Success to Abundant Water Supply in Kathmandu Valley

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Dedication

This thesis is dedicated to all Nepalese who are in acute problem of water crisis.

Abstract

Despite being renowned as one of the richest countries in water resources with the snowcaps of the Himalayas, Nepal has not been able to utilize its tremendous water resources. Agriculture, which is the major occupation of Nepalese people, has a water requirement that is very high throughout the entire year. Besides the need of fresh drinking water for human consumption, the importance of surface water sources is also high because of the country's dependency on hydropower electricity.

Today, Kathmandu, the capital city, is already facing an overwhelming tragedy of clean potable water scarcity with only a few hours of water supply per week and blackout of more than 12 hours per day. Besides lack of quantity, quality issues are also contributing to the water crisis. Rapid population growth and direct waste disposal into the rivers within the city are the major two reasons for depletion of both surface and ground water quality and quantity as well. Cultural and political interventions further exacerbate the issue. Various government and non-government organizations both national as well as international, are attempting to fulfill the water demand for all of the water users in the valley. However, the progress towards both quality and quantity has been slow due to lack of appropriate technology, bureaucratic entanglements and lack of finance. Not to be forgotten are the huge roles of corruption at the various levels of bureaucracy and more than a decade long political unrest.

The case in Kathmandu Valley is not so unique water crisis compared to other parts of the world. Nepal water problems are not caused by lack of the resources but for other reasons unrelated to its abundant water resources such as distribution, management and lack of infrastructures etc. In this context, this paper intends to explore the major problems and the hurdles in supply of safe and sufficient drinking water, to study and analyze the ongoing efforts to resolve the problems and to recommend the most culturally appropriate, adaptable and cost effective principles and strategies to create sustainable water management system in the Valley. The study will include surveys to determine the public perception of the water crisis, conduct interviews of water officials in the rural and urban areas of Kathmandu Valley and given an analysis of recent reports and studies from previous experts, quantification of local water availability for sustainable management and future supply.

This research will reveal some of the hidden issues behind the water crisis and direct to appropriate and cost effective solutions for developing countries like Nepal. The water budget calculation will disclose the availability of local sustainable water and provides the measures

and necessity to maintain the balance in hydrological cycle which helps to assure water availability in future for the abundant water supply in Kathmandu Valley. I believe that abundant supply of safe drinking water is possible from the existing water resources if it can be used with a sustainably managed system. I hope to illuminate and clarify the issues surrounding the water crisis and make recommendations to help people move towards a more sustainable supply of potable water.

Abbreviations

BWR: Basic Water Requirement

CBS: Central Bureau of Statistics

CIUD: Center for Integrated Urban Development

DUDBC: Department of Urban Development and Building Construction

GWDB: Groundwater Resources Development Board

HKH: The Hindu Kush Himalaya

ICIMOD: International Center for Integrated Mountain Development

JICA: Japanese International Cooperative Agency

Ktm: Kathmandu Valley

KUKL: Kathmandu Upatyaka Khanepani Limited

KVWSMB: Kathmandu Valley Water Supply and Management Board

Lpcd: Liters per capita per day

ML: Million Liters

MLD**:** Million liters per day

MWSDB: Melamchi Water Supply Development Board

NGOFUWS: NGO Forum for Urban Water Supply and Sanitation

NLSS: Nepal Living Standard Survey

NWSC: Nepal Water Supply Corporation

UNW-AIS: UN-Water Activity Information System

VDC: Village Development Committee

WECS: Water resources of Nepal in context of climate change

Glossary of Non-English Words

Upatyaka: Valley

Khanepani: Drinking Water

Hitis: Traditional Water Spouts

Khola: River

Units

1 US Dollar = 87.60 Nepalese Rupee as of 05/17/2013.

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1. Introduction

1.1. Introduction

The concept of sustainability is usually considered from an anthropocentric point of view. Thus, human behavior greatly influences the character of demand management of water too. In general, water supply system is considered sustainable when it could supply adequate water quantity and appropriate quality for a given need, without compromising the future ability to provide this capacity and quality balancing the three goals of economic feasibility, social responsibilities and environmental integrity. The water supply is used for various purposes like drinking, domestic applications, agriculture etc and its sustainability is based on its best-integrated water resource management. There might be no better example for the unsustainable lifestyle than how Kathmandu Valley is living in terms of usage of available natural water resources. Water resources management is as much cultural as it is technical issue. Through this study, status of water resources, trend of water consumption, alternative approaches for water demand fulfillment of the city and the perspectives of Kathmandu Valley on water world are illustrated, the sustainable amount of available water quantified for various sectors and approaches for sustainable water supply, use and its management in Kathmandu Valley are recommended.

Chapter 1 contains a brief description regarding the need of this study, methodology applied and major research questions. Chapter 2 shows the facts about the country topography, climate and water resources of the country and Kathmandu Valley and water culture. Chapter 3 describes about the urbanization, Chapter 4 focuses on the water supply sector, scarcity scenarios and the trend of cultural adoption for demand fulfillment of city water by Kathmandu Valley, and Chapter 5 expresses the amount of available water and the possible sustainable use using the natural water cycle. With reference to the studies and based on the collection of data shown in previous chapters, some recommendations are suggested in Chapter 6 for the sustainable water supply in future Kathmandu Valley with some strategies which must be considered for its proper sustainable management.

1.2. Background

Nepal is a land locked country with three percent of its area covered with water resources. Because of the snowcaps of the Himalayan mountains, Nepal is known as one of the rich countries in water resources with more than 6000 rivers, and other natural sources including, lakes, ponds, and springs. Agriculture is one of the main occupations of Nepal, eighty-three percent of the population relies on natural resources for their livelihood, and even irrigation in Nepal is completely dependent on natural rainfall. In Kathmandu Valley including the capital city i.e. Kathmandu (Ktm), seasonal rivers are the main source of water for domestic purposes. Rivers in Kathmandu Valley are not only in use for domestic water supply, but also used as main repositories for the nation's untreated sewage, solid waste, and industrial effluent.

Kathmandu Valley is getting its water supply from surface sources and ground water sources but is still facing a huge gap between the demand and supply. Groundwater abstraction started in 1980 A.D. and became the most reliable sources for the increasing urban population. Since 1986, the abstraction rate exceeds the recharging rate, which resulted in depletion of the ground water level. This is already a sign of unsustainable management of the water resources.

The unplanned urban city development is the biggest challenge to accomplish the goal to meet water demand of current population even though there is an abundant available water resource but not the qualitative one. The disorganized urban sprawl without any proper zoning, unmanaged infrastructure and utilities has complicated the efforts to integrate the supply in every corner of the city.

The literacy level of Nepal is still low in comparison to the rest of the world. According to reports from the Nepal Living Standards Survey (NLSS) 2010/11, Nepal’s adult literacy rate is 56.6 percent with huge variation between men and women.[2] Lack of education is the key factor for unconscious misuse of water in household level, and negligence in the use of water and disposal of water. Besides this, lack of finance and political disorders are also affecting sustainable development of Kathmandu Valley along with natural resources.

1.3. Need for the Study

Kathmandu Valley is the most urbanized area in Nepal and considered as the cultural, historical and economical center of Nepal. The bowl shaped valley contains major river Bagmati and its tributaries, which are not only culturally important but also used to provide drinking water for the Kathmandu Valley. Most of these rivers in it are almost in dry condition containing more sewage than the fresh water especially in dry season. Kathmandu Valley rarely remembers its original beauty. These rivers were the main source of water supply and still are at least reliable during the wet season for Kathmandu Valley. Water supply here is facing growing challenges, including increasing demands, deteriorating infrastructures, degradation of fresh water sources and maintaining financially sound operations. To maintain the economic viability of city life and fulfill its demand, it has already started to look for alternate sources outside the valley. The Water Company of Kathmandu is looking adjacent valleys to import clean water resources. This will leave these valleys without adequate water resources for their use. The traditional sustainable water supply concept has almost diminished and adaptation of modern technology is facing these challenges for adequate supply.

I felt an acute need to study the issues of Kathmandu Valley on water use, conservation and alternatives for water demand. I believe, the government is working from a short-term technical perspective and attempting to remedy various problems for water supply, which will not be immediately available. Kathmandu Valley should prioritize social and cultural issues for successful sustainable management of the water resources. This study will contribute toward quantifying the sustainable water use and its management in Kathmandu Valley.

1.4. Research questions

Despite its richness in water resource, Kathmandu Valley is going through such scarcity in its water supply that I was struck by this extreme condition and prompted me to ask a few questions and investigate further to discover the details of the barriers in the water supply system. The following are some of the questions to which I tried to find the answers through analysis of available data from various organizations and, using antidotal stories from local people and interviews with professionals.

a) What is the magnitude of the growth of clean water demand in Kathmandu Valley in the near and far future?

b) What are the perspectives of Kathmandu's people regarding water supply, water use, reuse and conservation?

c) How can water usage become more sustainable in Kathmandu Valley in both in terms of supply and demand?

1.5. Material and Methodology:

This study is conducted using different secondary sources, spot observation in different locations of Kathmandu Valley and personal interviews. The survey questionnaires that have been used for surveys are attached in Annexure. Unscientific face-to-face surveys became my base point to analyze the different perspectives of people regarding water supply, demand, alternatives sources for demand fulfillment and water conservation. I had interviews with professionals working in water related departments including Ground Resources Development Board (GRDB), Department of Hydrology and Meteorology (DHM), Kathmandu Upatyaka Khanepani Limited (KUKL), some Village development committees (VDC), and the Center for Integrated Urban Development (CIUD).

Data collected through primary and secondary sources are analyzed through different frameworks and technologies such as time series comparisons for the change in urban pattern and development, water supply, demand and ground water extraction patterns. Separate open-ended questions were prepared for the behavioral analysis of the Kathmandu Valley towards water regarding 3 R's (Retention, Reduce, and Reuse) of sustainability including 4^{th} R i.e. recharging the groundwater.

1.5.1. Data Availability

The rainfall data and temperature data for 2011 is collected from Department of Hydrology and Meteorology for the year. The average monthly rainfall for 1991-2006 and 2011 is calculated as shown in table. From available data, the annual average rainfall is obtained for the calculations. The observed average monthly evapotranspiration data from 1968 to 1980 recorded at Kathmandu airport station is collected from the DHM, for 2001 from KUKL and for 2008 from GRDB.

2. Climatology and Hydrology of Kathmandu Valley

2.1. Introduction

Nepal is a small rectangular shaped landlocked country with an average North-South width of about 193 Kilometers (Km) and East-West length averaged to 885 Km located at 28° 00” N, 84° 38” E. It covers an area of 147,181 Km^{2}. It shares border with China at the north and India at the south, east and west. Its altitude varies between 60 m at flat Terai region and 8,850 m at the highest peak, Mount Everest. Geographically, Nepal has four horizontal regions i.e. Himalayan region, Mountain region, Hilly region and Terai region located from north to south respectively. The Himalayan range covers 15% of the total area of Nepal. World's famous peaks like Mt. Everest (8848 m), Kanchenjunga (8586m), Dhaulagiri (8167 m) are the essence of the region with sparse vegetation up to the altitude of 4,500 m. Hilly region where Kathmandu Valley is located covers 68% of the total land area of the country and. elevation ranges from 500 to 3,000m above sea level. The Terai region, lowland areas, covers 17% of the total land area of Nepal. It provides excellent farming land and the average elevation of lowlands is 100 to 300m above sea level.

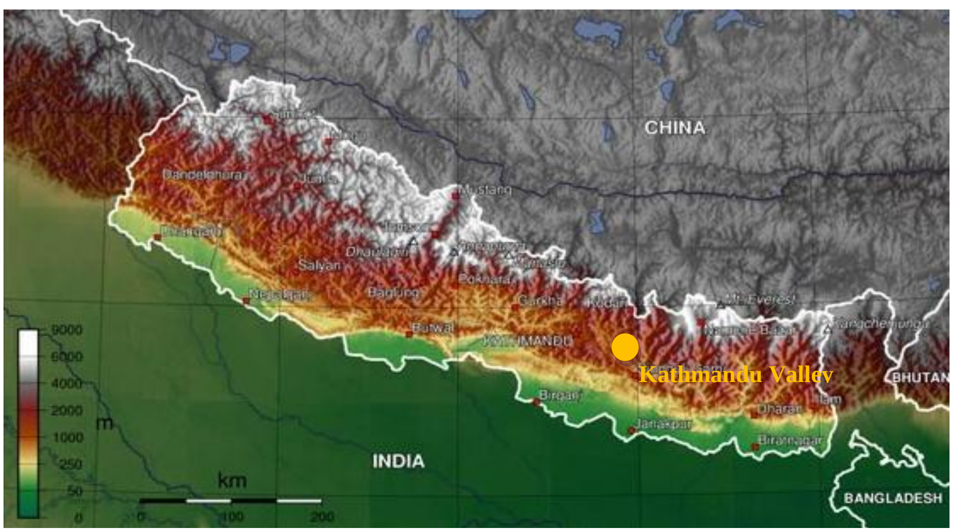


Figure 1 Map showing three different geographical region of Nepal with location of Kathmandu Valley. Source: http://www.uniquetreks.com

The Kathmandu Valley covers 900 Km^{2} whereas the study area i.e. actual Valley area of Kathmandu Valley area extends 30 Km East-West and 25 Km North-South encompassing an area of 650 Km^{2}. It is almost a circular intermountain basin exhibiting two major geographic units: Valley floor (1350m) and surrounding hills Shivapuri lekh (2732m) in the north, Nagarkot

(2166 m) in the east, Phulchoki (2765 m) in the south and Chandragiri (2550m) in the west. Half of Kathmandu Valley area including the Valley floor is gently sloped (less than 5 degree) towards the center and dissected in the radial direction by the networks of rivers. More than 20% of area has more than 20-degree slope.

Figure 2 Ariel View of Kathmandu Valley showing major roads. Source: www.googlemap.com

2.2. Climate

Due to geographic feature, Nepal experiences a wide range of climates varying from sub-tropical to the Alpine type with various elevations within a span of less than 200 Kilometers (Km). According to the Department of Hydrology and Meteorology (DHM), in the decades from 1981-2010, the highest temperature felt in Kathmandu Valley was 29.1 degree centigrade in June and lowest temperature is 19.1 degree centigrade in January. Temperature record for decade of 1981 - 2010 is attached in Table C in appendix

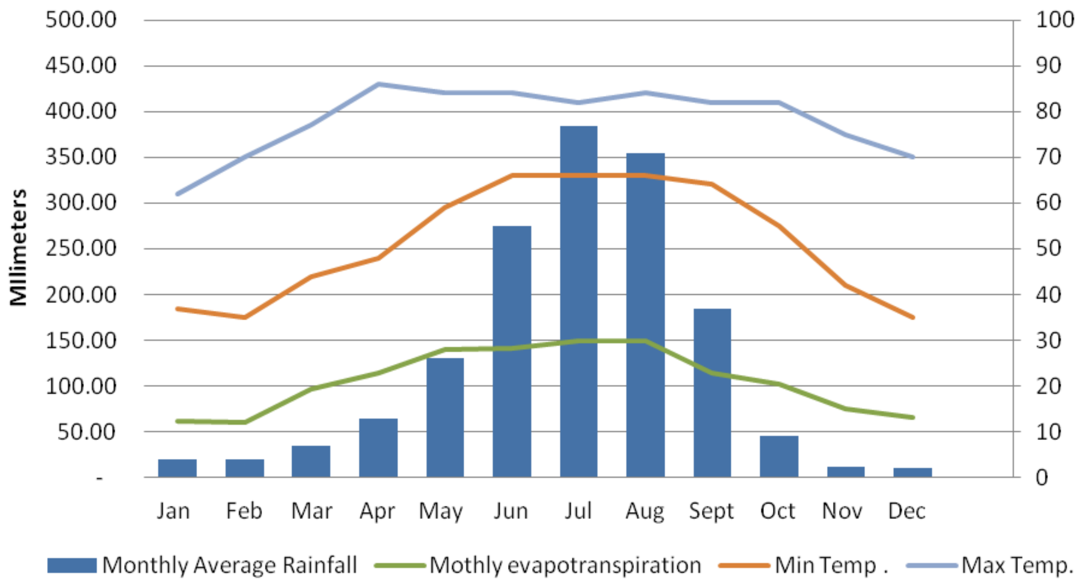


Figure 3 Average monthly precipitation, maximum temperature and minimum temperature and evapotranspiration in Kathmandu Valley, Source, Department of Hydrology and Meteorology, Main report from KUKL and Precipitation Analysis from 1991- 2006.

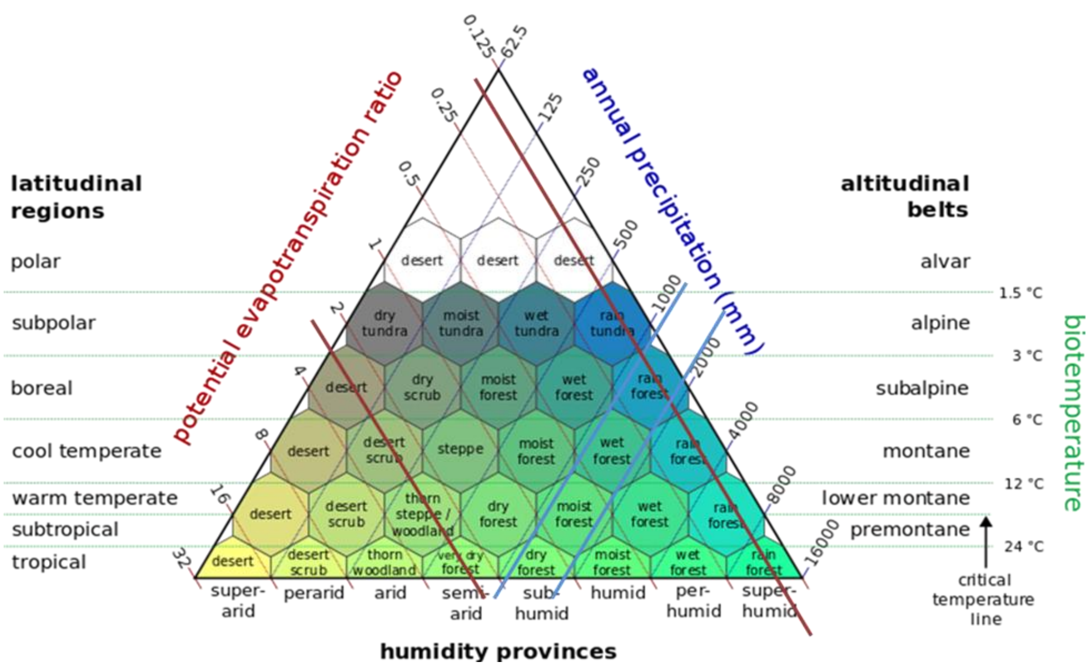


Figure 4 The Holdridge life zone climate classification system, showing the parameters of Kathmandu Valley. Source: http://en.wikipedia.org/wiki/File:Lifezones_Pengo.svg

Kathmandu Valley on average receives 1533.61 millimeters (mm) (60.38 inches) of rainfall per year i.e. 996,846.09 million liters (ML), most of which drains out of valley as surface runoff because of steep hills around the valley which makes the quick run off of rainfall before it infiltrate into ground. Rainfall, in rainy seasons (June to September) accounts for the 80% of annual rainfall. This four-month monsoon season is the dominating factor for shaping the climate of Nepal with uneven distribution of precipitation. The detail record of rainfall from various stations in Kathmandu Valley is attached in Table D in appendix.

As shown in figure. 4, according to the Holdridge life zone climate classification system, Kathmandu Valley falls under subhumid warm temperate rainy zone with two distinctive seasons i.e. wet summer and dry winter. The evapotranspiration in summer months exceeds the precipitation where as it is low in four months of wet season. The average relative humidity is 75%. The prominent biome is wet forest (Decidious monsoon forest) with different types of vegetations like pine, elm, beech, maple and so forth with coniferous trees at higher elevation.

2.3. Hydrology

Nepal is very renowned as the second richest country after Brazil for hydro potential. Besides the importance of water resources for hydroelectricity generation and household purposes, water resources have high demand for other various purposes like personal hygiene, agriculture, religious activities, industrial production, and recreational activities such as navigating, rafting, swimming, and fishing. Thus the economy of the country is highly dependable on water resources as agriculture and tourism are the major occupation of the country.

Nepal has abundant fresh water resources as the whole country lies on the Ganga river basin with 3% of its total land area covered by water as shown in figure 5 and 6.

Figure 5 Major River Basin in HKH Region showing the location of Nepal covered by Ganga River Basin. Source: ICIMOD

2.4 Water Availability

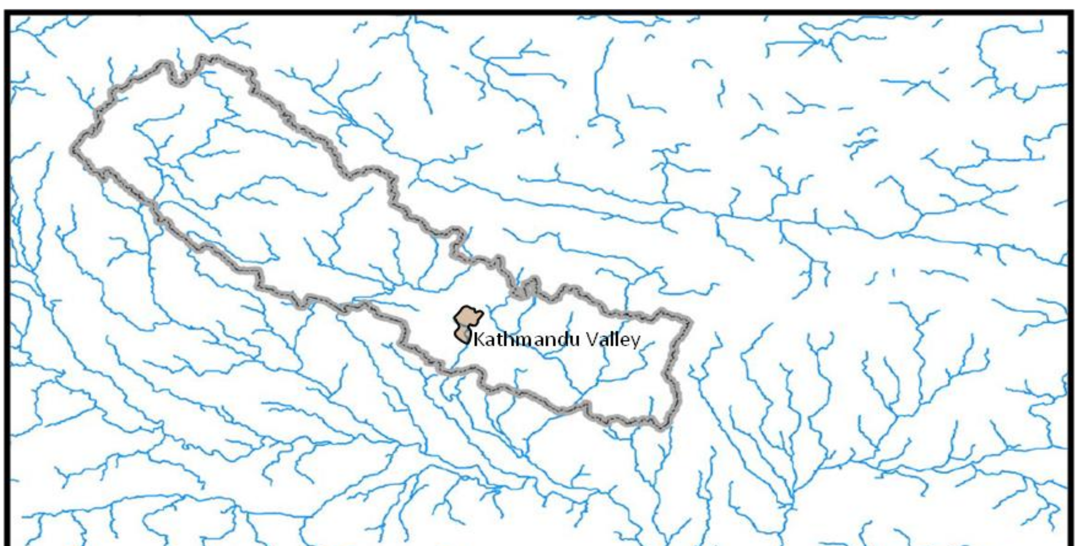


Figure 6 Map Showing trans border rivers and Nepal with location of Kathmandu Valley[3]

There are about 6000 rivers in Nepal having drainage area of 191,000 sq. km. Currently, about 10% of total precipitation in Nepal falls as snow, about 23% of Nepal's total area lie above the snowline of 5000 m, about 3.6% of Nepal's total area is covered with glaciers[4]. Among these resources, rivers and some springs are the major source point for the surface water for Kathmandu Valley water supply. Summary on the water availability and use in different sectors in Nepal is shown in Table 1.

Table 1 shows that per capita availability of water resources in the country, which is estimated to be 8,900 m^3/capital/ year, is 10 times higher than the water withdrawal of 890 m^3/capital/year. This shows the abundance of water resource in Nepal.

Assessment of Water Resources Availability and Use in Nepal (1991-2011)				
Particulars	**1991**	**2001**	**2011**	Remarks
Annual Renewable Surface Water (billion m^3)	225	225	225	Including the catchments outside Nepal
Annual Renewable Groundwater (billion m^3)	12	12	12	
Total Population	18,491,097	23,151,423	26,620,809	CBS, 2011
Per Capita Renewable Surface and Groundwater ('000 m^3/year)	12.81	10.23	8.9	
Per Capita Annual Withdrawal ('000 m^3/year)	0.69	0.72	0.89	

Table 1 Water resources available in Nepal (1991-2011), Source: Nepal Country Report 2011, UN-Water Activity Information System (UNW-AIS**)**

2.4.1 Surface Sources

Rivers are the main surface water source in Kathmandu Valley. According to the origin of these rivers in Nepal, they are of three categorizes. Category 1 is the rivers originating from glaciers and snow-fed lakes. Category 2 is originating from springs and ponds of mountains and Category 3 is stream and rivulet mostly from the Chure hills in the south.

Bagmati River is one of the major rivers of Kathmandu Valley originating at Bagdwar, Sundarjal and flows through the heart of Kathmandu falls in the second category. This is also a perennial river like other rivers of Valley, fed by storm flow, and springs covering 650 km2 of catchment in Valley. Thus, the production of potable water from these rivers is also not constant throughout the year. The main stream of this river is the 7th order drainage. Its major tributaries are

Manahara, Bagmati, Dhobi, Tukucha, Bishnumati, Balkhu, Chhaima, Nakh, Kodhkhu and Godawori which are respectively of 5th, 6th, 5th, 2nd, 6th, 6th, 5th, 5th, 5th and 6th order drainage forming centripetal drainage pattern in Valley with sole outlet at Chobhar as shown in Figure 7. Hydrological cycle of Kathmandu Valley has closed loop within the valley. According to the senior hydrologist of department of hydrology and meterology, even the groundwater flows outside the Kathmandu Valley via same single outlet through Bagmati.

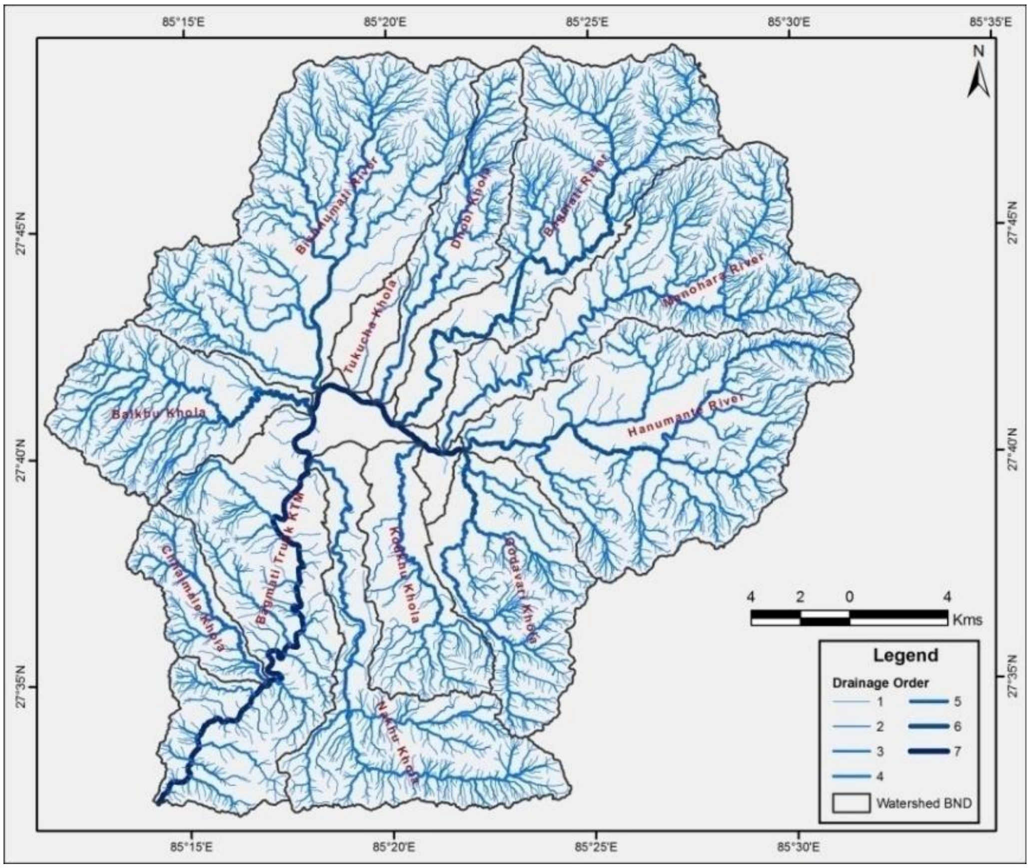


Figure 7 Map showing drainage order and river network in Kathmandu Valley. Source:[5]

2.4.2 Groundwater

The ground water basin of the Kathmandu valley covers 327 km^2 of 650 km^2 of total watershed area. Based on the physical and chemical properties and geological structure, the ground water basin is divided into three ground water districts as shown in figure. 8 i.e. Northern groundwater district, Central groundwater district and Southern ground water district. Table 3 shows more distinctive features of these zones. The Northern district has more potential for recharging and most of the water supply is extracted from this zone.

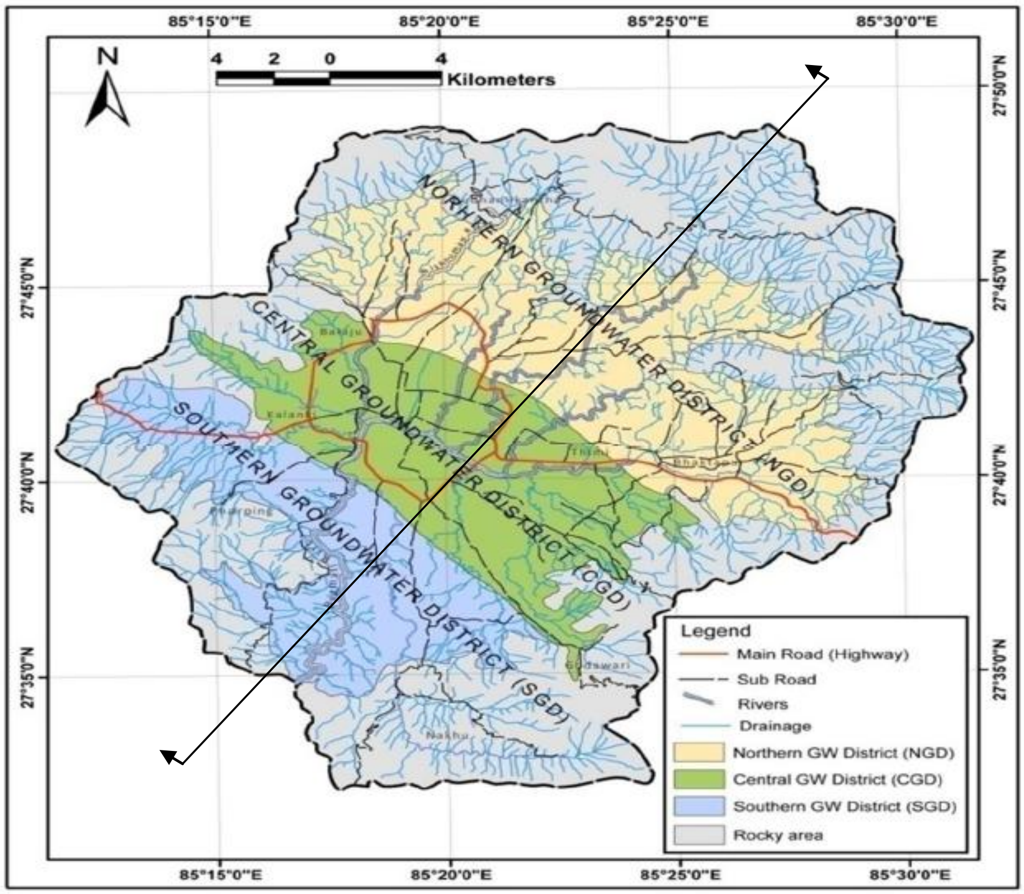


Figure 8 Map showing three groundwater districts of Kathmandu Valley. Source: GRDB

Groundwater aquifers found in Kathmandu are unconfined[1], semi-confined and confined conditions as shown in figure 9. In the central portion of valley, underlain by impermeable lacustrine clay, the water table occurs within these impermeable sediments of predominantly silts. This sediment thickness increases toward the southern side of the valley. About 200 m thick impermeable clay deposits confine the aquifer in central and southern part. Ground water aquifer system of Kathmandu Valley is considered as self-contained and isolated from other ground water basin with more or less interconnected aquifers.

[1] An unconfined aquifer is one that is open to receive water from the surface, and whose water table surface is free to fluctuate up and down, depending on the recharge/discharge rate.

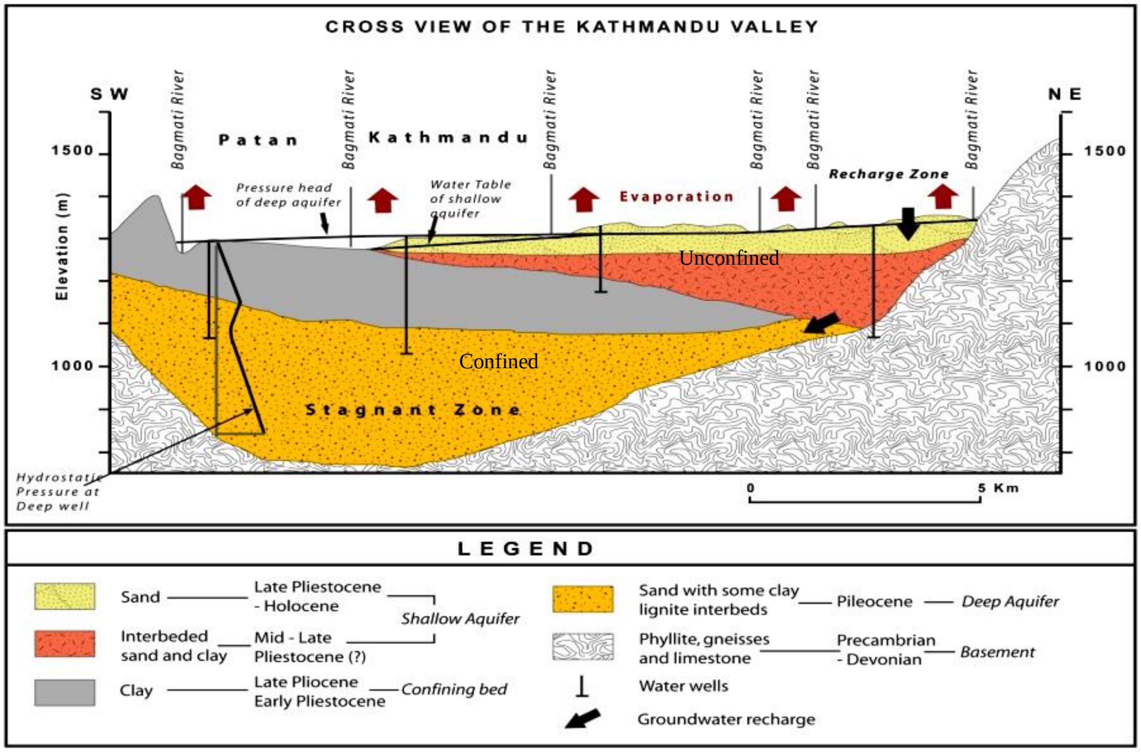


Figure 9 Cross-sectional view of Kathmandu valley showing the aquifers. Source: GRDB

Recharge to the shallow aquifers occurs mostly along the basin margins, directly from precipitation and by supply from a number of small rivers. However, recharge to the deeper aquifers is considered limited, due to the presence of clay beds that significantly restrict downward percolation. Some upward vertical leakage in the southwest of the basin is suggested through studies. The basin has been confined for 200,000 to 400,000 years. Out of 327 km^2, surface area of shallow aquifer is 241 km^2 of and only 86Km2 is by deep aquifer. The recharge rate of shallow aquifer is estimated at range of 165 mm/year i.e. 39,765 million liters per year whereas for deep aquifer it is less than 80 million liters per year only and water percolation into deep aquifer through the shallow aquifer is not viable process[6]. The deep aquifer water are the static reserves since more than 200,000 years and has very less recharging capacity in comparison to the shallow aquifer.

In Nepal, 8.8 Billion cubic meters (BCM) of ground water is annually available as a reserve for irrigation and domestic water supplies. In Kathmandu Valley shallow aquifer and deep aquifer has potential storage capacity of 1500 MCM and 600 MCM respectively and the annual rechargeable estimates vary from 4.75 (million cubic meter) MCM to 13.65 MCM[4]. Table 2 shows the availabiltiy of storage inside the aquifer to store 234,200 million liters of water.

Aquifer	Surface area Sq. Km	Aquifer Thickness (Meter)	Aquifer volume (Million liters)	Storage Capacity (Million liters)	Additional Potential storage space available (Million liters)	Recharge rate/ year
Shallow	241	0 to 85.4	7,261,270	1,425,000	226,000	165mm
Deep	86	25 to 284.4	56,813,700	572,000	8,200	55mm
Total			64,074,970	1,997,000	234,200	

Table 2 Shallow and deep aquifer details with potential water storage space. Source:[6] and [7]

Groundwater District	Use	Deposits character	Thickness of deposits	Water Character
Northern Groundwater District	Water Supply well field of NWSC; Basbari, Dhobikhola, Gokarna, Manohara and Bhaktapur	Highly permeable materials of micaceous, sand and gravel	60 m	Low electrical conductivity i.e. 100-200 micro-simens/cm
				Transmissivity: 83 to 1963 m2/day
				Few tube wells with artisan
Central Groundwater District	Private tube wells and dug wells	Impermeable black clay accompanied by some lignite and peat	200 m	High Electrical conductivity i.e. 1000 microsimens/cm
				Water age: 28000 years
				Transmissivity: 32 to 960 m2/day
				Stagnant deep aquifers
Southern Groundwater District	Water extracted from fractured bedrocks by mineral water companies.	Thick impermeable clay formation and layer of basal gravel of low permeability	More than 200m	NA

Table 3 Distinctive features of three groundwater districts of Kathmandu Valley. Source: GRDB

The northern groundwater district has more permeable deposits, ranging up to 60 meter and these area is mostly used for water supply by water utility company. The deposits of impermeable black clay layers increases more towards the southern side, which ranges from 200m in central groundwater district and more in southern groundwater district.

3. Demography and Urbanization

3.1. History of settlement

The historical document “Vanshavalis” records that initially Ktm was ruled by Gopal Bansi “Cow herds” and then from 900 to 700 BC by Mahisapals “buffalo herders” from 700 to 625 BC and by Karats kings from 625 BC to 100 AD. Lichhavi’s invaded at the end of the 5th century, which is also known as golden period in terms of cultural activities. In the 13th century, the Mallas from west Nepal came and ruled during which stratification of the caste and sub caste system was established. Kathmandu then divided into three kingdoms i.e. Kathmandu, Lalitpur and Bhaktapur. In 1769 A.D., Prithivi Narayan Shah unified small kingdoms into Nepal and declared Kathmandu as capital city. The Rana dynasty started from 1846 A.D powered by Prime Minister Jung Bahadur Kunwar and later ended in 1953 A.D (2007 B.S) due to the democratic movement led by King Tribhuwan. After Royal Massacre in 2001 A.D., Birendra’s brother Gyanendra became King but in early 2006 A.D, the unsatisfactory political factions ended the king’s government. Currently Nepal is officially the Federal Democratic Republic of Nepal.

3.2. Demography and Urbanization

In comparison, Nepal is a bit smaller than Minnesota but is crowded with a population of 26.6 million as of July 2011. It comprises of 58 municipalities and 3914 Village Development Committees. Kathmandu Valley comprises of three districts i.e. Kathmandu, Lalitpur and Bhaktapur which is divided into 5 different municipalities and 99 Village Development Committees (VDC). Village Development Committee of Nepal are the lower administrative part of its local development ministry. Each district has several VDCs, similar to municipalities but with greater public-government interaction and administration. The purpose of village development committees is to organize village people structurally at a local level and to create a partnership between the community and the public sector for improved service delivery system. Out of the 650 km^2 (230 Sq. miles) area of Kathmandu Valley, the municipality demarked area is only 97.03 km^2 where most of the services and infrastructure development is concentrated.

In the last decade, 2001-2011 population of Kathmandu Valley has increased by 14.99% i.e. from 1.4 million to 2.5 million as shown in table 4, with average annual growth rate of 1.40%, which is much lower than the 2.25% as recorded in 2001 Census. In 2001, the population density of the urban and rural areas was 985 and 138/ km^2 respectively. Kathmandu district recorded the highest population growth rate in a decade with 60.93 percent and a population density of

$4408/km^2$. Currently, Kathmandu Valley is with population of 2.51 million which is currently almost 55% of total urban population of Nepal (4525787).[8]

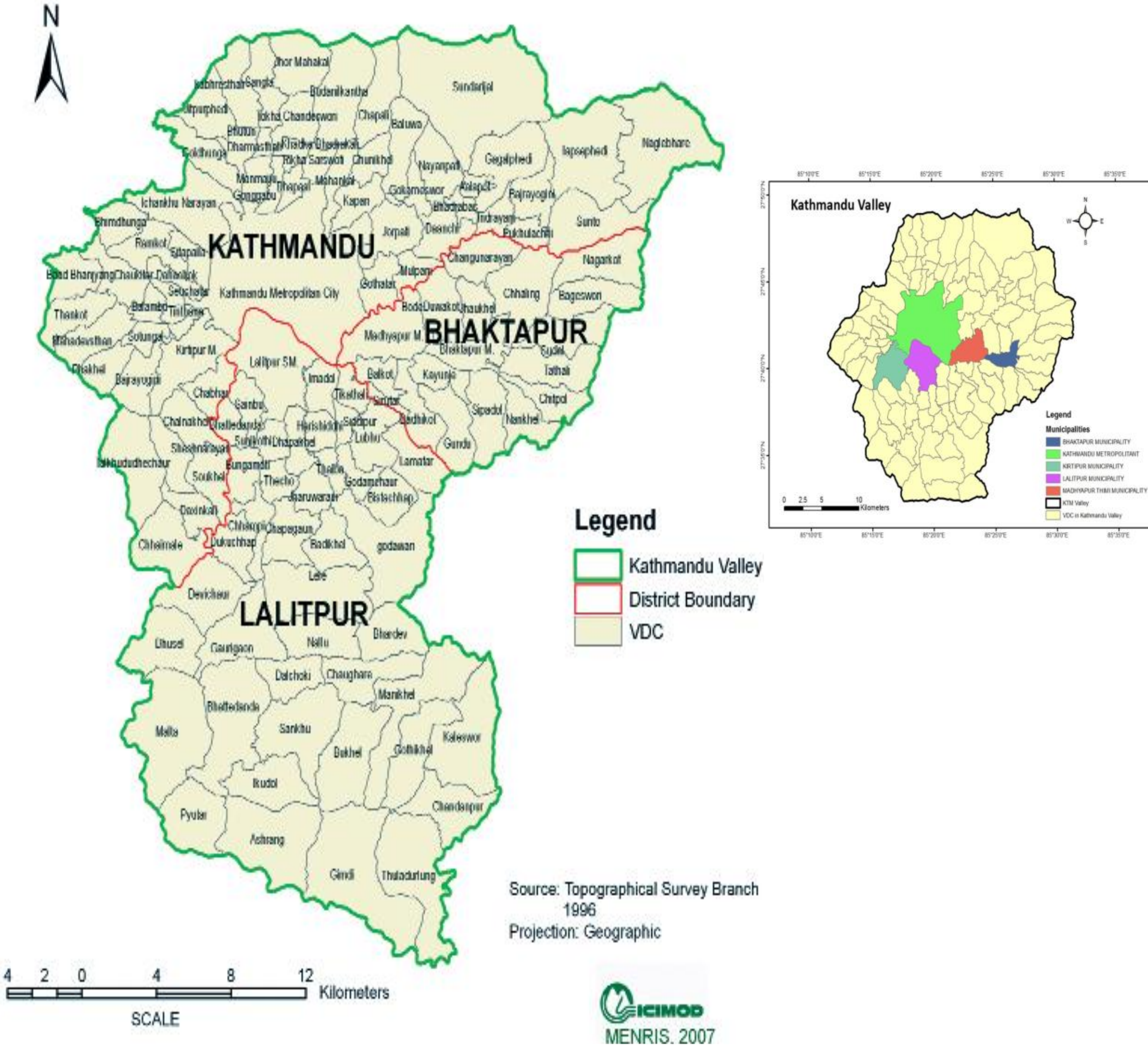


Figure 10 Kathmandu Valley map showing district boundary, municipalities and VDCs. Source: ICIMOD

Description	CENSUS 2001	% of Total Valley Population	CENSUS 2011	% of Total Valley Population
Country's total population	**23,151,423.00**		**26,620,809.00**	
Population growth rate	**2.25 %**		**1.40 %**	
Kathmandu	1,081,845.00	75.0%	1,740,978.00	**69.34%**
Lalitpur	337,785.00	23.4%	466,784.00	**18.59%**
Bhaktapur	22,461.00	1.6%	303,027.00	**12.07%**
Total Valley Population	**1,442,091.00**		**2,510,789.00**	

Table 4 Kathmandu Valley population, Source: CBS, 2011

Urban-Kathmandu Valley				
Owner	Renter	Rent Free	Other	Total
48.1%	48.5%	2.9%	0.5%	100%

Table 5 Distribution of household by occupancy status. Source: NLSS 2010/11, CBS

In Kathmandu Valley's urban area, one-half of households are living in rental space as shown in Table5. With population with no regular source of income, rental spaces are becoming more reliable sources of income for property owners in the core area of Kathmandu Valley. Thus with this benefit, mixed use of a building are more common. Almost every house built in the core area has commercial spaces in the ground floor and some have it in a few upper floors too. This culture has extended in such a way that houses permitted as residential buildings by government in core Kathmandu are functioning primarily as either business complexes or storage and people started migrating out of core city area for their residence. No records are available tracking this trend of commercial utilization of residential space and disobeying zoning laws. Recently the Department of Urban Development Building Construction (DUDBC) has started survey regarding ownership of the space.

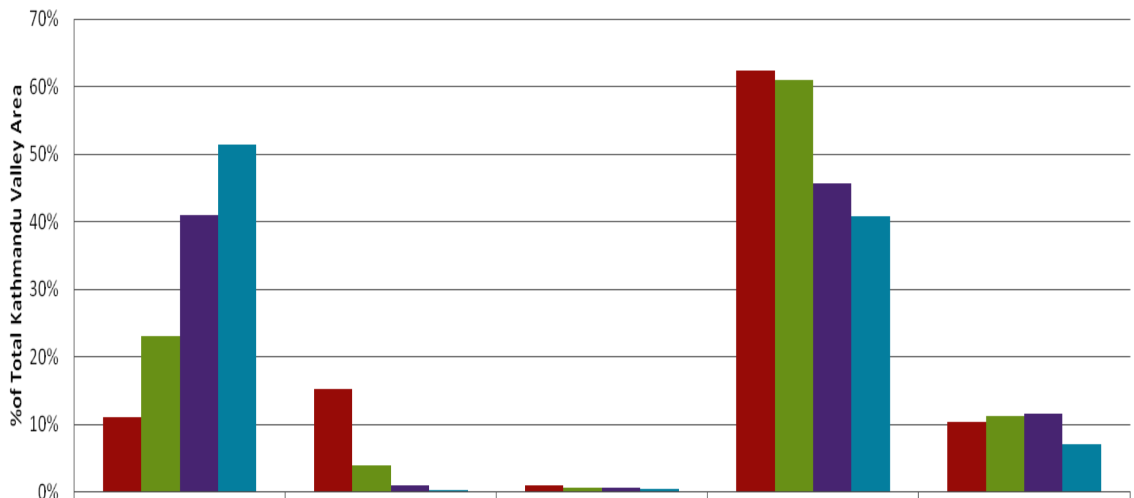
Culturally, in Nepali society, owning residence building or piece of land in capital city Kathmandu represents a good status. For this reason, people are ready to build even small buildings on the minimal land they have as permitted by the government. The policy of Kathmandu Metropolitan city regarding the land division allows to have land division up to 2 Anna 2 paisa i.e. equivalent of 855.625 sq ft area as minimum plot area. According to Nepal Living Standard Survey (NLSS) 2010/11, in the Kathmandu Valley urban area, housing plots on average are the smallest in the country. Kathmandu Valley has very diversely dispersed plot areas owned by individuals. The construction and allocation of houses on these individual plots is done without considering the rest of the urban environment. This trend is drastically different from traditional patterns of settlement as shown in figure 11. Agriculture being the main occupation, in the past, throughout Kathmandu Valley, housing was meticulously designed for compactness, thus saving precious agricultural land. The traditional urban dwellings in Kathmandu were built around courtyards that served as common open space for the surrounding plots. This avoided the need to have an individual plot for each housing unit. These courtyards acted as the water collection point from the sloped clay tiled roofs of the surrounding building and direct rain to the dug well at the center of the courtyard, which acted as the medium for recharging ground water. Later the haphazard encroachment has reduced the agricultural land and disturbed the organized development.

Figure 11 Picture showing traditional planning (left) with courtyards and new settlement (right). Source: www.google.com

Regarding the conservation of water, the recent policy by government states that in Kathmandu metropolitan city, a 10% rebate during building is permitted if a rain harvesting system is designed in newly designed building. The result of this policy could show positive impact if the people of Kathmandu incorporate this in the initial phase of building design. However, according to Kathmandu metropolitan city, nobody has come forward claiming this rebate discount. This shows the lack of financial incentive or public interest for the rainwater harvesting system.

3.2.1. Land use

Except the built up area which has increased from 11% to 51.6% from 1976 to 2009, al other natural settings in land cover are decreasing (Refer figure 12). Built up area is increasing rapidly however the graph in Figure 13 shows that the rate of increment of built up area is decreasing in comparison to the previous year's i.e. 77% increase in 2001 in comparison to 1989 which drastically decreases to 26 % and 2 % in year 2009 and 2010 respectively. Thus, Kathmandu Valley is expanding both vertically and horizontally with current density of 4480 person/Km^2. According to urban planners, from urban basic service management and disaster relief management aspects, the Kathmandu Valley only has a carrying capacity of 5 million populations.[9]



	Urban/Built Up	Open Area/ Nonuse	Water Body	Cultivated Land	Natural Vegetaion
1976	11%	15.3%	1.0%	62.3%	10.4%
1989	23.1%	3.9%	0.7%	61.0%	11.3%
2001	41%	1%	1%	46%	12%
2009	51.5%	0.3%	0.4%	40.8%	7.0%

Figure 12 Land use change in Kathmandu Valley (1976-2009), Source:[10]

People started constructing houses on their plots in their own planning and use, as they want. Dominating owner's will over the building codes with less penalty fees has made to ignore building code and build with more stories and ground coverage than what

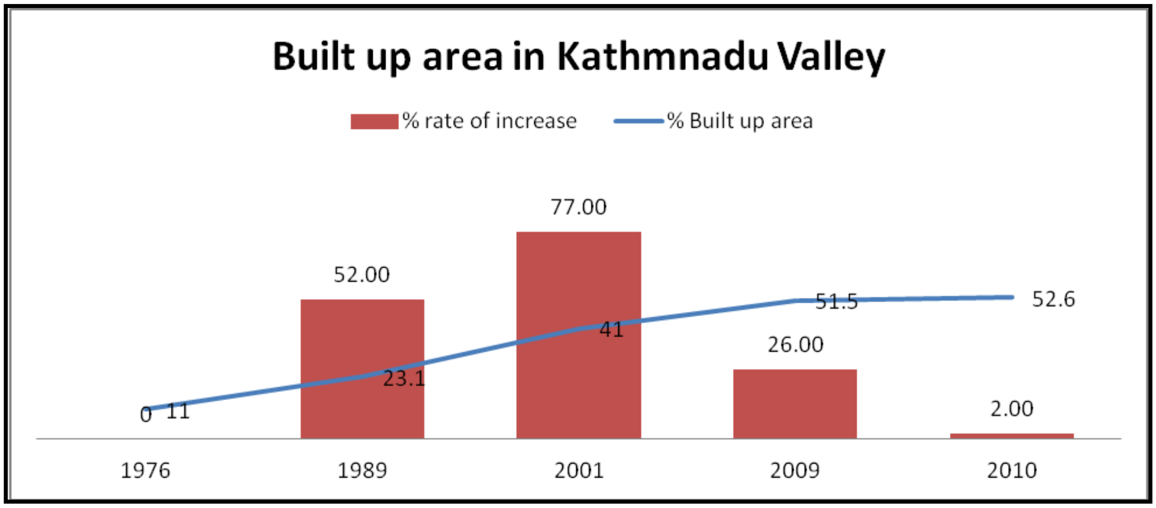


Figure 13Trend of built-up area development in municipal area. Source:[10] and[11]

building code permits. The intent of these building owners is to use the additional storey as rental space or for commercial purpose. This demand of land and space directly affects the water demand. Building construction bye law 2004 of Nepal has given proper guidance for building construction in designated zones which is not followed properly during building construction which resulted in haphazard development of urban setting. For example, in the core city area which lies under old mixed residential zone, building code has allowed for a floor Area Ratio (FAR) of 4.5 with maximum ground coverage of 80% for new construction in open area and 100% to demolish old buildings and rebuild. This allows the maximum five storey only with total height of 13.7 meter (45'-0"). In the case of commercial building, FAR is 2.5 with maximum ground coverage of 50% with 15% of land for parking space and the maximum height is 13.7 meters as for the residential buildings. With the increase in land value, the owners usually have the building registered as residential and use it for commercial purposes. Thus in the real world, the street scape is different that what we expect as result of the building construction bylaw 2004. Thus with the storey of the building, the occupancy level increases and accordingly the water demand. This is not happening in this zone only, it is the story of almost all the city core area and there is no record of such kind of unmanaged building trend in Kathmandu. The water demand can change according to the purpose of the building as shown in figure 12. Besides the changes in purpose, the unexpected additional floor areas for commercial purposes and it's occupany also affects the water demand even in same built up area.

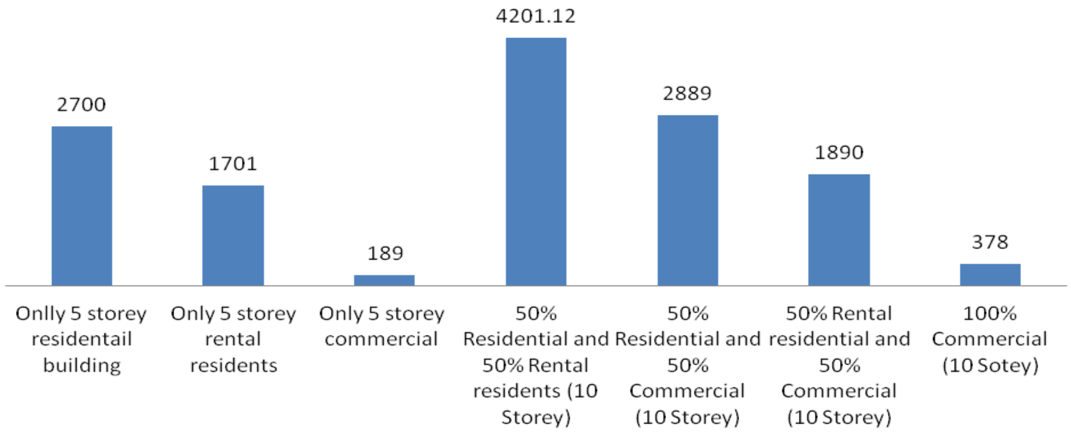


Figure 14 Water demand in buildings with different purposes.

3.3. Water and Culture

Water has pervasive influence on every facet of human life, including a sustainable ecosystem. Water resources have high environmental value to maintain a sustainable ecosystem. Rivers have always been the source of water from the start of civilization. Apart from fulfilling human needs in terms of its consumption, production, and cleaning purposes and environmental values, rivers as major source of water supply have highly influential social, cultural and historical values. The Kathmandu Valley is the central cultural spot of Nepal which is illustrated by seven groups of monuments and buildings (UNESCO World Heritage Sites) displaying the full range of artistic achievements. Kathmandu is also known as a city of temple and most of the big temples resides at river side. Thus, rivers are treated as a sacred site where rituals have taken place for generations. Since ancient times, in Nepal's cultural settings, water has had major spiritual and social dimensions. In Hinduism, after death, bodies are cremated at river banks. The rivers are treated as god and worshipped each time they had to cross rivers over a bridge. Early morning the worship of god starts with sprinkling water in statue of god or cleaning the temple areas with water. From birth to death, water has played a vital role for celebration and making everything auspicious (ready to use for ritual activities) even with few sprinkles over it. Most of the ritual activities are done with the water collected from running sources but not from the pond or stored water.

4. Water supply in Kathmandu Valley

4.1. Traditional water supply in Kathmandu Valley

Kathmandu lies in the Hilly region of Nepal was with one of the most sustainable water management systems and reliable source for the drinking water supply i.e. Stone spouts called "Dhunge Dhara or Hitis." from the time immemorial. They were built when needs were limited and the waste generated was minimal. They have been maintained over the years due to the unique rainwater harvesting system since the 6th century A.D. and few of them are still giving service and becoming part of our rich cultural heritage. The only reason this city is still habitable is due to these lively stone spouts as many of these kinds are still functioning but hundreds of them already dried out.

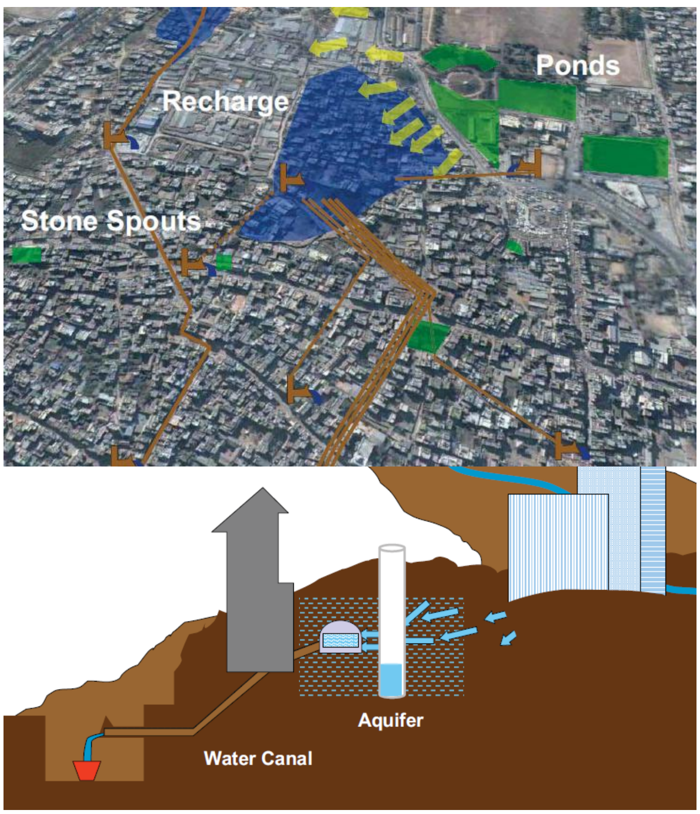


Figure 15 Traditional water supply system, Source: UN-Habitat

According to NGO Forum for Urban Water Supply and Sanitation (NGOFUWS), among 389 stone spouts, 233 of them still have natural flow, 43 of them are supported with city supply line, 68 of them are not working at all and 45 of them have disappeared due to the encroachment of urban population[12].

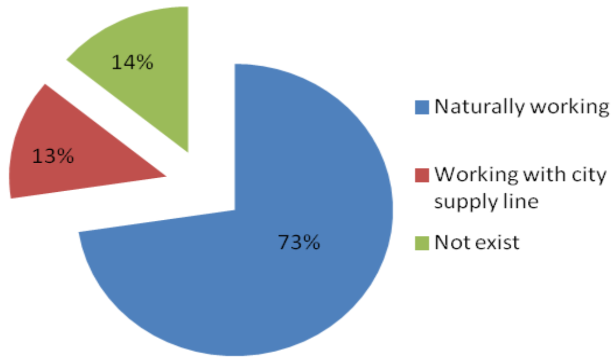


Figure 16 Status of stone spouts of Kathmandu Valley (Source: Traditional Stone spouts Enumeration and Mapping, NGOFUWS, 2008)

The Hiti system comprises of stone spout (Hiti) platform, intake, and water canal (Rajkulo), filtration system and reservoir. These stone spouts are channelled to the natural spring or shallow aquifers, which are usually 3 to 10 meters below the surface of the ground. “Dhunge Dhara” are feed by shallow aquifers or ponds which are connected with the water channels called “Rajkulos” for recharging them from another sources from distance (usually 10 kilometers or more)[13].

Figure 17 Traditional water supply system in Kathmandu Valley

The community level trust fund mechanisms called “Guthi” were also established to execute and sustain the activities of traditional water supply management. These Guthis are not related to government and are solely established by the community members with certain set of rules to perform in community for the operation and maintenance of the infrastructures including the water sources for the sustainable practice including few cultural and religious activities, which must be performed for their community development. There are many cultural festivals celebrated in the water sources to encourage water source protection and conservation such as the festival called Siti nakha (once a year), which is dedicated for the cleaning, dug wells, hities of Kathmandu Valley and is organized under these Guthis. This system is still in practice in traditional city of Kathmandu Valley and seems one of the significant steps needs to develop more for the sustainable management of the water resources.

These stone spouts are the example as one of the best sustainable and complete water management systems interlinked with socio-cultural activities and help Kathmandu survive even during such high water crisis. Kathmandu, city of temples, not only worships statues of god and goddesses but also live animals like the cow, crow, dog, ox, and many more including snakes and frogs. These water spouts are built with the well-managed drain system too which is not possible to get cleaned by humans but is always maintained due to the inhabited of snakes and frogs nearby. The water channels of these stone spouts always remain clean due to the regular circulation of these animals. In the past, these stone spouts were well managed due to the culture and ritual factors but now it is time to think to manage it through proper rules and regulation by the government because of the intense pressure of recent urbanization and population growth. Another way to fulfill the demand of city water to urban area would be that the government would collect water from stone spouts in storage tanks above the stone spouts and re-supply water for urban dwellers. Currently, individual communities are maintaining these systems. Some of them are not in operation. Exact data is not recorded yet. KUKL has not been involved with any kind of maintenance for those water storage systems since 20 years.

4.2. History of Piped Water Supply in Kathmandu

Before the piped water supply was introduced in Ktm, it was dependent on groundwater source i.e. natural springs, rivers and the stone spouts established by Lichhavi King Mandev I in 550 A.D in the form of water spouts in Hadi Gaun of Kathmandu. This was followed by his daughter Bhairavi by establishing another stone spout in Mangal Bazar of Patan in 570 A.D. 14^{th} to 16^{th} century is known for the establishment of most of the stone spouts in three kingdoms of that period i.e. Kathmandu , Lalitpur and Bhaktapur.

The piped water supply system in Nepal dates back to 1895 A.D when Rana Prime Minister Bir Shumsher commissioned water supply to Royal palaces and to the homes of ruling elites through private connections and called it Bir Dhara Water System. The Bir Dhara System also led to the establishment of Pani Goshowara Adda, organization for the development and management of water supply and wastewater system in the country. This organization provided limited private and community stand posts in a few selected parts of Kathmandu. The piped water service system was then gradually extended to a few other prominent places like Dudhpokhari system for Patan and Mahadevkhola System for Bhaktapur, which were established later in 1904 A.D. More systems were added later and the larger system was built in 1960 with support from the Indian government. Only sources supplied from shallow aquifer like Stonespouts (Dhunge Dhara), Dug Wells (Inar), ponds *(pokhari)*, springs, water holes *(kuwa)*, and rivers to fulfill their water demand. The first piped water system using groundwater was developed during the International Development Association (IDA) Project (World Bank Fund for Poors) in 1976-1980 A.D. Currently, Ktm is getting drinking water from only one water supply operator i.e. KUKL which is a public company. It has been granted license for 30 years from Kathmandu Valley Water Supply and Management Board (KVWSMB). The company was given authority to undertake and manage the water supply and sanitation systems of the Nepal water supply corporation (NWSC) and to provide quantitative, qualitative and reliable services to consumer on their full satisfaction at affordable price.

Out of total water supplied by KUKL, surface water counts for 80% in wet season and 54% for Dry season. The remaining of the supply is through the ground source i.e. wells and tube wells which are mostly at the northern area of Kathmandu Valley. Thus, most of the surface sources are being tapped for the water supply in Kathmandu Valley. The water supplied by KUKL in Ktm is shown in Table 6. Out of huge demand of (as per KUKL,135 Liters per capita per day (Lpcd)) 350 million liters per day (MLD), KUKL is supplying only 58.6 mld in the dry season and 86.9 mld in the wet season due to the leakage in supply pipe lines ie about 38% of production is not reached up to the user.

Season	**Demand**	**Production**	**Surface Source**	**Ground Source**	**Total Supply**
Dry Season	350	94.6	60.3	34.3	58.652
Wet Season (MLD)	350	140.3	122.5	17.8	86.986

Table 8 Water demand, production and supply in Kathmandu Valley by KUKL. Source: KUKL. *All units in MLD*

4.3. Water supply and Demand of Kathmandu Valley

4.3.1. Supply from KUKL

Forty eight VDCs out of 99 and Five Municipalities of Kathmandu Valley are receiving their potable water from one water utility i.e. Kathmandu Upatyaka Khanepani Limited (KUKL). KUKL is using 35 surface sources including small tributaries of rivers, 47 reservoirs, 78 Tube wells (only 59 are in operation), 31 pumping stations, and 21 treatment plants (only 14 are in operation) and provided with 1400 Km of pipelines in Kathmandu Valley. KUKL is not being able to supply enough water as per demand. 38% of leakage is being one of the biggest challange for the supply of produced water. According to the acting manager of KUKL, KUKL has already started working on fifteen-year long project to replace the old pipes in Kathmandu Valley with new ones to control leakages. This project is estimated to be complete in 2025, which could significantly reduce the waste of water during supply and help to improve water supply. During this project, KUKL is replacing both the larger and smaller sizes of pipes. However, the pipe size has been increased in some region the supply is still not enough. KUKL has been adding the pipelines in different sectors as per the request of the individual communities rather than following the long-term plan of the area.

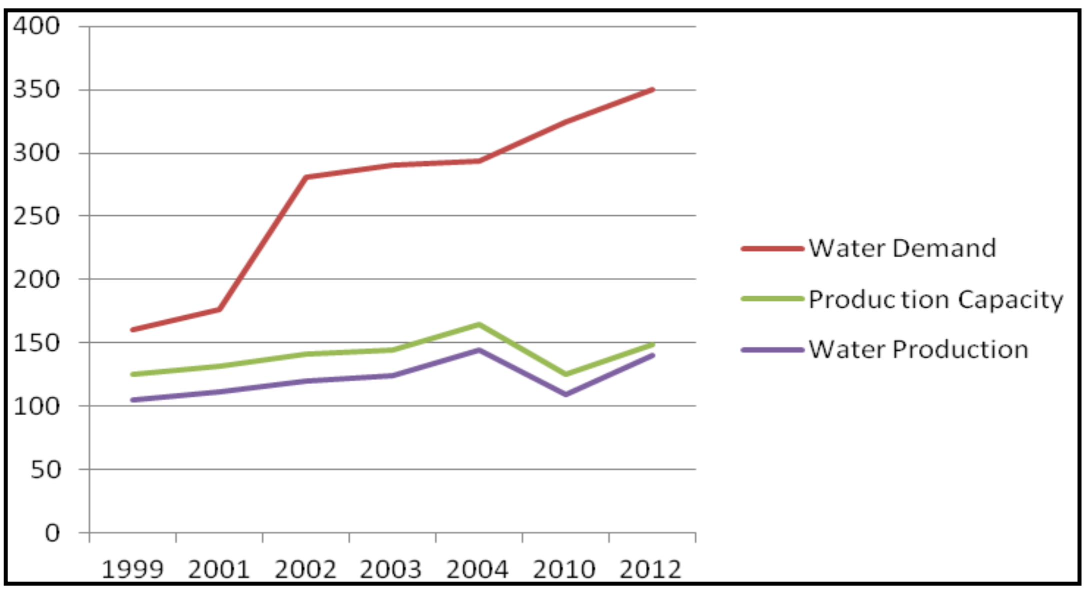


Figure 18 Estimated water demand, production capability and average production by KUKL. Source: GRDB and KUKL.

The huge gap of demand and production from KUKL in various years is shown in Fig. 18. Water supply from KUKL is in a deficit of 78 % in dry season and 70% in wet season. KUKL, serves around 73% of population of Kathmandu Valley through an eight branch system in five municipalities and 48 VDC's as shown in Fig. 19. The remaing population of VDC's and other temporary populations and VDCs get water from other various sources without proper treatment such as the traditional water spouts, use ground water via wells or tubewells, river/ streams etc.

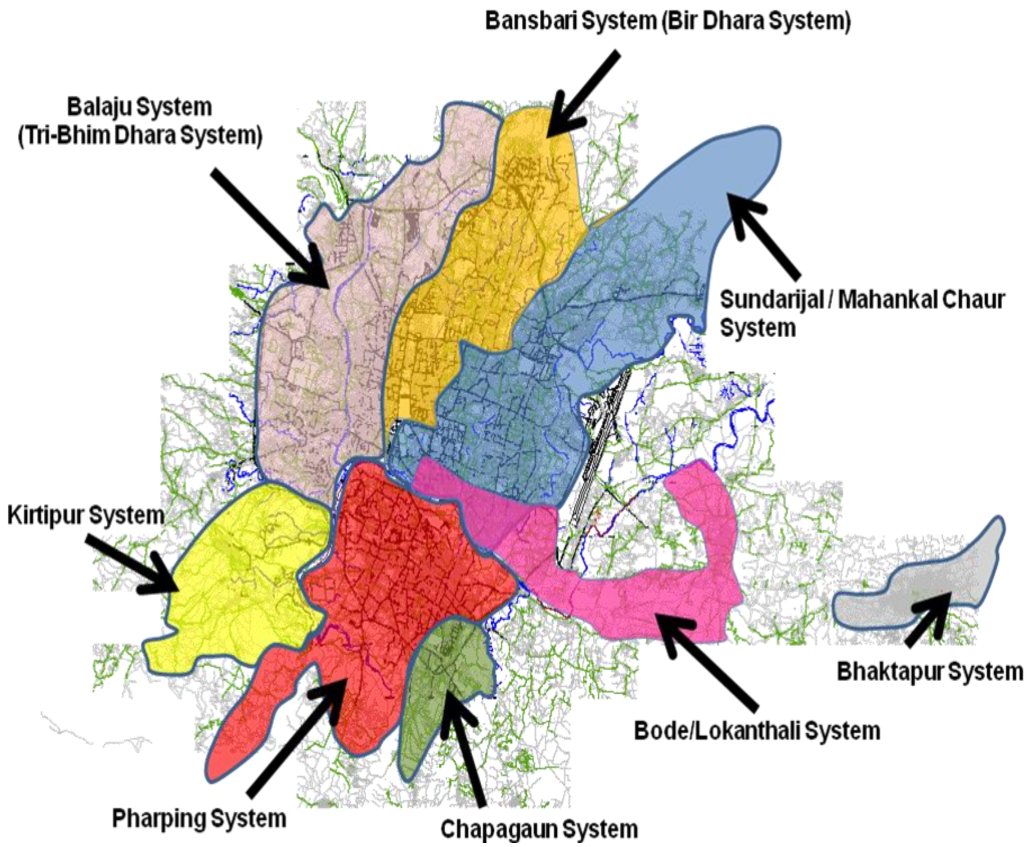


Figure 19 Water distribution system in Kathmandu Valley by KUKL. Source: GRDB

Besides surface sources, 34% of water supply from KUKL is from groundwater sources in dry season and 13% in wet season.

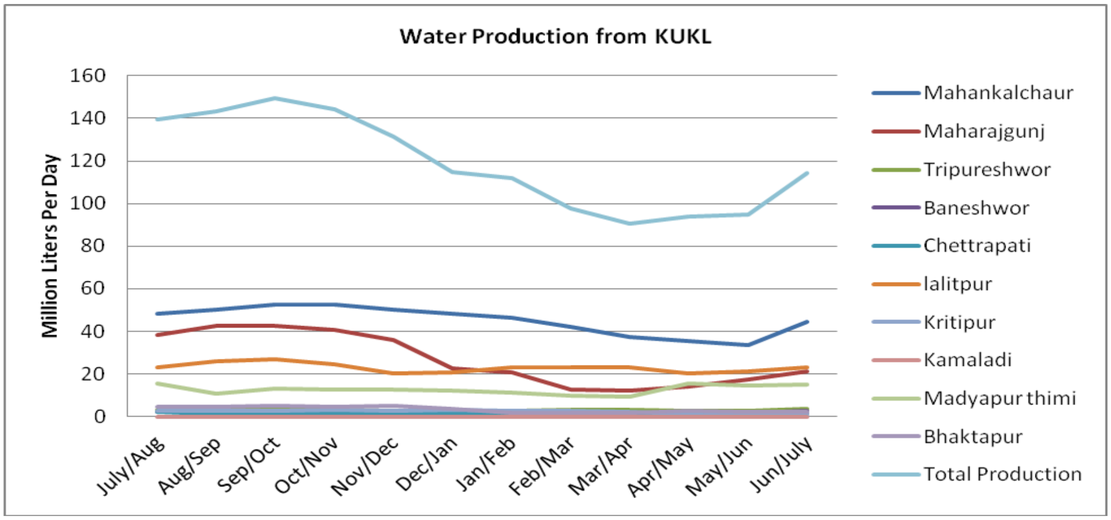


Figure 20 Monthly water production from KUKL from various sources for water supply in Kathmandu Valley. Source: KUKL

Among these eight branches, six of the branch systems are supported from ground water ie deep tubewells as shown in Table 9.

SYSTEM	TUBE-WELLS LOCATION
BANSBARI	BANSBARI ABD GONGABUN
MAHANKAL CHAUR	GOKARNA AND DHOBIKHOLA
BALAJU	MAHADEV KHOLA, CHAKRAPATH AND PARTIALLY GONGABUN
BODE LOKANTHALI	BODE, MANOHARA AND LOKANTHALI
BHAKTAPUR	BANSBARI AND JAGATE
PHARPING	PHARPING

Table 9 Ground water use from KUKL for water supply. Source: GRDB

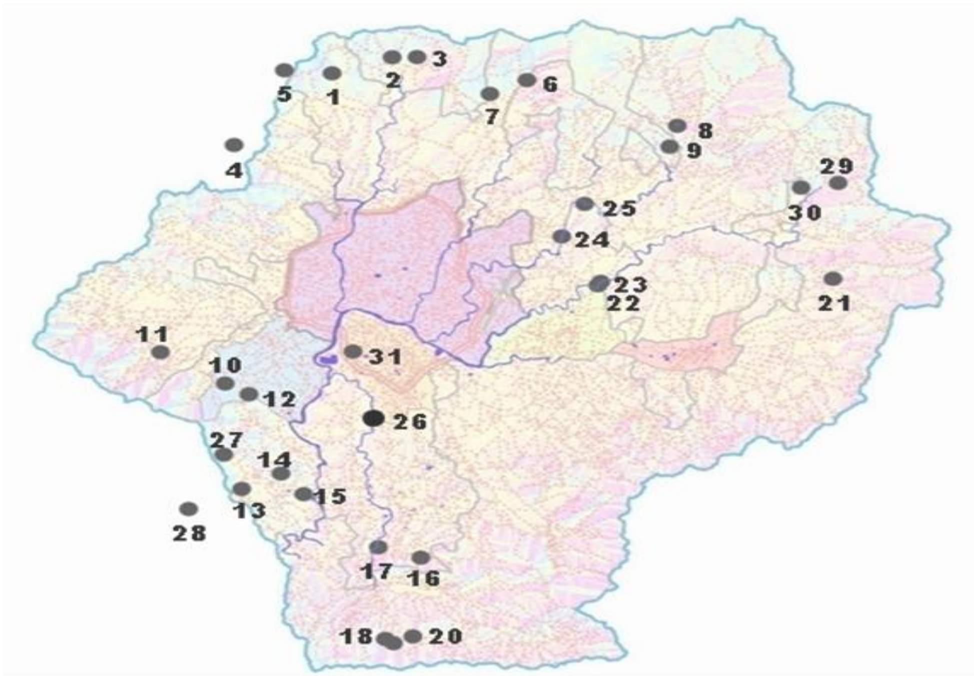


Figure 21 Kathmandu Valley map showing location of surface sources abstraction by KUKL for the water production. Source: KUKL

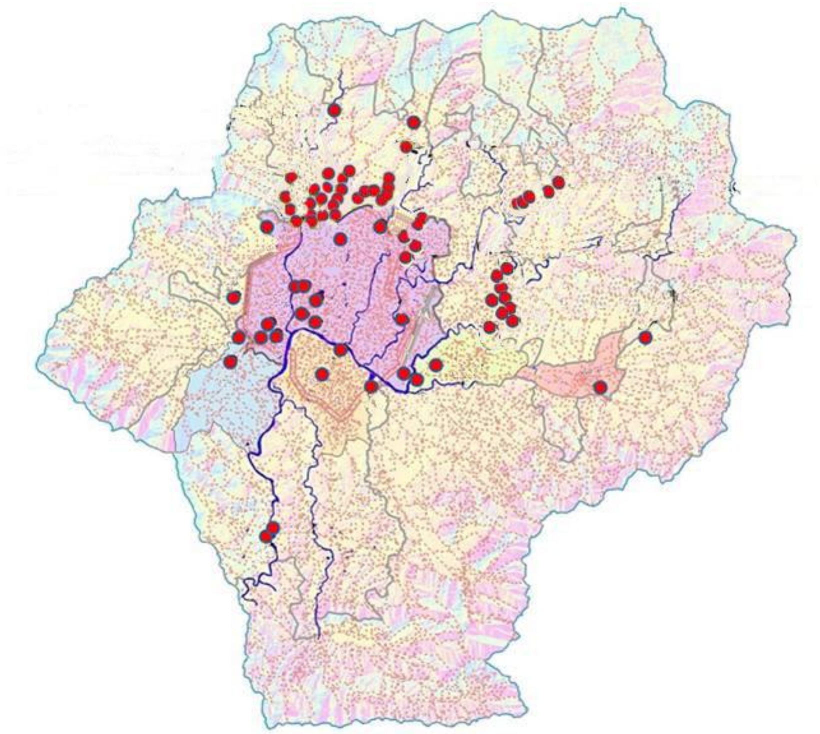


Figure 22 Kathmandu Valley map showing location of deep tube wells used by KUKL for water supply. Source: KUKL

According to NGOFUWS in 2005, 55 % of urban population has access to a legal connection provided by NWSC/ KUKL with minimum monthly tariff for each household of Rs 55 ($0.62 as of may 17, 2013 with exchange rate of US Dollar = 87.60) per 10,000 liters and with above usage of 10,000 liters, it charges Rs 17.5($0.199) per 1000 liters. Every consumer of KUKL water supply pays equally for water either it is for domestic purpose or commercial. This tariff becomes too expensive for some groups of people making piped water supply inaccessible for them as according to the NLSS, 2011 published by the National Planning Commission, 25.16 percent of Nepal’s population lives below the poverty line, i.e. out of the roughly 28 million Nepalese, roughly seven million live below the line. In urban Kathmandu, you need to make at least Rs 112 ($1.28 every day to keep you above the poverty line [14].

Altogether, KUKL has 178,832 metered/unmetered connections and 1196 public stand posts as of 2010/11 record by KUKL. KUKL assumed that 15 households share each water stand posts located mostly at the nodes so that individuals can collect water from there with only few minutes of fetching. From interviews in some VDC areas, new pipeline systems are provided but most of them are dependent on public stand posts provided by the government which received its supply mostly from the reservoir nearby 24/7 flow of water but without shut off valves. Installation of shutoff valves could have saved significant amount of water, which has never given concern. Thus, clean drinking water is wasted during the time when it is not collected. Though private water supply pipelines are not connected to every household, people in VDC’s are more satisfied with water quality and quantity.

4.3.2. Supply from Private Tankers

Besides KUKL, communities have alternative suppliers too i.e. Private Tankers who collect water from the deep wells or the spring sources from the periphery of Kathmandu Valley and distribute to the parties with a request. According to Valley Drinking Water Tanker Entrepreneurs’ Association, there are 216 water tanker entrepreneurs as registered members in the association, who are operating 370 tanker trucks of different size (9000-12000 liters). About 21% of water consumption of Kathmandu is supplied by around 700-800 tankers which are delivering water in Kathmandu Valley from different locations like Balaju, Matatirtha, Godavari, Swayambhu, Chobhar, and Jorpati. Exact numbers have not yet been recorded by the government for the amount of water supplied in Kathmandu Valley through private tankers but a study by Dibesh Shrestha has shown that in average 25.58 MLD and 15.36 MLD of water is supplied in dry season and wet season respectively.[15]. Refer table 10.

Figure 23 Picture showing water supply from private tankers at the right and water selling station for local vendor at the node of core city area.

Water Extraction From Private Tanker				
Season	**Wet**		**Dry**	
Source	**Surface**	**Ground**	**Surface**	**Ground**
MLD	0.92	14.4	1.48	24.1

Table 10 Average water abstraction from private tankers.[15]

According to the need, individual households or a community together orders water from these private water tanker companies, which provide water on the same day or within a week during peak demand. Tankers collect water directly from the source and supply to the communities without any treatment. People using this kind of water supply are satisfied with the quality of water supplied. Interviewees had expressed that they would rather use water from tankers for cooking and drinking purposes after their regular boiling and filtration process than using their own dug well water or water from KUKL especially in rainy season. These water tankers are more costly than the KUKL supply. In spite of expensive service, the trend of water transactions through tankers is increasing as shown in Table 11.

Year	Estimated Volume of Tanker Water Supplies (MLD)	Water Demand (MLD)	Percentage of water demand catered by water tanker (%)
1987	0.38	30.5	1.2
2001	6	177	3.4
2010	25.58	32	8

Table 11 Growth pattern of water abstraction from private tankers.[15]

4.4. Groundwater level depletion

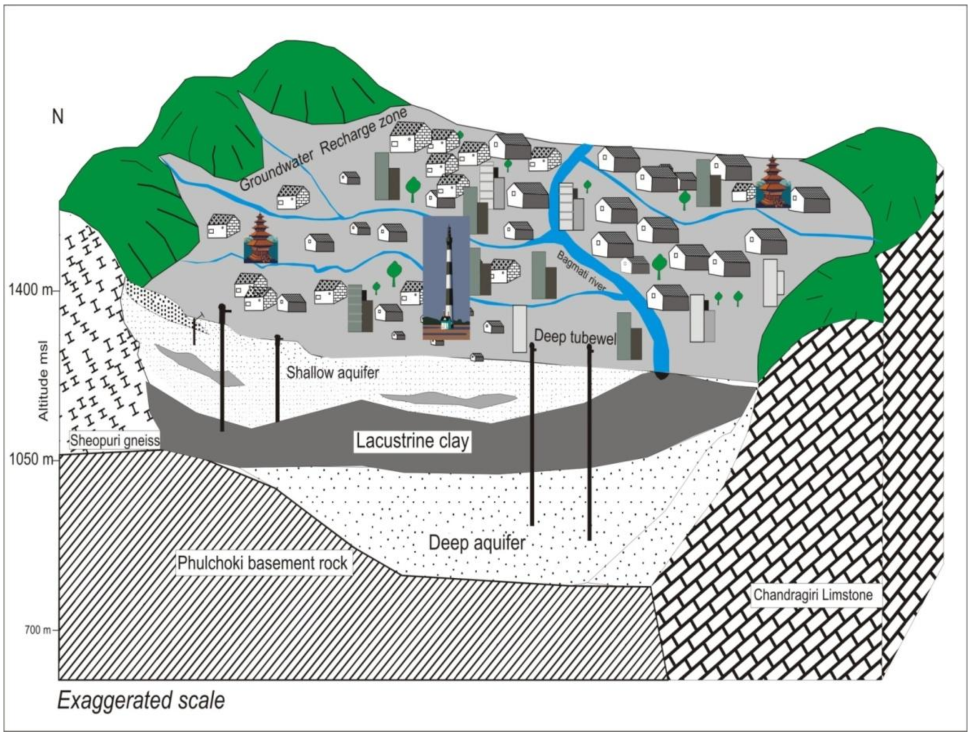


Figure 24 Conceptual diagram showing the hydro-geological condition and ground water abstraction in Kathmandu valley. Source: DHM

According to KVWMSB, in 2010 78.4 million liters of water is extracted in the Valley daily, out of which around 40.2 million liters is extracted from private sectors [16]. In 2010, KUKL extracted about 38.2 MLD of groundwater i.e. 49% of total ground water abstraction. In 2012, KUKL records for 68.4 MLD of groundwater. Besides stone spouts using shallow aquifer, dug wells and deep tube wells are the major contributors of groundwater. Dug wells in Kathmandu Valley are owned by most of housholds for domestic purposes which are mostly used by people in dry season when the municipal supply is low or absent. The over abstraction might create worse scenarios as the aqufiers in Kathmandu are isolated from other more permeable aquifers outside the valley.[17] The only source of recharging these aquifers is rainfall; however, the infiltration rate is decreasing due to an increase in impervious surface.

This extraction of ground water is increasing beyond the capacity of it's ability to replenishment. According to the studies done by JICA in 1990, 15 MLD was considered as sustainably abstractable ground water in Kathmandu Valley. The figure 25 shows the groundwater abstracted in various periods which already exceeded the sustainable abstraction limit ie 15MLD.

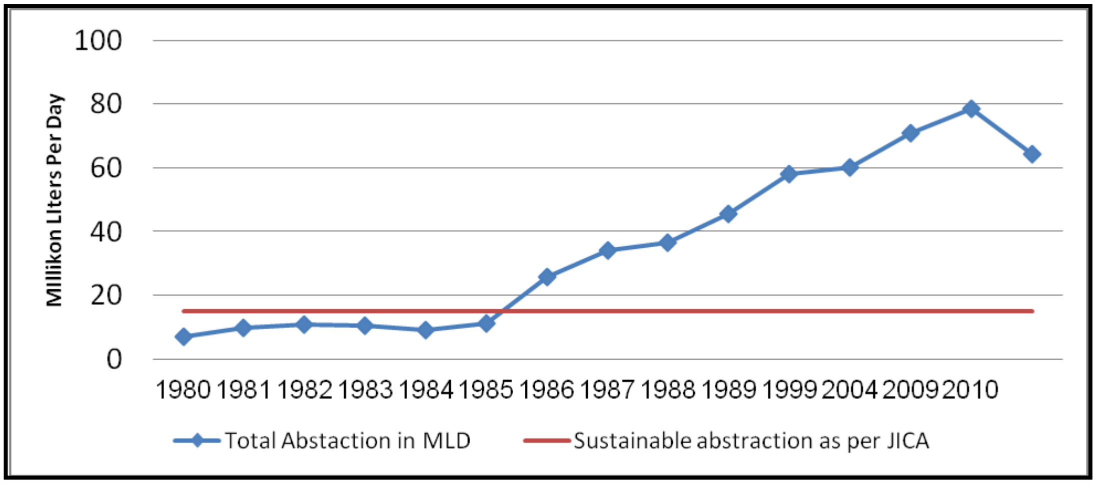


Figure 25 Groundwater abstraction. Source: GRDB

Around 65 MLD abstractions exceed four times the sustainable abstraction of 15 MLD. Due to over abstraction, the water table has already started depleting as shown in table 12. Due to high water extraction, the water ground level have declined between 1.7 m/year and 0.7 m/year at southern ground water district[18]. The table 12 shows the water level changes within the decade of time. Available records from DHM shows that Monitoring wells in VDC areas are increasing where as in municipal areas are decreasing.

Well ID	Location	Base year	Water Level below ground (Meter)	Water Level below ground in 2011 (Meter)	Difference in 2011 and Base year (Meter)	Remarks
DK-1	Tanker Section, Mahankal Chaur, kathmandu	1999	28.9	32.1	3.2	Depleted
G-2a	Nayapati VDC-6, kathmandu	1999	16.41	11.6	-4.9	Raised
Bal-1a	By Pass Balaju, Kathmandu	2000	5.27	22.7	17.4	Depleted
I-26	Kathmandu Dying, Dhobighat, Lalitpur	2000	7.37	16.8	9.4	Depleted
DK-8	Bekh, Kapan VDC-3, Kathmandu	2001	3.89	3.7	-0.2	Raised
M-1	Kritipur MCPL-15, Taudaha, Kathmandu	2001	3.89	9.7	1.2	Depleted

Table 12 Water level monitored in several wells in Kathmandu Valley. Source: GRDB and [18]

Water Consumption

The basic water requirements for domestic purposes is 50 Lpcd as shown in table 13 [19]. According to the Nepal Building Code (NBC) the designated amount of water supply for the residential building has been declared as a 100 Lpcd. About two decades ago, in 1990, 19.14 million people of Nepal were receiving from public sources only 17.0 liters per capita per day (Lpcd). In the survey done in 2003 by CBS, the residential average water consumption was 93.85 Lpcd, the average consumption for the primary household is 80 Lpcd while for the secondary or renter’s households is are 46 Lpcd. According to the survey by CBS 2005, the average existing water consumption for all types of households is found to be 73 liters per capita per day [20].

Purpose	**Recommended minimum Lpcd**	**Range in Lpcd**
Drinking water	5	2 to 5
Sanitation Services	20	0 to over 75
Bathing	15	5 to 70
Cooking and Kitchen	10	10 to 50
Total Basic Water Requirement	**50**	

Table 13 Recommended basic water requirement for household purposes. Source:[19]

4.5.1 Survey and results

Along with interviews with various professionals, a random survey in Kathmandu Valley was conducted along the branch line distributed by KUKL. The survey questionnaire is attached in appendix. An unscientific survey and interview with the public helped to determine water usage behavior and attitudes towards water conservation.

Not all surveyed households were satisfied with quantity of water supplied from KUKL. On average, minimum water supplied to this dwelling is 63.8 Lpcd. People are adjusting with the amount they could get from alternate resources such as dug wells, private tankers and bottles or jars. An additional 48.8 Lpcd is required for daily household activities. Thus, altogether 113 Lpcd is required for household daily activities but only 57% of water is available per person per day in Kathmandu from the current municipal system.

All surveyed households have piped supply system in their household but only 66.7% of households have been metered. This shows lack of control in the proper maintenance and monitoring of water supply

To meet their water demand, Kathmandu residents have adopted several alternate resources. From the survey, 50% of households are using dug well as an alternate source out of which only 36% of which are satisfied with quantity of water but about 71% of them are not satisfied with the quality of water from these dug wells, which are usually from shallow aquifers. Only two percent of households are using deep tube wells, which Institutes and industries use.

Another reliable alternate source expressed in survey is private water tankers. 58% of households use this services out of which only 14% of them are not satisfied with the quantity of water they get but 52% of them are not satisfied with the quality of the water from these services.

As supply is less than demand, 47% of households are active about rainwater collection during rainy season in whichever way they can. Either using smaller containers or bigger drums out of which 70% of them do not want to use rainwater for household purposes as the filtration or cleaning techniques do not seem to be feasible in terms of cost and space for household in Kathmandu core area.

Insufficiency is a fact for the water supply in Kathmandu Valley. 90% of surveyed population is not satisfied with the quantity of water supplied by KUKL. This inadequacy and irregular supply of water from KUKL has forced the Kathmandu Valley to look for alternative sources of water for their daily purposes. An average of two hours of water supply in every 3 days is noticed during the survey. Besides that, the dependency in ground water is only helpful for the bathroom, washing and cleaning purposes, as the ground water extracted in Kathmandu Valley inside the municipality area is not safe to drink.

4.5.2 Water Consumption Trend

Besides supply from KUKL and Private tankers, various sources are being used by Kathmandu Valley to fulfill their water demand such as traditional stone spouts, dug wells in individual houses (covered and uncovered), river/ stream and other various indirect sources like purchasing water from private water vendors and bottled water. The figure 26 shows the percentage distribution of households using various sources Kathmandu Valley in 2011.

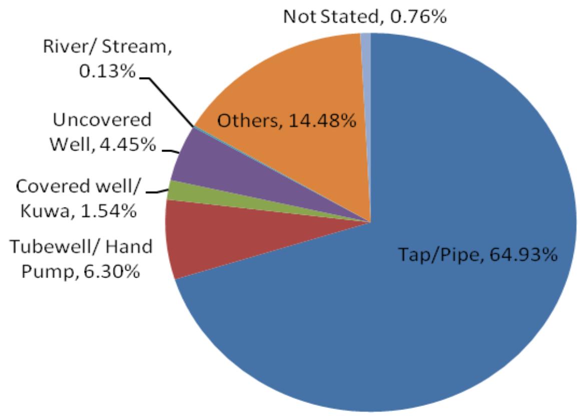


Figure 26 Distribution of water sources used in Kathmandu Valley, CBS 2011

Theoretical water demand (135 Lpcd) of Kathmandu Valley is fulfilled by only 52%, using various sources including KUKL supply and private water tankers. Out of 350 MLD, Kathmandu Valley is able to use only 183.2 MLD (73 Lpcd) of water through various sources as shown in figure 27. According to KVWSMB, altogether 6.5 MLD of water production is estimated from stone spouts in 2011, i.e. 2% of water demand. These spouts initially served the royal bath purposes but now, temporary residents and low-income groups mostly use these.

In the city core area, road network in city center was traditionally planned for the pedestrian movements only, thus are of small width. The big trucks cannot pass through every corner of city area. The common courtyards and street nodes became water distribution station from water tankers because city pipelines do not have enough water supplies or sometimes dry out for several weeks. This trend became an alternate source for collecting water from the local shop/retailers who are selling it for Rs 10-20 per 1000 liters with minimum fetching period. Besides government, some localities have established this as very viable water business for their living.

Due to the lack of municipal water supply and costly transport of water on-site from the distant sources, private dug wells in individual plots became the main source of water for construction purposes. These wells continue to serve the resident even after construction of their dwelling. Almost every plot consists of dug well and extracting ground water for their use. Government, neither for its quality nor for abstraction rate has monitored these dug wells. It is estimated that more than 10,000 dug wells are there in Kathmandu Valley. The government has set a policy of compulsory registration of deep tube wells since 2010 only. According to the provided data, most of the deep wells were constructed by organizations with high water demand such as hospitals, industries, and hotels.

According to KUKL, the theoretical demand of 135 Lpcd is estimated for Kathmandu valley for year 2011. The average water consumption of Kathmandu Valley is recorded as 73 Lpcd. Of total consumption, KUKL only supplies 37.2% in dry season and 48.7% in wet season. Dug wells abstracting water from shallow aquifer became one of the major water suppliers. As there is no recorded data for the amount of groundwater abstraction from the individual dug wells in households level, it is assumed that after supply from KUKL, private tanker and traditional stone spouts, the remaining amount of water consumption (73 Lpcd) comes from dug wells (Shallow aquifer) i.e. 72.15 MLD in wet season and 83.01 MLD in Dry season. In city center area, these shallow water wells (30-90 feet deep) in residential units is used for toilet flush, cleaning and gardening purposes only but not at all for drinking purposes whereas in outskirts of the main core city area i.e. in Thankot, Godavari, and Lubhu area, these dug well waters are used directly for drinking without any treatment. Though qualitatively, the water is not good enough, the ground water sources are being used in unsustainable rate for various purposes.

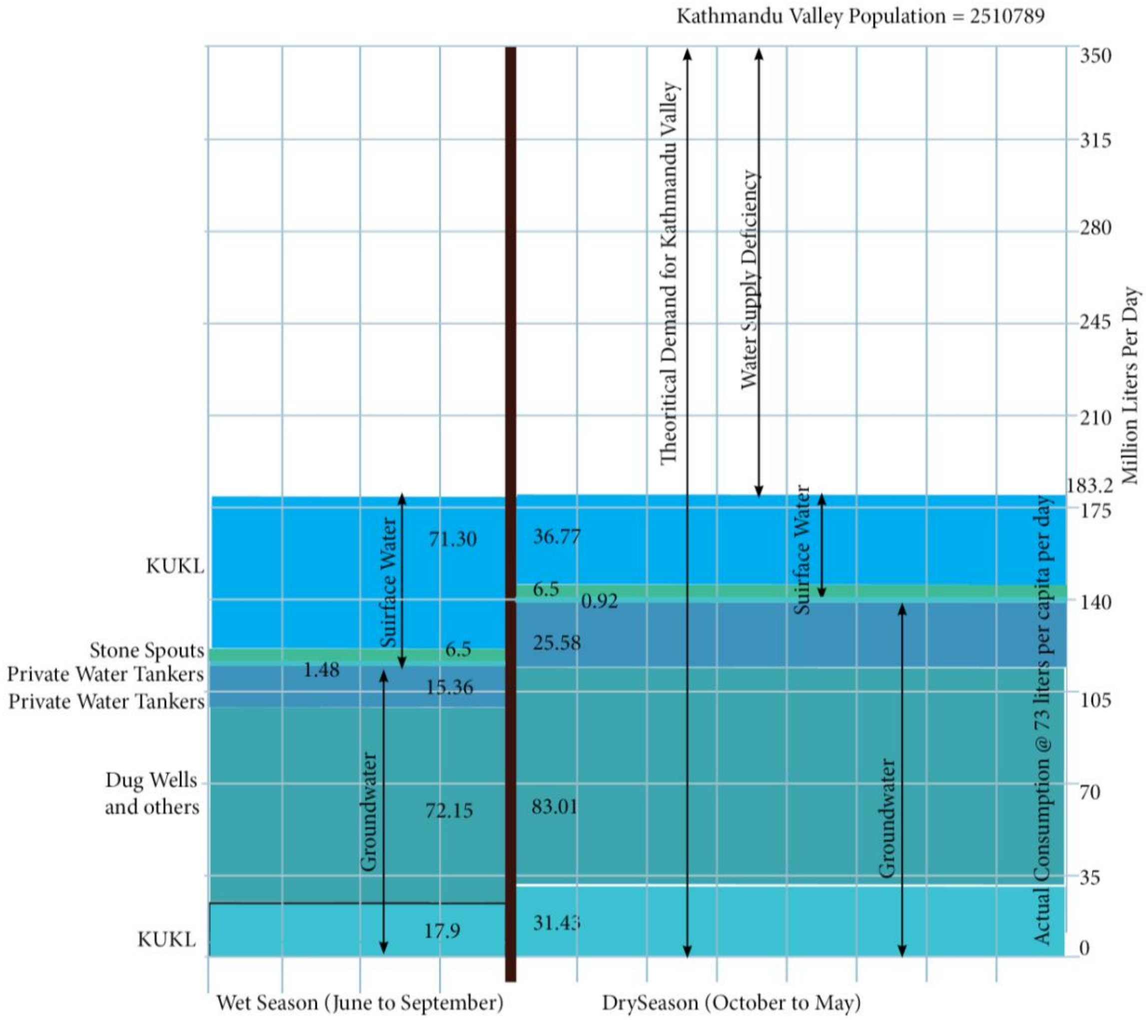


Figure 27 Quantity of water consumed in Kathmandu Valley using various sources.

In dry season, dug wells are providing more water i.e. 45% of total consumption than KUKL i.e. 37%. Private tankers are also providing significant amount of water consumed i.e. 14%. KUKL is the main abstractor from surface sources whereas private tankers are abstracting only about 6% of their total abstraction from surface sources. Refer figure 27 and 28.

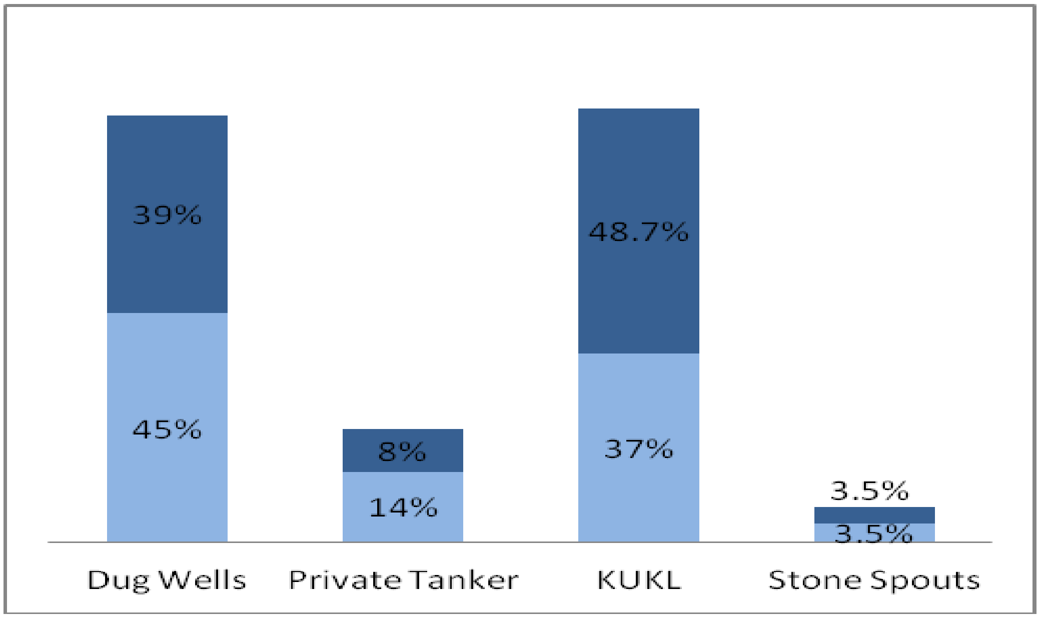


Figure 28 Water consumption using various sources.

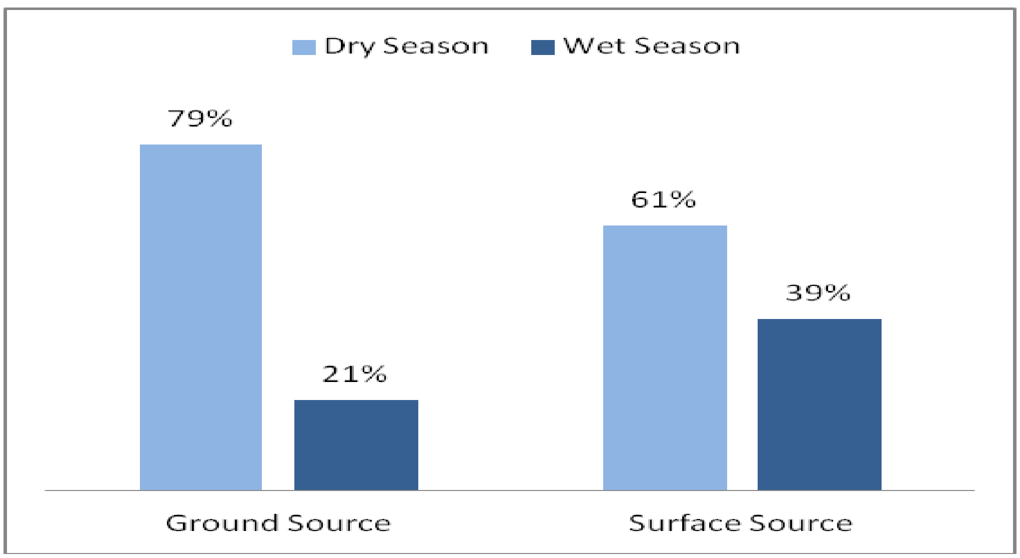


Figure 29 Groundwater and surface water use in dry and wet season in Kathmandu Valley.

Thus, in current scenario, Kathmandu Valley is using 79% and 21% of their total consumption from groundwater in dry season and wet season respectively. Refer figure 29.

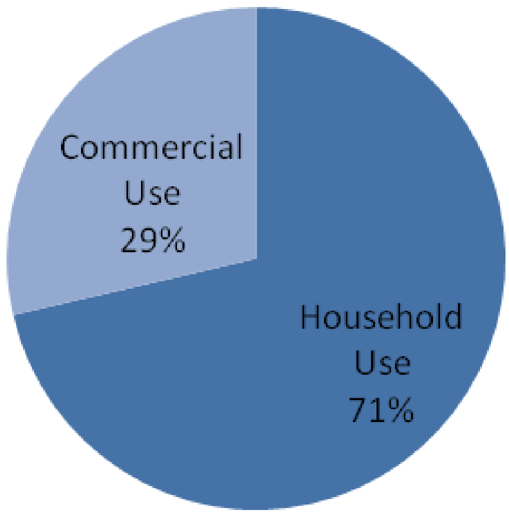


Figure 30 Water consumption for domestic and commercial purposes

According to KUKL, the supply and consumption amount in commercial and industrial sector is not yet recorded. Thus with reference to water consumption of 73Lpcd for domestic purposes and the recorded amounts of abstraction from all sources, it shows that the industrial and commercial sectors are using 29% of total water use ie 40% of total domestic consumption. Refer figure 30. Calculation is shown in table K in appendix.

4.5.3 Supply trend in VDC area out of KUKL Service areas

Communities outside of KUKL service areas have started creating additional water supply system for water demand fulfillment. For example, two of VDC's i.e. Godavari (South end of Kathmandu Valley) and Matatirtha (West end of Kathmandu Valley) are supplying water to the villagers by collecting water from their natural source nearby (main springs).

In the Godavari community, political leaders (themselves being local consumer) are actively engaged in the project rather than other local people. With the benefits of 24 hr water supply with low tariff system i.e. Rs 10 for up to 10,000 liters per month, local people are all satisfied with the quality and quantity of water supplied by VDC. This tariff increases with the increase in water use. They believe in a "use less and pay less" policy for water consumption. Providing water supply to nearby industries creates revenue for the maintenance and operation of the project.

Another case study was done at Matatirtha which is a popular sacred site for one of the most important festivals "Ama ko Muth Herne Din" i.e. Mother's day, decorated with 12 historical stone spouts flowing 24 hrs a day from the natural spring nearby. After a bath in these waterspouts, a belief of being ritually pure to worship their late mothers on that day has strongly influenced the identity of the community. VDC has collected water from 24/7 running waterspouts into distribution reservoirs for villagers of nine wards. Water distribution was planned for 2 hrs in the morning and 2 hrs in the evening with a tariff system of minimum Rs 80 per 10,000 liters. However, here the water is in such abundance; VDC is supplying water 24 hrs a day except during pipe maintenance. Although Government provided initial support for the construction of the project, later local officers of the VDC are responsible for sustaining the project.

Social, economic and cultural development and even political stability are closely linked to the water supply available to the population. The Tariff system in these two VDC has huge gap even with same pattern of supply amount. The political will has played a vital role in the water supply system.

4.5.4 Water use trend in Individual household

With the increasing demand and limited supply, people are changing the water use behavior. For example, the final buckets of water used for cloth washing are used for washing kitchen utensils and then after this grey water is used for gardening purposes. People have started to collect water in bathtubs while having showers to save water and then reuse it for toilet flushing and gardening purposes. This behavior shows that the water shortage is making people more conscious of water use at the household level and ultimately they will reduce the city water demand. This might be the reason they are still able to cope with water supply for 2 hrs in 3 days in wet season or in a week in dry season. However, water conservation is well known in the Kathmandu community, the recycling and recharging of water is still not actively implemented. These processes are both costly and space consuming to do it in larger scale for whole Kathmandu Valley. The curtailment behaviors (limiting the use of water in daily activities) are already in practice but the efficiency behaviors (using water efficient appliances) seems a bit difficult to be implemented in already established settlement due to the cost factor. On-site surveys have shown the unwillingness of employing costly water efficient utilities.

With the exception of the older buildings at the city center, most of the households in Kathmandu have underground water tanks for storage of water. This practice of installing concrete underground water tanks has not been effectively implemented in VDC areas. In every household, they are using similar patterns of water collection and water supply for household activities.

The water supply from KUKL or from private tankers is first collected in underground water tankers (9000-12000 liters) from which they pump it to the roof-top water tankers (500-2000 liters) and then the water is accessible to every floors through gravity flow. As the ground water from dug wells is not potable, most of households pump water from these dug wells to separate roof top water tankers for toilet flushing and cleaning purposes.

The necessity of these underground water tankers is a result of the shortage in the water supply to collect water when water is available from piped supply. The scarcity of water could become a scary moment in Kathmandu. These storage tanks are acting as emergency supplier. As the schedule for the supply is not regular people usually keep open the water taps in their houses connected directly to the underground water tank so that water can be filled whenever the pipe supply is active i.e. 2 hr per 3 days in minimum if they get electricity at the time of the piped water supply. Some households also expressed the need of pumps to collect enough water from municipal supply line because of low pressure in supply. People with more powerful pumps are able to secure more water.

The major transformation seen in Kathmandu regarding water conservation is in the use of dual water distribution systems as shown in Figure 31 for household use. This dual system helps to save potable water and untreated water from dug wells are used for all other purposes except drinking, bathing and cooking.

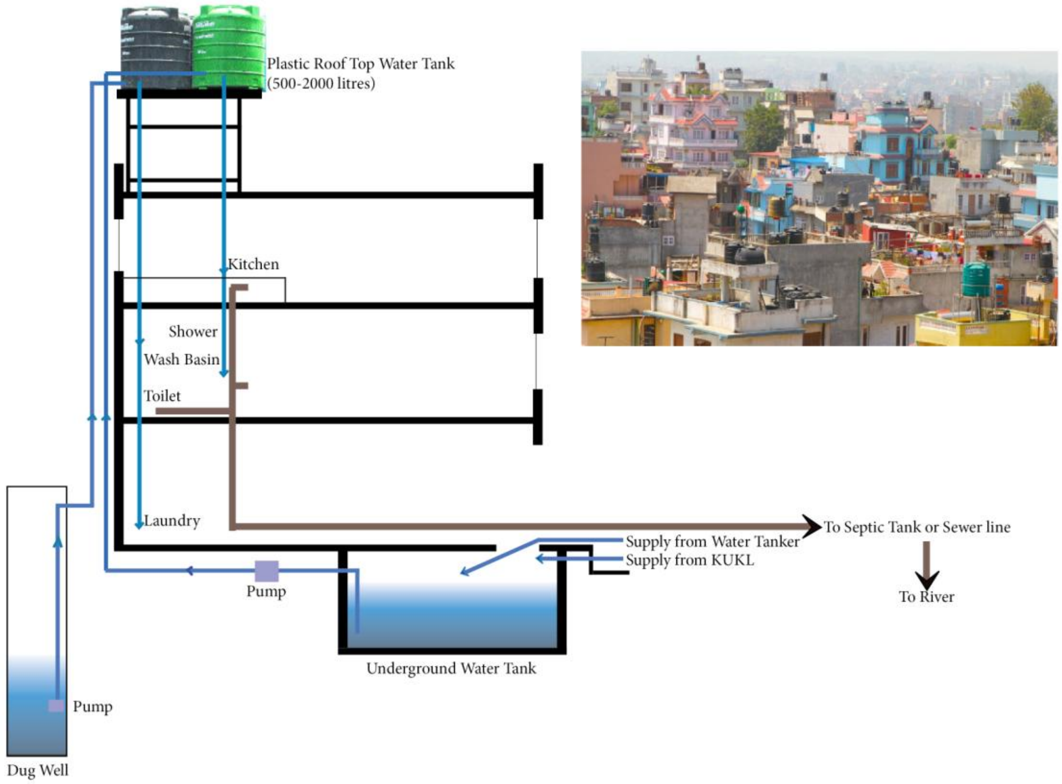


Figure 31 Diagram showing the water supply system for individual household in Kathmandu Valley.

4.6 Water quality

4.6.1 Surface water quality

The surface source i.e. rivers of Kathmandu Valley are in poor condition with extreme levels of pollution (direct waste disposals from municipal, industrial and agricultural sectors) due to the rapid urbanization increasing uncontrolled pressure to these water resources. Even the individual household wastes are dumped directly into rivers due to the infrequent and non-scheduled service from the municipal sector for the collection of the household garbage.

Figure 32 Picture showing the wastewater disposal directly in Bagmati River.

Figure 33 Picture showing the waste disposed layers along Bagmati River

These perennial rivers in the central area of Kathmandu usually dry out in the dry season with more sewer than water and are currently in such unsanitary condition that these rivers cannot supply any amount of drinkable water to the urban population. Following Table 12 shows the statistics of the quality of water of Bagmati River in different locations. This shows the surface water in Kathmandu valley is highly disturbed with high BOD and E coli bacteria.

Location	TSS (mg/l)	Total Hard ness (mg/l)	Total Alkalinity (mg/l)	Chloride (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	BOD (5days) (mg/l)	Ammon ia (mg/l)	E-coli (100ml)
WHO Standard	500	-	20-200	250	50	3	5.0	1.5	0
Sundarjal	<10	12.5	58	1.85	1	<0.06	5.2	0.04	41
Gokarna	77	30	99	5.3	4	0.24	6	0.04	93
Gaurighat	98.5	26.75	58	40.75	1	0.06	14.4	0.04	>2400
Sundarigha t	97	97	216.9	40.5	1	0.24	13.25	0.4	>2400
Khokana	80	90	159.7	40	1	0.06	13.2	0.4	1100

Table 14 Water quality of Bagmati River in 2012. Source: Department of Hydrology and Meteorology

4.6.2 Ground water quality

Ground water in Kathmandu valley is found to be contaminated with iron and Coliform bacteria. [21]. The concentration of iron is 1.9 mg/L in deep tube wells (are tube wells the same as shallow wells). In shallow well, iron concentration is found to be 1.5 mg/L and bacterial population is found to be 129 and 148 CFU/100Ml in tube well and deep tube well respectively. WHO guideline recommends for 0.3 mg/L of iron concentration and Coliform bacteria population should be less than 267 CFU/100mL. Likewise physically, the ground water in Kathmandu Valley exceeds the parameters for the turbidity and electrical conductivity of the WHO standards for drinking water. The higher turbidity, the higher is the risk that people get gastrointestinal. Pure water is not good conductor of electricity. The electric conductivity increases with the increase in water dissolved ionic species however hardness, chloride, arsenic and fluoride concentrations are within the limit of WHO recommendations for the drinking purposes [21].

4.7 Water treatment for domestic purposes

It is not possible to tell whether water is of an appropriate quality by visual examination. Simple procedures like boiling and filtration became the most effective ways for Kathmandu to make the polluted water usable at least in the household level. In spite of low quality, people of Kathmandu valley are forced to use the polluted ground water. Kathmandu Valley, even uses the municipal water only after few treatments like regular boiling and filtration. Among various ways, Solar Disinfectant Technique (SODIS) became one of the common, cost effective methods to treat water for human consumption in which the water in plastic bottle is left in sunny day for a day or two to get exposed in UV rays which kills microorganisms in water and make it drinkable. This method is considered to be easy, affordable and sustainable and is practiced by most of the household in Kathmandu Valley as shown in figure 34.

Figure 34 Resident of Matatirtha VDC using SODIS method for treating water

4.8 Challenges in Water Supply System

4.8.1 Production and distribution

As mentioned above, KUKL has been abstracting water from both surfaces as well as groundwater sources. The electric pump has been used for the pumping water from sources for collection. According to KUKL, the current twelve hours of load shedding makes the productivity less than what it is supposed to be as the power outage due to the lack of electricity supply from government for every alternate four hours disturbs the water pumping. Besides the issues in production and collection due to the electricity shortage and pipe leakage, the initial planning of the water distribution has been changed in many localities due to the rapid urbanization. Government has to intercept the water supply in between the source tapping point and treatment point to supply water to the newly developed adjacent communities as shown in conceptual diagram in figure 35. The same volume of water is supplied to additional number of household without treatment, with same storage and intake capacity.

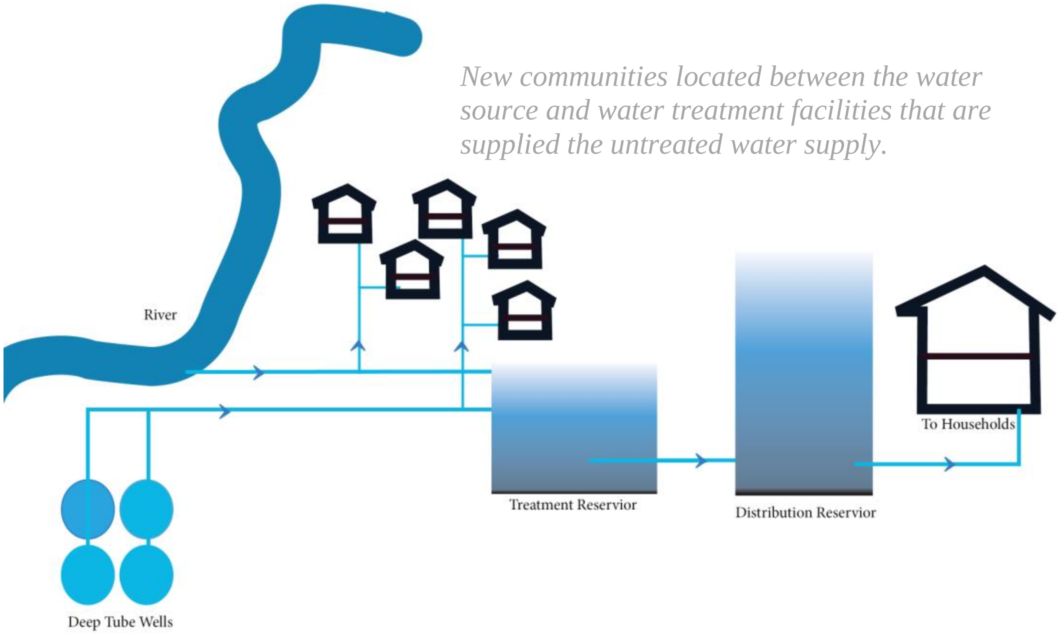


Figure 35 Diagram for the divergence of water supply from KUKL.

These new distribution lines were added without any changes in previous network, which makes the distribution system more costly and complicated. Whereas the hundred years old pipelines as shown in figure 36 are still there serving households with undetected leakage points losing 38% of total water production by KUKL which reduces substantial amount (loss of 96.52 MLD out of total production of 254 MLD) which could have fulfilled 27% of water demand (350 MLD).

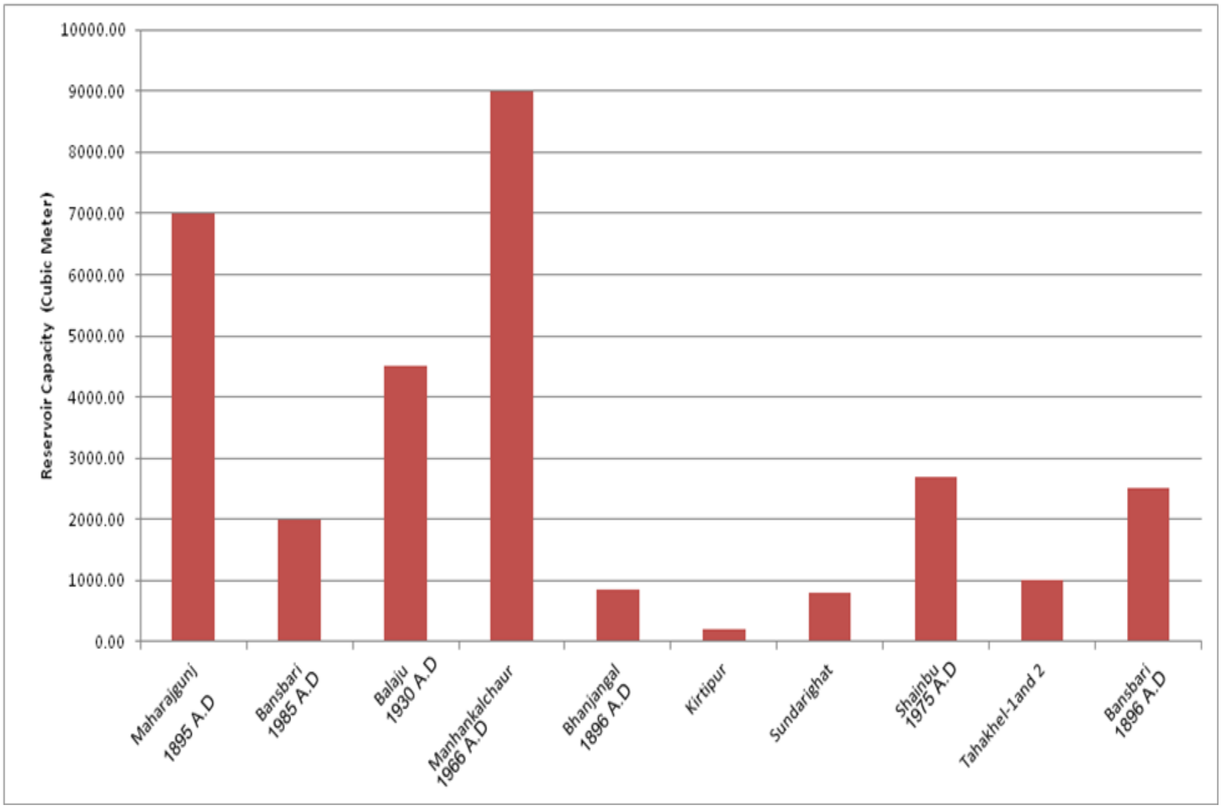


Figure 36 Reservoir capacity and year of establishment of different reservoirs used by KUKL for water supply in Kathmandu Valley. Source: KUKL

4.8.2 Estimation of water demand

KUKL has estimated the water demand of 350 mld with an average consumption of 135 Lpcd for 2.5 million people which includes 30% of temporary residents in Kathmandu Valley within it's service area due to the trend of high immigrants in recent decade. In 2001, Asian Development Bank (ADB) had estimated that each commercial and institutional had water demand is equivalent to 7% of total domestic water demand[22]. This trend might have changed but still estimations are still assumed . Currently for 2012, water demand estimation is done in a very general way. Though 100 Lpcd is the required amount as stated in National building code, KUKL has the estimation of 135 Lpcd which is the average for both commercial/ institutional and dometic purposes for whole Kathmandu Valley.

4.8.3 Waste Management in Kathmandu Valley

The trend of solid and sanitary waste disposal directly into river is not only making the surface sources polluted but also the groundwater because of their interconnection. This has made the available ground water unusable except for cleaning and flushing toilets. This waste management from the base level of each household is big step to be taken to keep rivers clean and for sustainable ecological system. The bigger scale of treatment plant is not being able to operate efficiently in Kathmandu Valley either due to financial matter or the uncontrolled excessive volume of waste for those treatment plants.

4.8.3.1 Current waste water management

In present, water-based sewage disposal systems and their unquestioned culural adoption and practice of dumping the waste at river side is one of the main reasons for the sorry state of Kathmandu's rivers.

According to NWSC, almost 50.8 Mld of wastewater was generated in Kathmandu Valley in 2001. 98% of households in urban Kathmandu has connection to sewerage line. Almost every household in VDC's have septic tanks which are either isolated or connected to the municipal sewer line and those which are connected to the sewer line ultimately drains off in the river sytem of Kathmandu Valley without treatment. Though piped potable water supply system was established from 1895, the piped sewer system was not introduced until 1920s and still the proper sewer planning sytem is not in record. No waste pipeline network system and quantity of wastewater discharged in local surface waters is recorded.

Residents are more concerned with the cleanliness of inside of the house not outside. In VDC people who are still involved with agriculture are using their own pits to decompose the waste and use it for agricultural purposes. In general surveyed people are consious about the waste management system which sends collected household wastes to the city collectors who ultimately dump the waste in dumping sites including rivers as well. But still the general concept of Kathmandu is that proper management of this waste is the responsibility of government bodies which is lacking far behind due to unplanned, uncontrollable and haphazad increase in population. Besides the household wastes dumped aside the river area, the culturally, the death possession is done in river bank and the remainings of cremation and burials are all dumped in riverwater as one of the major ritual activity.

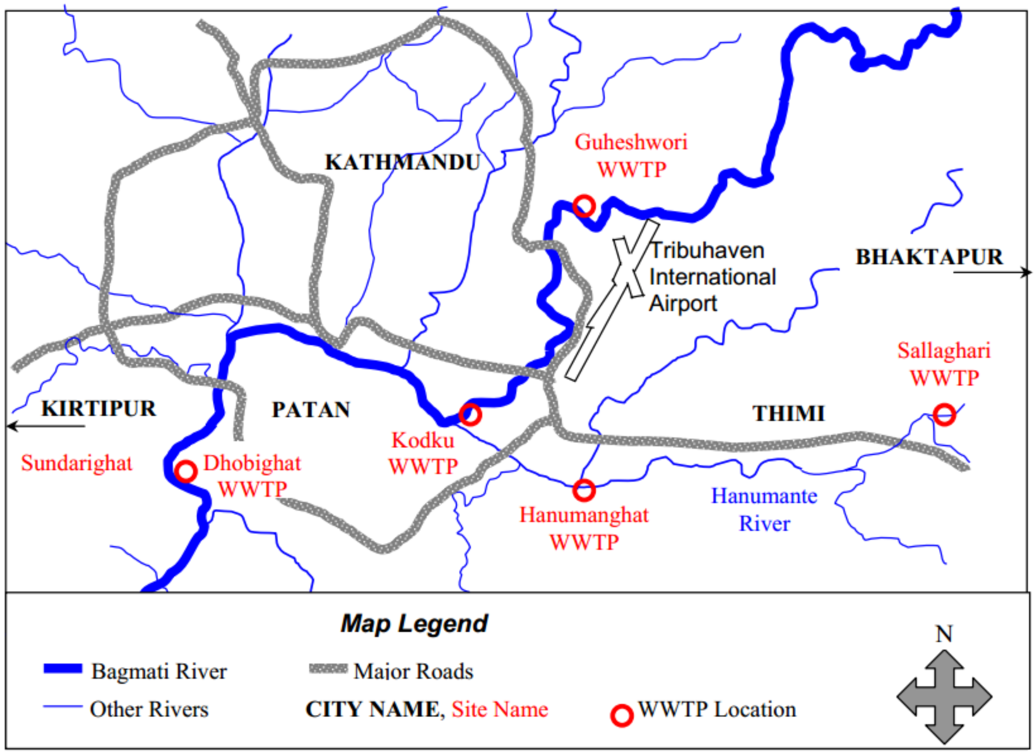


Figure 37 Map of Wastewatert plants in Kathmandu Valley. Source:[1]

There are five waste management systems in Kathmandu Valley as shown in Figure 37. Among five of them, only one of them was in operation i.e. in Guheshwori WWTP near Bagmati River ie Pashupati Temple area but currently it is not properly operation. As a result, the untreated sewer lines are ultimately dumping into the rivers polluting them.

4.8.3.2 Alternative approach for waste water management

Different studies have been conducted about constructed wetlands (CW) which are considered to be the most feasible solution for the wastewater treatment in Kathmandu Valley. The basic necessity of CW is land which is not easily available for these kind of treatment process as people are not ready to utilize for this system instead of using them for economical benefits because of the high cost of land in Kathmandu Valley. 1.6 m^2 of land is required to treat the waste of one person per day or $4m^2$ of land for treating one cubic meter of wastewater per day. Currently, constructed wetland practice is done in different locations of Kathmandu Valley as pilot projects specially by various large organizations to treat the wastewater is listed in table G in appendix.

Though there is potential of this sytem but lack of knowledge, experts, proper maintenance and finance is making the adoption of this system difficult in household level. Besides this, culturally people are not comfortable in re using the waste water eventhough it has been treated. Awareness program regarding health, environment is required to move forward with this system.

4.8.3.3 Traditional wastewater management system

The traditional wastewater management system is considered as the most sustaianable system for the wastewater management. The historical Newari community had devloped clustered compact houses with couryards in between for the agricultural purposes. Waste generated from households is resued for the agricultural purposes. As studied by Shrestha, the sustainable waste management system used in Newari community for the collection, conveyence, storage and utilization of wastewater has been described in following box 2.[23]

"Traditional Wastewater Collection and Management in Traditional Newar Settlements in Kathmandu Valley

In traditional Newar houses, a traditional sink, locally called "Dhow Pwo" is generally made in the kitchen for the disposal of wastewater produced in cooking and hand washing and mouth rinsing. This traditional sink consist of bowl shaped burnt clay with narrow open burnt clay pipe called Chee Dha, conveying wastewater to a multipurpose wastewater collection pit, known as Saagah (Saa in Newari means manure and ga means pit, thus Saagah stands for pit excavated for the collection of wastewater preparation of compost manure). The wastewater collection pit or Saagah is generally found developed on an open space at the backyard of the house where solid and liquid wastes generated in the house are dumped for composting.

There is also practice of making a common Saagah in the courtyard. Traditional Newar

settlements generally involve clustered housing stem with a court yard at the middle which is a common open space shared by the inhabitants. Wastewater from kitchen, biodegradable wastes and excreta from livestock are all collected and dumped in Saagah for composting. A small outlet made in the Saagah, called 'Byeku Pwo' is connected to an earthen conduit, called the Nali.

'Nali' which drains the wastewater to the collector drains, collecting wastewater from all the households in neighborhood. The level of outlet in Saagah is set at a level that as soon as the pit is filled with wastewater to the level of the outlet it starts draining into the channel. Once the

wastewater comes out of the individual houses through the earthen duct, its subsequent management becomes the community responsibility. The wastewater thus collected is either conveyed directly to the crop lands for irrigation uses or stored in the system of ponds where from the wastewater is recycled for subsequent irrigation uses. The ponds serve the purpose of oxidation tanks and hence they are part of traditional wastewater treatment system.

The traditional Newar households also practice their own sustainable system of solid waste management within the homestead. In traditional houses, an ash collection pit known as 'Naugah' is made on the ground floor inside the house, usually located underneath wooden staircase, where the family members urinate which forms a mixture of urine and ash. This mixture gets matured in about three months time and then removed and transferred for use in the farm lands. In the early days an open space was kept close to the settlements for open defecation, called 'Mhola' or 'Gaa' for use by the female and male members in the community. This practice of open defecation is almost vanished in most settlements although this was widely in practice prior to 1960s."

As described above the decentralized solid and sanitary waste maangement system in ancient time was greener due to recycling the materials and recycling them without waste of energy and resue them for agriculture purposes. With decrease in agriculture land and increasing urbanization, this system has diminished slowly except in few VDC's areas. Smaller scale of these kind of decentralized waste and wastewater treatment system can be incorporated in small community level before discharging it to natural water resources.

4.8.4 Rain water harvesting

Rainwater harvesting is always in practice from ancient time either in households or in the form of collection in ponds for recharging and supply to the stone spouts.

Rainwater harvesting (RWH) for potable water in household level has been initiated last year in some communities in Kathmandu Valley. The Center for Integrated Urban Development (CIUD) has started to implement RWH in various areas like Dallu and Patan. Currently, the new project of RWH Phase 2 by CIUD is in the process of implementation at Hyumat and Bramha Tole of Kathmandu Metropolitan City with approximately 2053.5 Sq. feet of catchment area from which 13,142,947 liters of water is estimated for recharge. Some other exemplary projects of RWH, which are already established, and in process are shown in Table H. of appendix.

4.8.4.1 Rain water harvesting potential in Kathmandu Valley

Kathmandu valley on average receives 1533.61 mm of rainfall per annum, 80% of which occurs in wet season and remaining 20% of rainfall is dispersed in other months of the year. In Nepal, the seasonal storage index i.e. the volume of storage needed to satisfy annual water demand based on average seasonal rainfall cycle is 29.86 cubic km[24]. 650 Km^2 of Kathmandu Valley area receives 996,846.09 million liters of rainfall in a year which is 8.06 times the annual water demand of 2,510,789 people of Kathmandu (135 Lpcd). Rainwater harvesting could be the mechanism to both meet the water demand and help in recharging the groundwater. RWH could be a reliable, cost effective and sustainable alternative water supply system in Kathmandu Valley. Thus, it seems to have great potential to address the water crisis.

4.8.4.2 Current practice of rainwater harvesting

Even though RWH systems are acceptable in community, they had not been a helpful solution for the residents of Kathmandu. Due to the shortage in water supply, residents of Kathmandu already started collecting rainwater as alternate source and considered as one of the required processes for the collection of available water for the daily activities. Urban areas have already started to be active in collection of water from the roof in their open containers (Polythene drums of 500- 1000 liters, small silver containers called Gagri and Buckets of 20 liters) and use them for about 2 days or for a week for washing and bathroom purposes.

Most of the houses in core areas already have well managed storm water pipe system which drains away in the municipal sewer pipeline which ultimately drain to the adjacent river. Small investments could result in properly managed RWH systems, but according to the field coordinator Jeevan Kasula, people are not convince that investing in RWH system is a good idea. Education could help people understand the RWH system benefits. During interviews with local people around the Hyumat area, they believe water is a free service that they are getting from ancient time and do not feel that should have to invest in it. The installment of RWHS in the community does not require substantial funding but the space for the collection tanks and the place for recharging is difficult to find. Sometimes small width crossways into courtyards are not big enough even for the collection tanks.

During the face to face interviews with local people, various perspectives are mentioned in local area of Kathmandu Valley about the RWHS adaptation.

- They usually collect rain water directly from the roof in small containers and store it in open containers. Rain water collected is only appropriate for bathroom flushing and cannot be used even for the washing purposes because the water smells after a week.
- Water has sacred values. Day old water that is collected in rainy season is not good for ritual purposes. Fresh water from the running source is necessary either from stone spouts, well or city supply line but not from the collected containers.
- Rain in Kathmandu is seasonal and they need water year round. People are still skeptical about the usability of stored rainwater year round. Advanced filtering systems could bring positive thoughts in using the water for at least other purposed than drinking.
- The buildings which are already constructed in city core area are compact and skylines vary in each house. This makes difficulty in technical improvements for RWH system and cost also varies accordingly.
- In courtyards, the collective RWH system is an excellent idea but the conflict comes when there is need of space for collection tanks and recharging points.
- Government should be all responsible for the supply of water. People are not ready to invest more for the water supply besides the monthly tariff for KUKL believing that the amount they get from government is far less than what they pay for.
- In spite of the wish to have a RWH system in courtyard houses, some communities are not able to install this system due to the small width of entry ways to get the collection tanks inside the courtyard for rain water collection.
- The maintenance of the traditional architecture in historical zones is another problem for dwellers as it is difficult to install the RWH System in already constructed houses without disturbing the architecture of the building and area.

In terms of quality, the physical and chemical parameters of the rainwater are found to be well below the WHO guideline however it is contaminated with coliform bacteria which make it unsafe for drinking. However, a few simple treatment processes like SODIS (water treatment through UV rays), boiling, filtration and disinfection to kill bacteria, first flush technology could make the rain water acceptable for drinking purposes. These processes are already in practice in

Nepal for the treatment of the water even for the water supplied either from city pipeline or private tankers or dug wells, which would, makes it easier for people to accept RWH.

4.8.4.3 Water demand fulfillment through rainwater harvesting in Kathmandu Valley

For current condition of 2011/2012 , assuming that only the houses with galvanized roof, Rcc roof and tiles roof starts to harvest rain in household level, the amount of collected rain fulfills for 49.9% of water demand of the households with RWH. Refer Table T in appendix. Minimum land division allowed is 855.625 sq. ft, this area is assumed as the average house area for households with 4 person. In wet season, 415 MLD of water could be collected which is 75 mld greater than the theoritical demand. Similary 58 mld could be collected in dry season which could provide 15% of water demand. If the extra 75mld of water of wetseason (122 days), 41,760 mld could be stored to use it for 216 days (73 Lpcd) but the storage is the biggest challenge to implement RWH system effectively.

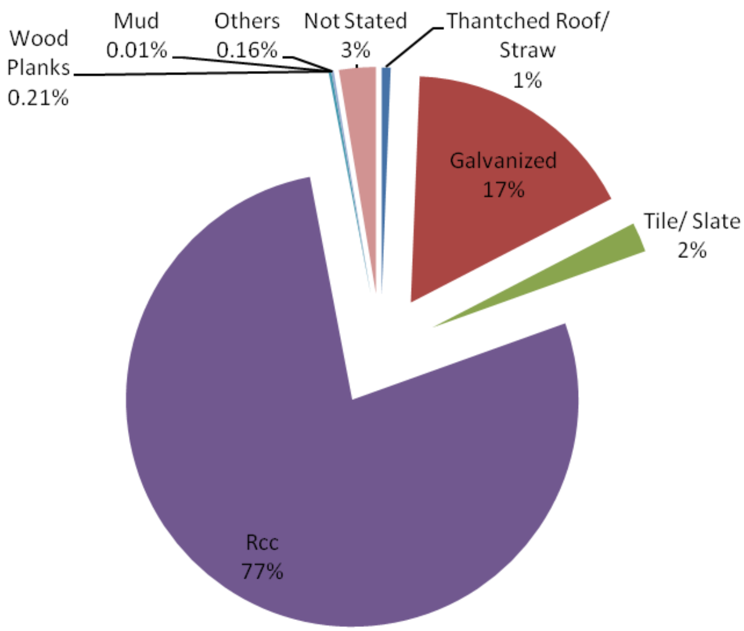


Figure 38 Distribution of houses according to types of roof material in Ktm. Source: CBS 2011

Storage is the biggest challenge to implement the RWH system effectively in Kathmandu Valley. During survey, 78% of house has underground water tank which ranged from 9000 liters to 12000 liters. Along with the underground water tank, 99% of houses have roof top polythene tank (500- 2000 liters) as storage of water for daily purposes. Along with this many of them use small storage units, Jars (Gagris) of about 20 liters as storage of rainwater and use it for few days. Assunming that only 10%, 10% and 80% of galvanize roofed house, tile roofed house and RCC roofed house respectively has underground tank of 12,000 liters of storage in their house along with 2000 liters of roof top storage tank(in households with RWH system), the total available storage would be 5,383.63 million liters which could provide water to these RWH houses for 15 days (theoritical demand 135Lpcd) and for 27 days if consumption is73 Lpcd. Thus results with fullfilling only 4% of theoritical annual water demand for current year. Detail calculation for availability of water for rainwater harvesting is attached in table T in Appendix.

4.9 Alternate water supply schemes in Kathmandu Valley

4.9.1 Melamchi Water Supply Project (MWSP)

The Melamchi Project, which was effective since Nov 2001, is a comprehensive water supply project aiming to improve the health and well-being of Ktm people by delivering out of watershed water from the Malamchi River to Ktm as shown in Fig. 39.

It is still a great hope to everyone in Kathmandu Valley. According to the Gyanendra Bhattarai of Melamchi Project Development Board (MPDB), of 26 Km of proposed tunnel project for water supply from Melamchi to Ktm. 6 Km of tunnel construction is finished. This project is estimated to be completed in 2016. It also claims it is an improved water supply system proposed to serve a total population of 722,053 in an area of 1700 hectare with a minimum supply of 2hrs per day. The MWSP is working on infrastructure development, which comprises of 26 K diversion tunnel, roads, water treatment plant and bulk distribution system, distribution network improvement and water source improvement in Ktm. This project not only looks for the bringing water from another source outside the Valley but also considers looking the issues of social and environmental support to mitigate potential negative project impacts and improve the living conditions of the beneficiaries. In first phase, this Project aims to supply 170 MLD of water from Melamchi river source to Kathmandu though Sundarijal treatment plants. In second

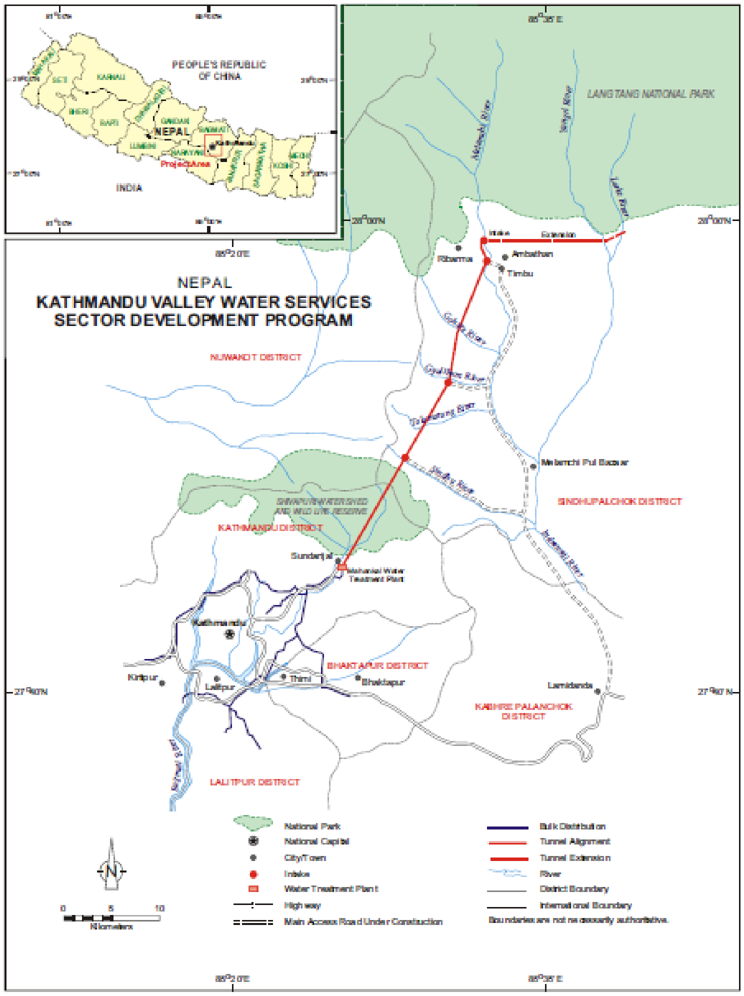


Figure 39 Map showing Melamchi water supply project detail.

phase, 540 MLD of water will be supplied from other two major sources i.e. Larke and Bangri Source. The total project is estimated to cost $317.50 million(Rs 27,813 million). As the current monthly cost of water for the drinking purpose provided from municipal supply is Rs 50 per 10,000 liters but also varies from Rs 10 to Rs 80 in VDC areas. Thus, the MWSP seems highly expensive. Besides this, water from another source inside the Valley could directly or indirectly affect the natural water balance of Kathmandu Valley with huge impact on environment, human socio- economic development and overall ecosystem.

4.9.2 Additional Groundwater supply

According to KVWSMB, 15 more deep tube wells extracting water from deep aquifers are planned to bore in various locations to meet the water demand of Kathmandu in 2012. 10 MLD of water is estimated to produce from each tube well in wet season and 9 MLD in dry season. This project is estimated to reduce the gap in water demand by 42.9% in the dry season and 25% in the dry season. Despite of awareness for the ground water depletion due to these kinds of extraction, the government feels it has no other option to get water for city until the great hope of Melamchi is completed. The sustainable abstraction rate has already been exceeded since 1985. These additional deep tube wells will add up more stress to groundwater. As recorded in figure 25 since 1980 A.D, 197,778.18 Million liters has already been abstracted from deep aquifers (Storage capacity of 572,000 Million liters). If the abstraction rate from deep aquifer is same as of 2011 i.e. 64.32 MLD, (377,871.80 Million Liters of remaining amount in deep aquifer), it could supply water for 16 years only. However, with additional abstraction of around 10 MLD from each of 15 deep tube wells (150 MLD) will limit the supply for 4.83 years only.

5 Sustainable water Supply in Kathmandu Valley

5.1 Introduction

Rainfall is the only source of water for the any local sustainable water budget. Some of this precipitation evaporates back into the atmosphere. Most of the remaining precipitation infiltrates the ground, where it accumulates in the soil. If the soil is saturated, the excess moisture runs off as surface or underground streams. The surplus amount from rainfall and groundwater drains off as surface runoff.

Water budget can be calculated with following formula;

P = Evt + I + RO

Where,

Precipitation (P) = Rainfall

Evapotranspiration (Evt) = Evaporation (Ev) + Transpiration (T)

Infiltration (I) = Shallow Infiltration (SI) + Deep Infiltration (DI)

Runoff (RO) = Drainage from Bagmati River from Chobhar

As mentioned before, in Dry season, groundwater contributes for the river water in Kathmandu Valley. During the dry season, the recorded evaporation rate is higher than precipitation. This condition is because the precipitation is less than potential evapotranspiration in which a water shortage exists. To make up for this shortage, water stored in the soil will evaporate. The monthly evapotranspiration data is attached in table E in appendix.

5.2.Pre-settlement water budget

The historical cities in Kathmandu Valley are estimated to be established more than 2000 years ago. Considering the origin of Kathmandu Valley, according to legend, it was once known to be a big lake. Similarly to Mexico City it was believed to be drained off by the China Saint called Manjushree and afterwards settlement started. There are some geological evidence which proves that the lake may not have drained off at once but in phases due to the geological changes.[25]

The accurate land cover of pre-settlement is hard to define. The land cover data of 2010 AD is collected from ICIMOD. As the exact land cover is not defined in the data collected, the area of the land cover were traced in Auto cad to calculate the approximate areas of land cover which lies just inside the Valley area i.e. Watershed area (650 Km^2). The built up area were considered to be woodlands and agricultural lands were considered to be grassland in pre- settlement period. The surface runoff amount is calculated using these areas as shown in Table15.

Land Cover	Area in Sq.Km	Runoff coefficient	Precipitation in mm	Total Runoff in million liters
Needle leaved closed Forest	118.73	0.45	1,533.61	81,944.94
Needle leaved open Forest	14.66	0.45	1,533.61	10,117.36
Broadleaved closed Forest	80.81	0.45	1,533.61	55,770.25
Broadleaved open Forest	34.04	0.45	1,533.61	23,492.31
Grassland	5.34	0.5	1,533.61	4,094.74
Woodlands (Existing :Agriculture)	264.74	0.25	1,533.61	101,505.46
Bare area	5	0.6	1,533.61	4,600.83
Grassland (Existing: Built-up area)	126.34	0.35	1,533.61	67,818.97
River	0.53	0	1,533.61	-
	650.21			349,344.85
			35.0% of Precipitation	

Table 15 Runoff in Kathmandu Valley at pre-settlement period

The Kathmandu Valley is the largest single lacustrine clay deposit in Nepal and the occurrence of fertile soil on that lacustrine has strongly influenced the development of the country. These fertile soils are fine textured, stable and are relatively easier to irrigate which is ideal for plants. Two distinct geographical features, central flat land with around 5 degree slope in average and surrounding hills i.e. more than 20% of land with more than 20-degree slope resulted for the 35% of rainfall gets runoff. Considering 165 mm per year as the recharge rate from 214 Km^2 of the shallow aquifer surface area 39,685 million liters/year is recharged in shallow aquifer (4.0% of rainfall). It is estimated that 80 million liters (0.01%) is recharged in deep aquifer. Thus remaining of rainfall is considered lost as evapotranspiration i.e. 607,736.24 million liters (61%). The hydrological cycle of Kathmandu Valley for pre-settlement condition is calculated as shown in figure 40.

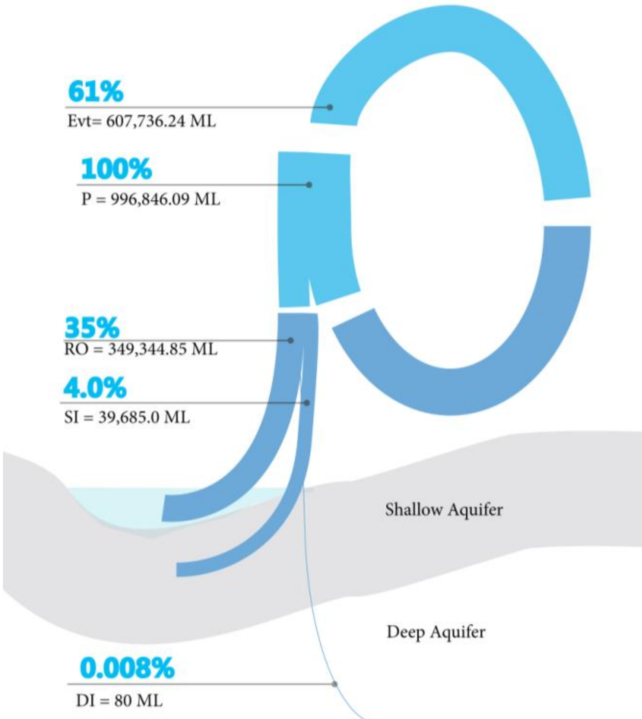


Figure 40 Water budget of Kathmandu Valley for pre-settlement condition.

5.3. Existing Water Budget

The perennial Bagmati river flow is generally governed by the surface runoff of rainfall during wet season and during dry season; it is more upon groundwater flow when the river does not receive rainfall. River flow rate of 2.71 m^3/s is recorded in 2006 even without rainfall of four months. During the dry season the pond irrigation in terrace agriculture land for rice cultivation also contributes for water infiltration which supplies water to shallow aquifer and ultimately drains as river discharge. As shown in table A1 attached in appendix, the Bagmati River has significant amount of flow in all season. The table 16 and 17 shows the comparison of the river flow and the rainfall relation.

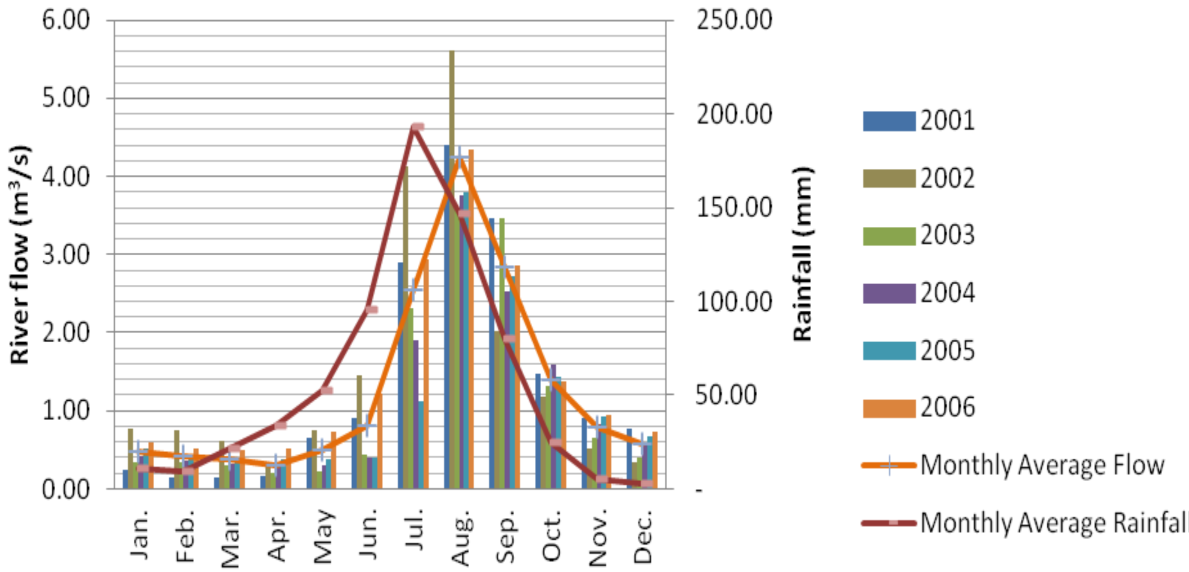


Figure 41 Relation between rainfall and river discharge.

Figure 41 shows that there is a lag of about one month between peak rain and it's impact in river flow. This shows that the infiltrated water during the rainfall slowly percolates through the surface soils and ultimately contributes for the river flow.

Year/ month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
2005 Rainfall in mm	57.6	17	50.1	36.5	38.4	222.9	253.5	309	126.5	126.1	0	0
2006 Rainfall in mm	0	0	30.9	132.8	145.5	216.2	337	248.4	217.5	43.9	1.5	17.5

Table 16 Rainfall in Kathmandu Valley in 2005 and 2006

Month	**Nov**	**Dec**	**Jan**	**Feb**
Year	2005	2005	2006	2006
Bagmati River flow rate at Sundarijal , m^3/s	0.68	0.68	0.595	0.51
Bagmati River flow rate at Khokana , m^3/s	5.17	5.17	3.88	3.22
Contribution from groundwater	4.50	4.50	3.285	2.71

Table 17 Groundwater contribution to river flow during no rainfall.

From the data collected from ICIMOD for the current land cover of 2010, 50.8% of rainfall is calculated as surface runoff as shown in Table18. The observed average runoff from Bagmati is more than calculated amount. The runoff as river discharge is contribution of both rainfall and groundwater discharge. Thus, the groundwater runoff is obtained after subtracting the rainfall runoff from observed runoff. Due to the unavailability of data for river discharge for year 2010, the comparison for the runoff is done considering no difference in land cover in 2006 and 2010.

2010 Land Cover	Area in Sq.Km	% of total area	Runoff coefficient	Precipitation	Total Runoff	
Needle leaved closed Forest	118.73	18.3%	0.45	1,533.61	81,944.94	
Needle leaved open Forest	14.66	2.3%	0.45	1,533.61	10,117.36	
Broadleaved closed Forest	80.81	12.4%	0.45	1,533.61	55,770.25	
Broadleaved open Forest	34.04	5.2%	0.45	1,533.61	23,492.31	
Grassland	5.34	0.8%	0.5	1,533.61	4,094.74	
Agriculture	264.74	40.7%	0.35	1,533.61	142,107.65	
Bare area	5	0.8%	0.6	1,533.61	4,600.83	
Built-up area	126.34	19.4%	0.95	1,533.61	184,080.05	
River	0.53	0.1%	0	1,533.61	-	
	650.21			Annual runoff calculated (TROa)	506,208.12	**50.8% of Rainfall**
				Annual runoff observed (R)	524,994.19	
				Ground water runoff (GR)	18,786.07	

Table 18 Runoff calculation for existing condition.

The evaporation from the impervious surface area i.e. built up area and water body is calculated as shown in Table19.

Land Cover	Area (Sq.Km)	Annual Precipitation (mm)	Coefficient	Total Evaporation (ML)
Built Up Area	126.348	1,533.61	0.05	9,688.42
Water Body	0.53	1,533.61	1	812.813
Annual Evaporation (Ev)				10,501.23

Table 19 Evaporation calculation

The maximum recharge rate of 165 mm/year is considered for the calculation of the total infiltration in shallow aquifer. As the current land cover has replaced the open surface area, the infiltration through the remaining surface area of shallow aquifer i.e. 200.652 Km^2 infiltrations 33,107.58 ML/year.

Shallow Infiltration (SI) = 33,107.58 ML

Deep Infiltration (DI) = 80 ML

With all the above-calculated parameters, evapotranspiration (Evt) is obtained as follow,

Evt = P – Ev - SI- DI – R

This calculation shows that 359,833.34 ML of rainfall contributes for the Evapotranspiration. Total annual evapotranspiration including evaporation is 45.9% of total rainfall i.e. 4457,530.39 ML.

Thus, Evapotranspiration is calculated using balancing formula, which resulted as 447,029.15 ML (44.8%). The current water budget of current Kathmandu Valley of 650 Km^2 is as follows:

100% P = 50.8% as R + 1.1% as Ev + 44.8% Evt + 3.3%SI + 0.008% DI

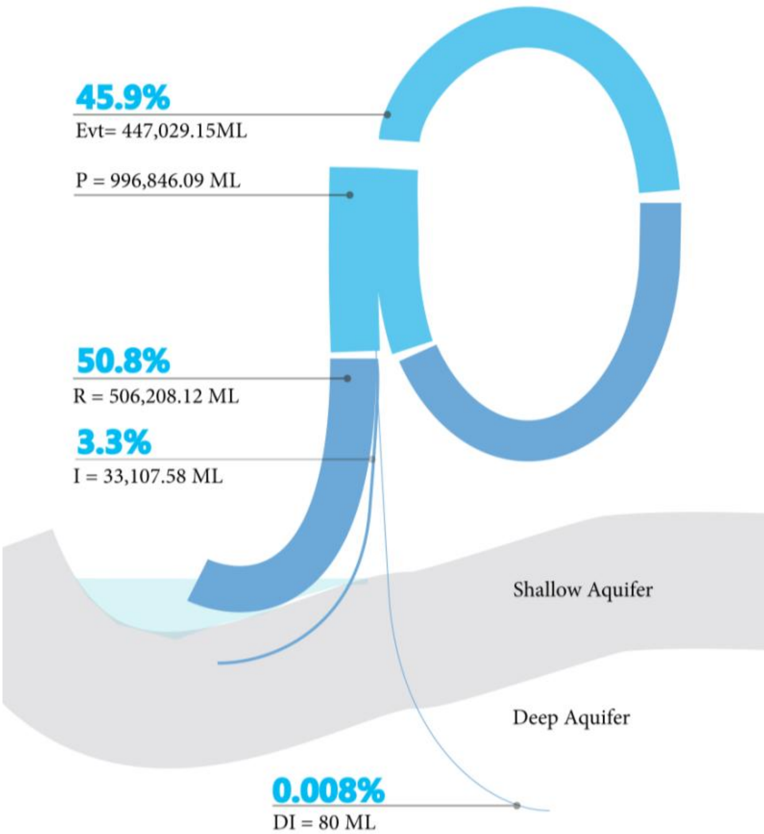


Figure 42 Current water budget of Kathmandu Valley.

The infiltration, runoff and evapotranspiration are not same for all the year round. It differs with the rainfall pattern, the temperature, and other various factors such as the wind, humidity, the soil moisture content and level of water table. In dry season, due to the lack of river flow, the abstraction from ground water increase which rapidly decreases the water table. In wet season, the rainfall again raises the water table due to which the soil moisture content is also high. This high moisture content is one of the causes for high observed evapotranspiration in dry season than the total precipitation.

The following figure 43 shows the water budget for the dry season and wet season in Kathmandu Valley.

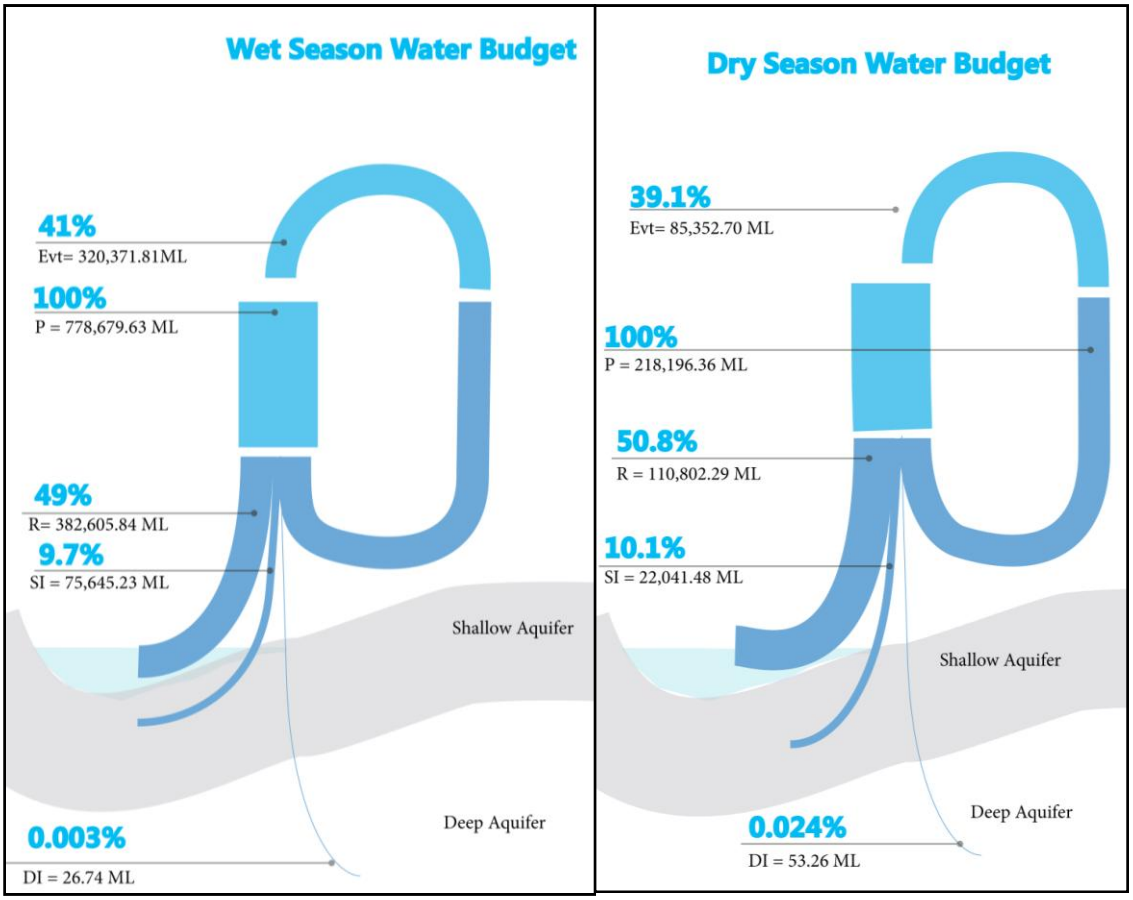


Figure 43 Water budget of Kathmandu Valley in wet season and dry season

The water budget calculation shows that in wet season the infiltration rate is 9.7 % (75,645.23 ML) which is higher than the estimated annual recharge amount. Thus it implies that about 60% of the infiltrated amount contributes for the shallow aquifer recharge. The remaining could be a part of soil moisture contributing to surface runoff or evapotranspiration. Only the recharges amount is considered as sustainable abstraction amount from shallow aquifer.

5.4 Sustainable water quantity

In Kathmandu Valley, as per current practice, the river water, shallow aquifer water and deep aquifer water are the main source of water supply. Perennial rivers of Kathmandu Valley cannot provide regular supply of same amount throughout the year. In Dry season it's mean flow reaches up to 1.53 m^3/s where as in wet season it has 53.3 m^3/s. The abstraction from the surface source affects directly or indirectly the natural habitat. The nature must not be disturbed and must be considered while using any natural resources. Richter has suggested that sustainable abstraction from river is only possible, if only +/- 11-20% of mean annual natural flow rate is maintained. This will at least provide the moderate level of environmental protection. Beyond this level, there is high chance of ecological risk. Figure 44 Shows the presumptive standard suggested for providing moderate to high levels of ecological protection. The greater the departure from natural flow conditions, the greater is the ecological risk to be expected.[26]

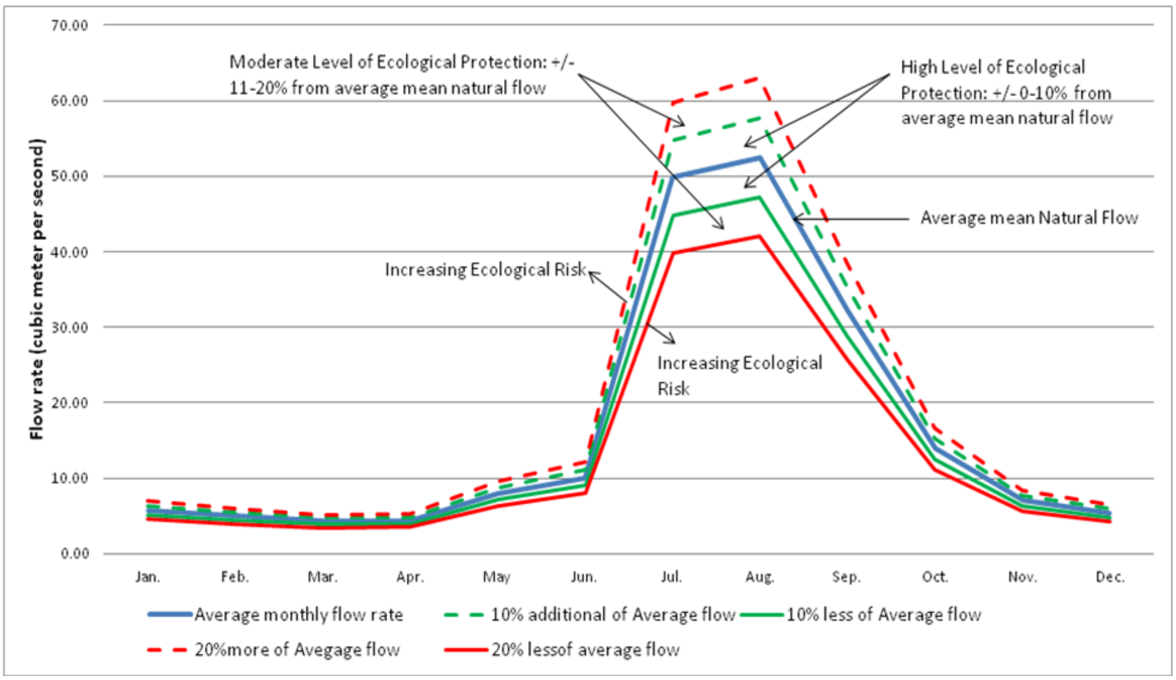


Figure 44 Presumptive standards for providing moderate to high levels of ecological protection. Source: [26]

Maintaining the flow rate i.e. 20% less than average flow, the annual sustainable abstraction from river system in Kathmandu valley is calculated as shown in appendix. Only 287 MLD of water (116.54 MLD in dry season and 628.50 MLD in wet season) can be abstracted as shown in Table 20. The current abstraction is still below the range of sustainable abstraction. Currently the abstraction ranges 59MLD and 115MLD in dry and wet season respectively from KUKL. Due to the leakage problem, the supply ranges from only 31.43 MLD and 17.93 MLD respectively. Different river have different flow rates and abstraction should be scaled accordingly.

Season	**Days**	**Average flow, ML**	**Percentage of total mean flow**	**Sustainable abstraction per day, MLD**
Wet season	122	76677.70	20%	628.50
Dry season	243	28321.14	20%	116.54

Table 20 Sustainable abstraction from surface source

The following table 21 shows total sustainable quantity of water i.e. 394.22 MLD is available that could be used by estimated maximum population i.e. five million people of future Kathmandu Valley.

Source	**Total Wet Season, MLD**	**Total Dry Season, MLD**	**Average annual Sustainable use, MLD**
Deep Aquifer	15.00	15.00	15.00
Surface Source	628.51	116.55	287.67
Shallow Aquifer	318.79	0	106.55
Total sustainable use of water	962.29	131.55	409.22
Water Available without using deep aquifer	962.29	116.55	**394.22**
Total Annual sustainable water available without using deep aquifer			143,890.84 ML

Table 21 Total available water quantity for sustainable use

The availability as well as the pattern of use of those available water is equally important to assure the availability of same amount of water in near future too. The current use of the surface water resources are not being used in sustainable way in dry season and has potential to use more than what is being used in wet season due to high rainfall. The use of deep aquifer has been already been exploited extremely. Because of the limited recharge rate, the deep aquifer is not considered as a sustainable source for water supply in Kathmandu Valley.

Thus, total 394.22 MLD is available in Kathmandu valley for water supply. The balanced sustainable use of these available resources is very important to be considered for water supply.

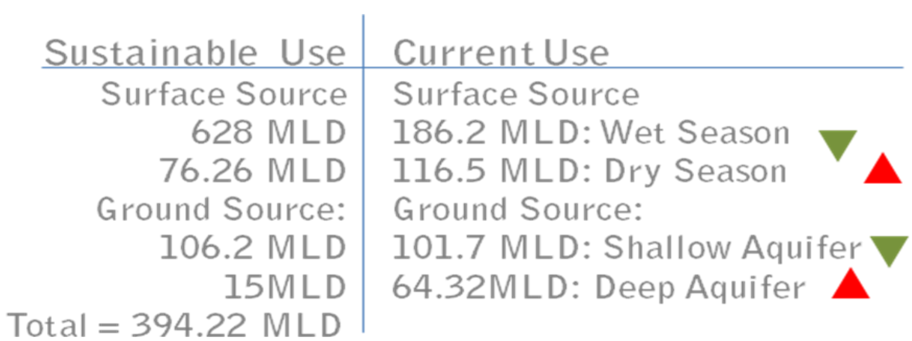


Figure 45 Comparison on sustainable use and current use of available water sources.

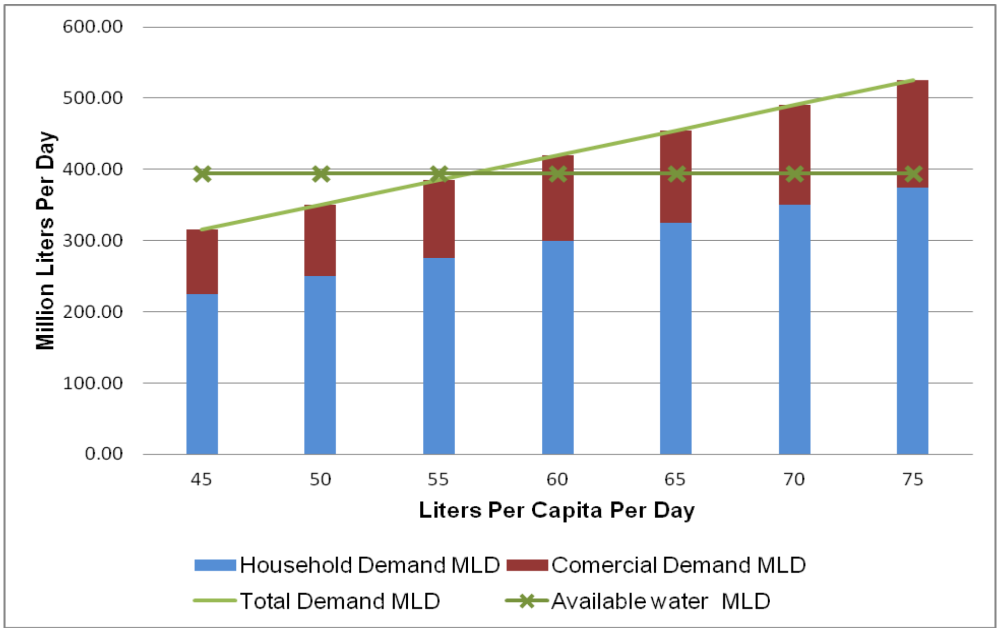


Figure 46 Total consumption, demand, and availability of water.

From the existing water use calculation (Refer table K in appendix), commercial demand is considered as 40% of domestic demand for the further calculations and the total demand is also estimated likewise. The comparative analysis done for the consumption level that should be maintained to meet the demand is shown in fig 46. This shows that for 5 million people, maximum limit of domestic consumption should be 59.26 Lpcd to use the abundant but limited amount of water (394.22 MLD).

Wet Season	Dry season	Annual	Units	Descriptions
5,000,000.00	5,000,000.00	5,000,000.00	Persons	**Population including migrant and temporary visitors**
56.29	56.29	56.29	Lpcd	**Water consumption**
281.46	281.46	281.46	MLD	**Domestic Demand**
112.76	112.76	112.76	MLD	**Commercial and Industrial Demand**
394.22	394.22	394.22	MLD	**Total Demand**

Table 22 Water demand of Kathmandu valley for maximum population

However, the water availability is not constant throughout the year. Thus, available water must be managed accordingly to balance hydrological cycle and the water supply for whole year round. There must be storage both on a centralized and decentralized basis

5.5 Water availability in future Kathmandu

With increased population, urbanized settings will be changing and the water availability too. With the landcover change, the water budget of future Kathmandu will have significant changes such as have high runof, less infiltration as shown in figure 46. Calculation table is attached in table O1 ans O2 in appendix. This imbalances the water availability in both surface and ground sources.

The 3.4% of rainfall infiltration in this calculation is almost similar with the current condition. This is only possible if the new constructions are not allowed on shallow aquifer surface areas or other areas are opened up for infiltration. With the increase in impervious surface, the runoff increases by 22.5% over the current condition. This might disturb the ecological processes. Groundwater and surface water are interdependent to one another. Both of them are being used for human purposes and ground sources are being used beyond the point of recovery. Thus, both sources need to be considered as one basin and the effective balancing management needs to be implemented to assure the same amount of water availability in future too.

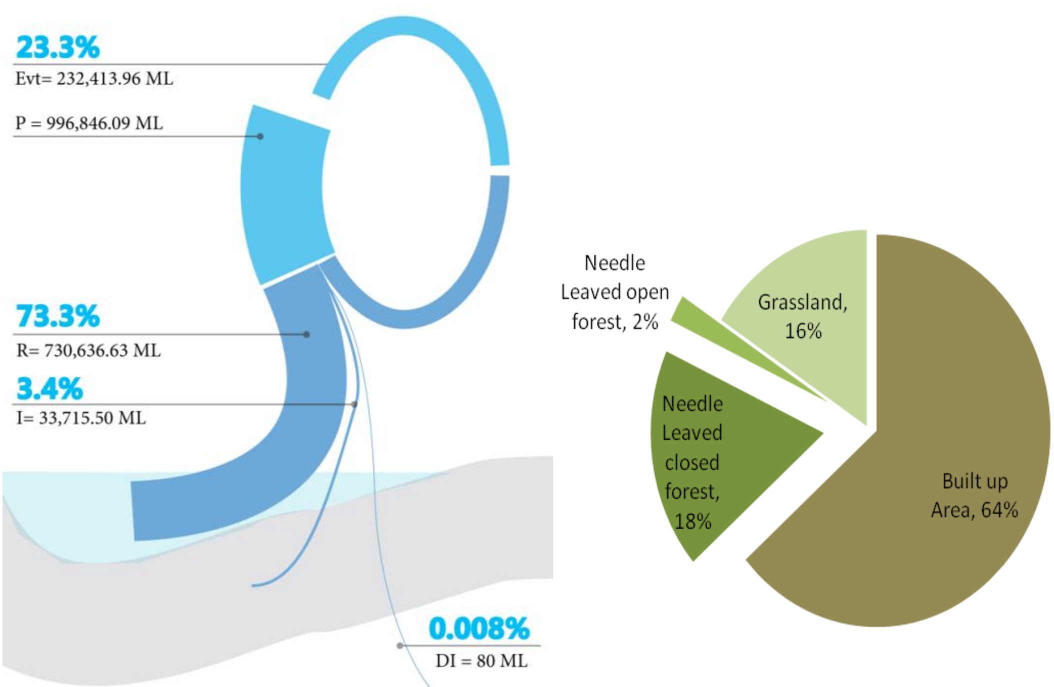


Figure 47 Future water budget of Kathmandu Valley and assumed land cover.

5.5.1 Watershed management

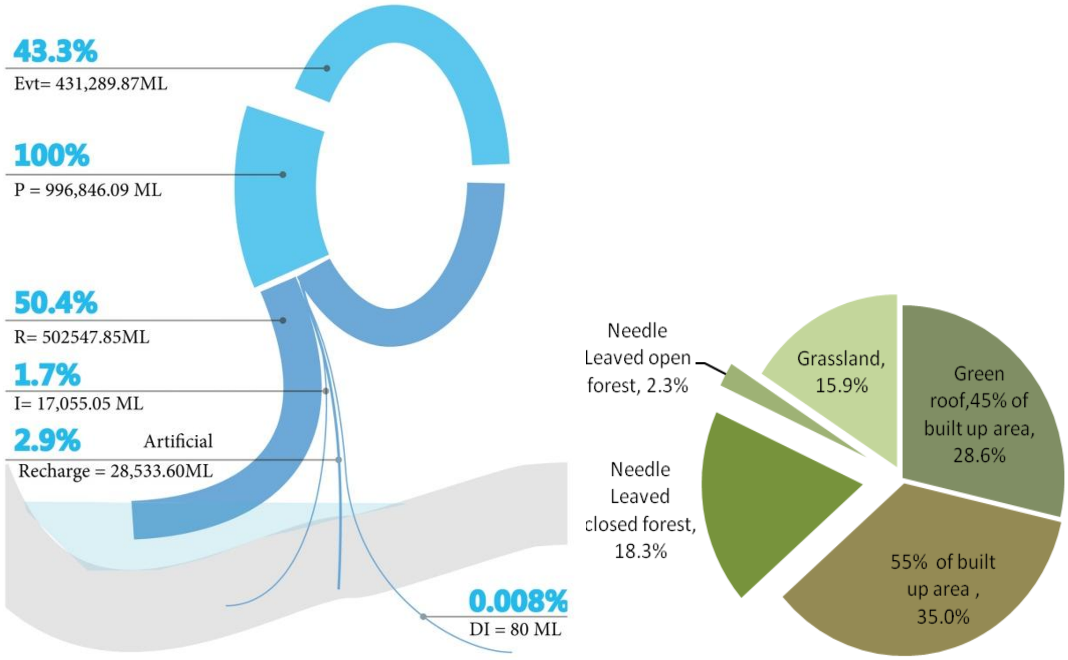


Figure 48 Water budget of future Kathmandu with proposed watershed management strategies.

The imbalanced water budget in future Kathmandu Valley can be balanced by applying few watershed management strategies. The changes in hydrological process of future Kathmandu Valley could have high impact in the ecological system. Few of the strategies applied to balance the green roof and pervious surfaces as shown in figure 48, which could help in balancing water budget and maintain water availability as of current condition are described below.

5.5.1.1 Green roof and pervious surface

The 45% of built up roof area is assumed as green roof. This reduces the runoff by 44.8% in comparison to the assumed future condition. The runoff from the remaining 55% of the total built up area will ultimately drain off to river (Runoff = 50.4% of rainfall), and counts almost same percentage of rainfall as it is in 2011 condition. The calculation is shown table K in appendix. The 20% of open space needs to be pervious through which 1.7% of rainfall infiltrates naturally. These simple techniques could maintain the hydrological cycle in somehow as of current condition. The green roof will only increase the transpiration rate, control the runoff quantity and not recharge the aquifer. The aquifers have the large storage capacity for the valley. Thus to make sure enough water infiltrates and stored in the aquifer, artificial infiltration is must.

5.5.1.2 Induced Infiltration

The water budget become impossible to balance without recharging the groundwater artificially. The study by Water Aid in Nepal in the Patan area (Southside of Kathmandu Valley) states that dug wells have higher (0.292cm/min) infiltration rate and have high recharge potential compared to pits (0.192cm/min) due to their direct access to aquifer horizon.[27]. Thus, the rainfall runoff from these proposed green roofs, which accounts for around 2.9% of total rainfall. This could be directed to the individual dug wells, which recharges the groundwater and the surplus runoff could be drain off to the ponds nearby which supports for more infiltration and maintains the flow of water in traditional stone spouts from where it ultimately drains off to river. The effective networking system needs to be established between the traditional ponds and each household. As there is trend of well construction in each individual plot, each plot has its own well where the rainwater runoff from green roof can be directed to these dug wells after passing through the filtration chamber to block the bigger impurities. This process could help in infiltration process for the shallow aquifer in wet season and provide water for dry season.

5.6 Water supply Capability of Kathmandu Valley

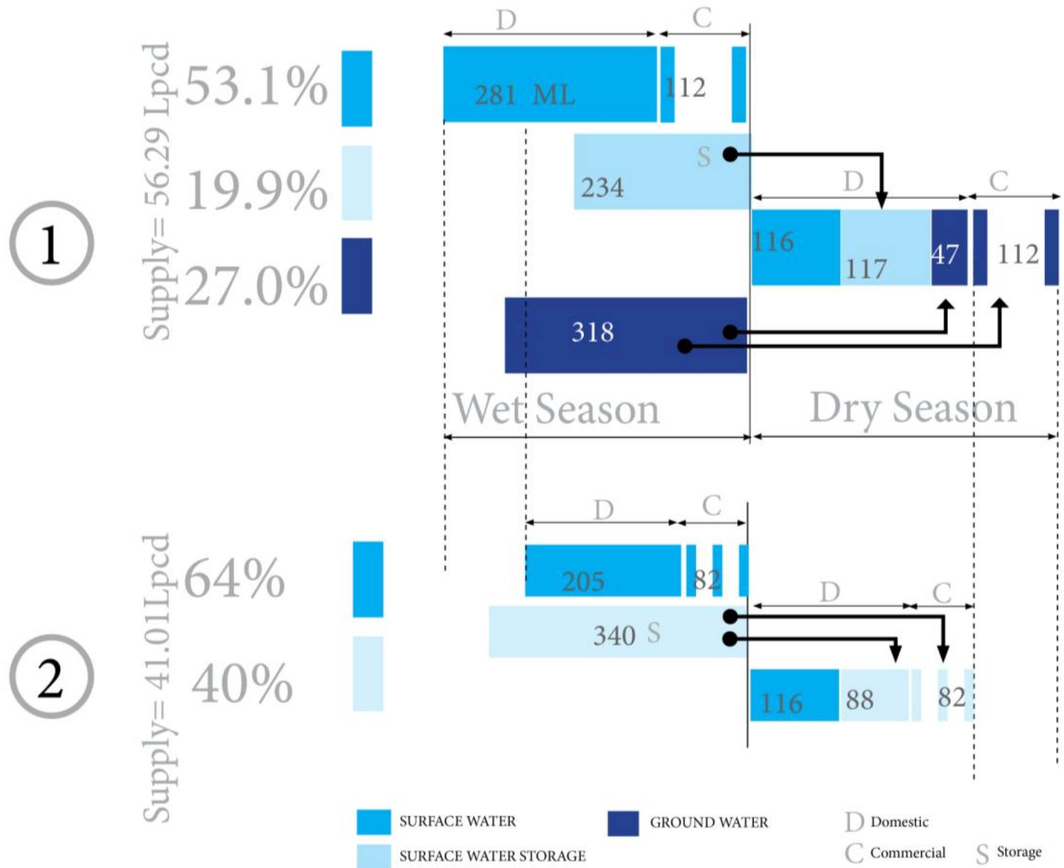


Figure 49 Alternate distribution patterns for available water in different season.

Kathmandu is currently extracting water supply using both sources. As shown in figure 49, option 1, using groundwater along with the surface water is one of the direct way to fulfill the demand of Kathmandu Valley with limited supply of 56.29 Lpcd to use only the sustainable available amount. No groundwater should be abstracted for wet season as surface water available could easily fulfill the demand. High flow rates of rivers during wet season due to high rainfall makes it possible to abstract more than the demand which need to be stored for using it in dry season. The surplus amount from surface source abstraction, 41,580 ML (234 MLD in Wet season = 117 MLD for dry season) could be stored for use in dry season. This storage can be done in shallow aquifer storage space as it has huge storage space as mentioned above or in surface reservoirs. Due to the high pollution level in ground water, it might be more expensive for water production to re-abstract from the aquifer and the return rate is unpredictable. Though surface storage will have few drawbacks, regular maintenance and watershed management (runoff control) could help for its easy maintenance and operation. In dry season, the river flow is low and the abstraction too. After using stored surface water and abstracted surface source, the remaining demand in dry season could be fulfilled by using groundwater from shallow aquifer recharged due to infiltration during wet season. This option is only viable if the abstraction from ground source from individual households is under controlled environment with strict monitoring for the rate of abstraction.

The second option for water supply in Kathmandu Valley is using surface source only. In Kathmandu Valley, there is huge gap between the monitoring sytem of government and individual household water use system. Considering the extreme possibility of misusing the groundwater from household level and might imbalance the whole supply system it seems a wise decision to use only one source ie surface source sustainably which could reduce the probability of the possible problems in water suppply and use. However, available surface source water ie 287.67 MLD could only supply water at the rate if 41.10 Lpcd for 5 million people which is even less than the basic water requirement. Both sources should be used to meet the water requirement of Kathmandu Valley.

5.6 Water Demand Reduction

In both options of water supply, the current average water consumption i.e. 73 Lpcd is higher than the capability of water resources of Kathmandu Valley. In option 1, reduction of 16.71 L is needed to balance the supply and demand with the consumption rate of 56.29 Lpcd whereas in second option, it requires more demand management strategies to follow to reduce the water consumption level. Few of the engineering practice and behavioural practice as shown in figure 50 is required to balance demand and supply. These strategies are described below. Also refer table S in appendix for calculated quantity of reduction.

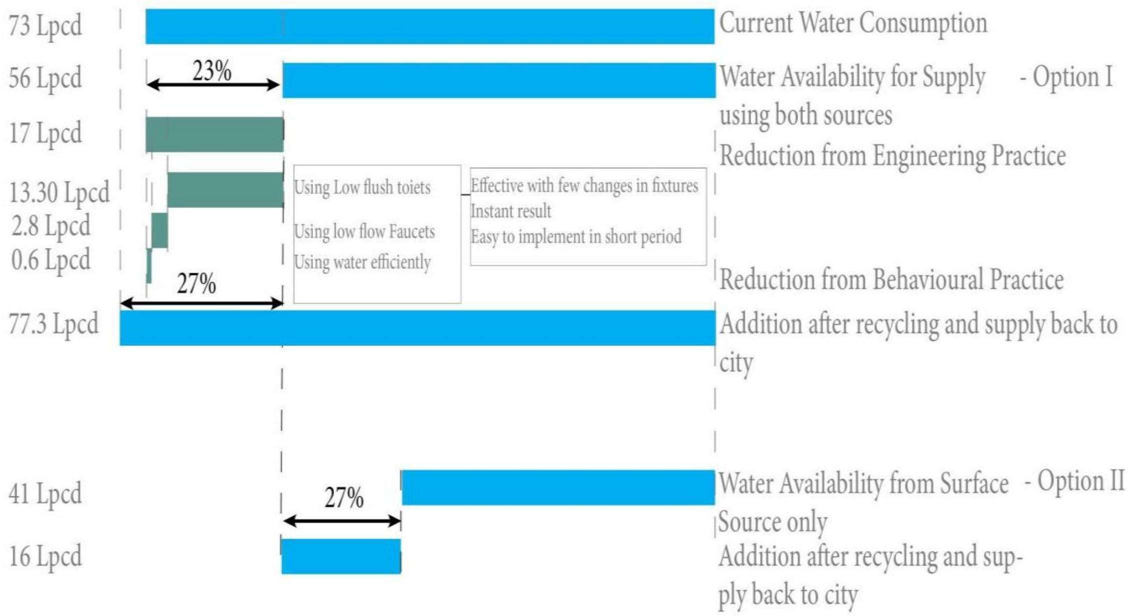


Figure 50 Demand reduction strategies applied to balance the demand and supply of sustainable water.

5.6.1 Low flush toilets

Use of 1.6 gallon per flush (gpf) (6.06 lpf) instead of using 3.5 gpf (13.5 lpf) could reduce the water need for flushing by 50% i.e. 18% of total current use.

5.6.2 Low-pressure faucets

Homeowners can reduce the water pressure in a home by installing pressure-reducing valves. The use of such valves might be one way to decrease water consumption in homes that are served by municipal water systems. For homes served by wells, reducing the system pressure can save both water and energy. From the study in Denver Colorado, the annual water savings of about 6 % was recorded for homes that received water service at lower pressure.[28]

5.6.3 Behavioral Practices

Behavioral practices involve changing water use habits so that water is used more efficiently, thus reducing the overall water consumption in a home. These practices require a change in behavior, not modifications in the existing plumbing or fixtures in a home. Behavioral practices for residential water users can be applied indoors in the kitchen, bathroom, and laundry room and outdoors.

Water can be saved in the bathroom by turning off the faucet while brushing teeth or shaving. Water can be saved by taking short showers rather than long showers or baths and turning the water off while soaping. Toilets should be used only to carry away fecal matter and not just urine.

5.7 Quality control

Like qualitative supply to human need, clean water returned back to nature is equally important. Currently, most households drain grey as well as black water directly in surface source. Although the dual system is installed in individual household, the municipal line combines it in single pipeline and ultimately drains off to river. Dual sewer system in municipal sewer pipe system could help to improvise the quality of surface source. The grey water could be recycled and reuse for city supply where as Black water could be used to produce composting and use for the agricultural purposes.

This reduces the cost and time of water treatment and recycling. The grey water production from domestic use is assumed to be 50% of their use and commercial sector produces 7 % of domestic wastewater volume. This grey water recycling could provide additional water could provide 21.04 Lpcd which raises the consumption to @ 77.3 Lpcd for the first option ie using both the sources whereas for second option it raises the consumption level to 56.46 Lpcd only as shown in figure 51.

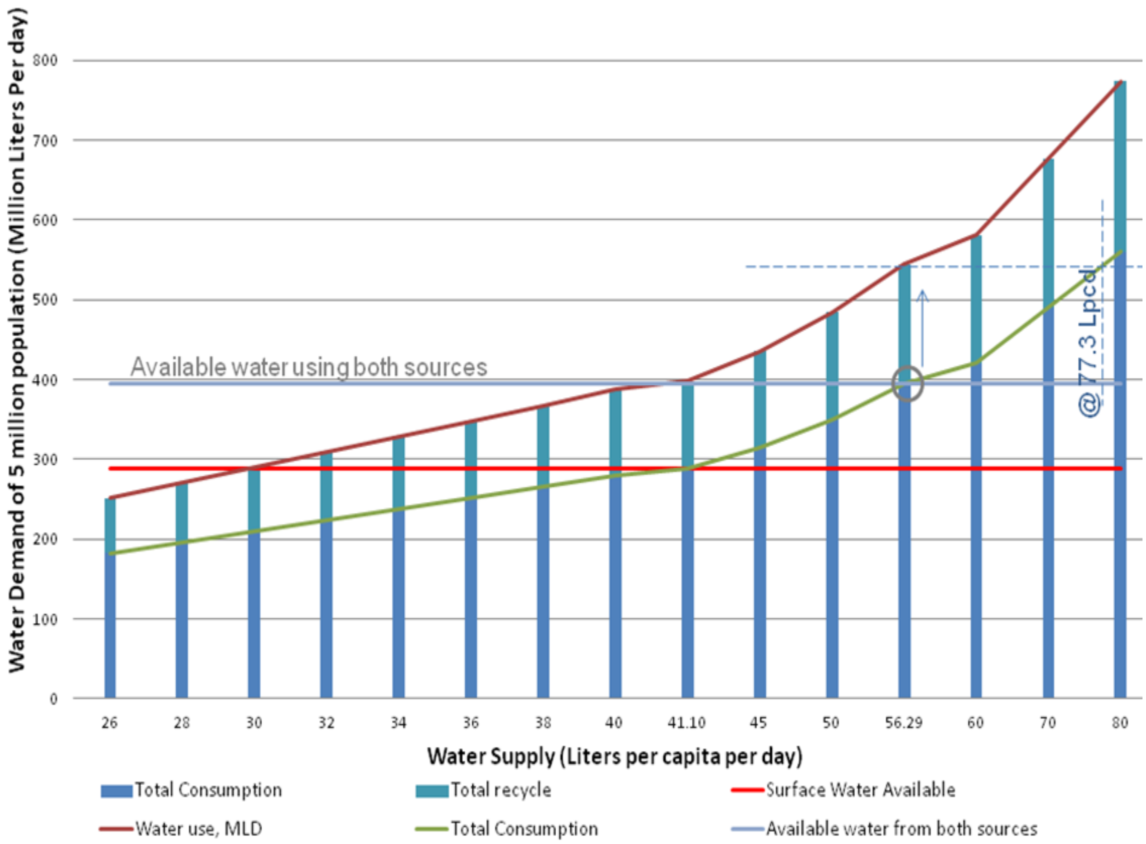


Figure 51 Graph showing the water demand and water consumption with recycling practice in Kathmandu Valley.

Using only surface source, the demand could not be met easily, not even to the average scale of current consumption level. Thus, conjunctive sustainable use of surface and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects and to optimize the water demand/supply balance if the system implements the proper river basin management considering both the river and the aquifer belong to the same basin.

To use the available sources, water supply needs to be limited at the rate of 56.29 Lpcd for 5 million people. Thus 17 Lpcd needs to be reduced for the current average consumption which can be reduced by using engineering practices such as using low flow faucets and low flow toilets and few behavioral practices. However, as shown in figure 50 and 51, the recycle of the grey water (50% of use) in bigger scale could supply extra 16 Lpcd which counts as total consumption level up to 77.3 Lpcd.

6. Conclusion

The water supply capability of future Kathmandu is only 77.3 Lpcd for 5 million people. For the socio economic development of the country with high human development , country requires a minimum water supply of 135 Lpcd [29] which is the theoretical demand estimated by KUKL for the water supply of Kathmandu Valley. The survey gives 113 Lpcd as a requirement for domestic purposes. The figure 52 shows that Kathmandu Valley should have limited its population to certain level 2.5 Million to supply water at the rate 113 Lpcd. However, with practice of using reclaimed water could raise the water availability and accordingly Kathmandu valley could limit the population to 4 million using the available water at the rate of 113 Lpcd. If this is not the case then, Kathmandu Valley with 5 million population should live with water supply @ 77.3 Lpcd even after using reclaimed water and applying possible demand reduction strategies.

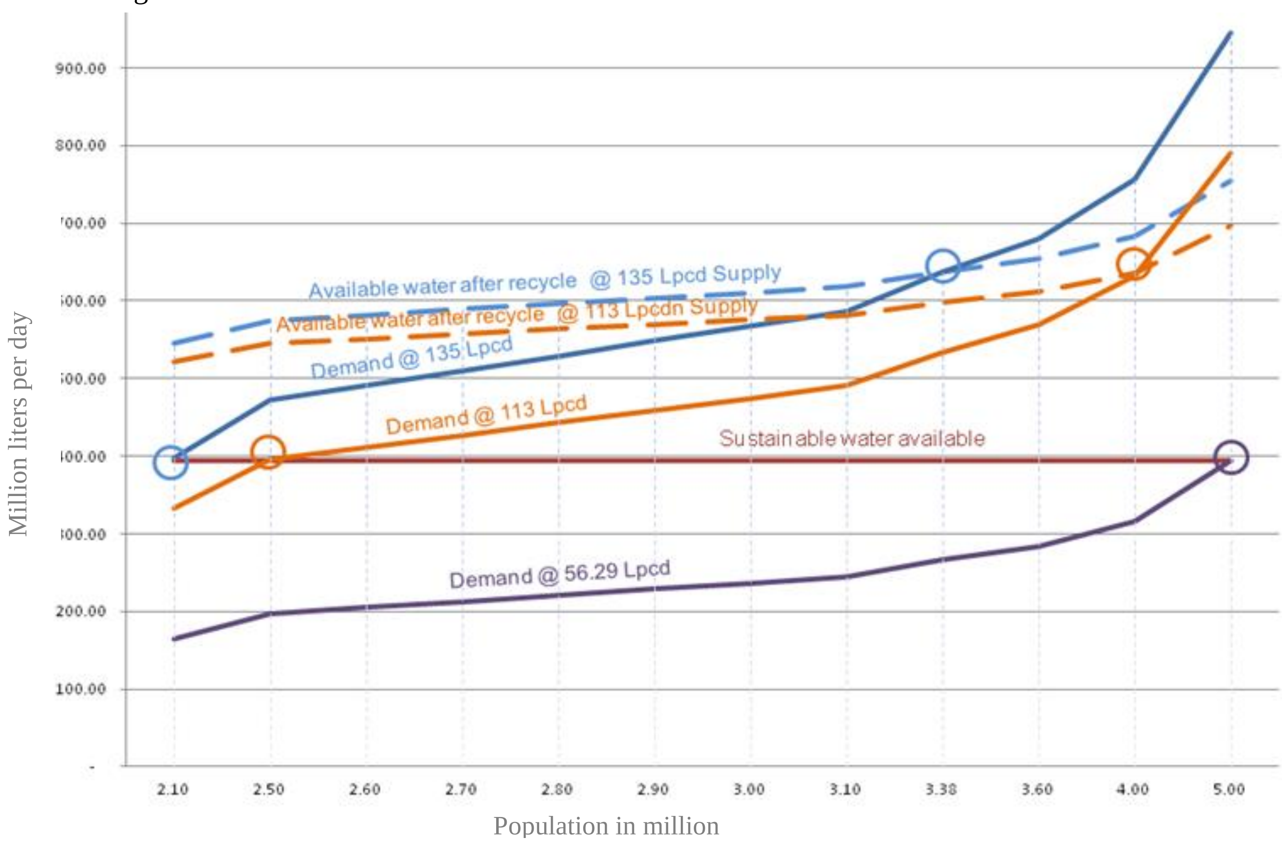


Figure 52 Population limit and consumption level for available sustainable water.

7. Recommendation for sustainable water supply and management

The water supply planning process continues to evolve in response to changing natural, human-made stressors and evolving social values. In the extreme condition, 5 million people might cover 80% of its land as a built up area. This might affect both ground and surface water availability. Strong water planning is required to assure the water availability in future Kathmandu. Thus, some of the considerations described below need to follow as preventive measures in various sectors with high prioritization to keep sustainable water supply stable in Kathmandu Valley along with interdependency among natural, social and economic interests associated with water use.

1. **Ground water Recharge**

a) Infiltration in shallow aquifer is estimated to be 165mm/year i.e. 39,685 ML from surface area 241 km^2 of shallow aquifer. The water budget calculation shows that in wet season with 80% of total annual rainfall, the infiltration amount is 75,671 ML.

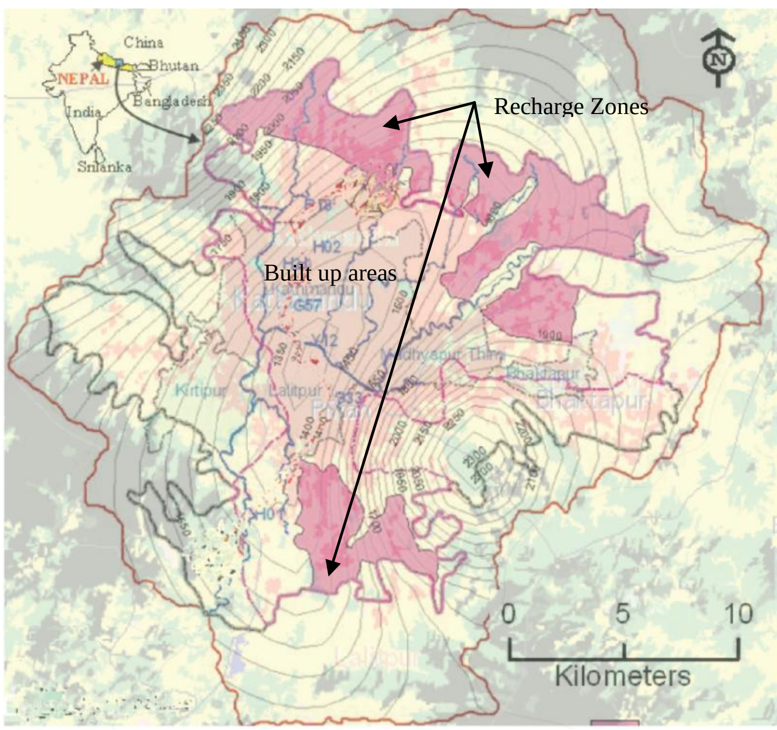


Figure 53 Map showing built up area and recharge zone of Kathmandu Valley.

Due to the increase in impervious surface, only 33,107 ML is currently recharged. The surface areas of shallow aquifer is reducing due to the increased built up area as shown in figure 53. Only the recharged amount could be used as sustainable amount from the shallow aquifer, which is less than the amount consumed from water supply in Kathmandu valley. Thus, direct storage of the water in shallow aquifer's storage space through artificial recharge needs to be arranged which also helps in balancing the water cycle to make sure that same amount of water is available in future too. Thus, ground water recharge is necessary to create sustainable water in Kathmandu. Government as well as individuals/community must be active in recharging the ground water either in a small or large scale. Some of the solutions are being studied as described below, which has not been implemented but theoretically has shown potential for water storage and infiltration.

i) Groundwater Resource Development Board is actively working on studies for accessing potential areas of water recharge into two major areas as shown in figure 51 and 52 but is not yet quantified how much could these solutions solve the Kathmandu Valley water crisis. Among these, first one is rainwater storage potential in Chandragiri Valley to the west of Ktm, which has similar geological and soil structure as of Kathmandu Valley. The second one is high recharge potential through surface flooding in the areas where existing river have changed their course and left dry porous river channels

As shown in figure 54 and figure 55, rainwater collection and artificial flooding could be the solution for recharging in wide-open areas. Further research is required to study the appropriate solutions, which might work in some area, and other solutions in other areas. The only option for recharging within the built up areas is direct injection through well as shown in figure 56 in individual household level with or without the storage tank outside the building as there might not be such enough space in near future constructions like as shown in this figure.

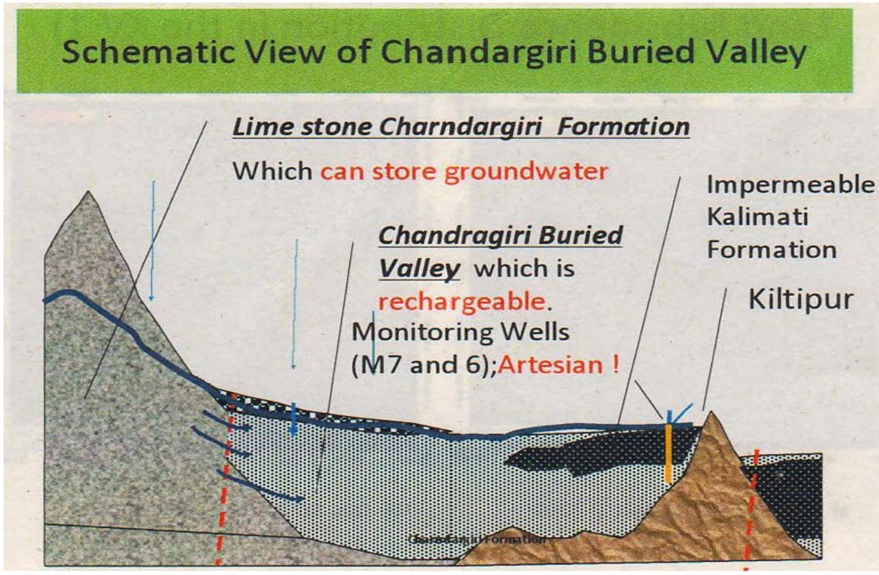


Figure 54 Diagram showing cross-Section of Chandragiri Valley.

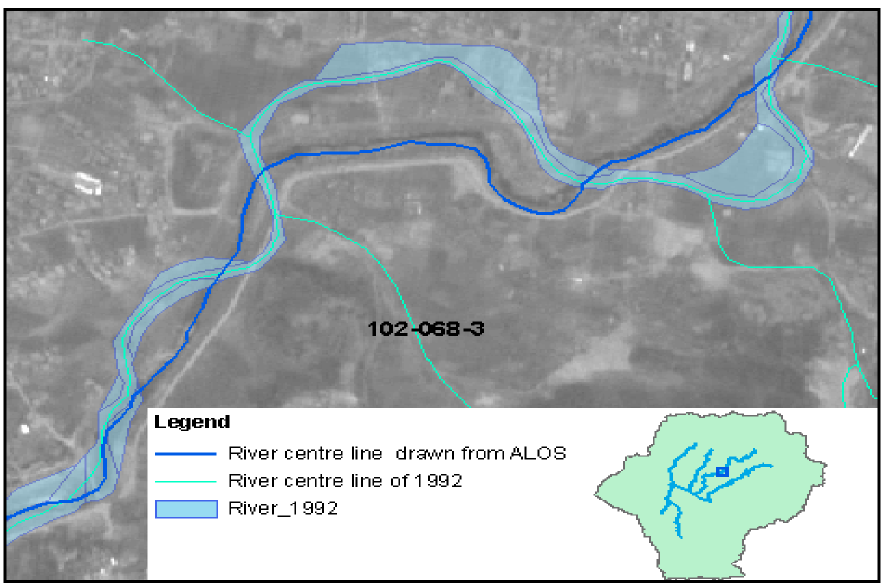


Figure 55 Diagram showing Bagmati River shifting within a decade.

Several areas at Northern Groundwater District, Patan and at west of central groundwater zone are considered to have potential for recharging. However, these have not been utilized for ground water recharging.

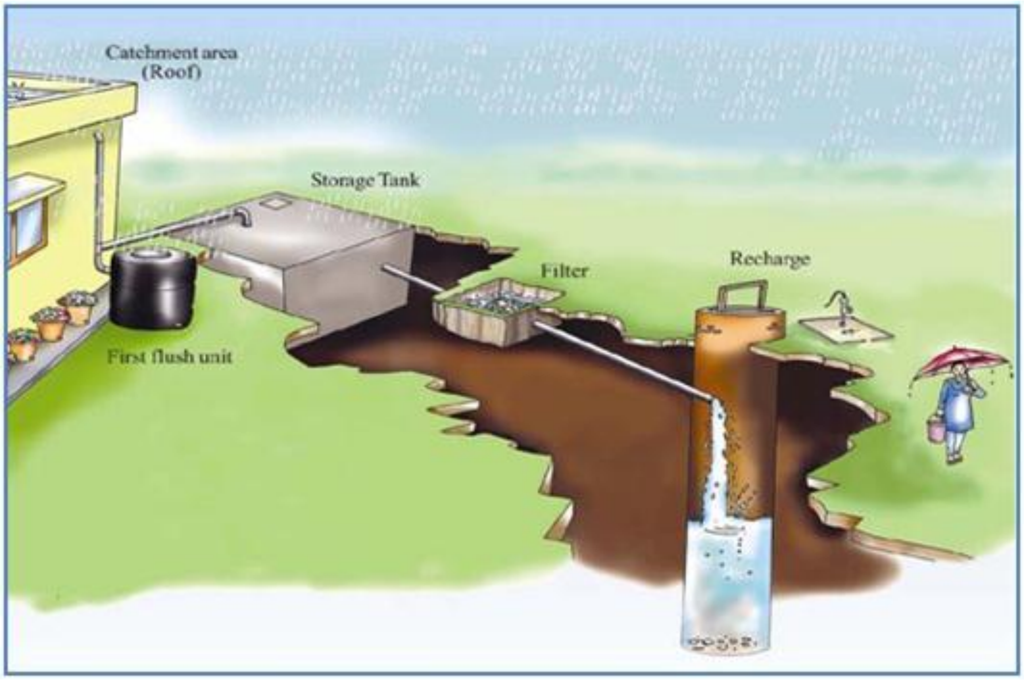


Figure 56 Diagram showing the rainwater harvesting system and recharging of groundwater.
Source: CIUD

b) Promote recharging through rainwater harvesting system

i) Collecting rainwater directly in huge amounts for longer periods might affect the natural habitat and hydrology but considering the would be increased built up area, decreased infiltration rate and increased runoff rate in future Kathmandu Valley, recharging through rainwater harvesting system seems necessary to recharge the ground aquifer through artificial infiltration balancing the development pattern and hydrology. Projects done by CIUD in few core areas in Kathmandu Valley has recorded increase in water level in the dug wells recharged through RWH system.

ii) Demonstration on sites should be implemented to encourage the public for acceptance of the new system. Department of Urban Development and Building Construction (DUDBC) has started installing RWH system in several public areas especially targeted at schools and start educating the public for the importance of ground water recharge. The college and Universities should take initiatives on educating the younger generation as well as the community through various workshops and coursework on protecting, conserving natural resources. The water they infiltrate during the wet season will be the water they use during the dry season. If they don't infiltrate (or Plant) they can't extract (or harvest) during the dry season. Public support is critical for the continuation of this effort of water sustainability. Education geared to the culture and average education levels of general public might bring the local peoples interest on their own community development and help to make this project a success.

iii) An incentive program could be promising for effective conservation practices. Incentive programs such as a 10% discount on the new building registration process fee for buildings designed with RWH system, which is already in practice inside valley in some municipalities.

2) Monitoring and maintenance

a) The government should actively organize the regular monitoring, recording and maintenance of water services in both household level and industrial level involved organizations are currently lacking complete data.

b) Monitoring methods includes groundwater level monitoring, but also production monitoring, water quality monitoring and subsidence monitoring.

c) The use of deep aquifer should be banned and shallow aquifer only should be used with strict monitoring system because of lack of recharge.

d) Every activity concerning water usage should have properly managed records. This helps in the efficient research and studies for proper and accurate solutions in right time otherwise, it will always be too late to just experience the problem and think on the temporary solutions rather than look for the base of the problem for permanent solution.

e) Only trained plumbers and professionals, for the maintenance of services of water supply or sewer system.

f) The construction on the surface area of the shallow aquifer must be prohibited and proper planning is required in terms of zoning and construction to ensure the rate of natural infiltration is maintained from the surface area.

3) Change in water use behavior

The water budget of Kathmandu Valley is currently in imbalance will be in critical condition in future when the population of 5 million will start residing in this area resulting in higher runoff, less infiltration resulting less recharge, higher evaporation etc. This ultimately affects the availability of groundwater and surface water. Many of the measures/ strategies could be helpful to balance natural hydrology and maintain the sustainable local water supply inside the Kathmandu Valley.

a. Reduce stress on water resources:

This above quantification of sustainable water supply can be real project only if the water available in the sources is clean enough to use for human purposes. The waste management system should be prioritized from government as well as from household level. As mentioned above, the traditional wastewater management system could be one of the solutions for reducing direct black water into the sources reducing the pollution level, which helps in reducing treatment and operation cost the wastewater treatment plants in Kathmandu Valley. As Kathmandu Valley is already conscious on dual water supply system for using different quality water for different purpose, introducing the dual wastewater system for grey water and backwater should be equally prioritized for the proper management of wastewater starting from household level.

b. Mandatory rules from the government:

This could change the human behavior pattern in more planned and effective way by introducing the policies in few sectors to reduce the water consumption. Some of them are as follows;

i. Use water efficient fixtures and reduce the water consumption level. For example, new toilets sold or installed in the valley must be high-efficiency toilets.

ii. Start dual sewer line system to get grey water recycle at community level for additional infiltration or at least and use for flushing toilets or in gardening purposes. Black water can also be treated and composting could be used for agricultural purposes. The acceptance for the black water might take a while to be acceptable in the Kathmandu Valley's cultural setting.

iii. Proper metering and recording the data for water use in every household.

iv. Use appropriate methods of water quality improvement before using it in household levels. Develop conservation policies for the use and maintenance of the traditional water supply system and wastewater management system, organic farming practice and enforce them for its implementation.

v. Manage the water tariff system according to season and demand to control total water use and encourage water re-use.

c) Public Outreach

i. Public should be educated on how the municipal system works for water supply and sewer system, ongoing water supply problem and some of its solutions so that they aware of their impacts which might encourage them to start thinking about conserving the water resources and implement through various possible strategies..

5. Co-ordination between the different wastewater sewerage disposal utilities, water supply utilities including private sectors and solid waste collection etc. should be integrated to create a comprehensive and Integrated water resource management system.

Predicting and satisfying the water supply needs of an uncertain future is challenging task but the proper tools and strategies might help the utility companies for securing water supply in future. Success to the abundant water supply is possible even with maximum population of Kathmandu Valley only if the integrated water resources management and demand reduction strategies are implemented effectively along with wastewater management in and around Kathmandu Valley. Introducing modern practices for demand reduction and reintroducing traditional practices for wastewater treatment could be the quick start for the positive result in short period to get the possible sustainable water supply in future Kathmandu valley using the local water within the valley.

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Appendix

Survey Question

Main Supply Branch of KUKL, if you know:

VDC	Municipality

1 Location:

2 Name:

3	Are you Owner of this house?	Yes	No
4	No. of Family Members		
5	No of renters		
6	Are you renting a house? If Yes, How many members are there in owner's family?	Yes	No

8	Do you know the source of water for your household daily activities?	Yes	No
9	If Yes, Please Specify:		

10 Where do you get your water from for your daily activities?

Government pipeline system in your house	Yes	No	Other
Government pipeline system in public tap			
Well, Depth of well?			
Tube well, Dept of Tube well?			
Government Water Tankers			
Private water Tankers			
Rain Water			
Other			

11 How much water do you get form the sources for your household in a day? How much do you use?

	Daily quantity in liters					other	Use/ Day/household including water from all sources (overall)
	0-50	50-100	100-150	150-200	200-500		
Government pipeline system in your house							
Government pipeline system in public tap							
Well							
Tube well							
Government Water Tankers							
Private water Tankers							
Rain Water							
other							

Who uses water from your household and how much quantity?

Owner only	Renter only	Owner and renter combined

12 Are you satisfied with the water you get from the sources?

`

	Daily quantity	Quality	Note:
Government pipeline system in your house			
Government pipeline system in public tap			
Well			
Tube well			
Government Water Tankers			
Private water Tankers			
Rain Water			
other			

13 For whar purposes do you use water that you get from these sources?

	a- Drinking, b-Cooking, c- washing laundry, d- cleaning house, e- gardening, f - toilet, g- Shower	Other
Government pipeline system in your house		
Government pipeline system in public tap		
Well		
Tube well		
Government Water Tankers		
Private water Tankers		
Rain Water		
other		

14 If not, How much more water do you need in a day than what is supplied?

15 If not, How much more water do you need in a day than what you have altogether?

16 a	Do you have Underground water tank?	Yes	No			
16 b	What is size of the underground water tank ?					
16 c	How ofter you fill it, full?					
	Comment:					
17 a	Do you have roof top water tank?	Yes	No			Other
17 b	How many do you have?	one	Two	Three	Four	
17 c	What is the size of it ?					
17 d	How often do you fill it?					
17 e	From where do you get water to fill it?					

18	Do you have well?	Yes	No	Depth:
19	Do you have tube well?	Yes	No	Depth:

20 a	Do you use Water Tanker?	Yes	No
20 b	How ofter do you order it?		
20 c	How much do you order at one time?		

21 a	Do you use Rain water?	Yes	No	
21 b	How much could daily you collect in rainy season?			
21 c	Where you you collect rain water?			
21 d	Do you have separate storage space for rain water?	yes	No	Where:
21 e	How long could you use those collected waters?			

22	Do you want to reuse the waster water from your kitchen, shower or household activities?	Yes	No
23 a	Have you ever tried to save water?	Yes	No
23 b	How?		
24	Is your water supply system is metered?	Yes	No
25	How much is the monthly bill?		
26	Do you want to pay more for qualitative and enough water supply to government or other companies?		Yes / No

27 How much are you comfortable to not creamting dead bodies near river?

Comfortable		Not Comfortable	

Comment:

28 Do you have any idea on how we can get sufficient water for daily activities?

Table A1: Monthly flow rate of Bagmati river at it' origin and outlet in Kathmandu Valley.

Bagmati at Sundarijal													
Year/Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Annual**
2001	0.24	0.14	0.14	0.17	0.64	0.91	2.89	4.41	3.46	1.48	0.90	0.77	1.35
2002	0.77	0.76	0.61	0.30	0.74	1.45	4.12	5.62	2.01	1.18	0.51	0.34	1.53
2003	0.33	0.33	0.30	0.21	0.22	0.43	2.32	3.58	3.46	1.31	0.65	0.39	1.13
2004	0.42	0.35	0.32	0.28	0.29	0.40	1.91	3.75	2.53	1.59	0.83	0.58	1.10
2005	0.52	0.40	0.39	0.37	0.38	0.40	1.13	3.80	2.72	1.44	0.92	0.68	1.09
2006	0.60	0.51	0.50	0.52	0.72	1.22	2.93	4.35	2.86	1.38	0.95	0.73	1.44
Monthly Average Flow a	**0.48**	**0.41**	**0.38**	**0.31**	**0.50**	**0.80**	**2.55**	**4.25**	**2.84**	**1.40**	**0.79**	**0.58**	**1.27**
Bagmati at Khokana													
2001	5.35	5.18	4.21	3.39	7.54	11.40	37.60	67.40	42.90	17.40	7.00	5.85	215.22
2002	5.65	5.87	5.97	6.66	14.50	13.40	108.00	80.40	27.20	8.52	5.00	3.18	284.35
2003	3.83	5.22	3.16	2.39	2.71	6.06	57.40	64.10	48.80	17.10	9.73	7.60	228.10
2004	7.94	5.28	3.97	5.02	9.56	11.40	48.10	36.20	28.10	16.70	8.55	6.63	187.45
2005	8.01	5.19	5.05	3.74	4.65	6.75	20.60	42.70	20.10	14.20	7.83	5.17	143.99
2006	3.88	3.22	3.34	5.23	8.86	11.50	27.40	24.00	25.50	9.40	4.08	3.82	130.23
Monthly Average flow a	**5.78**	**4.99**	**4.28**	**4.41**	**7.97**	**10.09**	**49.85**	**52.47**	**32.10**	**13.89**	**7.03**	**5.38**	**198.22**
Days	31.00	28.00	31.00	30.00	31.00	30.00	31.00	31.00	30.00	31.00	30.00	31.00	
Dry Season	**15472.22**	**12079.87**	**11472.48**	**11417.76**	**21346.85**					**37194.05**	**18226.08**	**14396.40**	**141605.71**
Monthly Wet Season Discharge, millionliters						**26140.32**	**133518.24**	**140526.72**	**83203.20**				**383388.48**
Annual Discharge in million liters													**524994.9**

Table A2: Sustainable water withdrawal from the river source

Description	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Annual**	**% of Average flow in wet and dry season**
Average monthly flow rate	5.78	4.99	4.28	4.41	7.97	10.09	49.85	52.47	32.10	13.89	7.03	5.38		
Sustainable Abstraction , m3/s	1.16	1.00	0.86	0.88	1.59	2.02	9.97	10.49	6.42	2.78	1.41	1.08		
	3094.44	2415.97	2294.49	2283.55	4269.36	5228.0	26703.64	28105.34	16640.64	7438.80	3645.21	2879.28		
Remaining water flow in river	4.62	3.99	3.43	3.52	6.38	8.07	39.88	41.97	25.68	11.11	5.63	4.30		
Days in a month	31.00	28.00	31.00	30.00	31.00	30.00	31.00	31.00	30.00	31.00	30.00	31.00		
Sustainable Abstraction per month, million liters	**3094.44**	**2415.97**	**2294.50**	**2283.55**	**4269.37**	**5228.06**	**26703.65**	**28105.34**	**16640.64**	**7438.81**	**3645.22**	**2879.28**	**104998.84 = 287.67 MLD**	
Abstraction in Wet season, million liters	76677.70										Abstaction in wet season per day, MLD	**628.50**		20%
Abstraction in Dry season, million liters	28321.14										Abstraction in dry season per day, MLD	**116.54**		20%

Table B: Bagmati Discharge at Khokana (cubic meter per second) in 2006

Day/ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1.00	4.42	3.12	3.12	2.44	4.42	4.42	8.38	8.83	17.10	16.50	5.15	3.12
2.00	4.42	3.12	2.76	2.44	8.38	4.57	98.10	37.00	14.80	13.20	4.86	3.12
3.00	4.42	3.12	2.76	3.12	6.26	4.13	15.40	46.90	14.50	12.90	4.86	3.12
4.00	4.42	3.12	2.76	2.86	4.86	6.45	11.60	18.70	12.60	11.10	4.86	3.12
5.00	4.42	3.26	2.76	2.65	4.42	4.71	9.05	13.70	18.20	11.10	5.15	2.97
6.00	4.28	3.26	2.76	2.65	10.30	40.90	9.09	14.20	11.60	10.90	4.86	2.97
7.00	4.28	3.26	2.76	4.86	5.52	12.40	8.15	16.00	9.50	10.20	4.42	2.76
8.00	4.28	3.41	2.76	7.78	21.00	9.05	29.80	14.80	8.15	18.70	5.15	2.76
9.00	3.99	3.41	2.65	5.15	16.10	36.20	11.30	18.40	67.50	13.20	4.28	2.76
10.00	3.99	3.41	2.65	5.15	24.20	13.70	15.10	12.90	33.60	10.20	3.99	2.76
11.00	3.99	3.55	5.52	5.34	10.60	9.50	16.30	9.95	23.40	13.40	5.34	7.12
12.00	3.70	3.55	4.57	4.42	11.60	7.00	22.30	10.40	118.00	10.20	4.42	6.08
13.00	3.84	3.55	4.28	3.99	5.00	5.28	36.10	11.20	30.60	9.73	4.42	5.15
14.00	3.84	3.41	3.99	3.99	12.10	4.28	18.20	12.10	20.90	8.83	4.28	4.86
15.00	3.84	3.12	3.99	3.84	7.37	3.84	15.00	13.40	17.10	8.83	3.99	4.71
16.00	3.84	3.12	5.00	3.55	6.45	4.71	19.40	16.30	46.80	7.56	3.99	4.42
17.00	3.84	3.12	4.42	3.55	5.34	3.26	15.10	16.00	17.10	7.56	3.99	4.42
18.00	3.84	3.12	3.99	17.40	5.15	3.41	30.30	10.40	16.00	8.05	3.99	4.42
19.00	3.84	3.12	3.99	11.10	4.86	3.55	122.00	13.20	14.00	7.86	3.84	4.42
20.00	3.84	3.12	3.55	7.00	4.86	3.16	62.50	25.00	15.60	11.10	3.55	4.28
21.00	3.84	3.12	3.55	6.82	8.15	15.80	41.80	16.30	15.00	7.74	3.55	3.99
22.00	3.84	3.12	3.55	6.45	6.82	9.73	25.60	17.10	14.00	7.74	3.55	3.99
23.00	3.84	3.12	3.12	6.82	6.45	38.70	15.00	16.60	16.80	7.00	3.41	3.55
24.00	3.55	3.12	2.97	5.71	6.08	12.50	38.00	96.00	15.60	6.82	3.41	3.55
25.00	3.55	3.12	2.97	4.71	12.40	17.40	35.30	73.70	59.20	6.45	3.41	3.55
26.00	3.55	3.12	2.97	4.71	7.19	10.30	26.00	36.00	31.60	6.26	3.12	3.55
27.00	3.55	3.12	2.76	4.42	23.00	14.40	18.70	31.80	21.30	5.89	3.12	3.55
28.00	3.55	3.12	2.76	4.42	9.05	11.60	30.70	28.60	16.50	5.71	3.12	3.55
29.00	3.26		2.76	5.19	6.63	17.70	18.70	29.80	14.80	5.34	3.12	3.55
30.00	3.26		2.65	4.42	5.56	11.50	16.60	36.60	33.70	5.71	3.12	3.12
31.00	3.26		2.44		4.57		9.28	20.90		5.71		3.12
Min	3.26	3.12	2.44	2.44	4.42	3.16	8.15	8.83	8.15	5.34	3.12	2.44
Mean	3.88	3.22	3.34	5.23	8.86	11.50	27.40	24.00	25.50	9.40	4.08	10.80

Table C: Temperature in Kathmandu Valley

Government of Nepal

Ministry of Environment, Science and Technology
Department of Hydrology and Meteorology
Babarmahal, Kathmandu.

NORMALS FROM 1981-2010

Maximum Temperature Normals (°C)

STATION NAME	Latitude	Longitude	Elevation	Station ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DADELDHURA	29.30	80.58	1848	**104**	14.0	15.2	19.4	23.6	26.1	26.0	24.2	23.8	23.3	21.7	18.5	15.7
DIPAYAL (DOTI)	29.25	80.95	652	**218**	22.2	24.7	29.7	34.3	36.1	36.3	34.2	33.7	33.0	31.3	27.4	23.4
DHANGADHI(ATARIYA)	28.80	80.55	187	**209**	20.8	24.8	30.4	35.9	37.2	36.3	33.1	32.8	32.4	31.5	27.8	23.3
SURKHET(BIRENDRA NAGAR)	28.60	81.62	720	**406**	19.9	22.5	27.6	32.8	33.9	33.1	30.7	30.6	29.9	28.4	24.9	21.2
NEPALGUNJ(REG.OFF.)	28.07	81.62	144	**416**	20.9	25.2	30.9	36.5	37.4	36.5	33.3	33.0	32.5	31.5	28.0	23.4
JUMLA	29.28	82.17	2300	**303**	13.9	15.0	18.5	21.7	24.1	26.0	25.0	24.6	24.2	21.9	18.6	16.1
POKHARA AIRPORT	28.22	84.00	827	**804**	19.7	22.2	26.7	29.8	30.1	30.6	30.0	30.2	29.3	27.5	24.1	20.7
BHAIRAHAWA AIRPORT	27.52	83.43	109	**705**	21.0	25.4	31.3	36.1	36.4	35.5	33.0	33.4	33.0	32.2	28.9	24.1
SIMARA AIRPORT	27.17	84.98	130	**909**	21.6	25.5	30.7	34.9	34.9	34.3	32.5	32.7	32.3	31.5	28.7	24.6
KATHMANDU AIRPORT	27.70	85.37	1337	**1030**	19.1	21.4	25.3	28.2	28.7	29.1	28.4	28.7	28.1	26.8	23.6	20.2
OKHALDHUNGA	27.32	86.50	1720	**1206**	15.0	16.8	21.3	23.8	24.6	25.4	24.1	24.4	24.3	22.7	20.0	16.6
TAPLEJUNG	27.35	87.67	1732	**1405**	14.0	15.6	19.5	22.3	23.5	24.8	24.7	24.9	23.8	22.0	18.8	15.6
DHANKUTA	26.98	87.35	1210	**1307**	17.8	19.2	22.8	25.9	26.6	27.0	26.8	27.0	26.6	25.1	22.5	19.5
BIRATNAGAR AIRPORT	26.48	87.27	72	**1319**	22.7	26.1	30.9	33.9	33.3	32.9	32.1	32.5	32.1	31.6	29.3	25.4
JANAKPUR AIRPORT	26.72	85.97	90	**1111**	22.2	26.0	31.2	34.8	34.6	34.1	32.5	32.7	32.3	31.7	29.3	25.1

Table D: Rainfall Data from 1991 to 2006 and 2011

month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
1991	20.7	11.4	45.2	106.1	144.2	114.4	190.3	280.9	127.6	0.4	0.2	24.9	1,066.30
1992	6.4	17.2	0.2	44.4	70.3	232.8	223.7	219.9	209.1	51	15.5	3.1	1,093.60
1993	10.20	15.40	42.00	86.80	184.60	204.40	296.30	293.80	156.20	14.50	1.80	-	1,306.00
1994	27.30	19.40	13.90	8.30	141.80	413.60	254.10	445.60	243.20	-	12.00	-	1,579.20
1995	3.30	28.80	39.80	3.20	60.50	590.50	336.10	404.10	100.60	38.30	61.60	7.00	1,673.80
1996	70.80	15.20	7.10	47.40	57.70	337.80	318.50	485.50	207.30	52.40	-	-	1,599.70
1997	16.4	5.5	13.9	100.1	90.3	245.4	511	370.7	70.9	12	4.9	87.4	1,528.50
1998	0.1	22.2	70.6	74.9	282	247.7	440.5	376.3	193.6	44.2	12	-	1,764.10
1999	4.2	-	-	6	106.5	315.6	485.2	391.5	266.9	152.2	-	1.2	1,729.30
2001	6.8	15.7	8.4	34.6	179.9	250.4	498.8	460.3	145.5	20.5	-	-	1,620.90
2002	33.8	29.9	93	93.9	158.8	227.8	544.8	499.9	144.6	15	26.5	-	1,868.00
2003	19.5	60.3	85.9	38	37.7	227.3	591.5	275.7	294.2	17.7	-	18.6	1,666.40
2004	26.9	-	32.3	139.1	168.8	183	459.5	232.5	168.1	117.4	38.4	-	1,566.00
2005	57.6	17	50.1	36.5	38.4	222.9	253.5	309	126.5	126.1	-	-	1,237.60
2006	-	-	30.90	132.80	145.50	216.20	337.00	248.40	217.50	43.90	1.50	17.50	1,391.20
2011	5.25	47.03	15.43	84.28	214.03	364.62	413.75	367.77	284.12	29.67	21.20	-	1,847.15
Monthly Average	19.33	19.06	34.30	64.77	130.06	274.65	384.66	353.87	184.75	45.95	12.23	9.98	**1,533.61**
Dry Season	335.69 mm												
Wet Season	1,197.92 mm												

Table E: Evapotranspiration in Kathmandu Valley

	1968-1980	2001	2008			
	mm/month	mm/month	mm/month	Annual average	Wet	Dry
Jan	54.0	62.0	50.4	55.5		55.5
Feb	81.0	60.0	70.2	70.4		70.4
Mar	123.0	96.1	55.0	91.4		91.4
Apr	150.0	114.0	137.5	133.8		133.8
May	165.0	139.5	74.9	126.5		126.5
Jun	144.0	141.0	96.9	127.3	127.3	
Jul	132.0	148.8	102.3	127.7	127.7	
Aug	123.0	148.8	94.3	122.0	122.0	
Sept	114.0	114.0	119.5	115.8	115.8	
Oct	99.0	102.3	88.1	96.5		96.5
Nov	69.0	75.0	44.0	62.7		62.7
Dec	51.0	65.1	60.4	58.8		58.8
	1305.00	**1266.60**	**993.59**	**1188.40**	**492.88**	**695.52**

Table F: Surface water Production from KUKL

Sr.No.	**Name of the System**	**Name of the Source**	**Yield (MLD)**		**Name of the Reservoir**	**Constructed year**	**Capacity cubic meter**
			Dry	**Wet**			
1	Bir Dhara System	Shivapuri Bishnumati	4	24	Maharajgunj Bansbari	1895 1985	7000 2000
2	Tri Bhim dhara System	Alley Boude Bhandare Panchamane Chhahare	4	8	Balaju	1930	4500
3	Sundarijal	Bagmati Nagmati Shyalmati	27	47	Mahankalchaur	1966	9000
4	Doodhpokhari	Doodhpokhari	1.5	2.5	Bhanjangal	1896	850
		Shimjhyahity	1	1			
5	Lunhkot	Lunhkot	0.3	0.5	Kirtipur		200
6	Nakhu	Nakhu	2.5	3	Sundarighat		800
7	Pharping	Satmul Sesh Narayan Kutorimul	14	20	Shainbu	1975	2700
8	Chapagaun	Muldol Basuki Devki Nallu Charghare	3	5	Tahakhel-1 Tahakhel-2 Bangedhara		500 500
9	Mahadev Khola Bhaktapur	Mahadev Khola	2	4	Bansbari	1896	2500
	Total		**59.3**	**115**			30550

Table G: Existing Wastewater Treatment Plants in Kathmandu Valley and Other Urban Areas of Nepal

Location	Type/Stage	Capacity (MLD)	Present State	Service Details
Dhobighat, Patan (Kathmandu Valley)	1st pond- Aerobic	15.4	Not working	HH Connections-53,900
	2nd pond- Anaerobic			Sewerage Lines- 61,650
	3rd pond- Facultative			Combine Channel-44Km
	4th pond- Aerobic			
Kodku,(Kathmandu Valley)	1st pond- Aerobic	1.1	Partially working	HH Connections-15,500
	2nd pond- Anaerobic			Sewerage Lines- 20,443
	3rd pond- Facultative			Combine Channel-11Km
	4th pond- Aerobic			
Sallaghari, Bhaktapur (kathmandu Valley)	Aerated lagoon	2.4	Not Working	Details not available
Hanumanghat, Bhaktapur (Kathmandu Valley)	Oxidation Ditch	0.4	Not Working	
Guheshwori, Kathmandu (Kathmandu Valley)	Oxidation Ditch	16.4	Partially Working	Sewers- 6km
				Population Served- 53,000
				Urban Area- 21 Ha
Hetauda Industrial Estate, Hetauda	Oxidation Ditch	1.1	Working	Industrial Wastewater Treatment Plant
Dhulikhel Hospital	Reed Bed (Constructed Wetland)	<0.10	Working	Without Primary Treatment
				Bed size- 261 sq. m.
				Population Served- 330
Kathmandu Municipality	Reed Bed (Constructed Wetland)	<0.40	Working	No Primary Treatment
				Bed size- 362 sq. m.
				Population served-330
Mulpi International School	Reed Bed (Constructed Wetland)	<0.25	Working	No Primary Treatment
				Bed size- 376 sq. m.
				Population served-850
SKM Hospital	Reed Bed (Constructed Wetland)	0.15	Working	Bed Size-141 sq.m.

				Population Served- 500
Kathmandu University	Reed Bed (Constructed Wetland)	<0.035	Working	No Primary Treatment Bed size- 587 sq. m. Population served-1300
Middle Marsyangdi Hydropower Project	Reed Bed (Constructed Wetland)	<0.026	Working	No Primary Treatment Bed size- 298 sq. m. Population served-870
Pokhara Municipality	Reed Bed (Constructed Wetland)	<0.115	Working	No Primary Treatment Bed size- 3,308 sq. m. Population served-3830
Kapan Monastery (Kathmandu Valley)	Reed Bed (Constructed Wetland)	<0.015	Working	No Primary Treatment Bed size- 150 sq. m. Population served-300
Tansen Municipality	Red Bed (Constructed Wetland)	<0.030	Working	No Primary Treatment Bed size- 583 sq. m. Population served-1000
Sunga Communiy Wastewater Treatment Plant (Kathmandu Valley)	Red Bed (Constructed Wetland)	50 cu. M./day	Working	Community Wastewater Treatment Plant Bed size- 583 sq. m. Population served-1000

Table H: Phase I, Invaluable Drops Kathmandu Project, CIUD

SN	Name	Catchment Area (Sq. m)	Amount of Rain Recharge (Liter/Year)
	Chowks/ Courtyards		
1	Kumanani	4440	825000
2	Baranani	4345	807240
3	Laskanani	1800	2175000
4	Tanani	540	691200
5	Kanya Mandir school	2300	2200316
6	Bansbari School	1000	1200000
7	Shivapuri School	534.2	615552
8	Nepal Japan Children Library	864	NA
9	Mahendra Rastriya Ma. Bi	NA	NA
10	Dhumrabaraha Ma. Bi	NA	NA
11	Rastriya Ni. Ma. Bi	NA	NA
12	Nepal Rastriya Ma. Bi	NA	NA
13	Rani Devi Ni. Ma. Bi	NA	NA
14	Kanteshwori Ma. Bi	NA	NA
	Open Space	NA	NA
15	Bhuikhel	334434	32000000
	Total	350257.2	40,514,308

Table I: Water Consumption using Various Sources and dug well abstraction calculation

	Dry Season		Wet Season	
	Ground MLD	Surface MLD	Ground MLD	Surface MLD
KUKL Production	50.70	59.30	29.00	115.00
Loss	38%	38%	38%	38%
KUKL Supply	31.43	36.77	17.98	71.30
KUKL Total Supply	68.20		89.28	
Private tankers	24.10	1.48	14.44	0.92
Private Tanker total Supply	25.58		15.36	
Stone Spouts	6.50		6.50	
Supply	62.03	38.25	38.92	72.22
Total Supply	100.28		111.14	
Remaining from Dug wells and others	83.01		72.15	
Total Consumption	145.04	38.25	111.07	72.22
% of total daily consumption @ 73 Lpcd	79%	21%	61%	39%

Year	NWSC /(KUKL)	Private	DMG*	Total
1980	3.6	3.24	0	6.84
1981	5.8	3.4	0.4	9.6
1982	6.8	3.4	0.6	10.8
1983	5.8	3.5	1	10.3
1984	4.4	3.6	1.2	9.2
1985	5.3	4.5	1.4	11.2
1986	17.6	6.6	1.4	25.6
1987	26.2	6.4	1.6	34.2
1988	28.7	6.3	1.6	36.6
1989	36.4	7.3	1.8	45.5
1999	34.6	21.8	1.8	58.2
2004	47	13.2	-	60.2
2009	22.9	48	-	70.9
2010	38.2	40.2	-	78.4
2012	79.7	40.94		120.64

Table J Total Groundwater extraction by different agencies in Kathmandu Valley. Source GRDB

Total Water Use		
Surface water abstraction from KUKL, wet season	14,030.00	ML
Surface water abstraction from KUKL, Dry Season	14,409.90	ML
Surface water abstraction from Private Tankers, dry season	359.64	ML
Surface water abstraction from Private Tankers, wet season	112.24	ML
% of rainfall collected*	1%	of rainfall
Total Rainfall Collected and used	9,968.46	ML
Water from Stone Spouts	2,372.50	ML
Total Surface water used from KUKL, Private tanker	28,911.78	ML
Population	2,510,789.00	
Household Annual Water consumption @ 73 Lpcd, HHW	66,899.97	**ML**
Abstraction		
Abstraction from Household Dug wells	28,972.85	ML
Total water from shallow aquifer and Surface source, SW	70,225.59	ML
From deep tube wells		
KUKL	15,858.10	ML
Privates	7,617.98	ML
Annual deep tube well Abstraction, DW	23,476.08	ML
Total water use, TW = DW+SW	93,701.67	**ML**
Industry and commercial Use (TW- HHW)	26,801.70	ML
% of total domestic use	40%	
% of total water use	29%	

Table K Water absraction from various sources and consumption

5,000,000.00	Household Demand	Commercial Demand	Total Demand	Available water
Demand/person/day	MLD	MLD	MLD	MLD
45	225.00	90.00	315.00	394.22
50	250.00	100.00	350.00	394.22
55	275.00	110.00	385.00	394.22
60	300.00	120.00	420.00	394.22
65	325.00	130.00	455.00	394.22
70	350.00	140.00	490.00	394.22
75	375.00	150.00	525.00	394.22

Table L: Water demand comparison for different water consumption level

		Dry Season Water Budget				
		IN	Out	Units	Remark	% of Rainfall
Precipitation	Pd	218,196.47		M L	Natural rainfall	100%
Evapotranspiration	Evtd		452,085.36	M L	Average Evapotranspiration	
Total Runoff	TROd		141,605.71	M L	Average wet season river discharge (2001-2006)	
Calculated Rainfall runoff	Rd		110,802.29	M L		50.8%
Groundwater runoff	GRd =TROd-Rd		29,244.57	M L	Subtracting 7% of HH use as wastewater	
Evaporation	Evd		2,298.58	M L		1.1%
Deep Infiltration	DId		53.26	M L		0.024%
Infiltration	Id		22,041.48	M L		10.1%
GW runoff	GRd-Id		7,203.08	M L	From Ground water storage	
Evapotranspiration	Evt =P-R-Ev-I		83 ,054.12	M L		38.1%

Table M: Dry Season Water Budget of Kathmandu Valley

		Wet Season Water Budget				
		IN	Out	Units	Remark	% of Rainfall,
Rainfall	Pw	778,649.63		ML	Rainfall	100%
Evapotranspiration	Evtw		320,371.81	ML	Average Evapotranspiration	41%
Total Runoff	TROw		383,388.48	ML	Average wet season River Discharge (2001-2006)	
Actual runoff	Rw = TROw-20% of TROa		382,605.84	ML	After Subtracting 7% of HH use as wastewater	49%
Infiltration	Iw= Pw-Evtw-Rw		75,671.97	ML		10%
Deep Infiltration	DIw		26.74	ML		0.003%
Shallow Infiltration	SIw		75,645.23	ML	Annual Infiltration = 207.25 MLD	9.7%
	SIw		68,442.15	ML	After Subtracting GW contribution for surface runoff in dry season	
Actual Recharge			554.50	MLD	Sustainable Abstraction limit (Subtracting the stone spouts discharge)	

Table N: Wet Season Water Budget of Kathmandu Valley

Future Land Cover	Area in Sq. Km	Runoff coefficient	Precipitation	Runoff
Needleleaved closed Forest	118.7394	0.45	1533.61	81944.9691
Needleleaved open Forest	14.6602	0.45	1533.61	10117.3632
Builtup area	80.8119	0.95	1533.61	94,189.79
Builtup area	34.0407	0.95	1533.61	39,675.92
Builtup area	5.34	0.95	1533.61	6,224.00
Builtup area	264.7492	0.95	1533.61	308,576.74
Builtup area	5	0.95	1533.61	5,827.72
Builtup area	126.348	0.95	1533.61	184,080.13
River	0.53			
	650.2194			730636.63
				73% of rainfall

Table O1: Future Runoff calculation

		Input in ML	Output in ML	Remark	% of rainfall
Rainfall	R	996,846.09		Rainfall	100%
Calculated Rainfall runoff	RO		730,636.63		73%
Evaporation	Evt		40,402.17		4.1%
Deep Infiltration	DI		80.00		0.008%
Infiltration			33,715.50		3.38%
Evapotranspiration			192,011.79		19.26%

Table O2: Water Budget of Future Kathmandu

Land cover	Area in Sq.Km	Runoff Coefficient	Total Runoff, ML	
Green roof,45% of built up area	186.05	0.1	28533.60049	
55% of built up area	227.40	0.95	331306.8056	
Needle Leaved closed forest	118.73	0.45	81944.96906	
Needle Leaved open forest	14.66	0.45	10117.36319	
Grassland / Pervious paving (remaining 20% of land after building construction)	103.26	0.5	79178.72002	50.4% of Rainfall
Total Runoff			502547.8579	

Table O3: Balancing water budget of future Kathmandu to maintain existing water budget.

S.N.	Location	Maximum Shifting (m)
1	Near Ruketar	50
2	SE of Nayapati	158
5	NE of Guheshwari	145
6	N of Gairigaon	45
7	Sankhamul Dobhan	65

Table P: Bagmati River dry channels occur in various locations. Source: GRDB

Water Supply from	Wet Season		Dry Season	
	Domestic	Commercial	Domestic	Commercial
Surface Source	337.50	135.21	116.55	
From Surface water storage , SS			78.22	
Shallow Aquifer			142.73	135.21
Total water required to get from Shallow aquifer in dry season = 277.94 MLD = 67,540.47 ML				
Total water infiltrates in Wet season = 68,442.15 ML				
Additional potential storage space available in Shallow aquifer = 226,000.00 ML				
Available water from Surface Source for storage (MLD)= SS		155.80	From wet season	
Total Storage Required (ML)		19,007.02	78.22 MLD for Dry season (243 days)	

Table Q Water distribution for proper use of available water in Kathmandu Valley

Water Supply from	Wet Season		Dry Season	
	Domestic	Commercial	Domestic	Commercial
Surface Source	281.46	112.76	116.55	
From Surface water storage , SS			117.62	
Shallow Aquifer			47.29	112.76
Total water required to get from Shallow aquifer in dry season = 160.05 MLD = 38,892.55 ML				
Total water infiltrates in Wet season = 68,442.15 ML But recharge amount = 39,685 ML				
Additional potential storage space available in Shallow aquifer = 226,000.00 ML				
Available water from Surface Source for storage (MLD)= SS		234.28	From wet season	
Total Storage Required (ML)		28,582.49	117.62 MLD for Dry season (243 days)	

Table R: Proposed water distribution in future Kathmandu

Purpose	**Normal Use**	**Lpcd after reduction strategies**	**Reduced % of total use**
Drinking water	6.50	3.7	4%
Toilet flush @twice a day	26.50 @13.25 lpf*	13.20 @6.6 lpf	18%
Wash Basin @ twice a day	10.00	9.40	1%
Bathing/ once a day	20.00	20.00	0%
Cooking and Kitchen	10.00	10.00	0%
Total Consumption	**73.00**	**56.30**	**23%**

Table S: Demand Reduction using various strategies.

Districts	Households	Galvanized Roof Household	Tile/ Slate Roof Household	Rcc Roof Household
Kathmandu	435,544.00	73,112.00	9,215.00	337,404.00
Lalitpur	109,505.00	24,862.00	6,550.00	72,083.00
Bhaktapur	68,557.00	21,042.00	6,630.00	38,641.00
Total Household with RWH	613,606.00	119,016.00	22,395.00	448,128.00
Total Household with RWH		**19.40%**	**3.65%**	**73.03%**
Runoff Co-efficient		0.8	0.5	0.95
Total roof area, Assuming average area of 855.625 Sq. ft per household ie 79.4 m2	79.48240593	9,459,678.02	1,780,008.48	35,618,291.60
Rainwater collection in a year in million liters		**11,605.97**	**1,364.92**	**51,893.34**
Populaiton using RWH, 4 person per household		476,064.00	103,017.00	2,061,388.80
Total Population using RWH (RWHP)		**2,640,469.80**		
Annual Water Demand of RWHP, 135 liters per person per day in Million liters		130,109.15		
% of water demand fullfillment by rain water harvesting for RWHP, MLD		49.9%	1,066.47	
Considering 80% of RCC HH, 80% of tiled HH and 10% of Galvenized roof HH has Collection tank of 12,000 liters + 2000 liters of roof top tanks				
Number of household with storage tank , Galvanized Roof		23803.2		
Number of household with storage tank, RCC Roof				358502.4
Number of household with storage tank, Tile Roof			2239.5	
Total available storage volume for RW collection in million liters		**5383.6314**	**4%**	of total water demand is fulfilled
Water Available for each person from storage in liters		2038.891488		
No of days a person can use the stored water, 135 Lpcd		15.10		
No of days a person can use the stored water 73Lpcd		27.93		
Extra amount of rainfall except storage can be used for recharging		59480.59323		

Table T: Estimating the water demand fulfillment by RWH System in Kathmandu Valley

Organizations and Purposes

ICIMOD:
The International Centre for Integrated Mountain Development is a regional intergovernmental learning and knowledge-sharing centre serving the eight regional member countries of the Hindu Kush Himalayas.

NGOFUWS:
NGO Forum for Urban Water & Sanitation is a forum of civil society organizations active in water supply policy reforms, policy analysis of water, sanitation and other relevant issues. NGO Forum conducts researches on different aspects of urban water and sanitation issues which form strong basis of its advocacy activities. It also shares the research findings in addition to engaging the stakeholders in consultations, debates and policy dialogues for better policy influence.

KUKL:
Kathmandu Upatyeka Khanepani Limited is a public company registered under the Nepal Government's Company Act 2063 and operates under the Public Private Partnership (PPP) modality. KUKL is responsible for the operation and management of water and wastewater services in the Valley. It operates the water supply and wastewater services under a License and Lease Agreement with the Kathmandu Valley Water Supply Management Board (KVWSMB) for 30 years. KUKL is responsible for the maintenance of all assets received on lease from KVWSMB. The company will also take over the responsibility for infrastructure built by the Melamchi Water Supply Project.

KVWSMB:
Kathmandu Valley Water Supply Management Board is an autonomous government body formed under Water Supply Management Board Act, 2063. The reporting line ministry of the Board is Ministry of Physical Planning and Works.

KVWSMB :
Kathmandu Valley Water Supply Management Board is the asset owner of all assets associated with water supply and sewerage system in Kathmandu Valley. It is responsible for developing and overseeing service policies, and providing license to service providers for the operation and management of water supply and sanitation service system in Kathmandu Valley and monitoring the same in order to ensure supply of sufficient potable water with an acceptable residual pressure head at an affordable price to its consumers.

CIUD:
Center for Integrated Urban Development is a Civic Society Organization, established in the year 2002, and has been working vigorously for sustainable urban solutions to support and compliment government's effort as well as its own initiative to tackle urban challenges. To achieve its goals, it has mainly been focusing on areas such as community based urban management, sustainable development of poor settlement