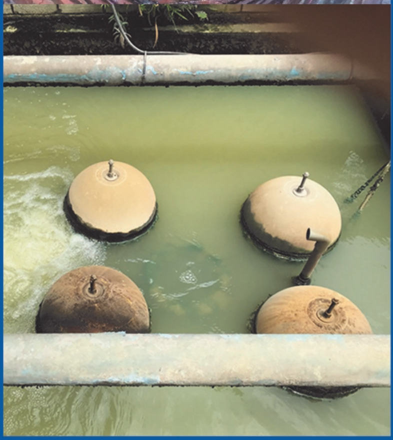
NATIONAL GROUNDWATER SYMPOSIUM since 2009

# Proceedings of the 10th National Groundwater Symposium Challenges and Opportunities for Sustainable Management of Groundwater Resources in Nepal

*18 March 2019, Kathmandu*



1. Groundwater extraction

5. Distribution of treated water

2. Sponge layer filtration

4. Denitrification

3. Dropping nitrification

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Proceedings of the

# 10th National Groundwater Symposium

# Challenges and Opportunities for Sustainable Management of Groundwater Resources in Nepal

*18 March 2019, Kathmandu*

**Organized by**
Center of Research for Environment, Energy and Water (CREEW)
The Small Earth Nepal (SEN)
Environment and Public Health Organization (ENPHO)
Kathmandu Valley Water Supply Management Board (KVWSMB)
Groundwater Resources Development Board (GWRDB)

**Co-organized by**
WaterAid Nepal
SmartPhones4Water-Nepal (S4W-Nepal)

**In association and supported by**
Water and Energy Commission Secretariat (WECS)
Institute of Engineering (IoE), Tribhuvan University (TU)
Asian Institute of Technology (AIT), Thailand
Interdisciplinary Centre for River Basin Environment,
University of Yamanashi (ICRE-UY), Japan
Kurita Water and Environment Foundation (KWEF), Japan

**Editors**
Salina Shrestha, PhD
Rabin Malla, PhD



**Cover photo**: Piloting of groundwater treatment for removal of ammonia, nitrate, iron and turbidity by developing locally fitted compact design (LCD) system through hydro-microbiological approach. (Piloting site: Jwagal, Lalitpur under the SATREPS Project; photo credit: CREEW)

**Back cover photo**: Participants of the 10th National Groundwater Symposium (Photo credit: CREEW)

**Design & layout**: Pradeep Kharel, Print Batika
Ph: 01-4414581

# ACKNOWLEDGEMENTS

It is our pleasure to present the proceedings of the 10th National Groundwater Symposium consisting the abstracts of keynote, plenary, oral and poster presentations.

We are thankful to all the presenters who made oral paper presentations and poster presentations and experts who delivered keynote and plenary presentations.

We extend special thank distinguished dignitaries from various organizations during the inaugural session and acknowledge the members of technical committee, chairpersons, rapporteurs and participants for their participation in the symposium and providing expertise.

We appreciate the contribution of WaterAid Nepal and SmartPhones4Water-Nepal as co-organizer and acknowledge the support provided by Water and Energy Commission Secretariat (WECS), Asian Institute of Technology (AIT) Thailand, Interdisciplinary Centre for River Basin Environment at University of Yamanashi (ICRE-UY) Japan, Institute of Engineering (IoE) of Tribhuvan University (TU), Kurita Water and Environment Foundation (KWEF) Japan.

Finally, we thank the staffs of CREEW, SEN, ENPHO, KVWSMB, GWRDB and S4W-Nepal for their hard work to make the symposium successful.

All these contributions are very instrumental for successfully holding the symposium in future as well.

**Organizers**
CREEW, SEN, ENPHO, KVWSMB, GWRDB

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## POSTER SESSION



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# PREFACE

Groundwater is predominantly used to meet water demand for domestic, agricultural and industrial sectors in Nepal, and it is obviously increasing. Nonetheless, the climatic as well as several anthropogenic activities such as over-extraction, encroachment of recharge areas, and unmanaged land use has altered the groundwater quality and quantity increasing threats to its sustainability. Therefore, in-depth and timely study is needed for upgrading the existing policies and technologies for sustainable management of groundwater.

Center of Research for Environment, Energy and Water (CREEW), The Small Earth Nepal (SEN), Environment and Public Health Organization (ENPHO) in collaboration with relevant government agencies like Kathmandu Valley Water Supply Management Board (KVWSMB) and Groundwater Resources Development Board (GWRDB) have been organizing National Groundwater Symposium that brings together the scholars, researchers, managers, policy makers and entrepreneurs to share the knowledge and discuss the various issues of groundwater.

The 10th National Groundwater Symposium on Challenges and Opportunities for Sustainable Groundwater Resources Management in Nepal was held on 18 March 2019 in Radisson Hotel, Kathmandu to commemorate the Nepal National Water and Weather Week 2019 on the occasion of UN World Water Day 2019. WaterAid Nepal and SmartPhones4Water-Nepal are the co-organizers of the symposium. Water and Energy Commission Secretariat (WECS), Asian Institute of Technology (AIT) Thailand, Interdisciplinary Centre for River Basin Environment, University of Yamanashi (ICRE-UY) Japan, Institute of Engineering, Tribhuvan University (IoE, TU), Kurita Water and Environment Foundation (KWEF) Japan supported to organize the symposium. The symposium was attended by 77 participants from universities, government and non-governmental organizations, water companies and media.

The thematic areas addressed in the symposium are enlisted below:

- Groundwater/spring exploration
- Groundwater policy, regulations and governance specially in the context of federal structure
- Groundwater and sustainable development goal
- Groundwater quality and quantity and its associated impacts (social, economic, environmental, etc.)
- Groundwater recharge and dynamics
- Groundwater and climate change

- Groundwater-energy nexus
- Groundwater science and innovations

Altogether one keynote presentation, one plenary presentation, four technical sessions on (i) groundwater management (ii) groundwater recharge and potential zoning (iii) poster viewing session and (iv) panel discussion were included respectively in the symposium. The first session comprised four presentations related to groundwater systems of Kathmandu valley, construction of irrigation systems in hills, revival of dried spring and groundwater irrigation management through solar powered irrigation system. The second session included four presentations related to linkages between groundwater level, rainfall and land use; spring assessment and potential springshed identification; identifying the spatial distribution of the deep groundwater recharge process; and water balance component analysis of spring catchment. There were 10 posters displayed in the poster session. A panel discussion on *'Review of challenges and opportunities for sustainable groundwater resources management in Nepal and way forward'* were carried out in fourth technical session mainly raised and highlighted the legal issue 'who owns the groundwater', poor database, poor technology, misconception about leaving half the area unbuilt by urban households, surface water more in priority by government/policy makers than groundwater, lack of dedicated and well equipped government agency for groundwater, inadequate effort for research/study, perception of public that there is huge storage of water beneath the ground, need of including the transboundary groundwater depletion in bilateral talk with neighboring country, and making sure whether inadequate forest cover is depleting the groundwater level.

We hope the papers presented in the symposium will help to upgrade the technology and policies for sustainable management of groundwater. We look forward to continue the symposium successfully in the future as well.

**Organizers**
CREEW, SEN, ENPHO, KVWSMB, GWRDB

# KEYNOTE PRESENTATION

# Groundwater's 21st Century Challenge: Shifting the Paradigm from Open Access Private Good to Regulated Common Pool Resource

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*E-mail:dipakgyawali.dg@gmail.com*
*dipakgyawali@ntc.net.np*

Water management in general and groundwater management in particular suffers from being a conjunctive reality that is in practice managed disjunctively. Groundwater is nothing but stored rainwater, and except for the trunks of major rivers, surface flow is nothing but groundwater backflow, except in the four monsoon months. So are the springs and spring-fed streams across the Himalaya. In that sense, only flood run-offs should be considered surface flows.

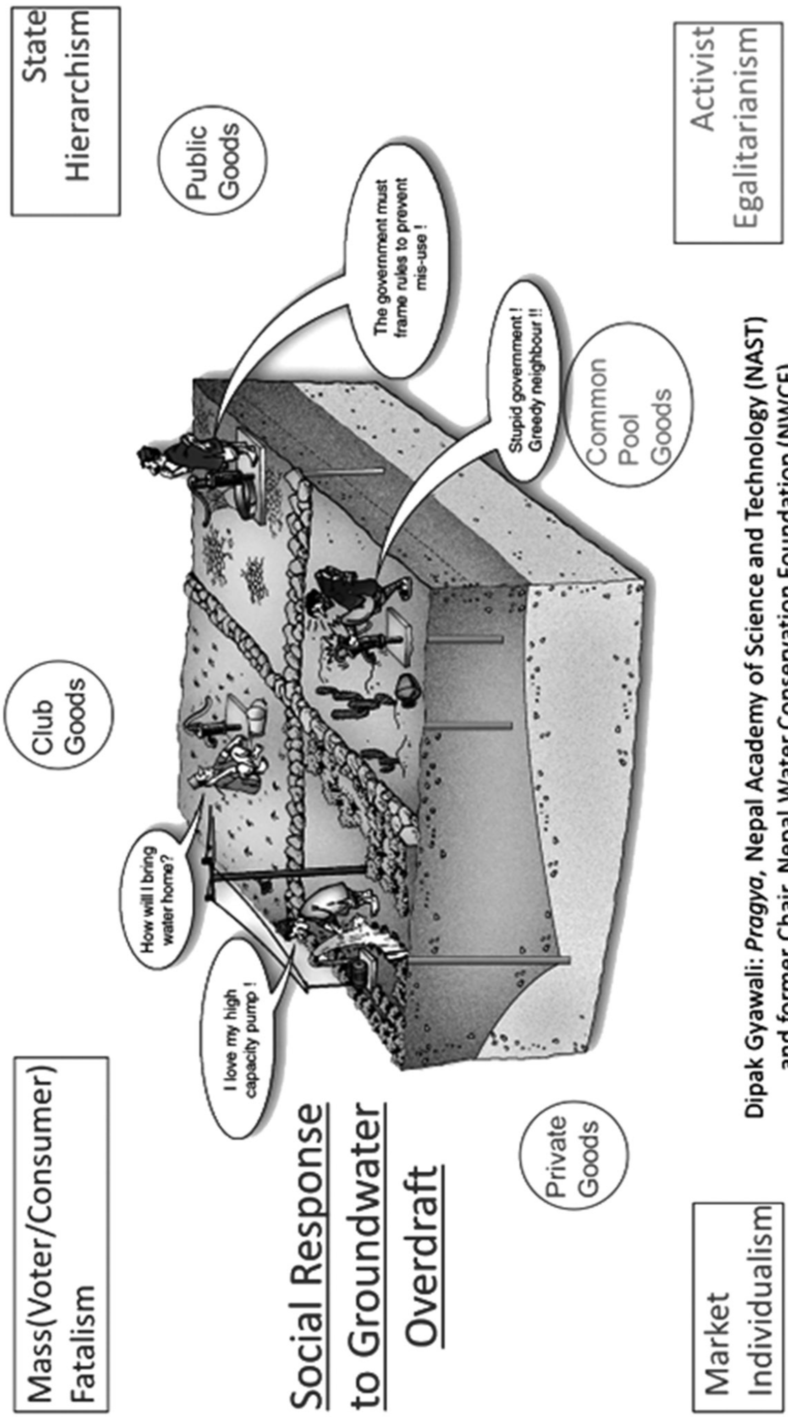
What this means in real policy implementation can be seen from the example of Marchawar (Gyawali, 2004). In the Tinau Basin, from Madi Phaant in Palpa to Marchawar next to the Indian border in Rupandehi, farmers have since time immemorial used brushwood dams to divert dry season streamflows to produce the second, non-monsoon crop. Towards the early part of the second half of the 20th Century, a concrete dam was to built at what is today known as Hattisunde below the East-West highway bridge at Butwal, to bypass the Gurbaniya brushwood system (a community-built and managed technology using local material). Unfortunately, the Tinau river moved west and not only was the dam was left high and dry but the agrarian economy of Marchawar collapsed, since the old had been destroyed and the new did not work.

Some twenty years later, a lift irrigation system was installed with the support of UNCDF which helped somewhat; but given that it had technical flaws (the main canal had water flowing "uphill" as it was part of the old, bypassed Hattisunde system that was meant to convey water from north to south, but the lift irrigation main canal was to carry water from south to north; the country from where the pump was purchased (Yugoslavia) ceased to exist etc, and its operation was a constant challenge. What helped was the arrival of the private sector's ubiquitous Kirloskar diesel pumps that could be installed easily (if you could not buy one, you could rent one that would arrive on a bullock cart at Rs 50/hour); and the groundwater table was shallow at

10 to 16 feet. Ironically, while groundwater pumping has led to agriculture revival in Marchawar and in the rest of the Terai, which is officially classified as a surface water command area by the Department of Irrigation. This policy blindness is leading to the tragedy of over-pumping and water table decline. In the midhills of Nepal, where the bulk of the upland population resides, mostly dependent on spring sources for irrigation and domestic water supply. Springs are leaking groundwater storage in the hills. Therefore, in reality, every hill is actually a "water tower", not because it has snow on it (midhill mountains of Nepal get practically no snow) but because it stores monsoon rain within it which slowly discharges as the dry season progresses and is filled up only in the next monsoon (Sharma et al 2016,Upadhya 2009). Indeed, all midhill rivers are spring (stored groundwater) fed and not fed by snow or glacier melt. Thus, Nepal is actually a groundwater-fed country.

If one takes soil moisture too into account, on which all of  the forests are dependent, then we quickly realize that the issue of real concern is not water flow in rivers but water storage, whether in nature as lakes, wetlands and groundwater or artificially built ponds and reservoirs. The unfolding tragedy in Nepal is that, in terms of official policy, springs are invisible and groundwater storage is treated as an infinite resource, there for just drilling and extracting. We do not have a drought policy since "we are second richest in water resources after Brazil" and don't have to worry about water scarcity, a crass bit of stupidity if we realize that Brazilians don't say they are number one and we are really a semi-arid zone with four months of floods and eight months of drought. Unchecked groundwater over-pumping as well as the use of uncontrolled PVC pipes and electric motors over-extracting spring water at the foothills leading to drying of uphill ones further results scarcity including the abandoning of villages. One should not blame climate change for it, as yet! It is the result of drivers mentioned above as well as filling up of recharge ponds including buffalo wallowing ponds that are under our control to do something about but we do nothing. If one looks at this from the perspective of social sciences, Cultural Theory (Gyawali et al 2017, Fig) describes the policy dilemma as follows. While much of social sciences have, in the past, focused only on market individualism or state hierarchism, i.e. free market or socialism, Cultural theory posits that there are two other social solidarities – activist civic egalitarianism and voter/consumer fatalism – that are equally important to explain the social dynamics underway to explain groundwater overdraft. Not only do that all have different views of risk and nature (individualism is risk-taking and sees nature as robust and taking care of itself; egalitarianism is risk sensitive and amplifying, seeing nature are fragile and in danger; hierarchism is risk managing seeing nature as robust but within limits of EIAs and other legislative means; and fatalism is risk absorbing seeing nature as capricious), they also have different ideas of what economic goods are. Markets see private goods, bureaucracy sees public goods, civic movements see common pool goods, and finalized consumers see club goods they are excluded from.

The tragedy for groundwater is its policy mismanagement where it is treated as an unregulated private good whereas in reality it should be treated both as a public good requiring proper legislative regulation as well as a common pool good that we are morally obliged to handover in good order to future generations. One should not let markets manage public or common pool goods because they are genetically not designed to do so. This is the way out of the tragedy that is unfolding in Nepal as in much of South Asia as well as other parts of the world.


Mass(Voter/Consumer)
Fatalism
Social Response
to Groundwater
Overdraft
I love my high capacity pump !
How will I bring water home?
Club Goods
Public Goods
State
Hierarchism
The government must frame rules to prevent mis-use !
Stupid government ! Greedy neighbour !!
Private Goods
Common Pool Goods
Activist
Egalitarianism
Market
Individualism
Dipak Gyawali: *Pragya*, Nepal Academy of Science and Technology (NAST)
and former Chair, Nepal Water Conservation Foundation (NWCF)

# TECHNICAL SESSION I: *Oral Presentations*

**Chair: Gautam Rajkarnikar**
CREEW
**Rapporteurs:** Prerana Amatya (CREEW), Amber Bahadur Thapa (S4W-Nepal)

# Groundwater Issues in Kathmandu Valley and Way Forward

***Anoj Khanal***
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History of groundwater goes back to centuries for Kathmandu Valley. People of this valley are using groundwater in the form of spring, stone spout or ponds since centuries. Systematic exploration of groundwater was started on 1961 under Indian Cooperation Mission. Similar mission was there on 1964 by USAID to conduct similar study. The latest comprehensive study was made under JICA on ground water resource of the valley in 1992. This JICA report is the main document referenced till date for various research and policy document. Despite of multiple exploration projects since 60's, commercial use of groundwater was initiated only in the 80's by then Nepal Water Supply Cooperation (NWSC) by developing the well fields in Bansbari, Dhobikhola and Gokarna area to enhance the water supply of the city. Only in 2063 (2009) Kathmandu Valley Water Supply Management Board (KVWSMB) was entrusted by Government of Nepal for the sustainable development of groundwater resource of Kathmandu Valley. Over the past 30 years, hundreds of deep tubewell were constructed by multiple private water users in the valley. The trend is increasing since last decade due to massive population growth creating more water demand in the valley. With increased number of deep tube wells, managing groundwater sources in the valley has become more challenging recently. Different issues like groundwater recharge dynamics, groundwater depletion trends, hydrogeological characteristics of different sub-basins, effect of excessive groundwater abstractions are still to be tackled with rigorous data and analysis. With 30 years of excessive groundwater abstraction in the valley, new study regarding hydrogeological properties of different groundwater sub basins is necessary. All existing judgment on groundwater characteristics of the valley are solely dependent on the study carried out 30 years ago, when abstraction was very low. Thus, new sets of research is very necessary which can provide more updated and meaningful insight into the groundwater system of this valley.

Recently, KVWSMB has conducted a study “Comprehensive Study of Groundwater Resources of Kathmandu Valley”, which has proposed multiple new concepts regarding valleys groundwater system. The study concluded that there might be some groundwater depletion in valley, but it differs from place to place. Different sub-basins were detected in the valley which has opened new avenues in the concept of aquifer setting of the valley. Besides, core part of the valley is mostly contaminated with Iron and Ammonia with geogenic origins. The study further highlights that the age of groundwater is still a big debate making groundwater recharge phenomena more complicated than ever. Multiple Tritium analysis throughout out the valley will only be able to answer the recharge process. Groundwater depletion need more rigorous measurement with well distributed monitoring network in future that will help to prepare proper groundwater exploitation master plan.

# Construction of Tubewell Irrigation System in Hills: A Case Study in Chyangli, Gorkha

***Jharana Khanal*and Kedar Shrestha***
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Groundwater exploration in hard rock terrain is an interesting job. Groundwater in hard rock topography generally occurs in secondary porosity developed due to various factors like fracturing, weathering etc., and is highly variable within very short distance. In such conditions topographic, geological and hydrogeological condition deliver worthwhile traces for the assortment of appropriate locations. Groundwater Resources and Irrigation Development Division, Kavrepalanchowk mostly works for groundwater exploration in hilly areas. The selection of proper drilling site in the hilly areas is very difficult. Generally, we select the drilling site on the basis of geomorphological, hydrogeological condition and geophysical survey. Based on this principal a pilot project was carried in Chyanglitar, Gorkha District. The potential zone in this area was delineated with the help of Vertical Electrical Soundings (VES) and Electrical Resistivity Tomography (ERT). The result of resistivity survey was verified as per the evidence inferred from geomorphological and hydrogeological investigation. Down-The-Hole hammer (DTH) drilling technique was adopted for drilling in the recommended site. The yield of these bore well vary from 7 to 9 lps, which is achieved from the continuous pumping test.

# Revival of Dried Spring by Horizontal Drilling: A Model Study of Kabhre Spring Dolakha

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The major sources of water for drinking and irrigation is the groundwater, mainly springs in the hills. The devastating 2015 Gorkha Earthquake has generated several new springs, meanwhile dried several existing springs. The Kabhre spring located at Dolakha district also dried by the earthquake. The main objective of this work was to revive the dried Kabhre spring. For this purpose, hydrogeological study followed by geological and discontinuity mapping and geophysical survey were conducted. These studies helped to assure the possibility of revival of spring. The main lithology around the dried spring is phyllite, talc and magnesite. The ERT survey performed at six different lines showed saturated rock below the surface.

Based on the geological and geophysical study, three different horizontal wells were designed of diameter 75 mm. Core logging was done to demarcate the potential fracture zone to tap the groundwater. Half circular perforated PVC pipe was inserted to release the water to the surface. Out of three holes, one was dry and remaining two provided the average discharge of 12 to 15 liter per minute. These horizontal wells which require no energy are the role model for other springs which has gone dry.

# Groundwater Irrigation Management Through Solar Powered Irrigation System is Viable Options in Nepal Terai?

***Bhesh Raj Thapa[1,*], Baburam Paudel[2,3], Rabindra Karki[3], Manita Raut[1], Michael Scobie[4] and Erik Schmidt[4]***

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*[2]Renewable World, Nepal Office*
*[3]International Development Enterprises*
*[4]University of Southern Queensland*
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Sustainability of groundwater pumping through different energy sources and identifying the most viable solution is always in question. This study attempts to assess the cost effectiveness of three (Solar, Electric, and Diesel) operated pumping technologies considering life cycle cost (LCC) in the context of Terai region of Nepal. Observation, key informant interview (KII), in depth interview, and focus group discussion (FGD) were conducted in 14 different sample sites to assess the performance of technology, life cycle cost and unit water cost (UWC) in different capacity utilization factors (CUFs), farmer's perception, affordability, and profitability. Low utilization factor of solar pumps has been observed in almost all sites. Solar pumps become expensive than diesel pump, if it is operated at less than 45% CUF. Grid operated electric pumps are found cost effective than diesel and solar, if gridline is near to pump site. If solar pump is operated at 10% CUF, the per unit water cost is NPR. 24.4, and the cost is reduced to NPR. 2.83, if it is operated at 90% CUF. Solar pumps need to be operated at least 700 hours per year to compete with diesel pump. The payback period for solar pump was calculated considering cost per unit of water at three different price NRs 5.51, 7.92, and 10 and found as 6.97, 4.1, and 3.14 year respectively for 70% utilization factor. High upfront cost of solar powered system, poor access to financing and technology seems to be hindering factor to popularize the system. To make solar powered irrigation system viable option in Nepal's Terai, effective supply chain network, easy access to repairing service, introduction of cash crops instead of traditional crops, promotion of micro irrigation techniques need to be initiated. In addition to this, better access to finance and technology, operation of solar pump at high CUF through grid connection to sell/buy surplus/deficit energy, and subsidized price of solar operated irrigation technology is also necessary to popularize the system. However, government needs to formulate and implement the policy for utilization and overexploitation of groundwater resources with expansion of solar, diesel, and electric operated pumps in near future to make groundwater resources sustainable.

# TECHNICAL SESSION II

**Chair: Iswar Man Amatya**
Institute of Engineering,Tribhuvan University
**Rapporteurs:** Ashok Kumar Shrestha (CREEW), Anusha Pandey (S4W-Nepal)

## Plenary & Oral Presentations

# Groundwater Recharge Intervention in Nepal: From Water-Food-Energy Nexus Promotion to Spring Revival

***Moti Lal Rijal***
*Central Department of Geology, Tribhuvan University*
*Chure-Terai Madhesh Conservation Development Board*
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In Nepal, uses of groundwater has been started from beginning of settlements by tapping spring water in the middle hills and by construction of dug-well in Terai region. Not only this, Nepal's first hydropower, which was constructed about a century ago also used water from large spring in the southern part of Kathmandu Valley. Groundwater is major source of water for drinking, irrigation and hydropower. Since last many years groundwater exploration and exploitation is mainly done in Terai for household uses and also for irrigation. Government offices related with groundwater were only operated in Terai until last three years. Groundwater either in the form of springs or by pumping from dug-wells or deep-wells were focused on using it for various purposes but, none of the work has been done for proper management of groundwater for making its sustainable without affecting its aquifer systems. Only limited information on aquifer systems of Terai are gathered till today. Hard rock aquifers or karstified aquifer systems in hilly regions are still very less understood groundwater systems in Nepal. Construction of deep-wells in the middle-hills region of Nepal is increasing rapidly and haphazardly after drying of traditional spring sources resulted huge amount of drinking water scarcity.

Department of Forests and Soil Conservation has been doing source protection of many springs by construction concreted structure around spring source, dug-well construction. However, recharge zone delineation and its conservation was not focused till government initiated Chure conservation program. After establishment of President Chure Conservation Program, more field interventions for water resource conservation are prioritized. Intervention activities in Chure and Terai region (Table 1) during consecutive fiscal years showed that water source protection concept has slowly shifted towards water resource conservation by constructing large scale ponds construction and runoff harvesting dams. The focus on source protection only aim to use water as drinking water source while conservation ponds and runoff harvesting dams construction has increased not only groundwater recharge but also promoted uses of water for irrigation for smallholders and for micro-hydropower generation.

Therefore, large scale systematic field interventions is required to promote groundwater recharge for sustainability of groundwater resources, that will also build a good water-food-energy nexus further beneficial for building climate change resilience of vulnerable ecosystems.

Table 1

| *Fiscal Year | 071/072 | 072/073 | 073/074 | 074/075 |
|---|---|---|---|---|
| Activities focused with water conservation | | | | |
| Water source protection and dugwell excavation | 195 | 106 | 128 | 116 |
| Conservation pond construction | 67 | 113 | 118 | 41 |
| Runoff harvesting dam | 6 | 16 | 35 | 53 |

(* Source: President Chure-Terai Madhesh Conservation Board)

# Exploring the Linkages Between Groundwater Level, Rainfall and Land Use in the Kathmandu Valley

***Rajaram Prajapati[1,*], Amber Bahadur Thapa[2] and Jeffrey C. Davids[2,3]***
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(*Corresponding author. Email: livaraja08@gmail.com)

Seasonal variations of shallow groundwater levels are mainly a function of rainfall, land-use (and by extensive withdrawals), and hydrogeology. The Kathmandu Valley, a heavily urbanized area, consists of highly dynamic micro land use patterns. Infrastructure development activities are accelerating rapidly, which makes the characteristics of shallow groundwater more complex and dynamic. This study attempts to unravel the spatio-temporal variation of rainfall and groundwater and their interrelationship with land-use and hydrogeology. Monthly groundwater level data were collected at 35 locations from July 2017 to June 2018 with a smartphone by local citizen scientists using an open source Android data collection platform called Open Data Kit (ODK) Collect. Within ODK Collect, each observation requires the citizen scientist to enter the groundwater level reading, save the current date, time, GPS coordinates, and take photographs of the observation. The present work describes the correlation between average monthly rainfall and monthly groundwater level along with its land-use type and hydrogeology. Recharge of shallow groundwater level was more in monsoon season (i.e. July-August) whereas from September to March groundwater levels continually declined. The study indicated a fast response of groundwater level to monsoonal rainfall in agricultural land than built land-use. The overarching potential benefit of this study is to facilitate closing knowledge gaps and contribute to a foundation for a more robust evaluation of groundwater resources.

# Springs Assessment and Potential Springshed Identification in Watersheds of Lake Cluster of Pokhara Valley

***Rajan Subedi*, R. Thapa, B. P. Heyojoo, K. R. Tiwari and M. Rijal***
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Springs are the important groundwater resources for mountain people and ecosystems. Drying springs and its pollution are being the major concerns for rural water supply, maintaining mountain agriculture, ecosystem health and ultimately river flow, lake water balance and wetland biodiversity in the low land areas. Recent practices of haphazard rural road and urban infrastructure construction in the catchment area and climate change phenomenon like prolonged drought and variability on rainfall pattern are making mountain spring more critical and thereby increasing vulnerability of associated mountain community and ecosystem. In this context, identification of springshed area and adoption of effective interventions work to revive or improve recharging is immediate need for sustained supply of water for the critical users in the mountain region. The adaptive action research project was designed and implemented by Institute of Forestry (IoF) in collaboration with National Institute of Hydrology (NIH), India with support from WWF Nepal USAID funded Hariyoban Program in watersheds of lake cluster of Pokhara valley in order to assess springs resource status, develop multi-criteria tools for sensitivity analysis to prioritize springs for conservation plan of action and develop appropriate approach to identify recharge areas for implementation of effective interventions.

The project assessed total perennial springs and prepared their baseline database through systematic approach of scanning catchment area and consultations with local stakeholders and key informants. Sensitivity analysis of explored springs using multi-criteria based on catchment risk character and conservation demand was performed to prioritize springs in different level of criticalness. Out of total 765 perennial springs in the area, around 15% springs are categorized as highly sensitive, 64% moderately sensitive and 21% are in less sensitive category. Two identified critical spring catchments were selected for detail hydro-geological and isotope study. The regular monitoring rainfall and spring discharge, periodical monitoring of in-situ water quality and sample analysis of rain and spring water for stable environmental isotope of oxygen and hydrogen (δ18O and δD) were conducted for one year. Hydrogeological conceptual model was prepared to identify potential springshed area based on surface geological survey and isotope study planned to verify potential springshed area. Field observation and preliminary analysis of hydrogeological conceptual model for potential springshed delineation with verification from isotope analysis of rainfall and spring water, establishment of rainfall-discharge relationship, water aging (tritium analysis) and water quality monitoring provide details of spring hydrology that requires effective interventions for improving spring recharge. Further, it was observed that there is a lack of awareness among the local people regarding spring conservation sources as they are getting water from different water supply project for their prime need. Lake water balance is under risk due to diversion of major spring sources for municipal water supply. Spring water pollution is increasing and mainly along the drainage channel due to waste disposal and eroded sediments. Anthropogenic activities such as deforestation, hilly road construction, urban infrastructure further creates problems in the spring resources. Therefore, the ecosystem perspectives catchment management could be efficient way to protect critical spring resources and maintain their use values.

# Identifying the Spatial Distribution of the Deep Groundwater Recharge Processes Using Hydrogeochemical and Stable Isotopes of Water

***Bijaya Man Shakya[1,*], Takasi Nakamura[2], Suresh Das Shrestha[3] and Kei Nishida[2]***

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[2] *Interdisciplinary Research Centre for River Basin Environment, University of Yamanashi*
[3] *Central Department of Geology, Tribhuvan University*
*(*Corresponding author. Email: g17de002@yamanashi.ac.jp)*

The present study focuses on Kathmandu valley, Nepal which is one of the large hydrologeologically closed intermountain basins of Himalayan region with high basin floor. Surrounded by the high rose mountain of gneiss and granite to the north and limestone dominated metamorphic rock mass to the remaining. The basin is marked as the one of the fastest population growing Asian city. Groundwater in this basin is one of the major drinking water source where the shallow groundwater (<50 m) are targeted by the households and deep groundwater (>50 m) are more targeted by the institutions. Although, the increasing trend of deep groundwater extraction is highly expected in Kathmandu Valley, knowledge about deep groundwater recharge processes is still limited.

This study focuses on identifying the recharge processes in deep groundwater of Kathmandu Valley. Twenty-five samples from deep groundwater and six samples from mountain spring were collected and analyzed during the wet season of the year 2016. Trilinear analysis of the deep groundwater showed uniqueness of water chemistry in the basin, with Na-HCO3 water type in the northern part and Ca-HCO3 water type in the central part of the Kathmandu valley. The value of δ18O and δD varied from -9.7 ‰ to -7‰ and -71‰ to -47‰, respectively for deep groundwater samples, and from -9.3‰ to -8.2‰ and -63‰ to -56‰, respectively for the spring water samples. Compared to the global and local Meteoric Water Lines, the deep groundwater supposedly originated from the recent precipitation and less affected by evaporation. Stable isotopes of water then further provided the information on recharge altitudes of the deep groundwater. The range of lighter water isotope values found in the NW part of the valley corresponded to the recharge from the higher altitude. The medium and heavier water isotope values were found in the NE and central part of the valley indicating the rainfall recharge at relatively low altitude. The study revealed the deep groundwater tube wells lying near to the river are vulnerable to the chances of contaminations. Combining the tracer techniques with stable isotope of water, this study indicates the wide distribution of the deep groundwater recharge processes from the other parts of the Kathmandu valley along with the northern part. The study also provides the information regarding the need of extending the research in the southern and western part of the Kathmandu valley for the understanding of central groundwater recharge process. Thus, along with the spatially distributed recharge processes for the deep groundwater, this study also seeks a need of the attention to the deep groundwater management sectors regarding the recharge and vulnerability to the deep groundwater contamination.

# Water Balance Component Analysis of Sikharpur Spring Catchment of Western Nepal

***Jibesh Kumar K.C.[1,*], Sanita Dhaubanjar[2], Vishnu Prasad Pandey[2], Rajan Subedi[3]***
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Springs in the mountains and hills are getting affected by both climatic and non-climatic changes. Hydrologic models are used to simulate the response of spring systems to the changes. However, there are limited studies that use hydrologic modeling approach for studying springs and spring dominated watersheds in Nepal. Therefore, this research aimed to understand changing hydrological processes through hydrologic modeling in a spring catchment. A micro-catchment of Shikharpur of West Seti watershed was selected to get insights into the process influencing the spring system. RRAWFLOW model with gamma distribution and time variant IRFs were calibrated and validated for the catchment to get the best fit model. The discharge was simulated according with respect to the future projected climate scenarios. A water balance was also estimated for the micro-catchment. Results showed that understanding of likely response of hydrologic variables to potential future climate scenarios is critical for water resources management. It was estimated that, the spring discharge will be decreased by more than 40% after 50 years mainly due to increased evapotranspiration (91.47% of precipitation evaporated). Certainty in the model simulation can be enhanced with the availability of long-term hydro-meteorological data. As -51.78% change in storage was observed, detail isotopic analysis and long-term monitoring of water balance is recommended for further characterization of water balance components. Evapotranspiration was found as a major hydrologic process impacting water balance in the spring catchment. Therefore its management for better spring resource conservation is recommended from this study.

# POSTER SESSION

# Study of Water Quality and Quantity of Stone Spouts Under Various Land Use in the Kathmandu Valley

***Anusha Pandey[1,*], Pratik Shrestha[1,2], Sudha Humagain[3] and Jeffrey Colin Davids[4, 5]***
[1]SmartPhones4Water-Nepal
[2]Golden Gate International College, Tribhuvan University
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SmartPhones4Water-Nepal (S4W-Nepal) has been monitoring water discharge and water quality in stone spouts of Kathmandu Valley since 2017. These stone spouts once served as primary sources of water in the Kathmandu Valley. Regardless their efficiency and cost-effectiveness, these traditional water harvesting and management systems are either, in decline, or have already been abandoned in the recent years. Similarly, skyrocketing population growth over the last 50 years has changed the predominant land use type of Kathmandu Valley from natural vegetation to developed built up areas. These landuse changes have created great stress on these stone spouts. Water discharge and water chemistry (temperature and electrical conductivity) of more than 300 stone spouts has been studied (n=199 in post monsoon 2017, n=228 in pre monsoon 2018 and n=327 in post monsoon 2018) spatially while 83 of them were repeated in all three cycles to study temporal variations in the Kathmandu Valley. The main objective of research is to analyze how these water discharge and water chemistry in stone spouts vary with varying land use types in the Kathmandu Valley. Each measurement was recorded using Open Data Kit (ODK); an android phone application used by Smartphones For Water Nepal (S4W-Nepal) team in their project. For discharge measurement, a measuring bucket was held under each spout with a timer and the time it took to fill the bucket was recorded. Based on Kruskal-Wallis H test performed on stone spouts EC and flow measurements (n=590) over three land use classes, EC (alpha=0.05, p=0.00) and flow (alpha=0.05, p=0.00) distribution were significantly different among three land use classes made by S4W-Nepal. EC difference between Natural-Built (alpha=0.05, p (adj.)=0.048) and Agriculture-Built (alpha=0.05, p (adj.)=0.05) land use pairs were found to be statistically significant. While, flow distribution was only significantly different between Agriculture-Built Landuse class pair (alpha=0.05, p (adj.)= 0.00). Hence, it is likely to conclude that land use has impacted the quality and quantity of water in stone spouts of the Kathmandu Valley.

# Seasonal Variation of Groundwater Quality in Bhaktapur, Nepal

***Pratik Shrestha[1,2], Amber Bahadur Thapa[1,3], Anusha Pandey[1], Rajaram Prajapati[1], Nistha Bhuju[3] and Jeffrey Colin Davids[4,5]***

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Nepal government is struggling to meet water quality and quantity demand of current population. Water pollution is the most persistent issue Kathmandu Valley is struggling to address in present context. Bhaktapur, one among the rapidly developing districts in Nepal suffer from rapid groundwater depletion, both in terms of water quality and quantity in the recent years. With the drastic increase in the population of Bhaktapur, the water demand has increased correspondingly. Stream water being polluted that seem impossible for individual to sustain their livelihood, people mainly rely on dug shallow wells for their domestic water use purposes. This study was carried out to evaluate if, groundwater quality of shallow dug wells in Bhaktapur municipality meets National standards. Smartphones4Water-Nepal (S4W-Nepal) has been monitoring water quality parameters of wells in Bhaktapur for three seasons i.e. pre-monsoon, monsoon and post-monsoon since 2018. Altogether 25 shallow wells were selected as sampling sites. The in-situ water quality parameters were measured on the spot with the help of EXTECH water quality probes and ENPHO water test kit was used to measure the concentration of other water quality parameters in the laboratory. Each measurement was recorded by using Open Data Kit (ODK); an android application used by SmartPhones4Water-Nepal (S4W-Nepal) team in their project. This application allows to record Date/Time, GPS, Pictures and data of the measurement. Seasonal water quality variations were investigated to quantify the extent of these groundwater depletion. Based on distribution of the variation of concentrations of various parameters, particularly, ammonia, nitrate, EC, chloride and hardness, and presence of E.coli, it would be fair to say that urbanization is affecting the quality of groundwater. It is advisable that proper standards for management and construction of dug wells are developed in order to achieve this. Long term temporal and spatial monitoring of groundwater quality data should be considered for better evaluation of this variability.

# Assessment of Citizen Science-Based Groundwater Monitoring in Kathmandu Valley

***Anurag Gyawali, Eliyah Moktan, Amber Bahadur Thapa and Rajaram Prajapati****
*SmartPhones4Water-Nepal*
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Sustainable groundwater management requires long-term monitoring of groundwater level with adequate spatial and temporal resolution. Since existing monitoring programs do not have sufficient spatial resolution, an alternative is to establish a locally-based monitoring program. Citizen science-based groundwater monitoring using existing wells is an economic and sustainable approach. A network of more than 35 monitoring wells was established in the Kathmandu Valley. The primary goal of this study is to understand the fundamentals of citizen science-based groundwater monitoring project. Different approaches such as personal connections (54%), outreach programs (39%) and random visits (7%) were applied for recruiting citizen scientists. Bulk SMS and follow up calls were done around the mid of the month to remind citizen scientists for taking measurements. All data were collected in an Android application called Open Data Kit (ODK). This application allows user to record GPS of the sites and take pictures of the measurement. An online survey was conducted among those 35 citizen scientists to recognize the major motivating factors, most liked and disliked aspects of the monitoring program. Most of the citizen scientists (75%) responded "Scientific aspect of the program" as the major motivating factor followed by "Responsibility as a Citizen Scientist" response of 54% citizen scientists. Most of the CS don't have any dislike but some of them (39%) were dissatisfied about the ODK errors in their smartphones. Measurement time, payment time and follow up calls were important in motivating the citizen scientists. From this study it can be concluded that citizen science driven groundwater monitoring will play an important role in closing the data gaps in groundwater society. Motivation parts and recruitment aspects can be challenging aspects in launching these projects. Scientific aspects of research plays an important role in motivating citizens for participating in citizen science projects.

# Dissolved Iron Oxidation Using Sponge Media

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Aeration is simple water treatment unit for removal of dissolved iron from groundwater. Everybody in today's world deserves a clean drinking water. High concentration of iron content in ground water source is one of the main undesirable water qualities in Kathmandu valley. Therefore, an attempt was made to reduce higher dissolved iron concentration only by aeration followed by sedimentation using sponge tray aerator. A small scale gravity inclined tray of size 0.9m x 0.45m x 0.15m with 0.03045m$^3$ volume of sponge media (with each size 0.9m x 0.03m x 0.03m in three layers with 0.96 porosity, 10 ± 1.5 hardness and 22 ± 2 kg/m$^3$ density) with surface area 0.405m$^2$ was built which aerates water by natural gravity flow as well as porous sponge media too. A study was carried out for the tray with the angle of inclination of 10° at different flow rates i.e. 600 and 1200ml/min for 240 hours respectively with reference to total iron, dissolved oxygen and turbidity. The average influent iron concentration was found to vary from 12 to 25mg/l. The average influent iron concentration was classified into different range of concentrations such as 12 to 14, 14 to 16, 16 to 18 and 18 to 20 mg/l. It was observed that the higher oxidation rate was found to be 95.01 and 91.01% for flowrate 600 and 1200ml/min in the influent with concentration of 12 to 14mg/l. Similarly, high turbidity removal rate i.e. 94.17 and 90.42% were also found to be at iron concentration range 12 to 14mg/l. Likewise, high DO increased rate i.e. 68.75 and 55.36%. were also found to be at iron concentration range 12 to 14mg/l. The results showed that the dissolved iron oxidation rate was highest at the lower discharge of 600ml/min. Also, sponge showed the better performance for bottom layer of sponge than that of upper two layers. On this basis, 1742 and 3253g/day/m$^3$ of total iron can be retained on the sponge surface for flowrate of 600 and 1200ml/min respectively. Hence, sponge tray model can be used as one of the option for the aeration unit for iron oxidation in domestic purposes since it is easy to use, have light weight than sand, easy to handle, low cost and high efficiency.

**Variation of DO in different range of iron concentration for discharge 600ml/min and 1200ml/min**

| Range of Concentration of Iron (mg/l) | Average concentration of Iron | Average Operating Hour (hrs) | Average Water Temp (°C) | Average DO inlet | 600ml/min | | | 1200ml/min | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average DO outlet | Average increase in DO | Average DO increased (%) | Average DO outlet | Average increase in DO | Average DO increased (%) |
| 12 to 14 | 13 | 6 | 21.45 | 2.80 | 4.73 | 1.93 | **68.75** | 4.35 | 1.55 | **55.36** |
| 14 to 16 | 15 | 6 | 18.63 | 2.82 | 4.17 | 1.35 | 47.87 | 3.85 | 1.03 | 36.52 |
| 16 to 18 | 17 | 6 | 18.08 | 2.83 | 4.02 | 1.18 | 41.76 | 3.78 | 0.95 | 33.53 |
| 18 to 20 | 19 | 6 | 18.68 | 2.70 | 3.78 | 1.08 | 39.81 | 3.53 | 0.83 | 30.56 |

**Variation of iron concentration in different range of iron concentration for discharge 600ml/min and 1200ml/min**

| Range of Concentration of Iron (mg/l) | Average concentration of Iron | Average Operating Hour (hrs) | Average Water Temp (°C) | Average T-Fe inlet (ppm) | 600ml/min | | | 1200ml/min | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average T- Fe outlet (ppm) | Average iron Oxidized (ppm) | Averaged iron Oxidized (%) | Average T- Fe outlet (ppm) | Average iron Oxidized (ppm) | Averaged iron Oxidized (%) |
| 12 to 14 | 13 | 6 | 21.45 | 13.00 | 0.65 | 12.35 | **95.01** | 1.17 | 11.83 | **91.01** |
| 14 to 16 | 15 | 6 | 18.63 | 15.03 | 1.53 | 13.50 | 89.83 | 2.40 | 12.63 | 84.03 |
| 16 to 18 | 17 | 6 | 18.08 | 17.12 | 2.39 | 14.73 | 86.03 | 3.16 | 13.96 | 81.53 |
| 18 to 20 | 19 | 6 | 18.68 | 19.39 | 3.22 | 16.17 | 83.40 | 4.46 | 14.93 | 77.00 |

**Variation of turbidity in different range of iron concentration for discharge 600ml/min and 1200ml/min**

| Range of Concentration of Iron (mg/l) | Average concentration of Iron | Average Operating Hour (hrs) | Average Water Temp (°C) | Average Turbidity inlet (NTU) | 600ml/min | | | 1200ml/min | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Average Turbidity outlet (NTU) | Average Removal (NTU) | Average Removal (%) | Average Turbidity outlet (NTU) | Average Removal Inlet (NTU) | Average Removal (%) |
| 12 to 14 | 13 | 6 | 21.45 | 60.00 | 3.50 | 56.50 | **94.17** | 5.75 | 54.25 | **90.42** |
| 14 to 16 | 15 | 6 | 18.63 | 70.06 | 6.70 | 63.36 | 90.44 | 8.29 | 61.77 | 88.17 |
| 16 to 18 | 17 | 6 | 18.08 | 86.17 | 11.00 | 75.17 | 87.23 | 12.08 | 74.09 | 85.98 |
| 18 to 20 | 19 | 6 | 18.68 | 106.50 | 12.25 | 94.25 | 88.50 | 13.25 | 93.25 | 87.56 |

# Water Poverty Index Analysis and Delineation of Groundwater Potential Zone in the Lower Reaches of Tamakoshi Sub-Basin, Ramechhap, Province No. 3, Nepal

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Springs are the source of groundwater for the mountainous people but emerging drought condition exacerbated by climate change has dried spring sources sparking water crisis. The present study has attempted to link water poverty with groundwater potential in the mid-hill regions of Nepal Himalaya. The study was conducted in four drought-prone declared Village Development Committees (VDCs) of lower reaches of Tamakoshi Sub-basin in Ramechhap, Province No. 3 Nepal. The VDCs are namely Bhatauli, Chisapani, Kathjor and Manthali.

A composite index called Water Poverty Index (WPI) was used to assess water poverty of the study area. The Central Bureau of Statistics (CBS) 2011 data and questionnaire survey was done to acquire data for WPI calculation. WPI map was prepared which picturize VDCs score. Groundwater potential zone delineation with the help of Remote Sensing (RS) and Geographic Information System (GIS) techniques was carried out where eight thematic layers and satellite images were used and analyzed in ArcGIS software using weighted overlay tool. Low, moderate and high classes of groundwater potential zones have been demarcated in the study area. Spring inventory was carried out in order to validate the delineated groundwater potential zone. The study showed that, the groundwater potential zone are represented by the most of the existing springs e.g. 16 springs are found in high potential zone, 12 springs and 5 springs are found in moderate and low potential zones respectively. Also, springs that belong to high groundwater potential zone are categorized by high discharge compare to that of low potential zone. Concerning WPI, VDCs score lower WPI than the score for Nepal. The study further depicts that the area with low ground water potential such as Bhatauli VDC has low water poverty index whereas, Manthali VDC has high ground water potential and high WPI score. It is important to take an action for improving its water availability situation in the areas with low water poverty index and low groundwater potential zone.

# Stream-Aquifer Interaction of Water Level Dynamics and Water Quality in the Kathmandu Valley

***Amber Bahadur Thapa[1,2,*], Surabhi Upadhyay[1,3], Rajaram Prajapati[1] and Jeffery Colin Davids[4,5]***

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Increasing population and urbanization has led to water demand escalation in the Kathmandu Valley. Stream water, being mostly polluted, functional for any domestic use. In such case, people are highly dependent on groundwater. However, there is linkages between surface water and groundwater in terms of both quantity and quality perspective as they are hydraulically interconnected. Despite this, there are limited research in this field in the valley. So, to understand the linkage in terms of both water quality and quantity, S4W-Nepal has been monitoring stream-aquifer interaction seasonally since 2018. A total of 16 stream-well pairs were assessed from 3 sub-watersheds (Bishnumati, Dhobi and Bagmati) during pre-monsoon and 35 stream-well pairs were assessed from 8 sub-watersheds (Bishnumati, Dhobi, Bagmati, Hanumante, Manohora, Godawari, Nakkhu and Balkhu) of the valley during post monsoon season in 2018. For each watershed, three to ten monitoring locations were selected. Topographic surveys were carried out to measure water level difference using Auto level and water quality was assessed by using ENPHO's water quality test kits and Baldwin Meadows water quality test stripes. Six water quality parameters were considered: electrical conductivity, ammonia, chloride, hardness, alkalinity and phosphorus. All data collected in field were recorded in an Android application called Open Data Kit (ODK). This application allows user to record GPS of the sites and take pictures of the measurement. Based on pre-monsoon (n=16), it is observed that 88% of water levels in wells were lower than adjacent streams, indicating a loss of stream water to the aquifer and post-monsoon (n=35) stream-well pair measurements. While in post-monsoon (n=35), 69% of wells had water levels higher than adjacent streams, indicating that monsoon rainfall had at least temporarily recharged the shallow aquifer, causing streams to transition from losing to gaining. All most every parameters (25 out of 36 possible pairs) have a statistically significant correlations between streams and wells. Except phosphorus in wells

appears to be uncorrelated with concentrations in streams. Similarly, alkalinity in streams seems to be uncorrelated with all well water quality parameters except groundwater alkalinity. We clearly observed seasonal refilling of the shallow aquifer, the timing and extent of this process, and the importance of managing streams and aquifers as a single integrated resource. Knowledge of stream-aquifer interactions is crucial component of developing effective and sustainable water management plans that integrate both water quantity and quality issues. Upstream sites tend to be losing year-round, so effort should focus first on protecting and improving water quality in headwater catchment areas and when building a sewage collection system, we suggest starting upstream and moving downstream. Understanding stream-aquifer interactions therefore is critical for sustainable management of both water quality and quantity in the Kathmandu valley.

# Modeling the Future Hydrological Climate Change Scenarios by Using SPHY Model in Budhi Gandaki Basin, Nepal

***Prerana Amatya[1,2,*], Sadmi Bhattarai[1], Sweta Shrestha[1], Kundan Lal Shrestha[1] and Rakesh Kayastha[1]***

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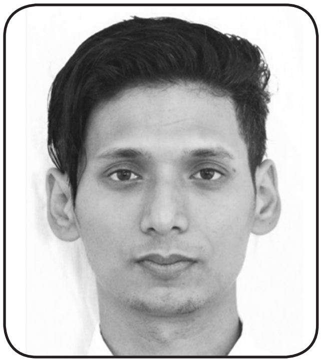
*[2]Center of Research for Environment, Energy and Water (CREEW)*
*(* Corresponding author. Email: preranamatya@gmail.com)*

Climate change can have adverse impact for developing countries like Nepal carrying abundant water resources. Warming trends have been observed in many regions. Melting of snow and ice and shrinking of glaciers are affecting water resources. Over the last few decades precipitation extremes have increased leading to floods and droughts in Asia. Such changes in climate influences all major components of hydrological system. The future climate change can be assessed through simulation of hydrological conditions with the help of hydrological model and climate model outputs. Therefore, this study evaluated the likely impact of climate change on water resource for Budhi Gandaki using a fully distributed hydrological model SPHY to simulate streamflow series for available hydrological data and future periods. The model shows a good Nash-Sutcliffe efficiency and coefficient of determination in calibration (0.73 and 0.82) and validation (0.8 and 0.83). This research employed daily precipitation and temperature output of three different CORDEX experiments namely RCA4 (ICHEC), CCAM (CNRM) and REMO2009 (MPI) for near future (2020s), mid-future (2050s) and far future period (2080s), each one under two different representative concentration pathways (RCPs) which were bias corrected against historical gauged data. The ensemble mean temperature predicts increase in temperature up to 1°C and 0.9°C during far future under RCP 4.5 and RCP 8.5 respectively. It is foreseeable that the minimum temperature will increase more than maximum temperature. The ensemble mean precipitation is projected to increase under both RCPs. The most increase is shown by MPI during 2020s by 18.4% under RCP 4.5 and ICHEC by 16% during 2080s under RCP 8.5. As there is variation in temperature and precipitation between three experiments along with time and RCP scenarios, river discharge also varies similarly. However, the ensemble mean discharge is expected to increase by 28% and 20% during 2080s under RCP 4.5 and RCP 8.5 respectively. Reservoir module is added to latest version of SPHY through which we quantified the changes in river discharge due to installation of reservoir. These outputs from the model can provide insight for future research and proper management of water resources of the basin under climate change.

# Comparison Between Up Flow and Down Flow Reactor for Optimization of Hydrogenotrophic Denitrification Reactor



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Groundwater is the major source of water in the Kathmandu valley which is mostly found to be contaminated with ammonia and nitrate. The microbial approach with the processes of the nitrification and hydrogenotrophic denitrification (HD) has come up in developing efficient nitrogen removal system that can be economically viable. This study is carried out to optimize the denitrification reactor types, the Up Flow and Down Flow Reactor, based on flow direction of influent water in the reactor keeping other parameters same in both the reactors. Both reactors have been constructed and fitted keeping in mind to minimize the cost using local materials and fittings. For this, the PVC pipe of 14cm internal diameter and 225cm length has been fitted with Bio Fix media and the aquarium pump with air-stone for bacterial growth and $H_2$ gas diffusion respectively. The difference in flow direction as up flow and down flow has been adopted forboth the reactors keeping other parameters same. This study has shown major incomplete HD reaction with very small amount of total nitrogen removed. Nitrate conversion reached 100% (134.51 N-gm/m3/d and 182.79 N-gm/$m^3$/d) as maximum for Down Flow Reactor at $71^{st}$ and $75^{th}$ day respectively. Similarly, for Up-Flow Reactor the maximum was 98.65% (180.32 N-gm/$m^3$/d) at $75^{th}$ day. Along with this, the total nitrogen removal was less as the $NO_2$-N (Nitrite) accumulations occurred. The maximum value of $NO_2$-N concentration noted in reactors were 72.55 mg/l and 78.89 mg/l for Up Flow and Down Flow Reactors, respectively. This is the main cause for the incomplete HD reaction. This gave maximum of only 41.11% (171.72 N-gm/$m^3$/d) and 33.89% (141.56 N-gm/$m^3$/d) both at $48^{th}$ day for Down- Flow and Up-Flow reactor, respectively as the total inorganic nitrogen (TIN) removed. This may have been caused due to the lesser detention time and heavy short circuiting. The reactor shows higher conversion efficiency of nitrate ($NO_2$-N) than nitrite ($NO_3$-N) as the detention time was practically found 45 mins which was very much less than the theoretical assumptions (11.29hrs). Apart from this, the study managed to draw conclusion for the comparison. This justified the better performance of Down-Flow (B) Reactor than Up-Flow (A) Reactor as the obtained equations "B=1.0273A + 8.3033" for nitrate conversion and "B=1.0149A + 2.0903" for TIN removed. This shows the optimization of HD can be done in same reactors just by changing flow direction of water to downward.

# ANNEX I: PROGRAM SCHEDULE

Date: 18 March 2019
Venue: Radisson Hotel, Kathmandu
Registration: 9:00 am - 9:30 am

**MC: Ms. Deepa Neupane**

| **OPENING SESSION** | |
|---|---|
| 9:30 -9:35 | Welcoming the dignitaries on dias |
| 9:35-9:40 | National Anthem |
| 9:40-9:45 | Lightening of the Traditional Oil Lamp by Chief Guest |
| 9:45-9:50 | Welcome address |
| 9:50-10:20 | Keynote address: **'Groundwater's 21st Century Challenge: Shifting the Paradigm from Open Access Private Good to Regulated Common Pool Resource'** by Er. Dipak Gyawali, Former Water Resource Minister, Academician at Nepal Academy of Science and Technology (NAST), and Chair of the Nepal Water Conservation Foundation |
| 10:20-10:50 | Remarks by Guests |
| 10:50-11:00 | Felicitation to contributors for the research and dissemination of groundwater |
| 11:00-11:05 | Remarks by Chief Guest |
| 11:05-11:10 | Vote of thanks |
| 11:10-11:15 | Closing remarks by Chairperson |
| **Group photo session and tea break (11:15-11:30)** | |

| **TECHNICAL SESSIONS** | | |
|---|---|---|
| **TECHNICAL SESSION- I (Groundwater management)** | | |
| 11:30-11:45 | Groundwater Issues in Kathmandu Valley and Way Forward | **Anoj Khanal**<br>Kathmandu Valley Water Supply Management Board (KVWSMB) |
| 11:45-12:00 | Construction of tubewell irrigation system in hills: a case study in Chyangli, Gorkha | **Jharana Khanal, Kedar Shrestha**<br>Groundwater Resources and Irrigation Development Division, Kavrepalanchowk |

| | | |
|---|---|---|
| 12:00-12:15 | Revival of dried spring by horizontal drilling: a model study of Kabhre Spring Dolakha | **Manoj Khatiwada**<br>Water Resource Research and Development Center (WRRDC), Govt. of Nepal, |
| 12:15-12:30 | Groundwater irrigation management through solar powered irrigation system is viable option's in Nepal Terai? | **Bhesh Raj Thapa, Manita Raut,** International Water Management Institute (IWMI), Nepal; **Baburam Paudel**, Renewable World, Nepal Office; **Rabindra Karki**, International Development Enterprises; **Michael Scobie, and Erik Schmidt** University of Southern Queensland, Toowoomba, Australia |
| 12:30-12:40 | **Questions and discussion** | |
| **Lunch Break** (12:40-13:30) | | |
| **TECHNICAL SESSION- II (Groundwater recharge, groundwater potential zoning)** | | |
| **Plenary Speaker: Dr. Moti Lal Rijal**, Assoc. Prof., Central Dept. of Geology/Member, President Chure-Terai Madhesh Conservation Development Board, Govt. of Nepal 'Groundwater Recharge Intervention in Nepal: From Water-Food Energy Nexus Promotion to Spring Revival' (13:30-13:45) | | |
| 13:45-14:00 | Exploring the linkages between groundwater level, rainfall and land use in the Kathmandu Valley | **Rajaram Prajapati, Amber Bahadur Thapa,** Smartphones4Water-Nepal; **Jeffrey C. Davids**, SmartPhones4Water-USA, Delft University of Technology, Delft, Netherlands |
| 14:00-14:15 | Springs assessment and potential springshed identification in watersheds of Lake Cluster of Pokhara Valley | **Rajan Subedi**,<br>Institute of Forestry, Tribhuvan University |
| 14:15-14:30 | Identifying the spatial distribution of the deep groundwater recharge processes using hydrogeochemical and stable isotope of water | **Bijay Man Shakya, Takashi Nakamura, Nishida Kei,** ICRE, University of Yamanashi); **Suresh Das Shrestha**, Central Department of Geology, TU |

| | | |
|---|---|---|
| 14:30-14:45 | Water balance component analysis of Sikharpur spring catchment of Western Nepal | **Jibesh Kumar K.C.**, ADAPT Nepal; **Sanita Dhaubanjar, Vishnu Prasad Pandey** IWMI Nepal; **Rajan Subedi,** Institute of Forestry, TU |
| 14:45-15:00 | **Questions and discussion** | |
| **TECHNICAL SESSION- III- Poster Viewing, discussion and feedback (15:00-15:25)** | | |
| **Tea break (15:25-15:40)** | | |
| **PANEL DISCUSSION SESSION (15:40-16:30)**<br>Title: Review of challenges and opportunities for sustainable groundwater resources management in Nepal and way forward | | |
| **Moderator:** Dr. Sangam Shrestha, Assoc. Prof., Asian Institute of Technology, Thailand<br>**Panelists**<br>Er. Madhav Belbase, Secretary, National Vigilance Center (former Joint Secretary of WECS), Govt. of Nepal<br>Dr. Suresh Das Shrestha, Prof., Central Dept. of Geology, Tribhuvan University (CDG/TU)<br>Dr. Sanjeev Bickram Rana, Executive Director, Kathmandu Valley Water Supply Management Board (KVWSMB)<br>Mr. Andy Prakash Bhatta, President, Nepal Hydrogeological Association (NHA) | | |
| **CLOSING SESSION** | | |
| 16:30-16:45 | Honoring the contributors and participants of the symposium since last 10 years | |
| 16:45-16:50 | Closing remarks | |

# ANNEX II: LIST OF PARTICIPANTS

| S.N. | Name | Organization |
|---|---|---|
| **Government Organizations** | | |
| 1. | Rishi Ram Sharma | Water and Energy Commission Secretariat (WECS) |
| 2. | Deepak Ghimire | Department of Water Resources and Irrigation (DWRI) |
| 3. | Sanjeev Bickram Rana | Kathmandu Valley Water Supply Management Board (KVWSMB) |
| 4. | Anoj Khanal | KVWSMB |
| 5. | Ram Chandra Dhakal | KVWSMB |
| 6. | Nabin Tiwari | KVWSMB |
| 7. | Sushil K.C. | KVWSMB |
| 8. | Bodhraj Dahal | KVWSMB |
| 9. | Radah Dhakal | KVWSMB |
| 10. | Tej Binod Pandey | KVWSMB |
| 11. | Chandan Kumar Shah | KVWSMB |
| 12. | Yogendra Pd. Bhatta | KVWSMB |
| 13. | Rita Niraula | KVWSMB |
| 14. | Anju Kumari Pandeya | KVWSMB |
| 15. | Deepak Gyawali | Nepal Academy of Science and Technology (NAST) |
| 16. | Laxmi Prasad Devkota | NAST |
| 17. | Moti Lal Rijal | Chure Terai Madhesh Conservation Development Board |
| 18. | Jharana Khanal | Groundwater Resources and Irrigation Development Division, Kavrepalanchowk |
| 19. | Manoj Khatiwada | Water Resource Research and Development Center (WRRDC) |
| 20. | Kishor Acharya | Nepal Reconstruction Authority |
| **Academic / Research Institutions** | | |
| 21. | Madhukar Upadhya | Watershed Expert |
| 22. | Suresh Das Shrestha | Central Department of Geology (CDG), Tribhuvan University (TU) |
| 23. | Goma Khadka | CGD, TU |
| 24. | Sangam Shrestha | Asian Institute of Technology |
| 25. | Ishwor Man Amatya | Institute of Engineering (IoE), Tribhuvan University (TU) |
| 26. | Rabin Maharjan | IoE, TU |
| 27. | Beena Maharjan | IoE, TU |

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|---|---|---|
| 28. | Nainisha Subedi | IoE, TU |
| 29. | Mahadev Singh Saud | IoE, TU |
| 30. | Rajan Subedi | Institute of Forestry, Tribhuvan University |
| 31. | Bijaya Man Shakya | ICRE, University of Yamanashi, Japan |
| 32. | Sadmi Bhattarai | Kathmandu University |
| 33. | Meera Prajapati | Khwopa College, TU |
| 34. | Sushila Gwachha | Khwopa College, TU |
| 35. | Shanta Chaudhary | Khwopa College, TU |
| 36. | Sharmila Shrestha | Khwopa College, TU |
| 37. | Sabina Ghimire | Khwopa College, TU |
| 38. | Uruxya Dongol | Khwopa College, TU |
| 39. | Rajendra Shahi | Khwopa College, TU |
| 40. | Rajita Prajapati | Khwopa College, TU |
| 41. | Anushiya Shrestha | Wageningen University |
| 42. | Shree Krishna Neupane | Pokhara University |
| 43. | Dhundi Raj Pathak | Engineering Study and Research Center/ CREEW |
| **International Non-Governmental Organizations (INGOs)** | | |
| 44. | Vishnu Prasad Pandey | IWMI |
| 45. | Bhesh Raj Thapa | IWMI |
| 46. | Palpasa Prajapati | JICA-KUKL |
| 47. | Kashi Raj bhandari | WaterAid Nepal |
| **Non-Governmental Organizations (NGOs)** | | |
| 48. | Gautam Rajkarnikar | Center of Research for Environment Energy and Water (CREEW) |
| 49. | Rabin Malla | CREEW |
| 50. | Salina Shrestha | CREEW |
| 51. | Sarad Pathak | CREEW |
| 52. | Upendra Shahi | CREEW |
| 53. | Ashok K. Shrestha | CREEW |
| 54. | Elisha Bhattarai | CREEW |
| 55. | Menuka Prajapati | CREEW |
| 56. | Prerana Amatya | CREEW |
| 57. | Deepa Neupane | Nepal Engineering College, Pokhara University |
| 58. | Rajiv Joshi | Environment and Public Health Organization (ENPHO) |
| 59. | Shankar Shrestha | Nepal Development Research Institute (NDRI) |
| 60. | Niranjan Bista | Small Earth Nepal (SEN) |

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|---|---|---|
| 61. | Shaheed Muslim | SEN |
| 62. | Suzu Nepal | SEN |
| 63. | Susmina Gajurel | SEN |
| 64. | Mahendra Bahadur Gurung | SEN |
| 65. | Jibesh Kumar K.C. | ADAPT, Nepal |
| 66. | Rajaram Prajapati | SmartPhones4Water-Nepal (S4W-Nepal) |
| 67. | Eliyah Moktan | S4W-Nepal |
| 68. | Amber Bahadur Thapa | S4W-Nepal |
| 69. | Anusha Pandey | S4W-Nepal |
| 70. | Pratik Shrestha | S4W-Nepal |
| 71. | Sudha Humagain | S4W-Nepal |
| 72. | Andy Bhatta | Nepal Hydrogeologist Association |
| 73. | Niraj Bal Tamang | Himalayan Earth Science Research Center and Solutions |
| **Private Companies** | | |
| 74. | Nabaraj Shrestha | 3D CONSULT |
| **Media** | | |
| 75. | Puspa Pokhrel | MTV |
| 76. | Pradip Acharya | MTV |
| 77. | Umeswar Sharma | Photographer |

# ANNEX III: COMMITTEES OF THE SYMPOSIUM

## Technical Committee

| | |
|---|---|
| Dr. Sangam Shrestha | Associate professor, Asian Institute of Technology |
| Dr. Suresh Das Shrestha | Professor, Central Department of Geology, Tribhuvan University (TU) |
| Dr. Narendra Man Shakya | Professor, Institute of Engineering, TU |
| Dr. Futaba Kazama | Professor, Interdisciplinary Research Centre for River Basin Environment, University of Yamanashi |
| Mr. Ishwor Man Amatya | Associate Professor (Institute of Engineering, TU) |
| Dr. Ashutosh Shukla | Professor, Nepal Engineering College, Pokhara University |
| Mr. Dhiraj Pradhananga | Assistant Professor, Central Department of Hydrology and Meteorology, TU |
| Mr. Madhukar Upadhya | Watershed Expert |
| Dr. Divya Ratna Kansakar | Department of Water Resources and Irrigation |
| Dr. Vishnu Prasad Pandey | International Water Management Institute Nepal |
| Mr. Surendra Raj Shrestha | Ground Water Resource Development Board (GWRDB) |
| Dr. Jeffery Colin Davids | Delft University of Technology/ SmartPhones4Water-USA |

## Organizing Committee

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|---|---|
| Dr. Rabin Malla | Center of Research for Environment, Energy and Water (CREEW) |
| Dr. Salina Shrestha | CREEW |
| Mr. Anoj Khanal | Kathmandu Valley Water Supply Management Board |
| Mr. Niranjan Bista | Small Earth Nepal |
| Mr. Shrawan Shakya | GWRDB |
| Er. Bipin Dangol | Environment and Public Health Organization |
| Er. Rajaram Prajapati | SmartPhones4Water-Nepal |


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