Groundwater Development and Management in the Changing Context in Kathmandu, Nepal

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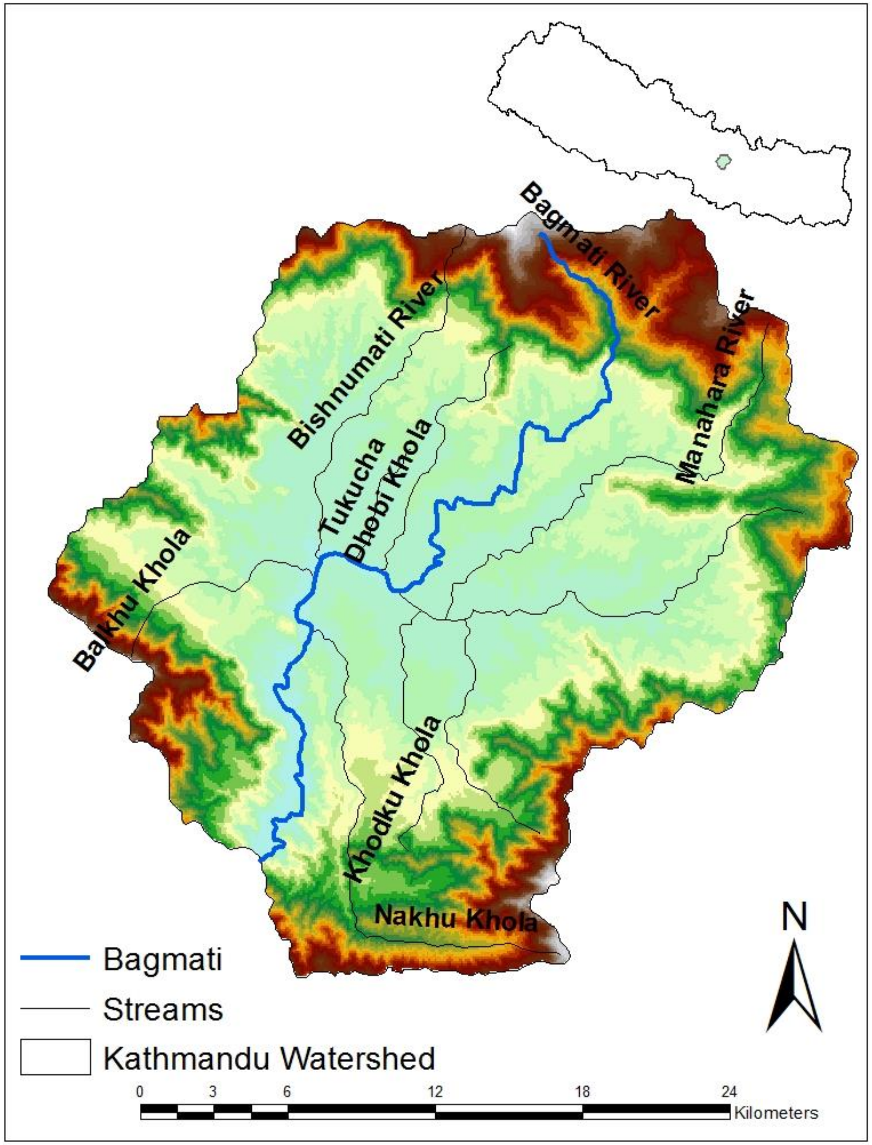
- Characteristics of groundwater (GW) aquifers and Hydrogeological properties of aquifers.
- GW availability and usage (historical trend)
- Trends in key drivers of GW stress in the city
  - Socio-economic; Climate change; Urbanization; etc.
- Information on GW monitoring wells, trends of GW level in monitoring wells and GW abstraction wells

Kathmandu

- Latitude: 27˚34‘N - 27˚48’N,
  Longitude: 85˚10‘E – 85˚32’E &
  Elevation: 1292 masl
- Administrative & commercial capital of Nepal
- Area 640 sq. km.
- Around 4 million inhabitants
- Surrounded by four mountain range (Shivapuri, Phulchowki, Nagarjun and Chandragiri)
- Warm temperate climatic zone
- Bagmati is the principal river

  Tributaries: Bishnumati, Manohara, Dhobikhola, Nakhhu, Balkhu and Tukucha



Climate Characteristics of Kathmandu

- Warm temperate climatic zone
- Humid subtropical climate (Cwa) in lowland portion of the valley
- Subtropical highland climate(Cwb) in highland portion of the valley
- Typical monsoon climate with rainy summer (June-September)
- Dry winter (December-January)
- Average annual precipitation 1505 mm
- South West monsoon (June-September) accounts 80% of total annual precipitation
- Annual average temperature is 18.1˚C *(Pokharel and Hallett, 2015)*
- (19˚C-27˚C during summer)
- (2˚C-21˚C during winter)

Climate change impact studies in Kathmandu

S.N	Study Area	Method	Impact identification	Reference
1	Bagmati River Basin	Downscaled precipitation and temperature data from and HadCM3 and simulated in HEC HMS Prediction: 2020's, 2050's and 2080's	The basin as a whole become wetter when water accounting is done annually **A2 scenario**: the Pre-monsoon water availability may decrease, indicating a worsening situation of water stress during the dry season. **B2 scenario,** water availability is expected to increase during both wet and dry seasons. Higher water availability during the wet season under both A2 and B2 scenarios may worsen the flood situation in the future	*(Mishra & Herath , 2015)*
2	Bagmati River basin	Hydro-meteorological trend analysis	The magnitude of flood is decreasing but its frequency and duration are increasing	*(Sharma & Shakya, 2006)*

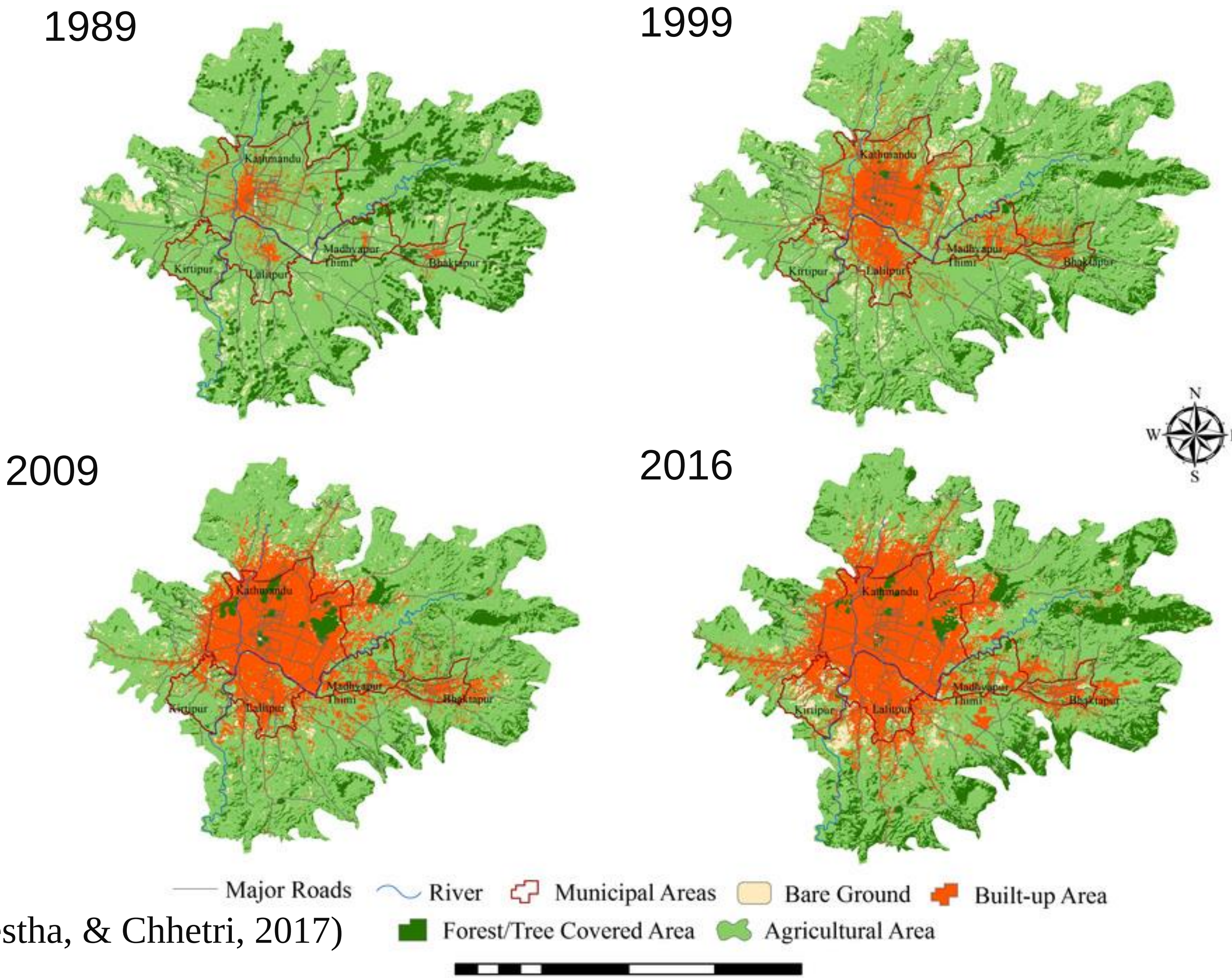
Climate change impact studies in Kathmandu….

S.N	Study Area	Method	Impact identification	Reference
3	Upper Bagmati River basin	GCM precipitation output of Meteorological Research Institute (MRI), Japan	Annual precipitation will increase significantly in the future. There will be significant increase in monsoon precipitation and decrease in other months. In relation to climate change impact on extreme precipitation events, the study found that there will be frequent heavy precipitations on future.	(Babel, Bhusal, Wahid, & Agarwal, 2014)

LULC change trend

- Trend of LULC change
  - Settlement, build-up area are expanding rapidly
  - Agricultural, forest and open spaces are being encroached
- Urban area expanded up to 410% in the three decades (1989-2016)
  - Increased from 5.10% (in 1989) to 26% (in 2016)
- 31% of agricultural land converted into urban area
  - Decreased from 80.5% (in 1989) to 55.3% (in 2016)
- Drivers of urbanization in Kathmandu Valley
  - Rural to urban migration
  - Capital flow
  - Weak governance

LULC change trend



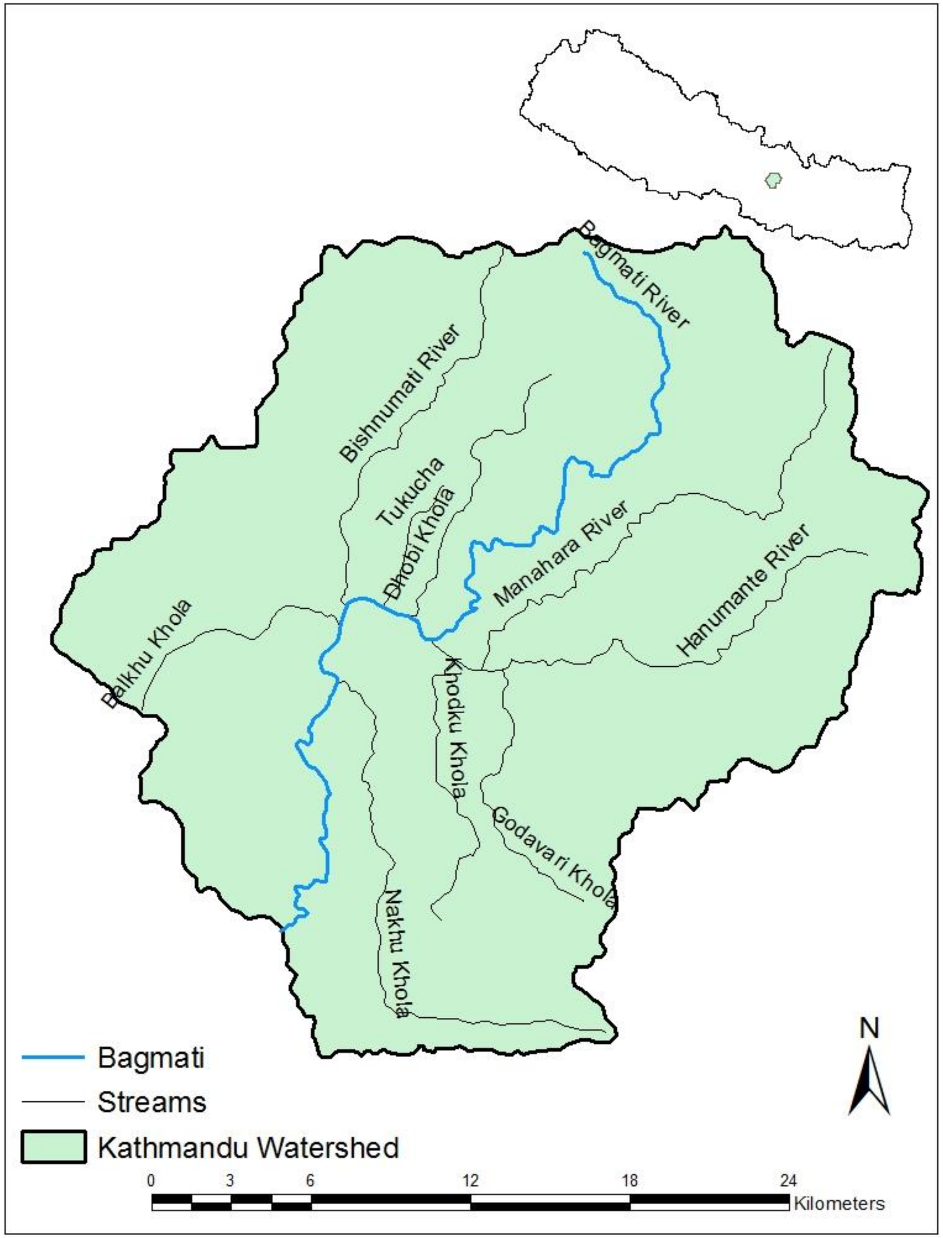
(Ishtiaque, Shrestha, & Chhetri, 2017)

Kathmandu Valley Basin

- 9 major tributaries in Kathmandu Valley:

Nakhu, Kodku, Godavari, Balkhu, Bishnumati, Dhobi, Manohara, Hanumante, Manamati.

- Area of upper Bagmati Basin: 656 sq. km
- Outlet at Chovar



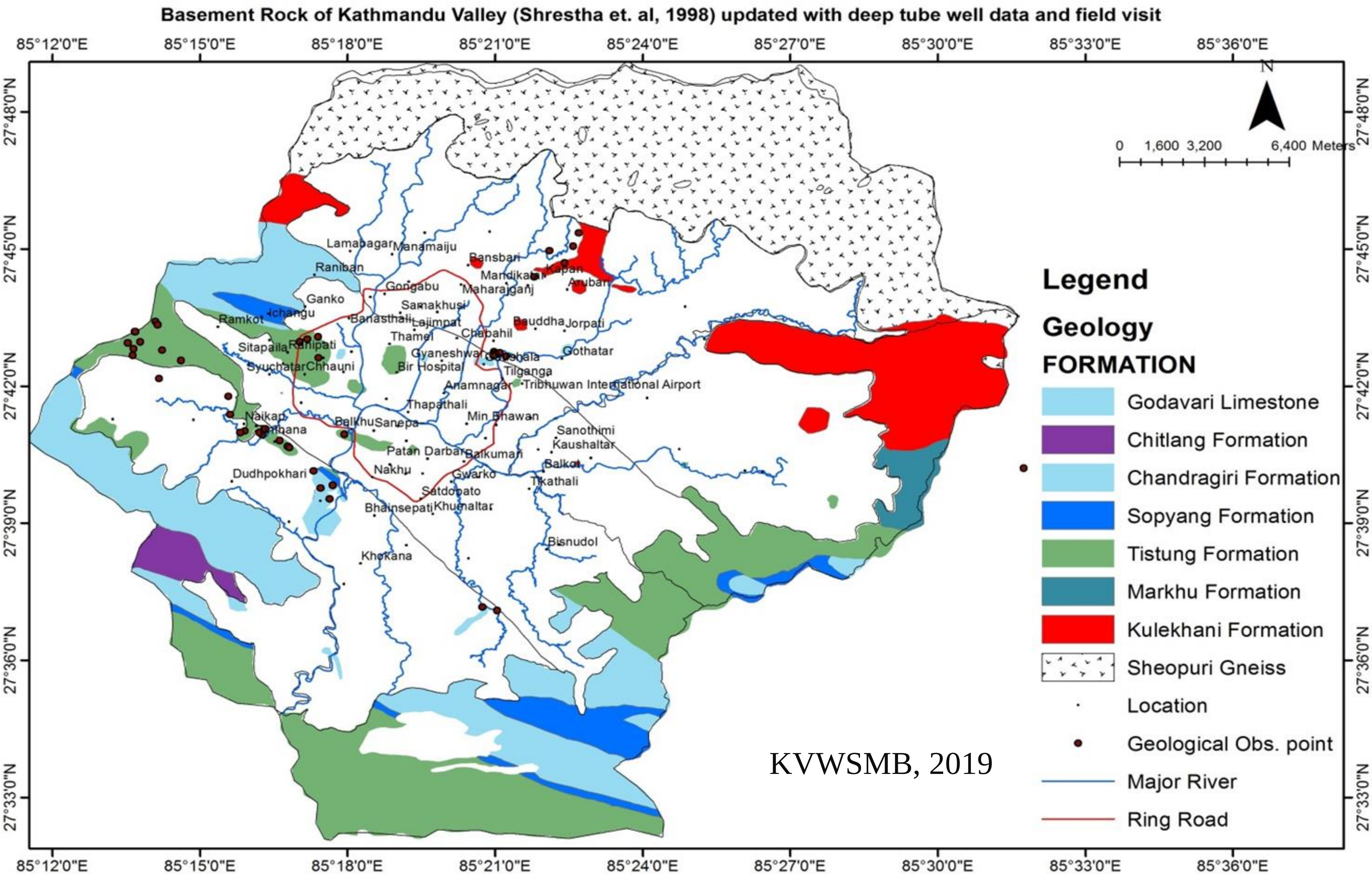
Hydrology of the basin

- Originates from the Shivapuri hills
- The central valley receives around 1,400 mm of rainfall annually; the adjoining hills receives more than 2,000 mm.
- 90% of flow occurs during the monsoon.
- The mean annual flow at Chovar is 15.5 m3/s.
- The flow is at a minimum in the months of April and May.
- The maximum monthly average discharge of 195 m3/s occurs in July, while the minimum monthly average flow of 0.51 m3/s occurs in April
- The maximum monthly flow ever recorded was 417 m3/s, in August 1966; the minimum, 0.04 m3/s in June 1965.

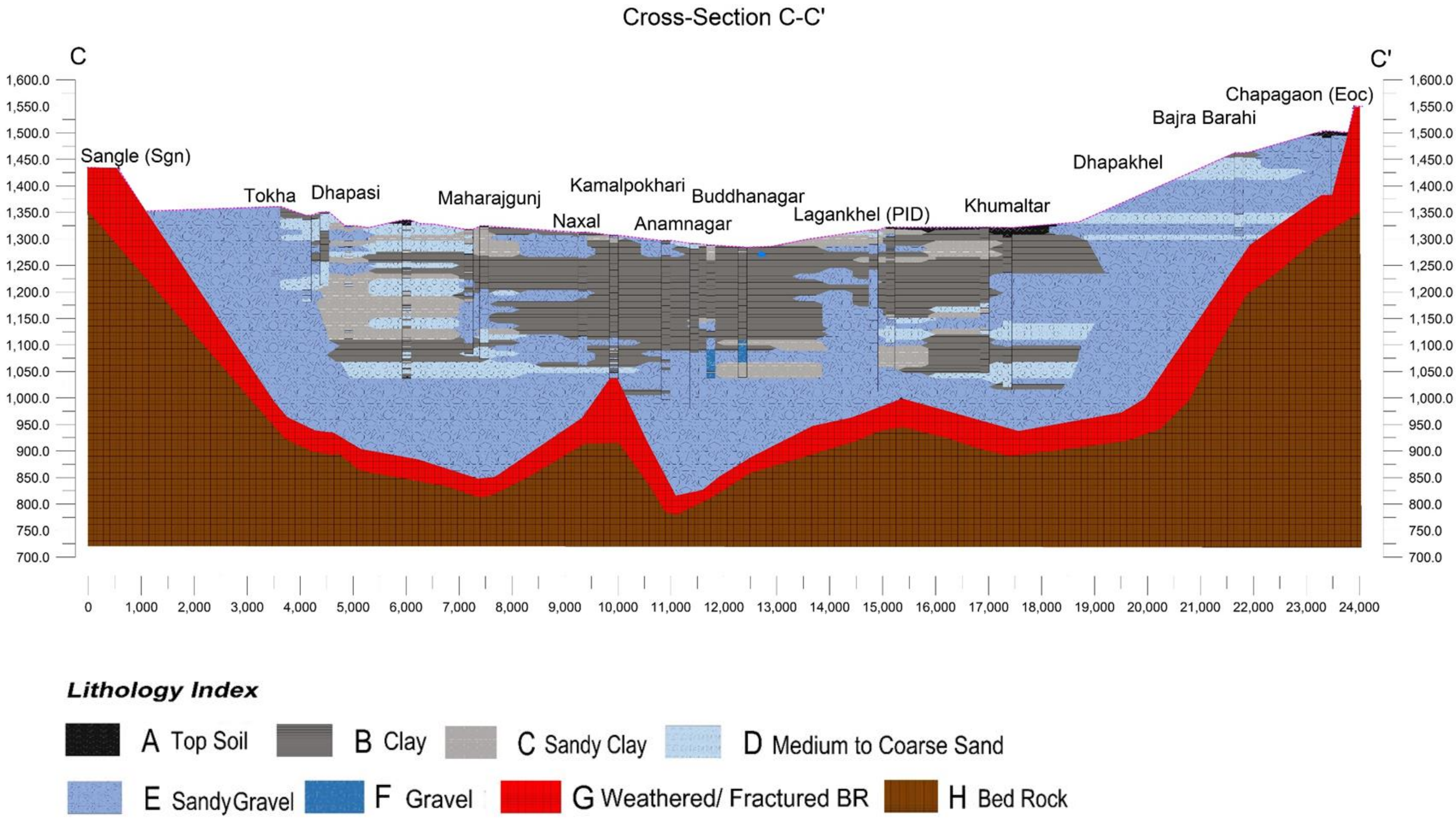
Characteristics of GW aquifers of Kathmandu valley

- **Aquifer Basement:** Intensely folded, faulted, fractured and igneous metasedimentary rocks
- **Aquifer Floor:** Unconsolidated to partly consolidated sediments
- **Aquifer nature:** Closed and isolated groundwater basin with irregular and discontinuous aquifers.
- **Aquifer system in the valley:** Four zones namely unconfined aquifer zone, Two aquifer zone, Confined aquifer zone, and No groundwater zone
- **Hydrogeological districts in the valley:** Three districts namely Northern Groundwater Districts (NGD), Central Groundwater District (CGD) and Southern Groundwater District (SGD)

Basement Rock of Kathmandu valley (Shrestha et. al, 1998)



Cross-section of valley (North-South) showing multiple aquifer layers



KVWSMB, 2019

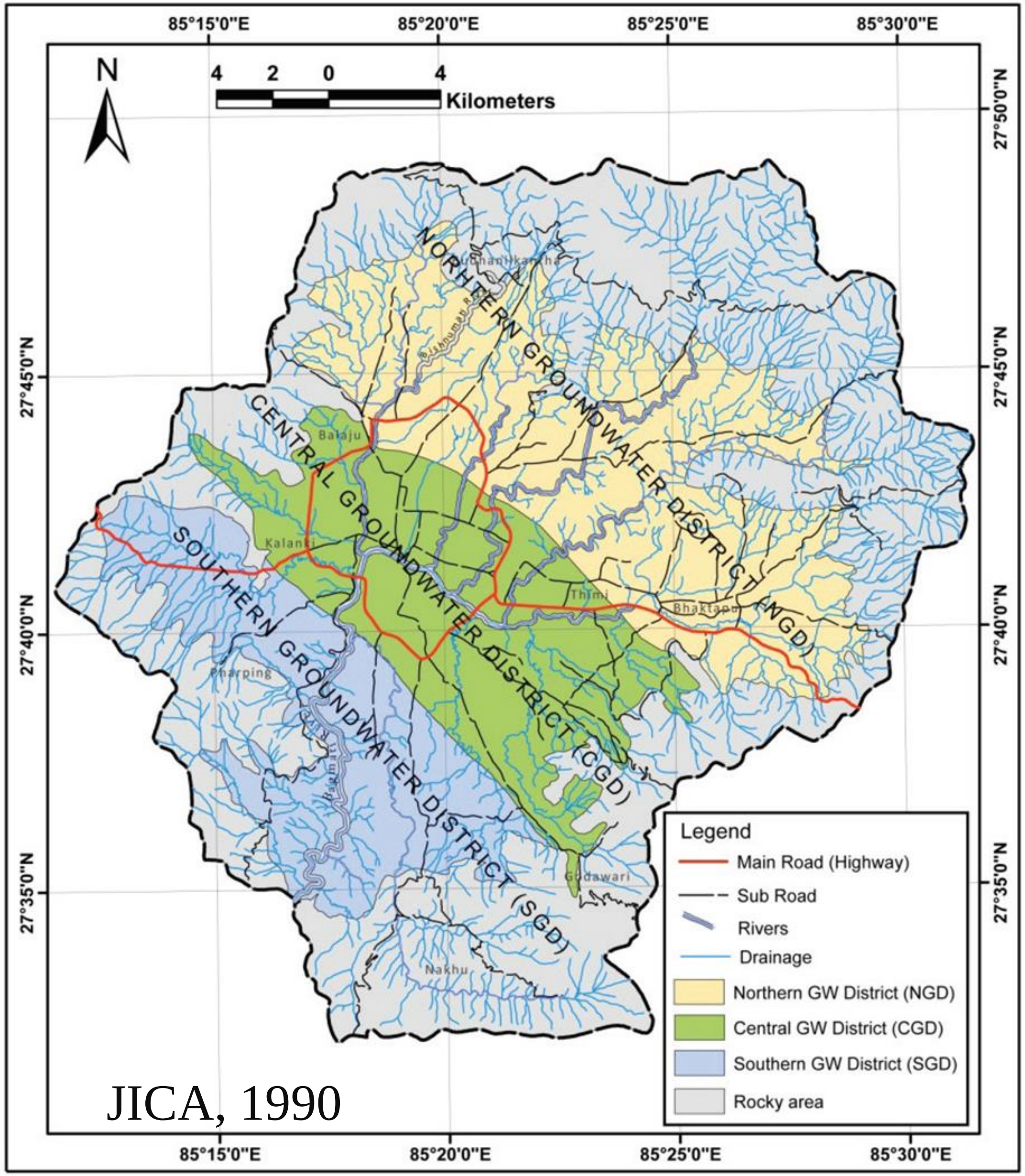
Characteristics of GW aquifers of Kathmandu valley

NGD:

- Northern part of the valley encompassing 156 sq. km
- Composed of unconsolidated highly permeable materials of sand and gravel
- Aquifers are in unconfined to semi-confined, conditions
- Low electrical conductivity 100-200 µS/cm.

CGD:

- Central part of the valley encompassing 114 sq. km
- Thick impermeable (about 200 m) black 'Kalimati' clay



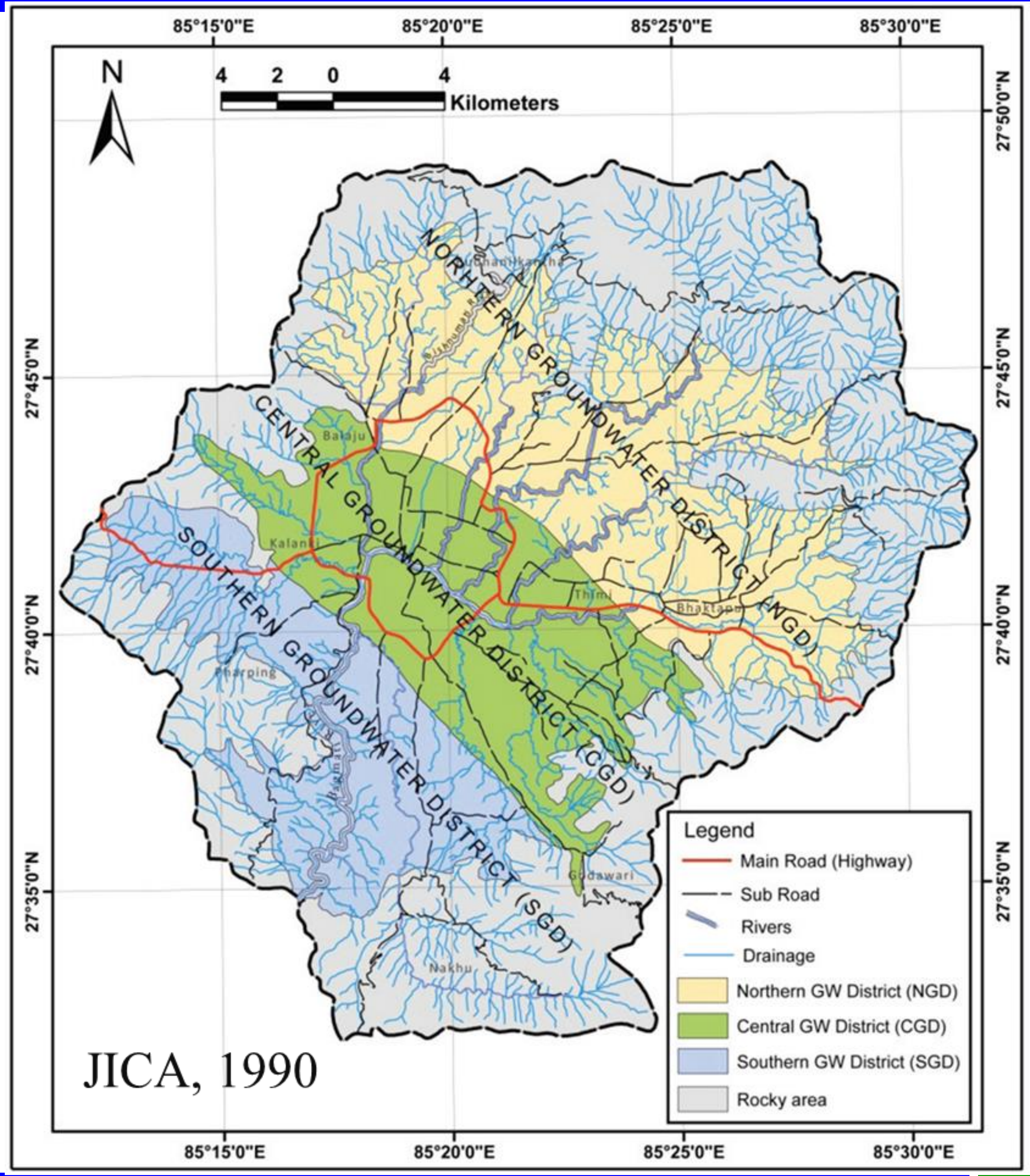
JICA, 1990

Characteristics of GW aquifers of Kathmandu valley

- Unconsolidated coarse sediments of low permeability underlie this thick black clay to form the aquifer in CGD
- Most of the aquifer are in unconfined condition
- High electrical conductivity upto 1000 μS/cm.

SGD:

- Sothern part of the valley encompassing 56 sq. km
- Not well developed aquifer
- Covered by thick permeable clay formation



Groundwater Availability and uses (historical)

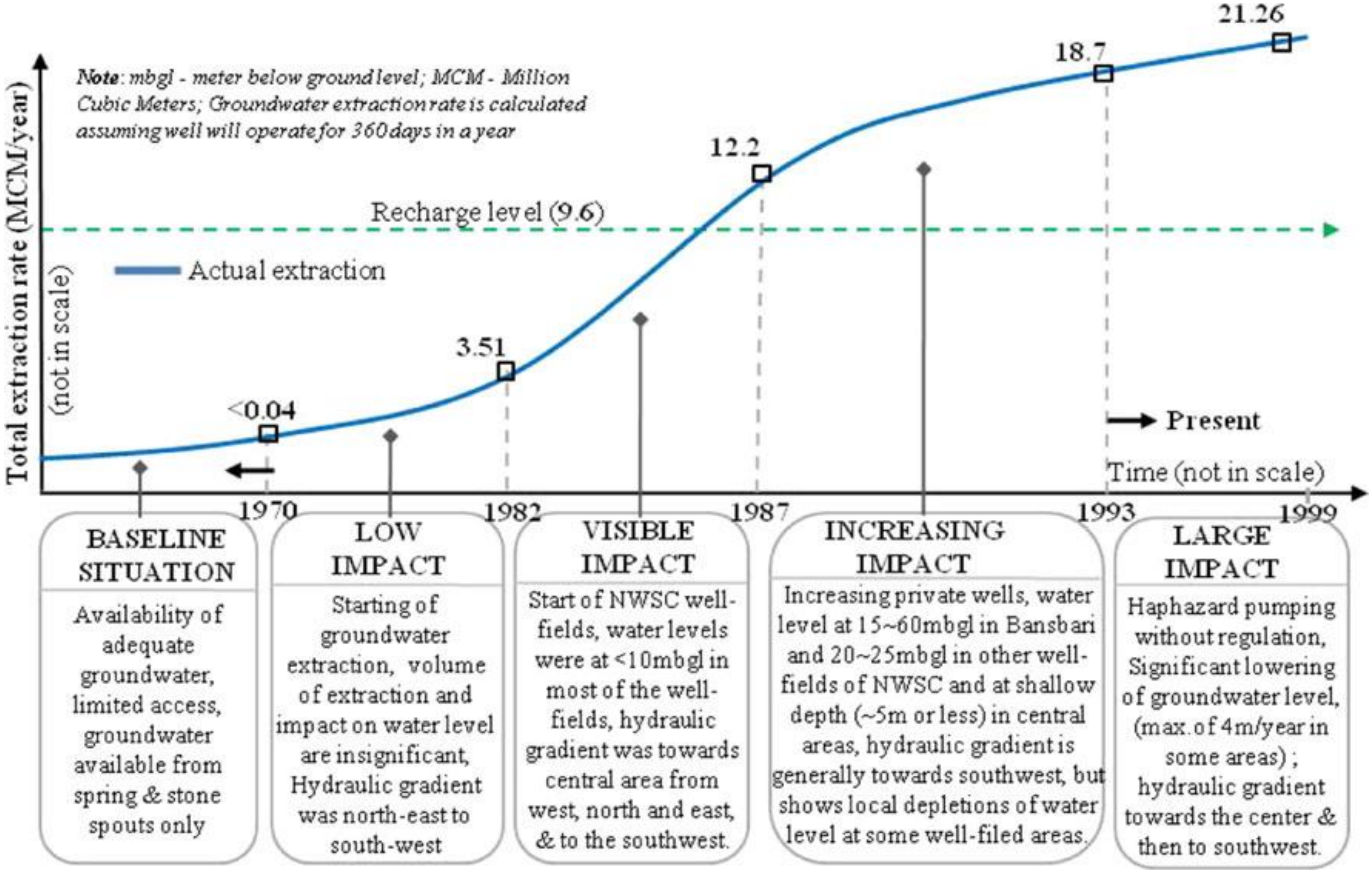


Fig. Stages of groundwater development in Kathmandu valley and their impacts (Pandey et. al 2010)

Groundwater availability and uses (historical)

Rainfall: 17,555 mm/year

=150.93 MCM/year at 86Km2 recharge area

Extraction of groundwater vs. Groundwater recharge

Year	Extraction	Recharge
1991	40 MLD Or 14.6 MCM/year	14.6 MCM/year Average 9.6 MCM/year
2001	59.06 MLD Or, 21.56 MCM/year	9.6 MCM/year
Rate of groundwater extraction exceeded rate of groundwater recharge! (Source: Pandey et. al 2010)		

Groundwater availability and uses (historical)

- The swallow aquifer is thicker towards northern part of valley. Estimated 7.26 BCM of water.
- Shallow groundwater in the Kathmandu Valley is recharged from different altitudes in the valley floor rather than mountains surrounding the valley.
- The deep aquifer is thicker towards central and southern part of the valley. Estimated volumes 56.8 BCM of water.
- Total storage potential of the shallow one is 1.5 BCM whereas that of the deep is only 0.6 BCM.
- Groundwater abstraction was estimated at 59.06 MLD (in 2000)
- Main use of groundwater in Kathmandu valley is for domestic especially for drinking purposes
- 46.4 % of 59.06 MLD of total GW abstraction was done by KUKL for drinking water supply purposes
- GW contribution in the total production of KUKL is 35% during dry season (Feb to May) and 11% during wet season.

Domestic water demand, supply and deficits

- KUKL: authorized agency supplying potable water to the Kathmandu Valley
- Supply capacity: 69 MLD and 115 MLD during the dry and wet seasons.
- Total Supply capacity of KUKL service area is 151.2 MLD (maximum in 2103)
- Future domestic water demand of Kathmandu valley is 445.3 MLD (For 2021)
- Total water Demand of the KUKL service are was estimated 361.6 MLD in 2016, with a supply deficit of 210 MLD
- Deficit is currently met through private groundwater pumping, traditional water spouts, wells and supplies from private vendors

(causes over-exploitation of groundwater storage, resulting in drawdown of the groundwater level and drying of wells)

Contamination/pollution of groundwater used for drinking

Parameter	Unit	Concentration in Groundwater			Remarks
		Shallow	Deep	WHO guideline	
NH_4^+-N	mg/L	5.3 (Avg.) 12.3 (Max.)	23.3 (Avg.) 119.8 (Max.)	1.5 (NH_4^+-N as NH_3)	In Kathmandu Valley
Fe	mg/L	4.8 (Avg.) 17.1 (Max.)	2.9 (Avg.) 10.7 (Max.)	0.3	
Pb	µg/L	52.4 (Avg.) 62.7 (Max.)	19.1 (Avg.) 75.0 (Max.)	0.01	
Cd	µg/L	9.9 (Avg.) 10.4 (Max.)	5.1 (Avg.) 10.0 (Max.)	0.003	
As	µg/L	1.0 (Avg.) 2.9 (Max.)	17.3 (Avg.) 73.1 (Max.)	0.01	

Mostly natural origin, suitable water treatment technology is needed!
(Source: Chapagain, 2012)

Chemical quality

- The concentrations of NH_4^+-N, Pb, Fe, Cd are higher than WHO guideline levels for drinking water in most of the places.
- Arsenic contamination is observed higher in deep groundwater (54% of 42 samples exceeded the WHO standard i.e. 10 µg/L)
- Arsenic concentration is relatively higher concentration in the central part of the groundwater basin.

Microbial pollution

- Of the 34 deep tube wells sampled, in 24 tube wells *E. coli* contamination was detected (0.0 – 26.5 cfu/100mL). So 29% of deep tube wells were found drinkable.

Trends in key drivers of GW stress in the city

❑ Socio-economic

- Main administrative, commercial and political hub of the nation
- Population influx is high (in search of education, employment and other opportunities)
- State restructured into Local, Provincial and Federal (shifting the economic, political and administrative authorities from the Kathmandu to province and local levels)

❑ Climate change

- Average annual precipitation 1505 mm (Current)
- The average annual precipitation projected 634-812mm by 2050 and 70-120mm (under worst case scenario)
- The capacity and potential of groundwater sources is expected to reduce significantly (under worst case scenario)

Trends in key drivers of GW stress in the city

❑ Urbanization

- Kathmandu valley: highest urban concentration in Nepal
- Expected population growth rate is 5%
- Municipal water supplies are inadequate to meet water demand
- Urban area has been expanded by 412% in last three decades (1989-2016)
- Permeable areas: Agricultural area (30% converted to urban area), forest and open spaces are being encroached

GW monitoring/abstraction wells

- ❑ Currently around 100 tube wells operated by KUKL and among them 90 are running (CIAMP 2019, Draft Report)

(Manohara, Gokarna, Dhobikhola, Bansbari, Mahadev,, Bhaktapur, Pharpping)

- Rated production is 33 MLD in dry season
- Rated production is 13.5 MLD in wet season

- ❑ Groundwater Research and Development/Department of Irrigation, Kathmandu, Nepal monitored water level at 11 wells of 7 locations

Bansbari, Gokarna, Dhobikhola, Manohara, Bhaktapur/Bode, Pharping and Central area

- Compared with respect to base year (1999-2001) to 2008
- Trend of depletion is recorded

GW monitoring/abstraction wells

- (Source: GWRDB)

GW monitoring/abstraction wells

Water-table stats

- In Pepsicola, water-level was just 30 metres in 2008 and fell to 38 metres below the surface in 2013
- Water level fell 10m in 10 years in Lubhu, Lalitpur district. In Lubhu, water was found at a depth of 30 meters in 2001; it fell to 40 metres in 2014
- Mulpani had water at a depth of 30 meters in 2002, but the level fell four metres and measured 34 meters in 2013
- In Kirtipur, water level fell from 8m to 11m between 2001 and 2014.

(Source: GWRDB)

GW monitoring/abstraction wells

- It has been reported that due to excessive abstraction of groundwater, it has lowered the groundwater levels by 13 – 33 m during 1980–2000;
- groundwater level has lowered by 1.38–7.5 m during 2000–2008 in the NWSC well-fields; and
- declined groundwater well yield by 4.97–36.17 l/s in the northern productive aquifers during mid-1980s–1998.

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