1726	1188.8	1067.811	1656.667	550.583	1581.717
219	804.399	1578	1722.711	1659.778	759.311	1802	1210.4	1083.2	1728.667	564.319	1642.057
220	855.928	1640.667	1724.744	1674.889	779.771	1882	1257.2	1114	1798	579.697	1683.226
221	883.966	1704.667	1711.589	1706.889	834.71	1946	1329.2	1154.8	1894	630.572	1715.825
222	869.189	1763.333	1705.456	1763.333	936.252	1994	1417.2	1188	1976.667	759.074	1758.426
223	805.914	1797.556	1702	1815.333	1065.581	2026	1478	1216.8	2035.333	1014.342	1846.404
224	767.647	1819.778	1698.167	1888.222	1120.021	2058	1470	1257.6	2096.667	1104.19	1915.893

225	747.566	1880.667	1689.622	1925.111	1160.4	2086	1454	1274	2166	1093.2	1975.488
226	738.093	1941.111	1649.156	1964.667	1196.4	2094	1478	1293.2	2251.867	1074.8	2055.286
227	743.777	2000.667	1574.056	2011.778	1255.6	2098	1542	1320	2312	1093.2	2112.226
228	750.597	2086.889	1542.122	2071.333	1328.4	2110	1618	1325.2	2363.933	1130	2163.726
229	771.057	2147.333	1505.578	2094.444	1397.6	2102	1654	1334	2478.733	1148	2211.219
230	844.94	2188.667	1456.8	2103.333	1436.889	2070	1682	1331.2	2645.286	1158.8	2255.749
231	951.787	2234.311	1425.307	2114.889	1474.889	2046	1722	1350.4	2709.892	1226.8	2314.44
232	1058.72	2292.878	1390.36	2138	1507.333	2034	1750	1411.111	2836.434	1403.911	2391.425
233	1157.284	2335.233	1361.2	2162	1548.222	2010	1778	1474.622	2979.796	1626	2482.797
234	1248	2379.878	1366.167	2180.667	1616.222	1986	1818	1542.444	3064.15	1774.444	2545.017
235	1326.4	2438.189	1490.856	2182	1680.667	2022	1870	1592.222	3069.592	1876.222	2604.528
236	1395.956	2501.511	1595.456	2180.222	1748.222	2118	1934	1623.333	3036.939	1933.556	2659.561
237	1448.044	2561.189	1686.367	2169.111	1825.556	2174	2018	1659.333	2971.633	1978.444	2718.905
238	1475.778	2620.806	1751.744	2144.222	1892.667	2174	2094	1665.556	2955.306	2011.333	2788.233
239	1509.111	2661.035	1789.333	2114.444	1942	2194	2154	1680.667	2919.932	2041.556	2882.012
240	1552.222	2700.932	1816.411	2098.889	1990	2263	2226.4	1707.333	2900.95	2066	2979.008
241	1603.778	2758.279	1825.289	2109.111	2032.667	2344.8	2279.2	1754.444	2863.118	2086.444	3071.584
242	1641.111	2799.946	1818.878	2106.444	2054.444	2406.3	2312	1756.222	2828.172	2100.667	3133.999
243	1667.778	2847.481	1813.456	2132.4	2070.444	2443.2	2344.8	1764.667	2795.914	2134.889	3173.224

244	1704.667	2907.726	1806.167	2258.889	2106.889	2422.7	2365.3	1824.667	2771.273	2174.889	2739.496
245	1759.333	2947.596	1797.622	2295.144	2139.333	2365.3	2377.6	1890.444	2744.839	2189.111	3260.7
246	1792.222	3013.356	1785.6	2327.944	2169.556	2316.1	2398.1	1963.778	2733.638	2190	3298.986
247	1790.889	3041.021	1816.078	2341.611	2194	2291.5	2426.8	2113.733	2723.333	2193.556	3321.606
248	1891.778	3063.696	1842.589	2365.3	2218.044	2303.8	2451.4	2443.022	2737.222	2201.556	3345.186
249	1918.444	3084.104	1887.744	2391.722	2245.967	2336.6	2471.9	2596.722	2784.713	2180.222	3349.856
250	1918.444	3117.664	1921.5	2418.6	2287.856	2361.2	2488.3	2626.333	2861.414	2141.111	3348.695
251	1899.333	3161.655	1950.967	2428.167	2329.311	2373.5	2496.5	2632.53	2929.483	2128.667	3352.172
252	1910.889	3216.077	2007.033	2430.9	2345.711	2389.9	2504.7	2700.461	2977.982	2135.333	3362.798
253	1924.667	3263.104	2045.333	2419.511	2358.011	2414.5	2508.8	2747.975	3035.578	2138	3358.179
254	1964.222	3295.825	2072.956	2418.6	2381.7	2439.1	2500.6	2704.964	3125.828	2123.333	3345.565
255	2028.667	3304.667	2090.211	2418.6	2409.944	2459.6	2488.3	2631.725	3153.492	2112.667	3330.141
256	2072.667	3295.233	2109.122	2418.6	2444.567	2467.8	2496.5	2562.1	3168.458	2121.111	3307.135
257	2092.667	3273.377	2117.833	2413.133	2465.978	2463.7	2549.8	2481.922	3178.889	2140.222	3276.806
258	2097.556	3260.521	2125.289	2391.722	2494.222	2447.3	2623.465	2468.711	3200.204	2173.111	3235.481
259	2110.889	3236.939	2126	2373.044	2511.533	2430.9	2680.323	2439.556	3306.843	2210.933	3211.584
260	2119.333	3212.449	2126	2343.433	2527.933	2426.8	2716.613	2414.5	3364.936	2240.056	3191.767
261	2127.333	3191.588	2125.456	2297.422	2544.333	2435	2736.775	2393.544	3395.357	2255.511	3176.443
262	2135.333	3178.889	2119.256	2254.233	2566.2	2443.2	2765	2388.078	3426.053	2260.522	3179.964

263	2143.333	3155.306	2120.911	2206.044	2598.544	2439.1	2793.226	2389.9	3457.027	2247.811	3188.978
264	2146	3134.445	2105.244	2156.222	2606.744	2422.7	2797.258	2374.867	3488.28	2220.256	3198.332
265	2129.556	3125.374	2075.756	2098.889	2605.378	2394	2777.097	2358.467	3519.817	2203.333	3211.595
266	2104.222	3131.723	2055.044	2044.222	2599.456	2365.3	2752.904	2345.711	3551.638	2190.889	3229.549
267	2070.889	3196.122	2041.078	2010.889	2597.178	2340.7	2728.71	2342.978	3601.25	2190	3252.36
268	2026	3286.311	2006.456	1960.222	2583.967	2316.1	2696.452	2337.056	3587.25	2193.556	3272.71
269	1961.556	3332.019	1959.378	1924.667	2552.533	2295.6	2664.194	2332.956	3572.75	2205.111	3292.325
270	1888.222	3360.583	1927.756	1910.889	2525.2	2275.1	2631.733	2319.289	3549.815	2204.222	3307.392
271	1812.222	3391.861	1913.622	1906.444	2513.811	2254.6	2594.9	2312.456	3510.667	2196.667	3326.955
272	1761.556	3433.824	1898.333	1891.333	2494.222	2226.2	2553.9	2310.178	3475.185	2188.667	3336.55
273	1768.667	3467.407	1905.306	1880.667	2460.511	2182	2508.8	2304.256	3445.629	2178.889	3341.833
274	1812.222	3479.852	1912.311	1878.444	2410.856	2142	2467.8	2301.978	3406.556	2163.333	3341.03
275	1847.333	3466.63	1877.456	1848.667	2334.778	2114	2435	2292.411	3347.259	2149.111	3338.226
276	1861.111	3445.111	1866.333	1820.222	2270.133	2094	2410.4	2276.467	3276.214	2138.889	3329.929
277	1862	3410.222	1854.711	1806.889	2216.289	2078	2389.9	2261.889	3166.348	2121.556	3317.999
278	1865.556	3364.065	1845.244	1807.778	2173.556	2058	2369.4	2253.233	3147.143	2092.667	3294.467
279	1880.667	3312.974	1817.956	1815.333	2129.556	2038	2357.1	2245.033	3171.463	2049.556	3251.25
280	1902	3252.377	1776.8	1823.333	2096.667	2018	2348.9	2213.722	3137.109	2018.444	3195.722
281	1938.889	3183.424	1753.078	1824.222	2064.667	1986	2344.8	2109.122	3105.816	1988.667	3142.332

282	1967.778	3121.746	1731.044	1807.333	2039.778	1938	2336.6	2015.333	3053.605	1942	3079.626
283	1993.556	3054.626	1711.044	1804.222	2029.111	1874	2312	1956.667	3011.939	1899.333	3012.85
284	2033.111	2998.844	1697.078	1796.667	1998.444	1806	2279.2	1904.222	2977.585	1868.667	2942.211
285	2035.778	2923.216	1673.956	1788.667	1992.222	1746	2254.6	1863.333	2956.157	1820.222	2868.027
286	2058	2840.301	1643.211	1778.889	1997.556	1694	2238.2	1825.111	2926.299	1766.444	2798.886
287	2082	2774.408	1620.7	1763.333	1996.222	1654	2222	1792.667	2902.078	1721.556	2731.17
288	2107.778	2702.664	1576.8	1749.111	1988.667	1622	2194	1762.444	2863.623	1692.222	2661.996
289	2135.778	2621.702	1543.211	1738.889	1977.111	1602	2162	1739.778	2869.61	1677.111	2595.05
290	2150.889	2578.044	1518.5	1723.333	1954	1590	2134	1723.333	2810.363	1670.444	2527.653
291	2159.333	2508.8	1494.5	1707.333	1931.778	1578	2110	1707.333	2772.7	1670	2453.621
292	2167.333	2432.722	1471.044	1693.111	1917.111	1566	2090	1693.111	2765.957	1668.222	2430.846
293	2177.111	2391.267	1457.622	1684.667	1908.667	1558	2066	1686.444	2724.892	1660.667	2399.439
294	2187.333	2337.056	1442.878	1676.667	1898.889	1558	2046	1686	2663.276	1652.667	2360.744
295	2177.111	2287.4	1433.677	1668.667	1881.556	1554	2030	1684.222	2578.185	1637.556	2306.533
296	2154	2240.156	1419.99	1660.667	1856.222	1550	2010	1678.444	2530.319	1601.111	2237.967
297	2124.667	2201.133	1411.66	1652.667	1824.667	1550	1990	1676.222	2455.671	1566.889	2186.022
298	2083.333	2168.667	1397.9	1644.667	1798	1550	1974	1670.444	2430.217	1529.111	2154.444
299	2059.778	2138.444	1386.95	1636.667	1788.667	1554	1954	1670	2410.571	1498.444	2130
300	2039.778	2110.444	1376.79	1628.667	1782.444	1558	1934	1670	2379.992	1475.778	2104.222

301	2008.667	2073.111	1368.46	1622.444	1782	1562	1922	1670	2329.288	1459.333	2074.444
302	1974.889	2042.444	1357.84	1620.222	1782	1566	1910	1671.778	2324.692	1438.533	2050
303	1935.333	2016.222	1352	1612.667	1782	1570	1894	1677.556	2273.313	1408.889	2022.444
304	1886.444	1988.222	1351.104	1604.667	1782	1574	1878	1681.556	2248.125	1401.6	1992.222
305	1815.778	1969.556	1353.969	1598.444	1782	1574	1870	1693.111	2229.517	1398	1970.444
306	1767.778	1946	1356.423	1598	1782	1574	1866	1690.444	2104.425	1386	1899.778
307	1732.667	1925.556	1358.876	1596.222	1782	1574	1858	1675.333	2050	1380	1868.222
308	1708.222	1913.111	1361.33	1590.444	1782	1570	1854	1661.111	2022.444	1376.4	1851.333
309	1663.778	1893.556	1363.783	1590	1782	1566	1854	1654.444	1983.333	1361.2	1837.111
310	1625.111	1881.111	1366.237	1590	1782	1566	1850	1654	1945.111	1343.2	1830.444
311	1594.444	1861.556	1368.69	1588.222	1782	1562	1846	1654	1914.444	1335.2	1819.333
312	1571.778	1852.667	1371.144	1582.444	1780.222	1550	1846	1654	1888.222	1328	1779.333
313	1555.333	1844.667	1373.598	1580.222	1774.444	1538	1846	1652.222	1858.444	1322.4	1757.556
314	1542.889	1836.667	1376.051	1574.444	1774	1534	1846	1644.667	1832.222	1320.4	1748.667
315	1538.444	1828.667	1378.505	1572.222	1772.222	1530	1846	1634.889	1806	1315.2	1742.444
316	1523.333	1820.667	1380.958	1566.444	1766.444	1526	1842	1619.333	1796.667	1314.8	1742
317	1509.111	1812.667	1383.412	1564.222	1766	1526	1838	1605.111	1788.667	1314.8	1740.222
318	1500.667	1806.444	1385.865	1554.889	1764.222	1530	1838	1596.667	1780.667	1314.8	1734.444
319	1494.444	1806	1388.319	1541.111	1758.444	1538	1838	1590.444	1772.667	1314.8	1734

320	1492.222	1806	1390.772	1532.667	1756.222	1542	1834	1590	1764.667	1314.8	1734
321	1486.444	1804.222	1393.226	1524.667	1750.444	1546	1830	1590	1758.444	1314.8	1734
322	1486	1798.444	1395.68	1516.667	1746.444	1554	1830	1588.222	1756.222	1314.8	1734
323	1484.222	1798	1398.133	1510.444	1733.111	1558	1830	1582.444	1750.444	1314.8	1734
324	1478.444	1798	1400.587	1510	1726.444	1558	1830	1582	1750	1316.4	1734
325	1479.778	1798	1403.04	1510	1724.222	1562	1830	1580.222	1748.222	1321.6	1734
326	1485.556	1798	1405.494	1510	1718.444	1566	1830	1574.444	1742.444	1322	1734
327	1486	1798	1407.947	1510	1716.222	1570	1830	1572.222	1740.222	1322	1734
328	1487.778	1799.778	1410.401	1510	1710.444	1578	1826	1564.667	1734.444	1323.6	1735.778
329	1493.556	1805.556	1412.854	1511.778	1710	1586	1822	1558.444	1734	1330.4	1741.556
330	1494	1806	1415.308	1517.556	1708.222	1590	1818	1558	1734	1336	1742
331	1494	1806	1417.761	1519.778	1702.444	1618	1810	1556.222	1735.778	1336.4	1743.778
332	1494	1806	1420.215	1525.556	1702	1626	1806	1550.444	1741.556	1338	1749.556
333	1494	1806	1422.669	1527.778	1700.222	1610	1806	1550	1742	1343.2	1751.778
334	1494	1806	1425.122	1535.333	1694.444	1618	1803	1550	1742	1345.2	1757.556
335	1494	1807.778	1427.576	1543.333	1692.222	1626	1798.333	1550	1743.778	1340.8	1689
336	1495.778	1813.556	1430.029	1549.556	1686.444	1630	1798	1550	1749.556	1310	1689
337	1501.556	1815.778	1432.483	1551.778	1684.222	1634	1796.222	1551.778	1750	1309.2	1697
338	1502	1821.556	1434.936	1559.333	1678.444	1638	1790.444	1557.556	1750	1316	1607

339	1502	1822	1437.39	1565.556	1676.222	1642	1790	1559.778	1750	1321.6	1705
340	1503.778	1823.778	1439.843	1567.778	1668.667	1650	1790	1565.556	1750	1323.6	1705
341	1509.556	1829.556	1442.297	1575.333	1660.667	1658	1790	1566	1750	1330.4	1705
342	1510	1830	1444.751	1581.556	1654.444	1662	1791.778	1567.778	1751.778	1336	1713
343	1510	1830	1447.204	1583.778	1654	1666	1797.556	1575.333	1757.556	1338	1713
344	1510	1831.778	1449.658	1589.556	1654	1674	1799.778	1581.556	1758	1343.2	1721
345	1510	1837.556	1452.111	1591.778	1655.778	1682	1805.556	1583.778	1758	1343.6	1721
346	1510	1839.778	1454.565	1599.333	1661.556	1686	1806	1589.556	1759.778	1345.2	1721
347	1510	1847.333	1457.018	1605.556	1662	1690	1807.778	1591.778	1767.333	1350.4	1729
348	1511.778	1855.333	1459.472	1607.778	1663.778	1698	1815.333	1599.333	1773.556	1352.4	1729
349	1517.556	1859.778	1461.925	1613.556	1669.556	1706	1821.556	1605.556	1775.778	1357.6	1729
350	1518	1854.444	1464.379	1615.778	1670	1714	1807.778	1607.778	1781.556	1358	1736
351	1519.778	1855.778	1466.832	1621.556	1671.778	1718	1761.556	1613.556	1783.778	1359.6	1736
352	1525.556	1861.556	1469.286	1622	1677.556	1722	1758	1615.778	1789.556	1364.8	1736
353	1526	1862	1471.74	1622	1679.778	1726	1759.778	1623.333	1790	1365.2	1736
354	1527.778	1863.778	1474.193	1623.778	1685.556	1726	1765.556	1631.333	1791.778	1366.8	1744
355	1533.556	1869.556	1476.647	1629.556	1687.778	1726	1766	1637.556	1797.556	1373.6	1744
356	1534	1871.778	1479.1	1630	1693.556	1730	1767.778	1639.778	1799.778	1380.8	1752
357	1534	1877.556	1481.554	1630	1695.778	1734	1773.556	1647.333	1805.556	1386.4	1752

358	1532.222	1878	1484.007	1631.778	1701.556	1738	1774	1655.333	1807.778	1386.8	1752
359	1524.667	1878	1486.461	1637.556	1702	1742	1775.778	1661.556	1813.556	1386.8	1752
360	1517.556	1878	1488.914	1638	1703.778	1746	1781.556	1663.778	1814	1386.8	1752
361	1511.333	1878	1491.368	1638	1709.556	1750	1783.778	1669.556	1815.778	1388.4	1760
362	1510.222	1878	1493.822	1638	1710	1754	1789.556	1670	1821.556	1393.6	1760
363	1508.222	1879.778	1496.275	1639.778	1710	1758	1790	1671.778	1823.778	1394	1760
364	1502.444	1885.556	1498.729	1645.556	1711.778	1762	1791.778	1717.941	1829.556	1394	1768
365	1500.222	1886.761	1501.182	1646	1717.556	1766	1797.556	1789.077	1830	1392.949	1768

Appendix C: Routed Hydrograph of 21 Subreaches