Engineering Hydrological Study of Kodku Khola for Water Supply to Lalitpur Submetroplitan City, Nepal

Laxmi Devi Maharjan

Lalitpur, Nepal

sulaxam@yahoo.com

Abstract

The city of Lalitpur is in severe deficit of drinking water for its population. The Kodku Khola as the nearest river from the Lalitpur city can be used for the water supply purpose. The engineering geological and hydrological investigation is essential for water supply so the existing data and information pertaining to hydrological, geological and geotechnical characteristics of the study area, etc. were collected and analyzed in order to identify their discrepancies. The geological study included the Basement rock of Phulchowki Group and thick semi-consolidated fluvio-lacustrine sediments. The Rainfall data analysis was done to estimate future rainfall trend that determines the rainfall intensity, duration, frequency, maximum and minimum rainfall. With the help of Mean Monthly Rainfall (M.M.R), the normal, abnormal and drought months of the year were predicted. The volume of water and discharge was calculated. The proposed dam site is along 200-m long rocky gorge formed by the Kodku Khola. The raw water drawn from the river is chemically analyzed to know the quality of the water.

Introduction

Bounded by the Himalayan Mountains, Nepal is a country rich in freshwater resources. These resources, however, are unevenly distributed and remain undeveloped. In rural Nepal, vast numbers of people lack access to safe drinking water and rudimentary sanitation services. The daily needed water supply for the Kathmandu valley is around 177 million liters per day, but we are having just 112 million liters per day (NWSC, 2001). The city of Lalitpur is in severe deficit of drinking water for its population.

This study was entirely focused on acquiring information about the Kodku Khola Watershed (Figure1 Location Map) in reference to water supply. The investigation was thus carried out to gather information on general hydrologic, geologic, engineering aspect and water quality of the study area. The engineering geological and geotechnical investigations included reconnaissance survey and detailed field study. The topographic maps (1:10,000 and 1:25,000) of the Kathmandu Valley were used for the preliminary and detail works.

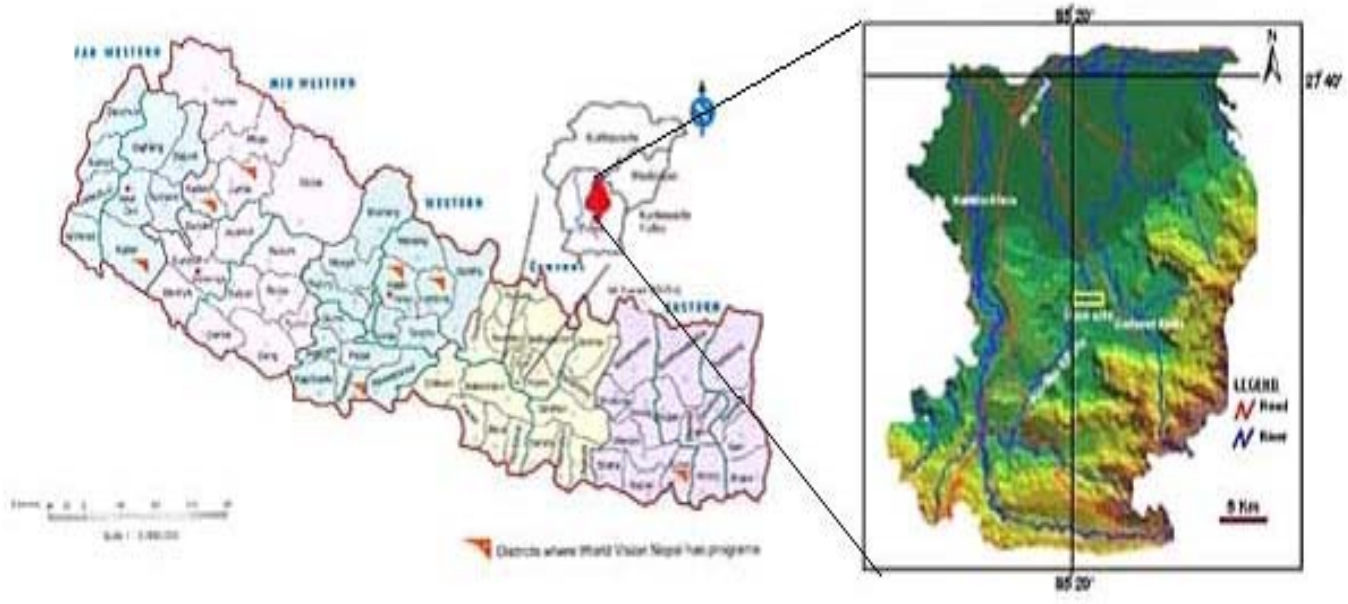

Fig.1 Location Map of the Study Area

Geology of the study Area

General Geology

The basement of study area was characterized by the Chandragiri Limestone belonging to the Phulchowki Group of the Kathmandu Complex. The age of these rocks is Paleozoic.

The rocks are blue gray fine-grained siliceous and dolomitic limestone. It is the prominent formation of the Phulchowki Group .The rock exposed at the dam site on the riverbed and both banks for about 250-m long. Orientation of the rock beds is oblique to the river flow direction. The dominant lithology is yellow to brown, weathered limestone, massive in appearance from distance but on closer view, well bedded and platy. The fresh rock has various colors ranging from white in the lower sections to gray and yellowish brown in the upper section .The beds generally trend NW/SE. Bedding thickness is typically 10 cm to 75 cm and dip in northeasterly direction at steep angles of 60-80 degrees.

Quaternary Geology of Study Area

The quaternary geology of the study area mainly comprised of Lukundol Formation and Baregaon Formation.

The Lukundol Formation dominantly consisted of weakly consolidated clay and silt and fine sand. The clay rich formation is black to dark gray at many locations of the study area. The Lukundol Formation is unconformably overlies the boulder bed and is composed mainly of carbonaceous silty-sandy clay to sandy-clayed silt. The Lukundol layer is exposed at the bottom part of the reservoir area Paddy terraces are usually carved out in the gentle slopes formed by this soil type.

The Baregaon Formation consists of gravel and sand with varying proportions of silt. It is exposed at the upper parts of the slopes on the bank of Kodku Khola stream. These Baregaon gravel usually forms steep slopes.

Recent Deposits

The recent terrace deposits occured along the valleys of the Kodku Khola watershed. These were the recent flood plain deposit. In the watershed area, these flood plains occurred at valleys below Barikhel; east of Bajrabarahi Temple. Another wider flood plain deposit was present below Khumaltar and north from Dhapakhel. The flood plain is wider in the lower reaches of the watershed.

The deposit comprised the materials derived from upstream, over the Lukundol Formation. The floodplains in the upper reaches consist of grey, clayey silt to light brown silty fine sand and the pebbles and cobbles of limestone, metasandstone, marble and phyllites. They have been derived from the surrounding gravel deposits. Similarly, in the lower reaches of the watershed, the lithology comprises of fine- to coarse-grained sand and gravel.

WATER RESOURCES IN AND AROUND KODKU BASIN

Basin Description

The Kodku Khola watershed is situated in between the Godawari Khola and the Nakhu Khola watersheds. It covers about 34 sq. km area of southeastern part of the Kathmandu Valley. The Kodku Khola is a tributary of the Manohara River, which is draining into the Bagmati River. The Kodku Khola watershed is triangular in shape, sloping gently from southeastern surrounding ridges of Godawari towards the central valley floor. Maximum

length is about 10 km along north south direction and approximately 5 km wide in east west direction along the Godawari hill area.

The Kodku Khola is the north flowing river. It originates from the north facing slopes of the Tileswor Danda and Bhagwan Danda, located at the southern area of the Kathmandu Valley. The general direction of flow is from south to north, reaching to the center of the Valley and joins the Manohara River.

Kodku Reservoir is situated about 10 km south of Kathmandu City. This basin is located in the Lalitpur district, Bagmati Zone. Nakhu Khola bound the basin on the east and south, Manohara River on the north, and Godawari Khola on the West. In the catchment area, the land is cultivated with paddy rice, wheat and vegetables extending from terrace up the mild slope of the upstream mountain. The drainage area at the proposed dam site is about 16.5 sq. km.

The river course originates from the mountainous area (elevation of about 1970 m) to the valley plain (elevation of about 1360 m). The length of the main channel from upstream catchment boundary to the dam site is about 6.7 km, and the associated catchment area is 16.5 km^2 (measured on 1: 10000 topographical map). This catchment can be classified as radial basin shape, of which water flows northward and finally join with Manohara River.

Rainfall

Rainfall in Kathmandu valley occurs mainly during monsoon months, which starts in the middle of June and lasts until middle of September. About 80 percent of annual rainfall occurs in this period. The other rainfall period is the pre-monsoon months from March to May.

There were ten rainfall stations in the Kathmandu. The rainfall data collected form rain gauge stations (Khumaltar1029, Godawari102294, Kathmandu Airport, 103093) were analyzed for determining different hydrological relationships. Rainfall data analysis provides an estimate of future rainfall trend that determines the rainfall intensity and occurrence of flood producing storms. Seasonal and annual rainfall variation was determined. Rainfall distribution at various frequencies was studied. The normal, abnormal and drought month/year predicted. Determining the different rainfall characteristics can do precipitation analysis. It includes intensity, duration, frequency, maximum and minimum rainfall etc.

Similarly the calculated mean annual rainfall data from the Khumaltar, Godawari and

Airport stations were 123.779 mm, 149.436 mm and 1599.22 mm, respectively.

The mean annual rainfall is used to find out the normal, abnormal or deficit rainfall, described as under.

Normal Year: Any year receiving the rainfall in between the limit of $\overline{X}$ + S.D. is known as the normal year. In other words, it has the range of precipitation from $\overline{X}$ +S.D. to $\overline{X}$ - S.D., in which $\overline{X}$ is denote as the mean annual rainfall and S.D. is used for standard deviation. The value of S.D. can be calculated using the equation:

$$S.D.= \sigma = \sqrt{\Sigma (X_i - \overline{X})^2 / n-1}$$

Where,

n =total number of data

X_i =i th data

$\overline{X}$ =Mean rainfall

Abnormal Year: The year, which receives the rainfall more than or equal to $\overline{X}$ +S.D., is called as abnormal year. $\overline{X}$ and S.D. are same as denoted earlier. The abnormal years are also known by the name of wet years.

Drought Year: The year, in which total rainfall amount is less that or equal to $\overline{X}$ -S.D is called drought year or deficient year.

The calculated standard deviation of the three rainfall stations are:

1. Khumaltar station 15.88 cm

2. Godawari station 61.07 cm

3. Airport station 17.06 cm

From the standard deviation of each year normal, abnormal, and drought year was determined.

Year	Year Type
1994	NY
1995	NY
1996	NY
1997	NY
1998	NY
1999	NY
2000	NY
2001	DY
2002	NY
2003	NY

Table 1 Table for describing type of each year

The intensity of the maximum rainfall in a day of each year falls in the heavy category. The intensity of 10-year lies in the heavy intensity. Thus, every year has at least one or more day of rainfall with heavy rainfall intensity. The knowledge of rainfall intensity has prime importance for deriving the flood hydrograph of the maximum possible flood or runoff for proper design of hydrologic routing.

Discharge measurement

River discharge is an important property and is frequently monitored along major rivers. The discharge (flow) cannot be measured directly in a river or stream like it can from a pipe or hose because the rate is too high (cubic feet per second, cfs) and it is distributed across too large of a cross-section. Thus, the discharge (Q) was calculated from the average stream velocity (V) and cross-sectional area (A):

$$Q = V \cdot A$$

Where Q is the stream discharge (flow), V is the *average stream velocity*, and A is the cross- sectional area perpendicular to flow.

Actual velocities vary along the river length, width, and depth. Stream velocities also vary similarly along the width, that is the velocity is near zero at the edges and reach a maximum in the central part of the stream. Deviations from ideal velocity profiles occur often, especially along bends in the river, around structures that disrupt the flow, and irregular bottom shapes.

Float Method specialized equipment is typically needed for measuring stream velocities beneath the river surface. The surface velocity can be measured easily with a stopwatch and small floats (small enough that their movement is unaffected by wind, e.g., ping pong balls).

A surveying tape was needed to measure the river/stream width and the distance traveled. It is more convenient to have 2 tapes placed transverse to the river flow just above the surface at two sections separated a distance at least 2 or 3 times the nominal river width so that it is easy to note when the float passes the start and finish positions.

The discharge of water in river was calculated by taking six different locations through out the whole river.

Location	Discharge m^3/sec
L1	22.241 m^3/sec
L2	17.346 m^3/sec
L3	56.943 m3/sec
L4	47.242 m3/sec
L5	38.99 m3/sec
L6	49.57 m3/sec

Table 2 Stream discharge measurement using float method

The drainage pattern of the Kodku Khola is dendritic with parallel system occurring in between the colluvial terraces present at the outer reaches. Major tributaries of the network are fed by perennial resources, with seasonal fluctuation of discharge amount. This fluctuation is enhanced by many seasonal tributaries. There are some springs and ponds with source from groundwater, which add to the discharge of the watershed.

ENGINEERING INVESTIGATION OF THE KODKU KHOLA BASIN

The topography at the gorge (dam site) and at the upper part of the Kodku Khola valley was steep with slope inclination varying from 25° to 50°. However, a major part of the Kodku Khola valley including the proposed reservoir area exhibited a rolling terrain, which has largely been carved out into cultivated terraces. Such terraces lie generally up to the elevation of 1500 m amsl. The valleys in this part were significantly wide with wider flood plain, low banks and meandering nature of the river.

The rocks exposed at the dam site belong to the Chandragiri Limestone Formation of Kathmandu Complex, and consist of blue grey fine-grained siliceous and dolomitic limestone with occasional argillaceous partings. Bedding thickness is typically 10 cm to 75 cm. The rock beds dip in northeasterly direction at steep angles of 60-80 degrees. Orientation of the rock beds was oblique to the river flow direction.

At the dam site bedrock was exposed on both banks for about 250-m long stretch of the river course. The rock is fresh to slightly weathered in the exposures along the gorge. At the top of the ridge and in the north or south facing slopes, the rock is moderately, and at places, highly weathered giving rise usually to 1-4 m thickness of residual soil.

Joint Analysis of the Dam Site

In the dam site area, three prominent joint sets were existed. The orientations of the Joint sets 1, 2 and 3 were $115^0/05^0$, $306^0/26^0$ and $151^0/73^0$ respectively and finally the attitude of the cut slope was $081^0/63^0$.Joint analysis of dam site area showed that the wedges formed by intersecting two joint sets 1 & 3 and 2 & 3 oriented in the opposite directions to the cut slope, this means there was not any probability of failure due to the wedges formed by joints 2, 3 & 1. The lateral wedge formed by the joint 1&2 is stable as it dips opposite to the cut slope.

Overall the joint set 2 has a great probability of failure as the joint set 2 orients to the opposite direction to the cut slope; this may a great chance to toppling failure. Among all joint sets joint set 2 may be the probable cause of failure in the dam site.

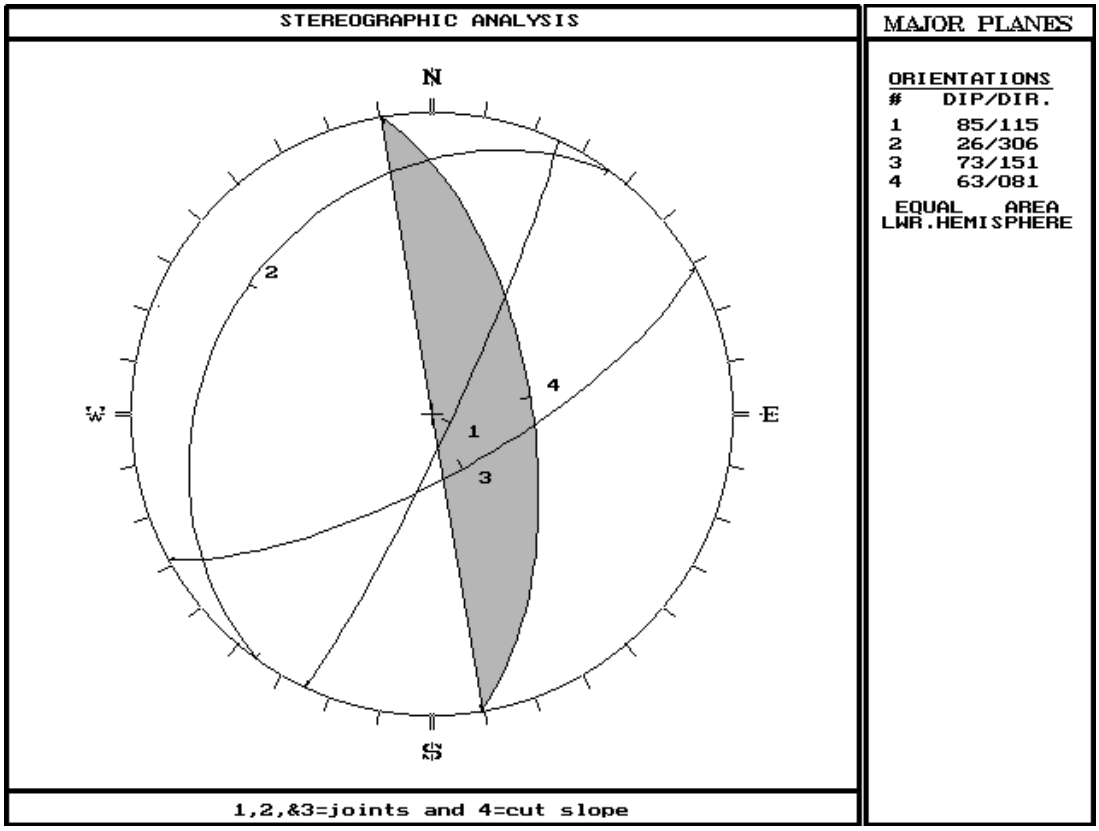

Fig 2 Stereographic projection of Joints in the Dam Site

Geotechnical Aspects of Construction

Dam Site Location

From the topography of the Kodku Khola basin, possible locations of the dam sites were limited and only one favorable site was located at a narrow V -shaped mountain gap, on the Kodku Khola near Baregaon village, which is only about one kilometer from the Kathmandu, Godawari Botanical Garden highway. At the dam site, there existed a small

concrete weir with an irrigation canal to serve agricultural area downstream. It is considered that moving the dam site further downstream is not suitable due to the unstable abutment on the left side (looking downstream) which has been opened for a rock quarry. Rock foundation is situated along the dam axis. The rock is thinly bedded siliceous limestone with a bedding thickness of 10 to 60 cm, mostly fresh to moderately weathered. The bedding plane was steeply dipping due northeast and the strike of the bedding plane is oriented at an axis of 50-60 degrees with the dam axis. The rock is medium hard to hard. The limestone contains argillaceous partings of less than a cm up to half a meter thickness.

Type of Dam

Judging from the available construction materials in the vicinity of the proposed dam site, and from the advantage of clayey and silty soils, which are highly capable of resisting seismic acceleration from earthquake, the main dam is preliminarily designed as a homogeneous earthfill type. The other possible alternative is a rockfill with impervious core type.

Spillway

The rock slope around the area is almost stable. However, the presence of the precarious rock slope in the quarry scar in the downstream left bank demands rock bolting in the excavated face. The colluvium at the north-facing slope has been found very thick.

The necessity of lining the spillway floor is obvious due to the presence of solution cavities in the limestone as revealed by the high permeability in boreholes along the spillway axis.

Main factors which indicate a proper type of spillway normally include topographic and geologic conditions, operation method and its, discharge capacity.

The spillway site for Kodku Dam was proposed on the left abutment of the dam after assessing the available information and results from several site reconnaissance. Such topographic and geologic conditions seemed to be suitable for a gravity overflow spillway.

Water Quality of the river

Raw water drawn from Kodku Khola is chemically analyzed to know the quality of water. Some water quality parameters can be improved by reservoir physical, chemical and biochemical processes. The quality is based in the chemical analysis if reference with the most important parameters like Turbidity, Hardness, Alkalinity, Iron, Chloride, Phosphates, Organic matters, Bacteriological etc.

Result/Conclusion

The study area comprised rocks of the middle sections of the Phulchowki group of the Kathmandu Complex. The rock of Chandragiri Limestone is blue grey fine-grained siliceous and dolomitic limestone. It is the prominent formation of the Phulchowki Group. The rock exposed at the dam site on the riverbed and both banks for about 250-m long. Orientation of the rock beds is oblique to the river flow direction. The fluvial and lacustrine deposits consisting mainly of gravel, clay, and clayey silt occupy a greater part of the project area. The sediments are more or less unconsolidated.

Kodku Reservoir is situated about 10 km. south of Kathmandu City. Nakhu Khola bound the basin on the east and south, Manohara River on the north, and Godawari Khola on the West. In the Catchment area, the land is cultivated with paddy rice, wheat and vegetables extending from terrace up the mild slope of the upstream mountain. The drainage area at the proposed dam site is about 16.5 sq. km.

The maximum rainfall occurs in Kathmandu in around the month of June and July. 70% of flow in the Kathmandu valley occurs in monsoon months, which is from June through September. Flow in the months after monsoon period is higher than that in the pre-monsoon months. The mean annual flow at the Dam site is 0.384 m^3/s.

The dam site for the Kodku Khola lied near the village of Baregaon in the southem part of Kathmandu Valley at one of a few outcrops of bed rock-within the basin. The reservoir area lies within the deposits of lacustrine and fluvial sediments. The rocks exposed at the dam site belong to the Chandragiri Limestone Formation of Kathmandu Complex, and consist of blue grey fine-grained siliceous and dolomitic limestone.

The kodkhu khola is appreciable for the drinking water source if implemented The river being the near to the Lalitpur is best source for the drinking water supply. The geological

and geotechnical investigation shows that quantity of water flow is enough and can be used as drinking water that will very much minimize the lack of drinking water in city.

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