ESTIMATING TI   )OD FROM UPSTREAM TO DOWNSTREAM USING MUSKINGUM METHOD: SUNGAI KUANTAN,PAHANG DARUL MAKMUR.

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Civil Engineering with Environment

Faculty of Civil Engineering & Earth Resources

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JUNE 2012

ABSTRACT

The social disruption caused by floods can seriously undermine the quality of life of individuals and impact on the fabric of affected communities (Gordon, 2004). As well as the physical and health dangers of flood waters, the psychological impact of the emergency and aftermath causes longer term effects that may be exacerbated by stresses such as having to move out of the home, cleaning up, negotiating with insurers and getting damage repaired and goods replaced (RPA, 2005). Muskingum method is a non-structural measure that helps in prevention of occurrence of flood. From Muskingum method, the lag time (Δt) when the flood is going to occur is predicted. The existence of the Chereh dam plays a major role in delaying the time taken for the water flow to the downstream, which in 2001 (before the construction of Chereh dam) the lag time is one day and there is an increase of lag time in 2011 (post construction) which is two days. Chereh dam is very effective for the flood mitigation. By using the same method, the lag time (Δt) is also being determined for the residential that is situated along Sungai Kuantan, where the lag time (Δt) for Kg Bayas, Kg Batu Enam, Kg Nada and Kg Sungai Caru is two days. As for Kg Kuala Reman, Kg Ah Tong, Kg Bala Sawar and Kg Permatang Badak are three days. The information provided by early warning systems (Lag time (Δt)) enables authorities and institutions at various levels to immediately and effectively respond to a disaster where the planning of the executed plan could be done before it is too late.

ABSTRAK

Gangguan sosial yang disebabkan oleh banjir serius boleh menjejaskan kualiti hidup individu dan kesan ke atas masyarakat yang terlibat (Gordon, 2004). Serta bahaya fizikal dan kesihatan yang berpunca dari air banjir, kesan psikologi kecemasan yang menyebabkan kesan jangka panjang yang boleh diburukkan lagi oleh masalah seperti menyelamatkan diri keluar dari rumah, membersihkan, berunding dengan syarikat insurans dan kerosakan yang perlu dibaiki dan kerugian yag menimpa(RPA, 2005). Kaedah muskingum adalah langkah bukan struktur yang membantu dalam pencegahan berlakunya banjir. Daripada kaedah Muskingum, masa lag (Δt) apabila banjir itu akan berlaku diramalkan. Kewujudan empangan Chereh memainkan peranan penting dalam melambatkan masa yang diambil untuk aliran air ke hilir, yang pada tahun 2001 (sebelum pembinaan empangan Chereh) masa lag satu hari dan terdapat peningkatan masa lag pada tahun 2011(selepas pembinaan) iaitu selama dua hari. Empangan chereh sangat berkesan untuk tebatan banjir. Dengan menggunakan kaedah yang sama, masa kelewatan (Δt) juga ditentukan bagi kediaman yang terletak di sepanjang Sungai Kuantan, di mana masa kelewatan (Δt) untuk Bayas Kg, Kg Batu Enam, Kg Nada dan Kg Sungai Caru dua hari. Untuk merebut kembali Kuala Kg, Kg Ah Tong, Kg Bala Sawar dan Kg Permatang Badak tiga hari. Maklumat yang diberikan oleh sistem amaran awal (Lag (Δt)) membolehkan pihak berkuasa dan institusi di pelbagai peringkat dengan segera dan berkesan bertindak balas terhadap bencana di mana perancangan pelan yang disempurnakan boleh dilakukan sebelum terlambat.

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CHAPTER 1

INTRODUCTION

1.1   Background of study

Flood can be defined as a body of water, rising, swelling and overflowing land not usually thus covered. There are no formal categorizations of floods in Malaysia but is often broadly categorized as monsoonal, flash or tidal floods. In addition, floods are also described based on its location, characteristics, the cause, the timing as to when it occurs and its duration (Thomas, 2009).

La Nina phenomenon which is common over the last few years has brought more rain to the country. For example, the 2009 El Nino was not a particularly severe one. Nonetheless, drought in the Philippines, for instance, is estimated to have cost at least US$175 million in crop damage, primarily in damage to rice and corn, with the loss of as much as 300,000 metric tons of rice in a country that is one of the world's biggest rice importers (Natural Disaster Risk Index 2010)

There are a number of factors, some natural and some man-made, which can determine whether a storm system will produce a flash flood or merely a significant amount of rain. One factor is the nature of the storm cell itself. A fast-moving squall line of thunderstorms, for example, may move through an area so quickly that the rainfall is absorbed by the ground or sewer systems and does not back up. A slow-moving independent storm system, on the other hand, may dump inches of rain in a small area and create the potential for a flash flood. A short, intense downburst may be preferable to a long, slow rain event.

Some methods of flood control have been practiced since ancient times. These methods include planting vegetation to retain extra water, terracing hillsides to slow flow downhill, and the construction of floodways (man-made channels to divert floodwater). Other techniques include the construction of levees, dikes, dams, reservoirs or retention ponds to hold extra water during times of flooding.

Despite on flood brings a lot of problem, flood also has it pros and cons. On the positive side, floods helps to sustaining, enriching and rejuvenating certain sector of biodiversity in the floodplains, replenishes the land with nutrient rich soils and therefore good for agriculture and natural vegetation, clear debris as well as remove sediments from the flooded area, recharges groundwater storage. Besides, for the negative side, it can threaten lives or inhabitants disrupt social and economic activities and destroy properties, causes distress and recovery can be costly both to individuals and the Government, and deterred new investments in the flood prone area. Below is the index of damage cost for every state in Malaysia.

Table 1.0   Flood damage by state in Malaysia

State	Damage (RM Million)	Persons Evacuated (no.)
PERLIS	2.76	13,000
KEDAH	31.20	124,000
PULAU PINANG	44.52	510,000
PERAK	22.64	244,000
SELANGOR	75.76	726,000
W.P KUALA LUMPUR	99.33	13,000
NEGERI SEMBILAN	3.96	42,000
MELAKA	2.29	31,000
JOHOR	64.00	297,000
PAHANG	76.15	615,000
TERENGGANU	101.58	457,000
KELANTAN	93.32	714,000
SABAH	140.96	635,000
SARAWAK	157.66	494,000
THE PENINSULA	616.62	3,786,000
SABAH & SARAWAK	298.62	1,129,000
THE PENINSULA	616.62	3,786,000
SABAH & SARAWAK	298.62	1,129,000
TOTAL	915.12	4,915,000

(Source: Based on 'Updating of Flooding Condition Study'- 2010)

We know that, in the downstream area where it is the area of human settlements while on the upper stream always be areas where flooding happens. What will be worrying in future is when the flood from upstream will flow to the downstream area. We know that the floods have more harm than good. Muskingum method will be used to investigate and solve this problem. In this method, execute plan can be implemented when the time for the floods to the region downstream from the upstream area is obtained. If this problem can be solved, we can prepare before the disaster comes thus avoids us from things that are not desired to happen.

1.2   Problems Statement

In terms of meteorological and past experience, there is party strive to provide service to forewarned on heavy rain and occurrence of possibility flood in area particular area straight to public. The initial information with regard to water level and time period taken for water from upstream reach to certain level in area that risky flood is also very important so that some precaution could be apply.

Flooding is inevitable for a country like Malaysia which has a high rainfall. We can only reduce the possibility of facing a flood. What is more important is the willingness to face flooding with information on where flood warnings can be delivered.

1.3   Objectives of Study

The objectives of this study are:-

a. To predict the lag time (Δt) before, during and post construction of Chereh dam.

b. To predict the lag time (Δt) of flood to occur over residential along Sungai Kuantan

1.4   Scope of Study

This study is limit to the following:

a. Study area was limited to river catchment of Kuantan

b. Analysis that was performed involved a few key aspects hydrological study namely flow rate data for three different periods which is before, during and after the construction of Chereh dam.

1.5   Study Area

The study area is Chereh dam where it is located approximately 64km in Kuantan, Pahang. It began to be built in the year of 2002 and completed in the middle year of 2008 with expenditure cost RM 69.3 million. The wide of Chereh dam catchment area is 152km square and was gazette under Pahang state forestry department and more than two years of process stagnation implemented start in 29th July 2008. The width of the dam is 16.2km square and can accommodate solid 260 million meters water. The width is equal 1 / 3 Putrajaya broadness. While the area of water reservoir is 16.2 km square. All catchment areas and the dam including Hutan Simpan Chereh were 15,200 hectares. Sungai Chereh is twig to Sungai Kuantan in upstream. Pooled water is going to reach maximum level about 3years on 2011. Dam will be full with water through rain water especially in rainy season and rivulets which flowed into the dam. This dam can supply 300 million liters per day. In year 2050, it can supply 1000 million liters per day.
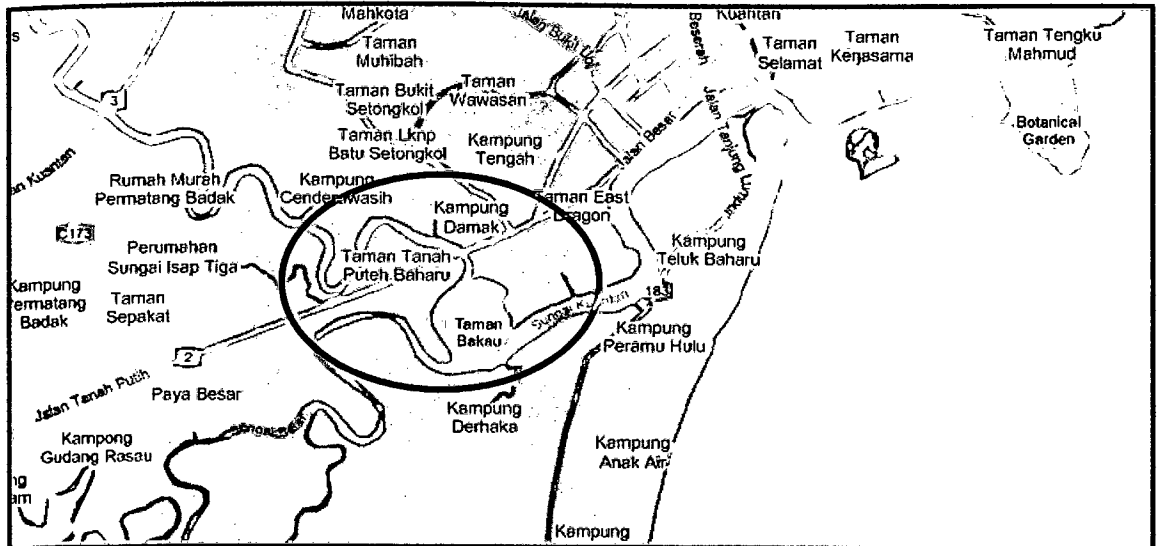
Figure 1.1   Map of Sungai Kuantan

Flow from Gunung Tapis (1502m above sea level) through Bandaraya Kuantan before discharge (5m above sea level) to South China Sea. Its length is 2.44km. The latitude is 3.8 to the North and the longitude is 103.35 to the East. Basin area is 28,682.2 km2. The catchment area Sg.Kuantan is 1684.4 km2. Sg.kuantan is categorized as category 1 as the basin area is located in the Pahang state itself.

Figure 1.2   Sg.Kuantan that is located in the Pahang state.

1.6 Significance of Study

The information of the time taken (Δ t) by the flooding from upstream area to downstream area is very crucial and very helpful so that some precautions can be implemented. Precautionary measure in question is that we can implement is the execute plan in which the public will be ready to reduce the impact of the flood.

1.7 Thesis Structure

This thesis is divided into five chapters. First chapter presents an introduction and an overview of the problem statement objectives scope of studies and study area. Chapter two describes the literature related to the research objectives. Chapter three details the methodology used in the research. Chapter four discusses the results obtained from the case study. Finally, chapter five presents the conclusions discusses drawn from the works and provides the direction for the future work.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

This chapter presents a review of the literature on floods in Malaysia especially at the study area; planning and implementation of the project alleviate flood, flood routing and also Muskingum method.

2.2   Floods in Malaysia especially at the study area (Sungai Kuantan)

In recent years, severe flooding has occurred in several parts of Malaysia, both as localized flash floods and as basin-wide floods on major river systems. Some of the badly affected areas are situated at the river basins in Penang (Juru River Basin), Pahang (Pahang River Basin), Terengganu (Setiu River Basin) and Perak (Kinta River Basin). By their nature, floods are generated by the random coincidence of several meteorological factors but man's use of the river catchment also has an impact upon the

severity and consequences of the events. Soil loss is a fundamental local, national, and global issue. Related effects include: long-term loss of soil fertility; non-point source water pollution (sediment); filling of reservoirs; and aquatic habitat degradation (Brady and Weil 2000). With a very slow rate of soil formation, any soil loss of more than 1 t ha-1yr-1 can be considered as irreversible within a time span of 50-100 years. Losses of 20 to 40 t ha-1 in individual storms, that may happen once every two or three years, are measured regularly in Europe with losses of more than 100 t ha-1in extreme events. The main causes of soil erosion are still inappropriate agricultural practices, deforestation, overgrazing, forest fires and construction activities.

The most severe natural disaster experiencing in Malaysia is flood. Two major type of flood occur in this country are monsoon flood and flash flood. The monsoon flood occur mainly from Northeast Monsoon which prevails during the months of November to March with heavy rains to the east coast states of the Peninsula, northern part of Sabah and southern part of Sarawak. Some of the recorded flood experiences in the country occur in 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1983, 1988, 1993, 1998 and 2001. Report from Department of Irrigation and Drainage stated that about 29,000 sq. km or 9% of total land area and more than 4.82 million people (22%) is affected by flooding annually. Damage cause by flood is estimated aboutRM915 million.

While monsoon flood is govern by heavy and long duration rainfall, more localized flooding which covers a large area has been reported in recent years. Flood of October 2-6, 2003 that affected a large area in the northwestern part of the Peninsula covering states of Kedah, Penang and Northern Perak. Flash flood is reportedly occurring quite rapid such as two events occur in April 2002 and October in Kuala Lumpur which has been recognized due to uncontrolled development and activities within the catchment and flood plain (Abd Jalil And Aminuddin,2000). Large floods had damaged properties, public utilities, cultivation, lost of lives and also caused hindrance to social and economic activities. Average annual flood damage is as high as RM100millions. In February, 2006 Shah Alam was heavily flooded due to poor drainage

system caused by surrounding development activities. In October 2006, Kelang area as well as Kedah & Perlis was severely flooded which was reported caused property damage and lots of millions of Ringgit.

2.3 Planning and implementation of the project alleviate flood

There are a myriad of ways to prevent floods. The creation of flood plains and winding streams are two of the best ways to hinder the accumulation of water by providing a route for the drainage of water. Also, the protection of wetlands helps to maintain a natural drainage system to provide a place for the excess water to gather. Such devices allow the water to evaporate before it can accumulate, creating flooding conditions.

Levees also impede the collecting of water. Levees are embankments composed of soil and earthen material that are used to prevent annual flooding in many areas. With a levee, a huge amount of rain water is required before flooding occurs. However, one drawback to their use is that if water is able to get past the levees, then the flooding is significantly worse and causes several times more damage.

A dam is a barrier across flowing water that obstructs, directs or retards the flow, often creating a reservoir, lake or impoundment. In Australian English, the word "dam" refers to the reservoir rather than the structure. Most dams have a section called a spillway or weir over which or through which it is intended that water will flow either intermittently or continuously.

2.4 Flood routing

The flood hydrograph is in fact a wave. The stage and discharge hydrographs represent the passage of waves of stream depth and discharge respectively. As this wave moves down, the shape of the wave gets modified due to channel storage, resistance, lateral addition or withdrawal of flows etc. When a flood wave passes through a reservoir its peak is attenuated and the time base is enlarged due to effect of storage. The reduction in the peak of the outflow hydrograph due to storage effects is called attenuation.

Further the peak of outflow occurs after the peak of the inflow; the time difference between the peaks of inflow and outflow hydrographs is known as lag. Modification in the hydrograph is studied through flood routing. Flood routing is the technique of determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one or more upstream sections. Flood routing is used in

(i)   flood forecasting,

(ii)   flood protection,

(iii)   reservoir design, and

(iv)   design of spillway and outlet structures.

Food routing types:

(a)   Reservoir routing, and

(b)   Channel routing.

A variety of routing methods are available and they can be grouped into (1) hydrologic routing, and (2) hydraulic routing. Hydrologic routing methods employ essentially the equation of continuity, on the other hand hydraulic methods use continuity equation along with the equation of motion of unsteady flow (St. Venant equations) hence better than hydrologic methods.

In very long channels the entire flood wave also travels a considerable distance resulting in a time redistribution and time of translation as well. Thus, in a river, the redistribution due to storage effects modifies the shape, while the translation changes its position in time. In the reservoir the storage was a unique function of the outflow discharge S = f(O). However in channel the storage is a function of both outflow and inflow discharges and hence a different routing method is needed.

The water surface in a channel reach is not only parallel to the channel bottom but also varies with time. The total volume in storage for a channel reach having a flood wave can be considered as prism storage + wedge storage. Prism storage is the volume that would exist if uniform flow occurred at the downstream depth i.e. the volume formed by an imaginary plane parallel to the channel bottom drawn at the outflow section water surface. Wedge storage is the wedge like volume formed between the actual water surface profile and the top surface of the prism storage. At a fixed depth at a downstream section of a river reach the 8prism storage is constant while the wedge storage changes from a positive value at an advancing flood to a negative value during a receding flood.

2.5   Muskingum method

Flood routing in open channels can be determined using a variety of modelling procedures. These methods follow a wide range of methodologies, which can be categorized as:

a. Simple like Muskingum-type approximations – Which have modest data requirements

b. Complex like Muskingum–Cunge methods – Where the typically calibrated Muskingum routing parameters are related to physical and

hydraulic characteristics such as reach length, flood wave celerity, unit width discharge and channel bed slope

c. Highly complicated like the solution of the full dynamic flow i.e. St Venant equations – Which require surveyed cross-sectional channel profiles and flow resistance data

Out of these the Muskingum and Muskingum–Cunge methods are well established in the hydrological literature, and the modest data requirements make these procedures attractive even though more rigorous hydraulic models are available for unsteady flow routing (Birkhead & James, 2002).

For Muskingum method which is a hydrologic method, the discharge measurements alone are sufficient for routing. This is because it is assumed that the parameters of the Muskingum model capture the combined flood-propagating characteristics of a river reach. When the water resources schemes to be built are in their initial planning stages, the river gauging system may remain either underdeveloped or insufficient to give precise and rigorous measurements of flow depths and discharges. The Muskingum method is useful for predicting the preliminary outflow hydrographs required at the initial stages of planning spillway capacities. In addition, these outflow hydrographs can also aid the design of stream gauges for future use. Hence, the Muskingum model has a high significance for modern civil engineers. (Das, 2004)

The Muskingum equation is frequently used for routing of floods in river channels. The Muskingum method for routing flood waves in rivers and channels has been widely used in applied hydrology, since its first use in connection with a flood control project in the Muskingum County of Ohio about fifty years ago. Since its development around 1934 by McCarthy, the Muskingum method has also been a subject of many investigations (Strupczewski, Napiorkowski & Dooge, 2002)
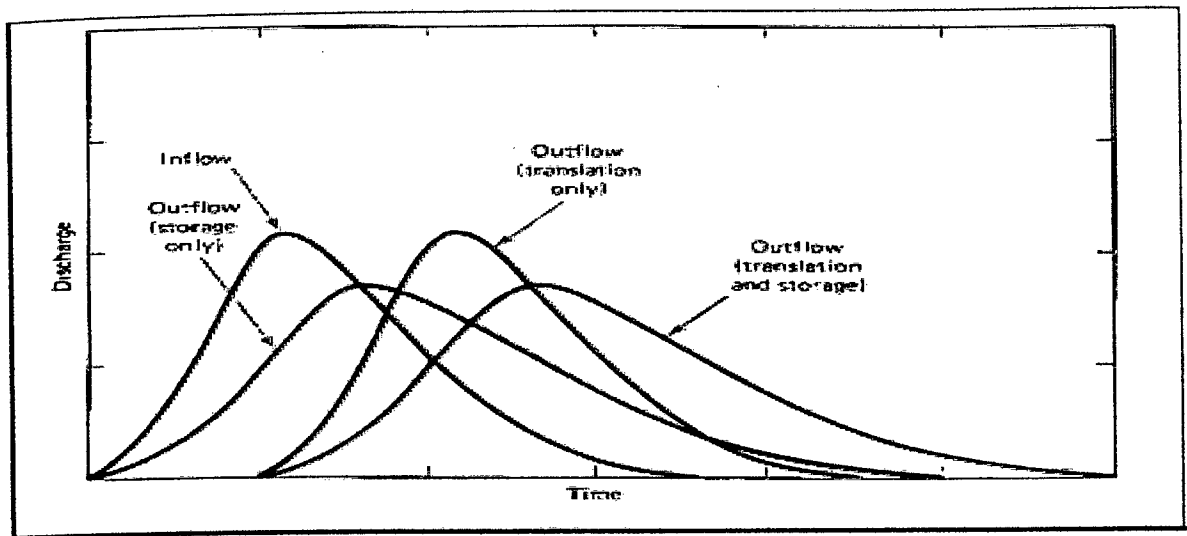
(Gill 1979)

Figure 2.1   The translational and storage processes in stream channel routing.

2.5.1   Procedure of applying Muskingum method

The Muskingum method as explained above is a widely used hydrologic method for routing flood waves in rivers and channels. The standard procedure for applying the Muskingum method involves two basic steps: calibration and prediction.

In the calibration step, inflow-outflow hydrograph data is taken from historical records to determine the parameter values for the Muskingum model of a river. This is used to solve the parameter-estimation problem. The prediction step is the solution of a routing problem in which the outflow hydrograph for a given inflow hydrograph is determined by using the routing equations.
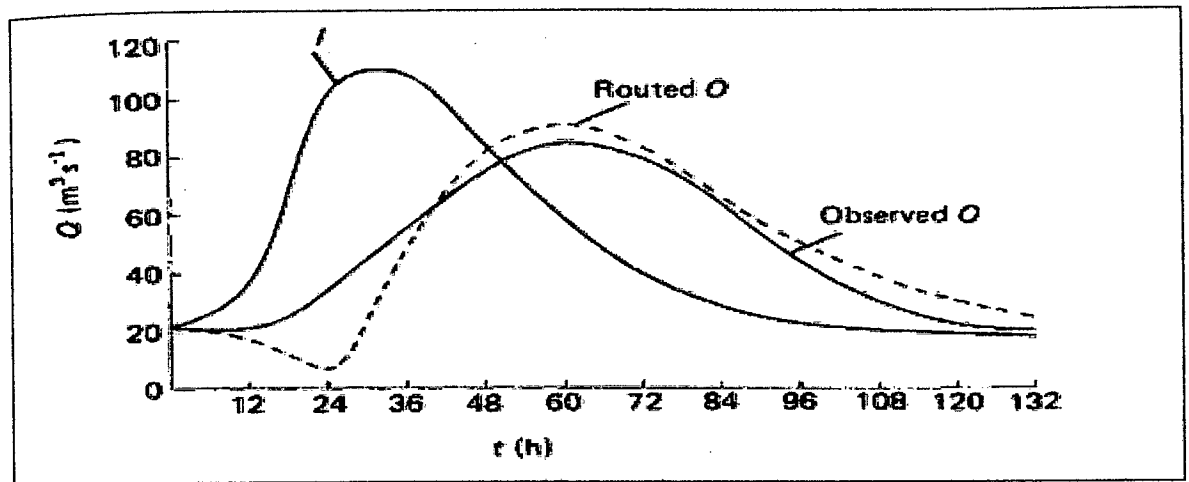
Figure 2.2 Example of routing using Muskingum method

2.5.2 Muskingum Equation

Muskingum equation is a spatially lumped form of continuity equation and linear-storage and discharge relationship for a specified river reach. The first equation is common to all conceptual models. It is a physical continuity equation i.e. law of conservation of mass, which is later integrated over the entire river reach

$$\frac{dS}{dT} = 1 - O \quad \text{------ (Eq 2.1)}$$

Muskingum method differs from other conceptual models with the second equations, which relates storage in the river reach, inflow and outflow.

$$S = K[xI + (1-x)O] \quad \text{------ (Eq 2.2)}$$

The equation (2.2) given above can be obtained by assuming that the total storage in the river reach is a weighted sum of the storages, corresponding to steady-state flow rates in terminating cross-sections, and that a linear relation exists between the prismatic storage and the flow rate. As we have seen in the sections above the two types

of storages prism and wedge, and the functions which they depend on. Revisiting the same we get

Prism storage = $f(O)$; Wedge storage = $f(I,O)$

The above equations can be rewritten as

Prism storage = KO; Wedge storage = $xK(I-O)$

The total storage volume at any time instant, t, can be calculating the above two storages.

i.e. $S_t = KO + xK(I_t - O_t) = K[xI + (1-x)O]$

In the equations above K is the travel time of flood wave in a reach in hours and x is the weighting factor, its values lies in the range $0 \sim 0.5$.

The Muskingum equation based on equation (2) and the water balance equation can be written as:

$$O(r+1) = C_1 I(i+1) + C_2(i) + C_3 O(i) \quad \text{Where, i} = 1, 2... \text{------ (Eq 2.3)}$$

Where,

$$C_1 = \frac{(0.5\Delta t - xK)}{(0.5\Delta t + (1-x)K)} \text{------ (2.3a)}$$

$$C_2 = \frac{(0.5\Delta t + xK)}{(0.5\Delta t + (1-x)K)} \text{------ (2.3b)}$$

$$C_1 = \frac{(-0.5\Delta t + K)}{(0.5\Delta t + (1-x)K)} \text{------ (2.3c)}$$

In the above four equations is the time interval given by ,gives the outflow at the end of the time interval, is the inflow at the end of the time interval, is the outflow at the beginning of the time interval and is the inflow at the beginning of the time interval (Guang-Te & Singh ,1992).

Variable Parameters K and x – The parameter K, substituted in the equations above, is usually referred to as the storage constant and has the dimension of time. K is the first moment of the impulse response of the Muskingum model. This means that it measures the delay between the centre of gravity or centroid of the input wave and the centre of gravity of the model output wave. However, studies have shown that this parameter cannot be identified with the transport delay in the sense of theory of dynamic systems, since the Muskingum model never yields ideal translatory properties (Strupczewski & Kundzewicz, 1980).

Physically speaking, the parameter K represents the average reach travel time, and is the function of length of the river reach and of the wave velocity. Its value and also the value of the parameter x can be analytically evaluated by matching the moments of impulse response of the Muskingum model and of the diffusion analogy or the linearized dynamic wave model (Overton, 1966).

While all the Hydrologists agree over the nature of the parameter K, but the views on the nature of the parameter x, a dimensionless quantity, and the range of values it varies over are not consistent. According to Yevjevich and Barnes, the parameter x relates to the difference between flow rates in the cross-sections terminating the modelled river reach. It is thus the measure of shape of the wave passing through the reach and, in principle, different for different types of waves.

In the literature two typical hypotheses for the range of variability of x can be found. The most popular opinion is that x as a weight coefficient should have a positive value from the range (0, 1), although some hydrologists like Cunge propose the choice of this parameter from the narrower range of values (0, 0.5). One scientist Dooge even permits the possibility of negative values of x. (Strupczewski & Kundzewicz, 1980).