ICIMOD Manual 2018/4

ICIMOD

FOR MOUNTAINS AND PEOPLE

ACWADAM

Protocol for Reviving Springs in the Hindu Kush Himalaya: A Practitioner's Manual

About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD) is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

About ACWADAM

The Advanced Center for Water Resources Development and Management (ACWADAM) is a think tank and knowledge facilitating organization working on the management and governance of groundwater. We carry experience on hydrogeological work across a *geodiverse* range across India and its neighbouring region. Drawing on a wide array of experiences from the academic, corporate and voluntary sectors, our work has found application into seemingly inaccessible *niches*, both geographically and thematically. ACWADAM has led the development of aquifer-based, participatory groundwater management in India through practice and policy. We have partnered with a multitude of organisations, ranging from International Agencies, NGOs and Government Departments, mainly in integrating hydrogeological science into programmes that deal with groundwater resources. ACWADAM is playing a pivotal role in the development of a rationale regarding knowledge driven management of spring water in the Himalayan region in partnership with different organisations. We train, build capacities, conduct action research and facilitate decision support and implementation around groundwater management and governance across a typology of groundwater systems and societies.

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Protocol for Reviving Springs in the Hindu Kush Himalaya: A Practitioner's Manual

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Acronyms and Abbreviations

ACWADAM	Advanced Center for Water Resources Development and Management
CGIAR	Consultative Group on International Agricultural Research
CHIRAG	Central Himalayan Rural Action Group
DFAT	Department of Foreign Affairs and Trade
DSCWM	Department of Soil Conservation and Watershed Management
FGDs	Focus Group Discussions
GIS	Geographic Information System
GoI	Government of India
GPS	Global Positioning System
HHs	Households
HKH	Hindu Kush Himalayas
IAEA	International Atomic Energy Agency
ICIMOD	International Centre for Integrated Mountain Development
KIIs	Key Informant Interviews
lpm	litres per minute
lps	litres per second
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme, India
NEPCAT	Nepal Conservation Approaches and Technologies
NGOs	Non-Governmental Organizations
PRA	Participatory Rural Appraisal
PSI	People's Science Institute
RM&DD	Rural Management and Development Department, Government of Sikkim
RMCs	Regional Member Countries
RRA	Rapid Rural Appraisal
TMI	The Mountain Institute
ToR	Terms of Reference
VDC	Village Development Committee
WLE	Water, Land and Ecosystems
WOCAT	World Overview of Conservation Approaches and Technologies
WUMP	Water Use Master Plan

1 Introduction

Springs are groundwater discharge points that appear where a water bearing layer (aquifer) intersects with the ground surface and water seeps out of rock pores, fissures, fractures, or depressions. Springs are the main source of water for millions of people in the mid hills of the Hindu Kush Himalayas (HKH) (Tambe et al., 2011; Negi and Joshi, 2004; Chapagain, Ghimire, and Shrestha, 2017). Both rural and urban communities depend on springs to meet their drinking, domestic, and agricultural water needs. In addition, springs play an important role in providing water for ecosystem services, such as base flow in rivers, while supporting vegetation and wildlife (Ghimire et al., 2014; Cantonati et al., 2006). Springs in the HKH also have religious and cultural significance. Over the years, there has been increasing concern that springs are drying up, becoming seasonal, or their discharge reducing. A study by Tiwari (2000) found that around 45% of springs in one catchment in the Central Indian Himalayas had dried up or become seasonal, while a survey of villages in another catchment in the same region found a decline in spring discharge by 25–75% over the previous 50 years (Valdiya and Bartarya, 1991). Chapagain, Ghimire, and Shrestha (2017) found that spring discharge in a mid-hill region in Nepal had declined by over 30% in 30 years. Most of these results, and the concerns in general, are based on anecdotal data and the general perceptions of local people due to the lack of long-term monitoring in the region. However, a recent study by Kumar and Sen (2017) in Uttarakhand (Central Indian Himalayas) used instrumentation and long-term monitoring to derive flow duration curves for spring discharge. These showed that discharge had declined in the dry season, thereby confirming decades of anecdotal evidence. A number of studies based on people's perceptions have attributed the drying of springs to causes such as an increase in ambient temperature (Pandey et al., 2018); late onset and erratic rainfall patterns (Macchi, Gurung, and Hoermann, 2014); changes in land use – mostly in the form of conversion of forest to agricultural land (Joshi et al., 2014), and forest degradation (Pandey et al., 2018; Rautela, 2015), including changes in forest type (Naudiyal and Schmerbeck, 2015; Ghimire et al., 2012). While it is well recognized that water supply from springs is one of the many provisioning services provided by forests (Paudyal et al., 2015), the role of springs in providing forest biodiversity (and hence habitat services) and regulating services in spring habitats (for example, in maintaining water quality) is less well known, but of critical importance.

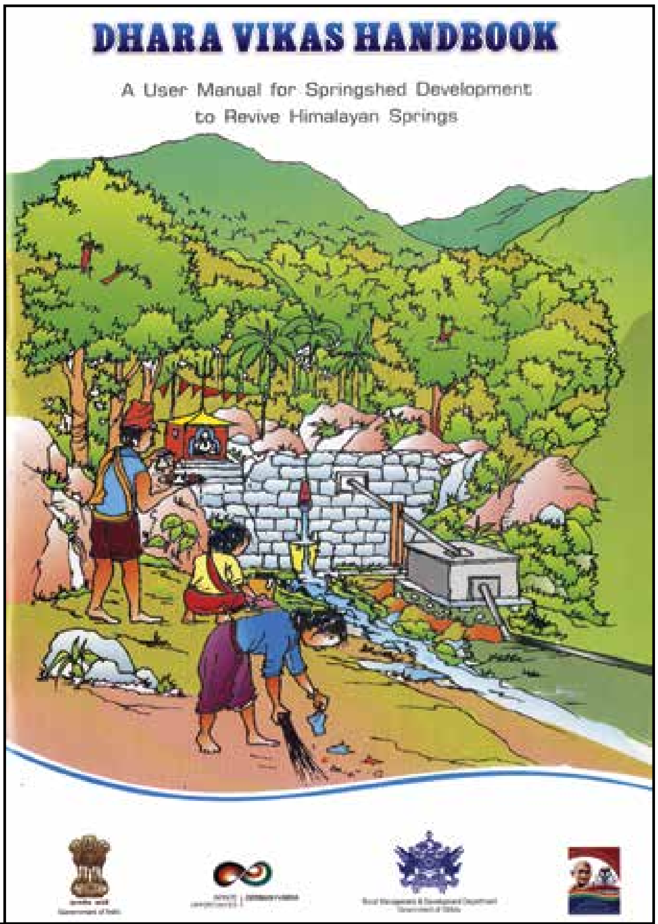
Springs are a part of the groundwater system, but the science of hydrogeology that governs the occurrence and movement of water in mountain aquifers, and thus the occurrence of springs, is poorly understood. This often results in misconceptions regarding springs, which in turn leads to misaligned policies that exacerbate the problem. Springs are also subject to complex socio-technical and informal governance systems with pronounced gender and equity dimensions. These systems are also not well understood, again leading to inappropriate policies and interventions.

Climate change and change in the biophysical landscape (e.g., land cover and land use change) are widely implicated in the drying of springs, but there is very little systematic knowledge to effectively link climate change, vegetation change, and spring discharge, especially because of the large data uncertainties. Rapid changes in demographics and infrastructure (such as dams and roads) have also impacted springs, but again the exact nature of the change is difficult to understand due to the lack of studies. Drying of springs – and the associated impact on communities – is a regional phenomenon that cuts across the entire HKH from Afghanistan to Myanmar, hence the topic is of immense importance.

Genesis of the Protocol for Reviving Springs Manual

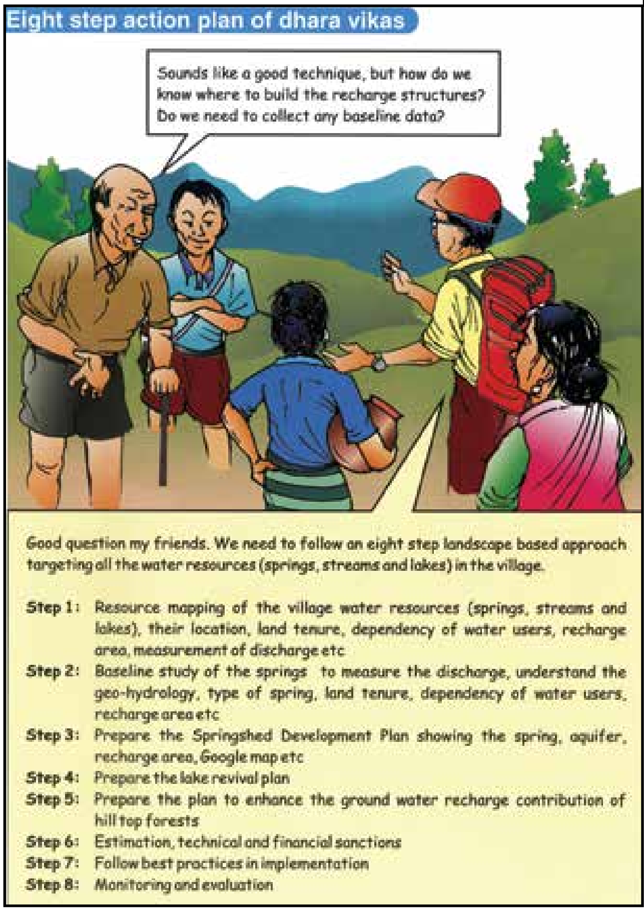
The Rural Management and Development Department (RM&DD) of the Government of Sikkim – a mountainous state in India – started a programme called Dhara Vikas (spring revival) in 2008 in response to people's concern that water sources were drying up. The programme started with a learning-by-doing approach, but it was soon realized that a thorough understanding of the underlying geology was essential for delineating recharge areas correctly. Limiting recharge activities to designated recharge areas was crucial both for increasing the efficiency of investments and for avoiding the unintended consequences of digging recharge structures in fragile areas, such as areas prone to landslides. The Advanced Center for Water Resources Development and Management (ACWADAM) worked closely with RM&DD to train para-hydrogeologists. These para-hydrogeologists were then deployed across South and West Sikkim to work closely with the rural communities to identify perennial springs that were drying up and develop implementation plans for reviving them. Since 2011, Dhara Vikas work has been included as a permissible activity under the Government of India's (GoI) 100 days work scheme – the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). Since then, spring revival in the state has been undertaken through MGNREGS funds. Many other mountainous states in India have followed suit and replicated the Sikkim Government's Dhara Vikas programme. In order to reach out to communities and build their capacity, RM&DD brought out a booklet on Dhara Vikas that uses pictures and simple illustrations to explain the concept of springs and the need for spring recharge (Figure 1). The booklet described an eight-step method for spring revival (Figure 2) – the first ever systematic step-wise spring revival protocol to be successfully implemented in India (RM&DD, 2014).

Figure 1: **Dhara Vikas Handbook developed by RM&DD, Government of Sikkim (2014)**



Source: RM&DD, (2014)

Figure 2: **Dhara Vikas eight-step process**



Source: RM&DD, (2014)

Rationale forthe Protocol for Reviving Springs Manual

The International Centre for Integrated Mountain Development (ICIMOD) is an independent inter-governmental organization which works in the eight countries of the HKH (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan). The Centre regularly conducts country consultations with national and local governments and other partner organizations in each of its regional member countries (RMCs). In the consultations conducted in the mid-2010s, drying up of spring water sources, especially in the mid hill regions, started emerging as a common theme across the region. Drying of springs has not only impacted people's everyday lives, it has also encouraged unsustainable practices such as drilling of deep bore wells in fragile mountain aquifers. Such practices stem from lack of understanding of the uniqueness and fragility of mountain aquifers and is often a short-sighted response to acute water stress.

Given the widespread concern about drying of springs and the deterioration in spring water quality, the desirable policy response is to revive the springs using both local and scientific hydrogeological knowledge. We define 'spring revival' to mean any of the following, individually or in combination:

- total discharge of spring has increased especially in lean season;
- spring water is available during more months than before;
- there has been an appreciable improvement in spring water quality, thereby reducing health risks;
- spring water is better managed so that there is more equitable access to water; and
- recharge areas are better protected and managed.

This handbook builds on the earlier work by RM&DD which was India specific and has been suitably modified to meet the generic requirements of all ICIMOD RMCs. ICIMOD and ACWADAM followed a consultative process with major partners such as The Mountain Institute (TMI) to come up with the detailed steps in a spring revival protocol, which were then verified at a workshop held in Gangtok, Sikkim, India in November 2015. The protocol is both useful and practical because:

- It incorporates hydrogeology, socio-economic and governance issues to come up with a comprehensive understanding of springs and springsheds.
- It combines aspects of research and knowledge generation (Steps 1 to 4) and implementation (Steps 5 and 6). Those who are interested only in knowledge generation can follow the first four steps; all six steps are needed for implementation.
- It is relatively easy to carry out. The step-by-step approach can be used by a diverse range of stakeholders – field implementers, grass roots workers, and non-governmental organisations (NGOs) and researchers.

The main target audience of this manual are the field level officials of government agencies and NGOs. The manual provides a step-by-step approach, which together with a two-week long practical classroom and field-based training will equip field level officials to implement spring revival programmes in their own areas. The manual will also be useful for researchers and higher-level government officials to gain conceptual clarity around the issues of spring management and revival. The manual may be less useful for local communities where a simpler and more graphical version along the lines of the Dhara Vikas handbook (Figure 1) is likely to be more appropriate.

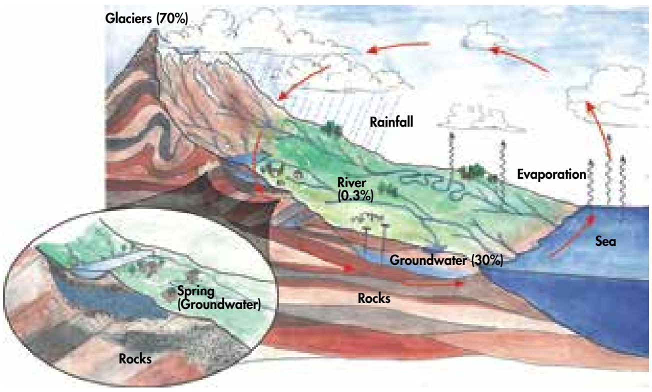
2 Basic Concepts

This chapter presents some of the basic concepts of hydrogeology and social science that are needed as background when implementing a stepwise spring revival protocol.

The Hydrogeological Cycle

The hydrogeological cycle begins with the evaporation of water from the surface of the ocean. As moist air is lifted, it cools and the water vapour condenses to form clouds. The moisture is then transported in the atmosphere until it returns to the surface as precipitation. Once the water reaches the ground, one or more of three processes take place: 1) some of the water evaporates back into the atmosphere; 2) some water flows away as surface runoff; and 3) some of the water percolates into the ground to become groundwater. Groundwater can seep into lakes, streams, rivers, and the ocean, or be released back into the atmosphere through transpiration from vegetation. The surface runoff empties into lakes, rivers, and streams and is carried back to the oceans, where the cycle begins again (Figure 3). Similar processes take place with snow and other frozen precipitation but with a delay (http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hyd/smry.rxml).

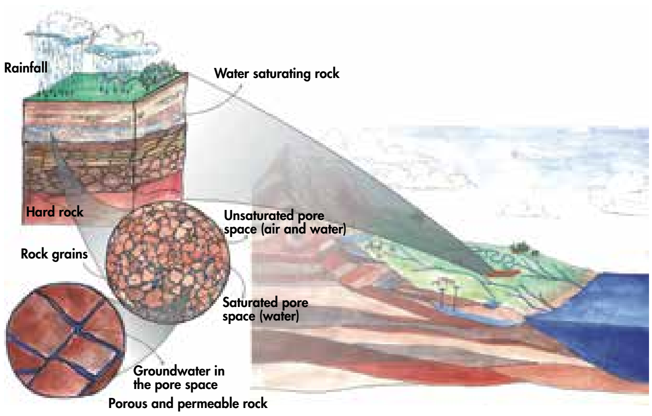
Figure 3: **The hydrogeological cycle**



Groundwater

The water that fills the fractures, cracks, and pore spaces in soil, sand, rocks, and rock formations is commonly known as 'groundwater'. Groundwater comprises less than 1% of the Earth's water but around 98% of the available freshwater. The oceans contain about 97% of the Earth's water, but this is not suitable for drinking, while about 2% is frozen at the poles or in glaciers. Of the remaining 1%, 95–97% is stored as groundwater and the rest as surface water. Groundwater is also a major contributor to streams and lakes in the form of base flows (Figure 4).

Figure 4: **The occurrence of groundwater in soil, rocks and fissures**



Aquifers

Groundwater is stored and transmitted through aquifers. Any saturated geological formation or rock formation which stores and transmits groundwater is called an aquifer. In order to qualify as an aquifer, a rock unit must have certain properties which allow storage and transmission of groundwater.

An aquifer should be considered as the basic unit for any study of groundwater or in any watershed development or recharge augmentation programme. Different rock types have substantially different porosities and permeability. Most aquifers are in porous regolith and fractured rock. Open pores gradually close with depth, so the base of the aquifer varies from place to place (Figure 5). In mountain regions such as the Himalayas, high relief and complex geological structures play a vital role in aquifer formation.

The Rock Cycle and Rock Types

The rock cycle is a basic concept in geology that describes the long-term transitions through geologic time among the three main rock types – igneous, sedimentary, and metamorphic – as a result of formation, breakdown, and reformation. Each rock type is altered or morphed physically and/or chemically when forced out of its equilibrium conditions (https://en.wikipedia.org/wiki/Rock_cycle).

Igneous rocks are formed by solidification of the molten matter known as magma which exists at great depths inside the earth and is brought to the surface in the form of lava and other associated material through volcanoes and fissures in the earth's crust. Granite, basalt, and rhyolite are typical examples. These rocks can be broken down by weathering or erosion to form sediment that is carried away and deposited elsewhere by agents such as water, air, and glaciers. The deposited sediment eventually compacts to form sedimentary rocks such as sandstone, shale, and limestone. When subjected to higher pressure and temperature at greater depths, both sedimentary and igneous rocks can be further transformed (or metamorphosed) into metamorphic rocks such as schist, gneiss, quartzite, and marble. These can be subducted deep below the surface due to plate movements (plate tectonics) where they again melt to form magma, which in turn can be expelled and cooled to form igneous rocks, thus completing the cycle which is repeated over geologic time. Other routes through the rock cycle are also possible, igneous rock can change into metamorphic rock, and metamorphic rock into igneous or sedimentary rock. The main features of the rock cycle are shown diagrammatically in Figure 6.

Figure 5: **Formation of aquifer**

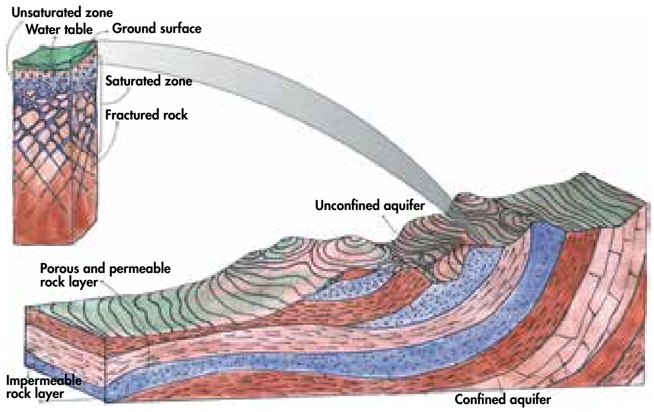
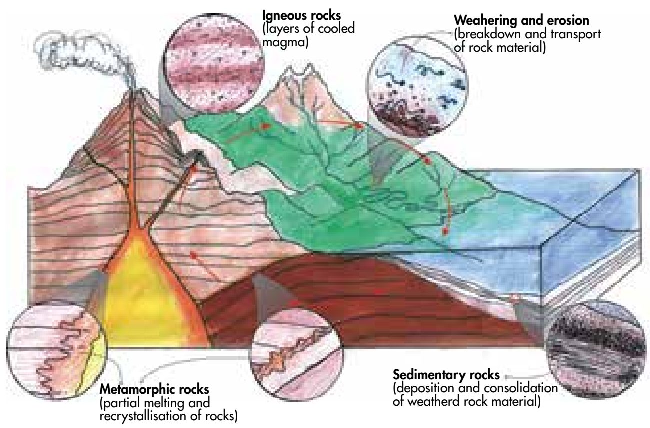


Figure 6: **Main features of the rock cycle**



Rock Structure

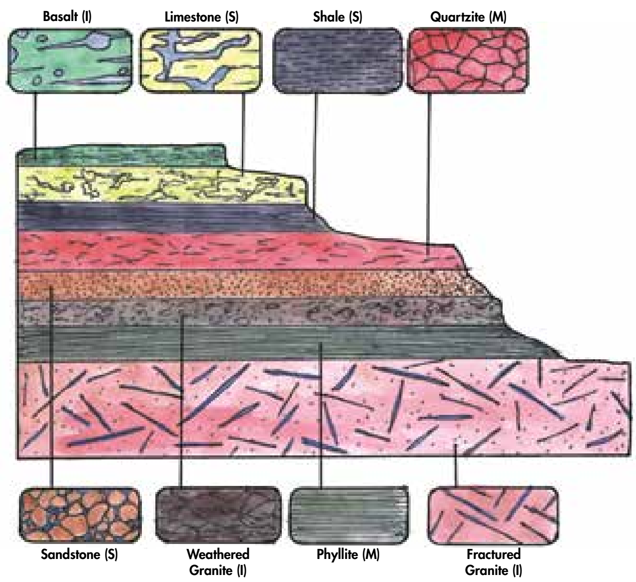
Rocks are made up of different minerals each with a definite chemical composition and properties which govern the properties of the rocks and their weathering products. The chemical properties of rocks also play a big role in determining the chemistry of surface and groundwater.

Groundwater in rocks

Groundwater is contained within the openings in rocks, i.e., the pores and cracks. The size and shape (geometry) of the openings (the rock structure) determine the direction of flow and ease with which the groundwater can move (Figure 7).

Groundwater moves slowly through the pore spaces with the movement controlled largely by the porosity

Figure 7: **Different types of rock showing the geometry of the openings in them which define their relationship with groundwater**



* I – Igneous; S – Sedimentary; M – Metamorphic

and permeability of the rocks through which it flows. Porosity is a measure of the void spaces and is the fraction of the total volume of voids over total volume of rock expressed as a number between 0 and 1 or as a percentage. Permeability describes the ability of the porous rock material to allow water to pass through it from one point to another under a hydraulic gradient. The porosity and permeability characteristics of different rock types determine the total volume of groundwater that they can hold.

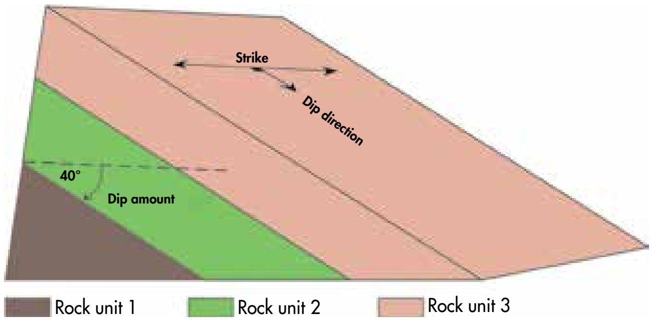
Planar structures and orientation

There are two types of rock structure: primary and secondary.

- **Primary** structures develop during rock formation (e.g., columnar joints in basalts, cross bedding in sandstone).
- **Secondary** structures develop after rock formation in response to tectonic stresses (e.g., fractures, faults, folds).

A variety of two-dimensional, or planar, structural features can be observed in the field including bedding planes, joints, fractures, faults, cleavage, and foliation (repetitive layering) or schistosity. The attitude or trend of bedding planes and other planar features is expressed in terms of strike, dip direction, and dip amount (angle) (Figure 8).

Figure 8: **Schematic diagram showing strike, dip amount, and dip direction**

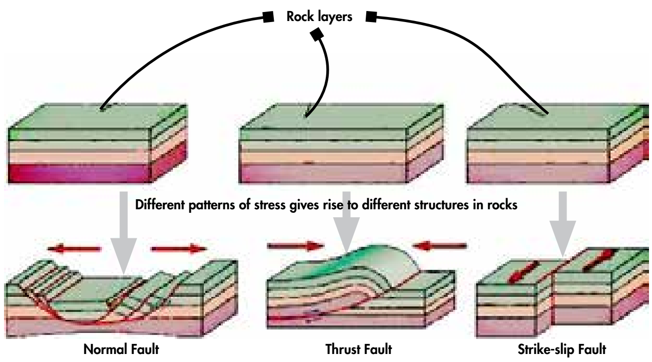


- **Strike** is the direction of the intersection of an inclined geological plane with an imaginary horizontal plane. Measurement of the bearing of this line gives the strike direction.
- **Dip direction** is the direction towards which rock beds are dipping and is measured with a geological compass along a plane perpendicular to the strike line.
- **Dip amount** is the angle of inclination of the dip plane from the horizontal.

Two of the most common structural features observed are faults and folds.

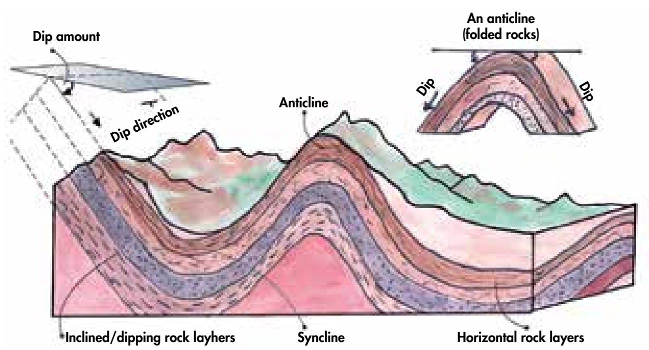
A fault is a planar feature in which there has been movement (displacement) of rock along a plane of weakness (joint or fracture). Different patterns of stress give rise to different types of fault (Figure 9). A normal fault is a rupture along which the hanging wall has moved downwards relative to the footwall; a thrust fault is a type of low angle reverse fault along which the older rocks have moved upwards over the younger rocks; and a strike slip fault is a fracture along which the blocks have moved past each other horizontally.

Figure 9: **Common types of fault structure**



A fold is a bend or wavelike feature in a rock layer formed by compressive tectonic stresses. A syncline is a fold in which the rocks in the limbs dip towards each other with the youngest rocks in the core of the fold, whereas an anticline is a fold in which the rocks in the limbs dip away from each other with the oldest rocks in the core of the fold (Figure 10).

Figure 10: **Development of simple fold structures**



The study of geological elements such as rock type, rock texture and structure, and strike and dip helps in understanding the aquifer systems that discharge groundwater through springs and thus in understanding the characteristics of the springs themselves.

Mountain Springs as Groundwater

In plain areas, groundwater usually has to be accessed by digging wells into the water-bearing aquifers. In hills and mountains, groundwater naturally discharges in the form of springs, which occur where a water bearing layer (aquifer) intersects with a hill slope and groundwater seeps out (Figure 11). The spring water is part of the groundwater system, and only becomes 'surface water' after flowing into a surface water body such as a stream or lake. Springs provide water to the mountain population for a wide range of uses (Figure 12). Every spring is unique in terms of its type, catchment, recharge, and discharge. The occurrence of springs and their behaviour depend on the aquifer and its properties, thus identifying and understanding aquifers is very important.

Types of Spring

Springs can be classified in various ways based, for example, on geology (location of discharge, bedrock, geological structure, topography); geography (location and source of discharge; magnitude of discharge; location, size, and flow path of aquifer; source of recharge water; permanence of flow); parameters of water chemistry; ecology that springs support; and conservation priorities and human use (Glazier, 2014). For the purposes of this manual and the focus on reviving springs that have deteriorated, we have chosen a definition based on the underlying geology. Using this, springs are classified into five types: depression, contact, fracture, karst, and fault (Figures 13–17).

Depression springs emerge at topographic lows where the water table intersects the ground surface (Figure 13). Springs can also emerge at the base of large trees – generally as a result of the roots penetrating the aquifer and change of slope. These could be categorized as a special type of depression spring.

Contact springs emerge at places where relatively permeable rocks overlie rocks of low permeability (Figure 14).

Figure 11: **Accessing groundwater in the plains and mountains**

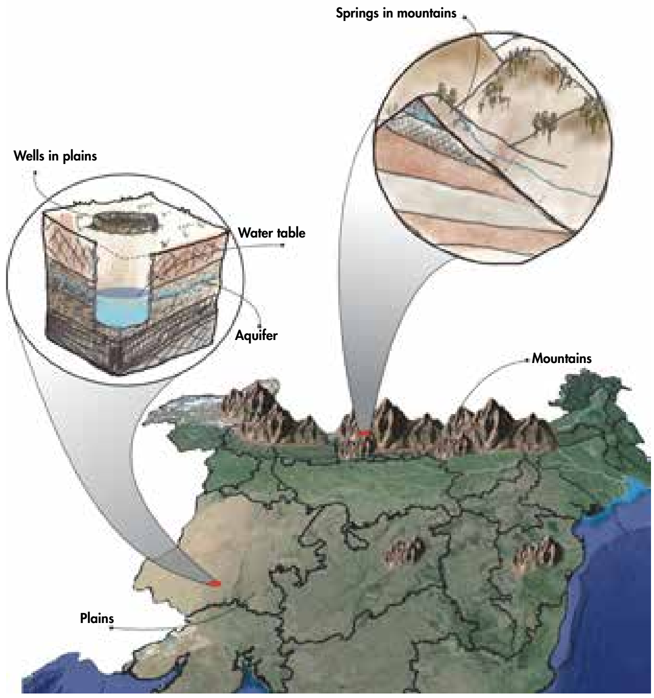


Figure 12: **Common uses of springs water**

Figure 13: **Depression spring**

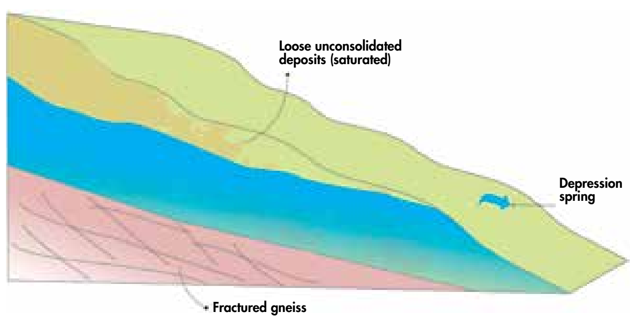


Figure 14: **Contact spring**

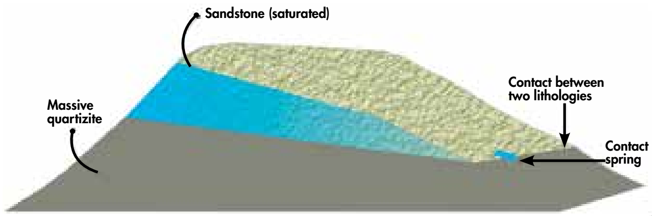
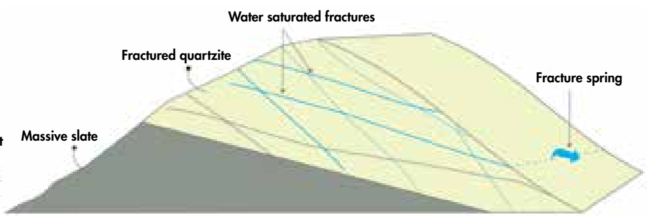


Figure 15: **Fracture spring**



Fracture springs occur as a result of permeable fracture zones appearing in low permeability rocks. Movement of groundwater is mainly through the fractures which tap both shallow and deep aquifers (Figure 15).

Fault springs are found where groundwater at depth is forced up a fault to the fault opening by hydrostatic pressure (Figure 16).

Karst springs occur where water flows through the cavities and openings in limestone that form as a result of dissolution of rock material and then emerges at the base of the limestone layer (Figure 17).

Springs can also be classified on the basis of size, i.e., the amount of water they discharge. Meinzer (1927) and later Alfaro and Wallace (1994) classified springs based on the volume of flow per unit time (Table 1).

Table 1: **Classification of springs based on the volume of flow per unit time (magnitude of discharge)**

Spring magnitude	Flow
First	>10 m^3/s
Second	1-10 m^3/s
Third	0.1-1 m^3/s
Fourth	10-100 l/s
Fifth	1-10 l/s
Sixth	0.1-1 l/s
Seventh	10-100 ml/s
Eighth	<10 ml/s

Source: Meinzer (1927) and Alfaro and Wallace (1994)

Watersheds

Watersheds are best described as the units of the land surface that drain water to a common point through a system of interconnected stream channels. The system of interconnected stream channels is called the 'drainage network'. The common point is usually the watershed outlet, the point where the highest order stream (that is, the major river or stream in the network) leaves the watershed. Watersheds, in other words, represent a hydrological unit of land defined by a particular topography that drains all the water falling on it to a common point. As such, a watershed separates two drainage units. Watersheds are also called catchments as they are the 'catchment area' for the point at which the drainage converges (Figure 18).

Figure 16: **Fault spring**

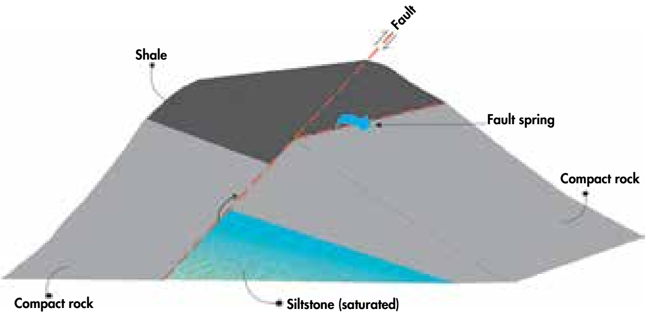


Figure 17: **Karst spring**

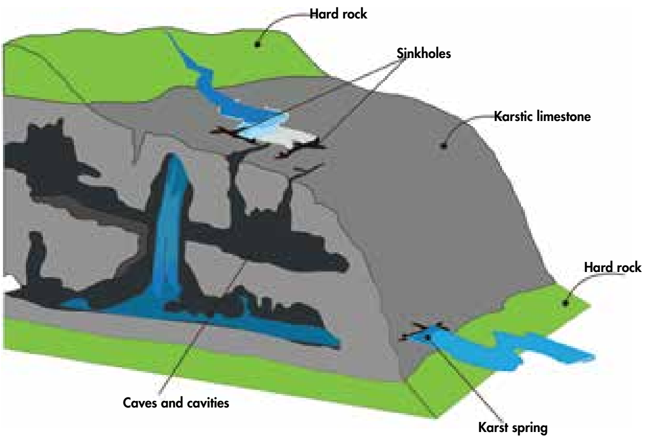
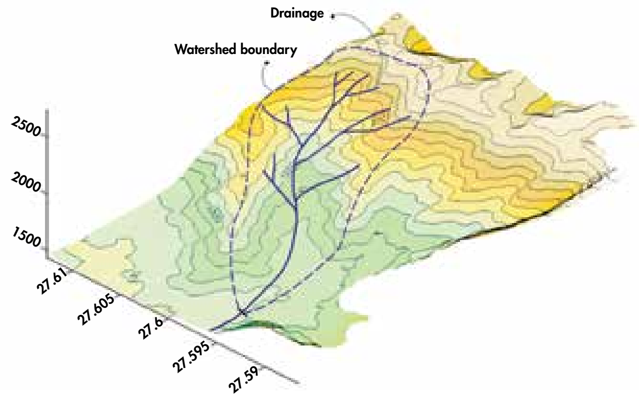


Figure 18: **The limits or boundary of a watershed (catchment)**

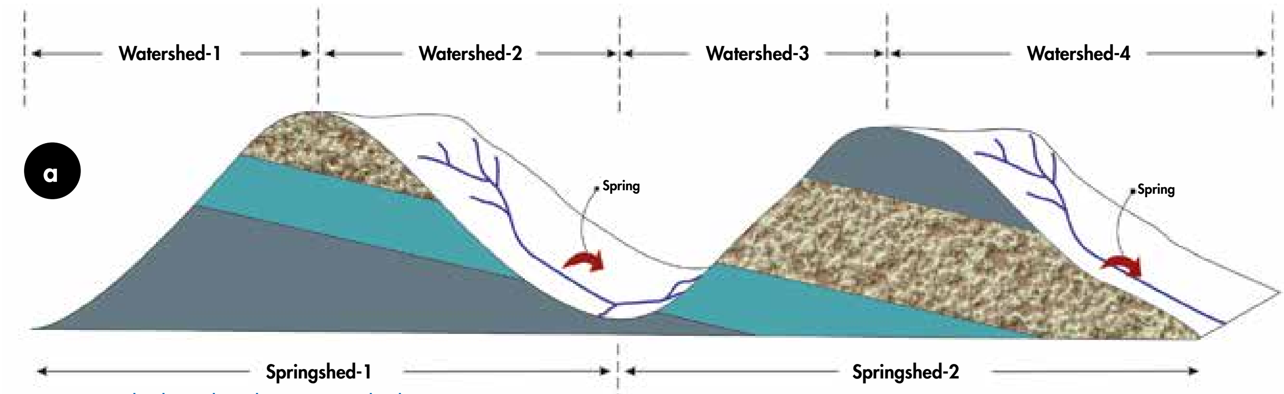


Springsheds

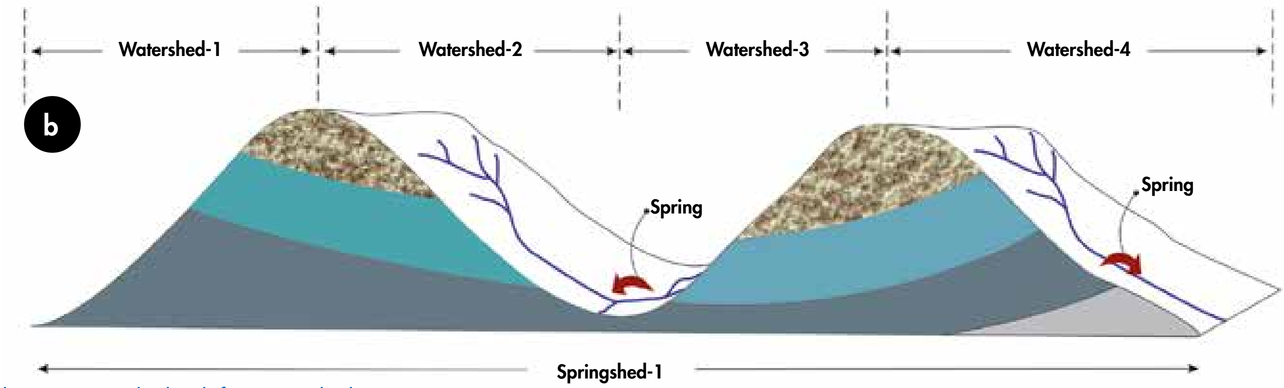
Majority of water conservation programs in the HKH have revolved around the concept of watershed in the past. Watersheds are easy to demarcate and hold great appeal to most policy makers and implementers alike. However, watershed concept only accounts for surface water movement over slopes.

Springsheds differ from watersheds because the source of spring water is determined by aquifer characteristics and not surface topography. Also, movement of spring water which is groundwater, is determined by underlying geology, that is, nature of rocks, their inclination and structure. The point where the spring emerges is based on the relationship of the aquifer to the watershed surface. As defined above, a typical watershed drains water from a ridgeline into the valleys (drainage lines) that converge to a common point – possibly at the confluence of a river, whereas *a springshed is a set of watersheds and aquifers that integrate into a system that supplies water to a group of springs* (Figure 19). The concept of watershed, therefore, cannot account for water which travels outside of the watershed boundaries, for example through rock beds that inclines towards an adjoining watershed.

Figure 19: **Springsheds and watersheds**



a) Two springsheds each with two watersheds



b) One springshed with four watersheds

For spring revival, the appropriate unit is the springshed – the unit of land where rain falls (recharge area), and then emerges at discharge points – the spring. Springsheds, given the folded and faulted nature of the Himalayan geology, often cover more than one watershed; in other words, recharge area of a spring in one watershed, may as well lie in another adjoining watershed and as such, spring revival programmes have to be cognisant of this concept of springshed.

As such, there are three possibilities:

- A springshed with one watershed and one aquifer.
- A springshed with one watershed and more than one aquifer, where the aquifers are not part of an adjoining watershed
- A springshed with more than one watershed and one or more aquifers

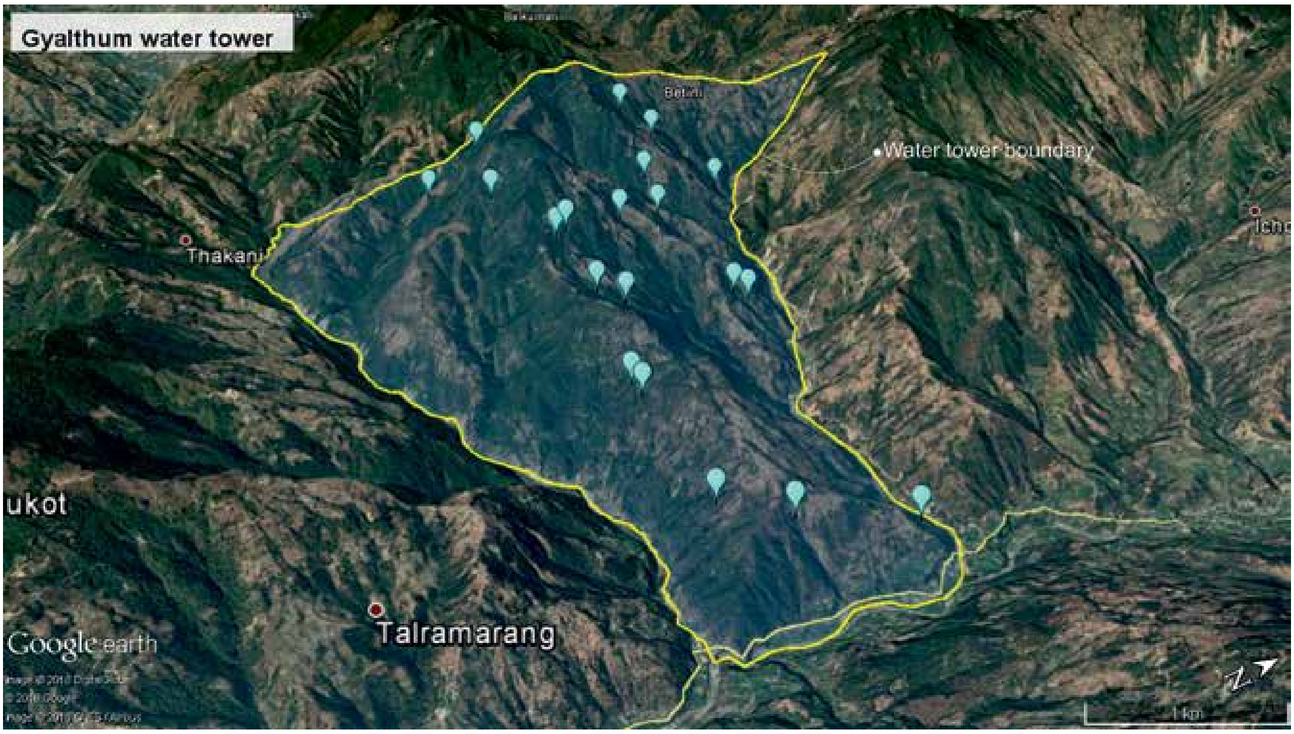
Therefore, identifying a springshed is important for managing springs because this is the system that integrates surface and groundwater and is instrumental for identifying recharge areas.

Water Tower

The concept of a water tower is best understood by expanding the concept of a springshed to a larger system. A water tower is a common area that hosts many watersheds (and springsheds) that drain out from a common ridge line, small mountain range, or even a large range. The entire Hindu Kush Himalayan range is essentially a large water tower as it is the source area for many watersheds and river basins. At a more local scale, a contiguous ridgeline that provides common high ground to a number of watersheds and springsheds can be described as a water tower (Figure 20).

Any springshed management programme is likely to involve numerous springs located in several watersheds with a number of springsheds which are often integrated into one water tower. The water tower is the largest land and water resource unit within springshed management programmes.

Figure 20: **Google Earth image of a water tower**



Springshed Management

Springshed management is a comprehensive term encompassing all aspects related to sourcing, distribution, maintenance, and management of spring water systems. Management includes both hardware, e.g., building of tanks and water pipelines, and 'software', e.g., laying down rules of water distribution, cleaning of source, and maintaining recharge areas. Since a majority of springs in the HKH are located on community land and water is used collectively, communities often come together to manage the springs.

The Oxford Dictionary defines a community as "a group of people living in the same place or having a particular characteristic in common". In the context of springs and springsheds, a community refers to the people who live in the vicinity of springs and derive their water supply from these springs. It is important to understand the community characteristics and their involvement in spring management when recommending ways to revive and manage springs.

Inclusive perspectives on management of spring water

In most areas in the HKH, communities manage the water from springs. But a community is not necessarily homogenous. Within communities, there are people who by virtue of their gender, caste, wealth, or ethnicity have more power and decision-making ability than others. For example, in some South Asian caste-based societies with norms of purity and pollution, the lower castes (*dalits*) are often discriminated against when it comes to collecting water from springs – they are either made to wait longer than others or are assigned to more remote and marginal springs. Similarly, women are often discriminated against, and especially menstruating women who are not allowed to touch water. Using a gendered and inclusive perspective in water management means knowing about and understanding the differences in power and position of different members of the community. In order to work towards an equitable spring water management system, we must recognize the societal inequities and develop systems that work in favour of disadvantaged groups such as women, lower castes, and ethnic and religious minorities.

Tools for participatory social science research

It is customary to use participatory rural appraisal (PRA) or rapid rural appraisal (RRA) tools to collect socio-economic data in the field to ensure that the data are not extractive and that local people are able to voice their opinions and describe the reality of their situation (Chambers, 1983). These tools generally yield qualitative data which can be analysed to understand local practices and perceptions. At the same time, quantitative data amenable to statistical analysis are needed to understand issues like quantum of water use and whether or not basic minimum water needs are fulfilled. Ideally, a mixed method should be used that combines qualitative and quantitative tools in order to understand the socio-economic and governance dimensions of a spring. The following tools are of particular relevance to this handbook:

1. **Transect walks** are systematic walks along a defined path (transect) across a community/project area together with local people to explore certain conditions. Transect walks should be carried out across the springshed and local water tower noting down the locations of springs using Global Positioning System (GPS) and gathering further information on each spring from the local community. Transect walks can also be used to understand the overall layout of the springshed and presence of other water sources.

2. **Focus group discussions** (FGDs) are a form of qualitative research in which a small group of respondents (5-12 is often considered ideal) are asked about their perceptions on a certain set of issues. FGDs are a powerful tool for eliciting a collective response on various aspects related to spring management. The format is often a free-flowing discussion guided by some key questions. By conducting separate FGDs with different groups of people (such as local leaders, women, men and women from marginalized communities), it is also possible to capture differences in perception among different groups of stakeholders. The interviews are transcribed in detail and can be analysed as qualitative data.

3. **Key informant interviews** (KIIs) are interviews conducted with individuals who are thought to be particularly knowledgeable about the issue under discussion, and hence have to be chosen carefully. KIIs are also held, like FGDs, as free-flowing discussions guided by a checklist or key questions, and the results once transcribed can be analysed as qualitative data.

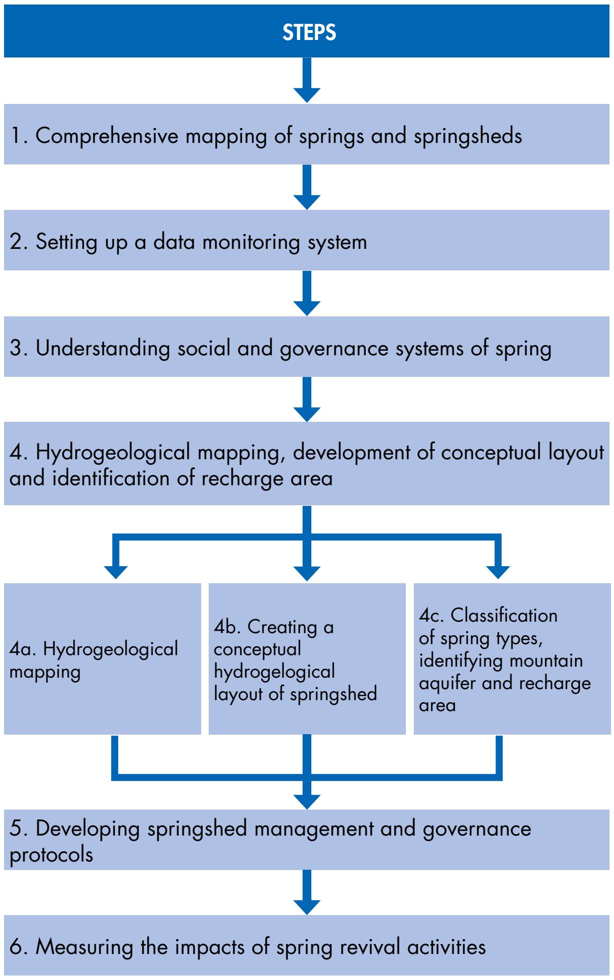
4. **Questionnaire surveys** are a research instrument comprising a series of questions designed to gather relevant data from respondents. Questionnaires must be properly designed and pre-tested, and respondents must be selected in such a way that they are representative of the population for which data is being collected. Data collected using questionnaire surveys can be analysed quantitatively using statistical analysis.

3 The Six-step Protocol for Reviving Springs in the Hindu Kush Himalaya

Following a broad consultation with wider stakeholders, and building on earlier work by the Rural Management and Development Department of the Government of Sikkim (RM&DD, 2014), ICIMOD and ACWADAM developed a comprehensive step-wise process for studying, managing, and reviving springs in the Hindu Kush Himalaya. The six-step protocol combines hydrogeology with social sciences and community action and can be used both as a research tool for generating basic knowledge and to prepare detailed local implementation plans for spring revival. The step-by-step approach can be followed relatively easily by a diverse range of stakeholders after some basic training. Figure 21 shows the main steps in the protocol; the following chapters describe the individual steps in detail.

Implementing the protocol requires an interdisciplinary team. The skills needed for each of the steps are given at the end of the individual steps. Overall, the team should include geologists and hydrogeologists (for Steps 1, 2, 4, and 6); individuals with a basic knowledge of plant types and species, such as foresters or botanists (for Step 1, especially for identifying broad forest and land use types); social scientists such as human geographers, socio-economists, sociologists, or anthropologists (for Steps 1, 3, and 6); and watershed experts with expertise in implementing physical recharge structures (Step 5).

Figure 21: **The six-step protocol for spring revival in the Hindu Kush Himalaya**



4 Step 1: Comprehensive Mapping of Springs and Springsheds

Objective: To generate comprehensive information about the springshed – including web-based maps, GPS locations of springs, and basic socio-economic information.

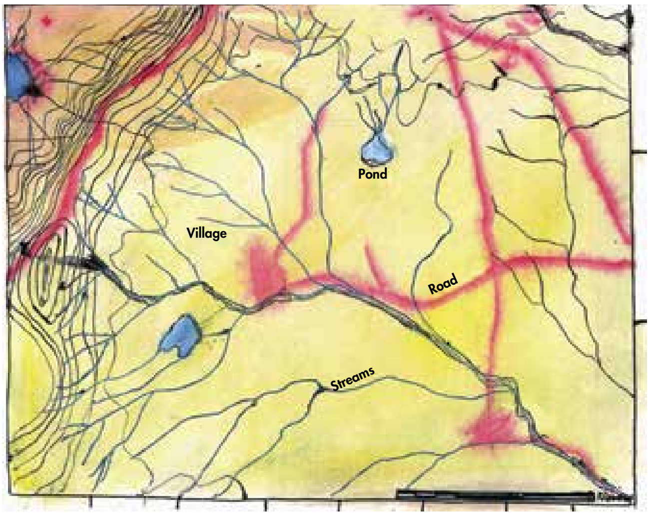
Output: A comprehensive spring database with the GPS location of all springs, one-time discharge and water quality values, and basic socio-economic data, and a field report that documents these findings

Background Information on the Study Site from Secondary Data

The first step in a spring-related investigation is to delineate the study area. For example, the area of investigation may be demand driven following the requirements of a local community, or it may be defined by a research or implementing agency based on previous data.

Once the area of interest has been clearly defined, secondary data for the area should be collected in order to obtain an initial understanding in terms of land use, settlements, distribution of springs, geology, and so on. Data that could be collected to understand the local geography and culture might include topographic (Figure 22) and geological maps, census and survey data from government sources, local survey data by NGOs or communities, and data derived from remote sensing and geographic information system (GIS).

Figure 22: **A topographical sheet to understand the topography, drainage patterns, and water sources**



Reconnaissance Survey

A reconnaissance field survey should be organized in the study area together with local people after the secondary data and information has been obtained. During the reconnaissance walks, the team should use primary field observation to familiarize themselves with the pattern of spring distribution, land use, forest, and vegetation patterns, the local socio-economic situation, local road distribution, and others. This reconnaissance will help in planning the fieldwork for comprehensive mapping of springs and data collection and in designing the socio-economic survey. It is important to involve local people in these survey walks and brief them about the objectives of the spring mapping and revival work.

Spring Mapping and Preliminary Data Collection

A detailed field survey is carried out following the reconnaissance survey using a transect walk approach that covers the entire area systematically and includes local people. All springs and any other water sources (ponds, dug wells, bore wells, hand pumps, and others) should be mapped using a GPS device to provide an inventory. One-time measurements should be made of spring discharge and water quality (salinity, total dissolved solids, electrical conductivity, pH, temperature, and biological contaminants like E. coli) for all springs in the study area. Some preliminary socio-economic information should be collected, in particular data on the households that depend on each spring, including those from marginalized communities, the nature of the distribution system (piped vs. non-piped), the purposes for which water is collected, people's perceptions of present water quantity and quality and any changes over the last decade, and whether there are any major conflicts related to water use.

The data should be tabulated in an Excel datasheet (Annex 1). The water sources should be marked on a base map, whether a topographical sheet (Figure 22) or Google Earth image (Figure 23) using the latitude, longitude, and elevation for each spring location obtained in the GPS survey to give a comprehensive map of all springs in the study area. In some cases, the data may already be available – for example, Water Use Master Plan (WUMP) data collected by Helvetas in Nepal – and these data should be used instead of conducting a new survey.

Figure 23: **Google Earth image showing distribution of springs within a watershed**

Delineation of Springshed

The next step after comprehensive mapping of the springs in the area of interest is to identify smaller sub-sets of springs located within a water tower for long-term monitoring. A water tower is chosen as the working unit for spring mapping and monitoring. It contains a number of springsheds as it extends across a valley-ridge-valley system located in two or more adjacent watersheds.

Resources Needed

Table 2 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 1.

Table 2: **Summary of requirements for Step 1**

Types of skill needed	Objective	Time estimate
Capacity to carry out a socio-ecological survey including basic understanding of the landscape and topography; mapping of spring locations, houses, and forest and vegetation types; and preliminary mapping of socio-economic dynamics (geologists, hydrogeologists, botanist/forester, socio-economists)	Delineate the area of interest and develop an inventory of information on springs and associated elements within the area	10 person-days for 100 ha (may vary depending on the topography, access, and level of field support)
Instruments required	GPS, field diary, container of known volume, water quality tester, stopwatch, measuring tape	

5 Step 2: Setting Up a Data Monitoring System

Objective: To collect long-term spring discharge data, water quality information, and rainfall data with the help of the local community by setting up instruments and data monitoring systems.

Output: Data stored in an Excel spreadsheet (or similar data software) on daily rainfall, bi-monthly or monthly spring discharge, and water quality. Rainfall and spring discharge hydrographs and water quality parameters should be plotted as graphs.

Periodic (at least bi-monthly or monthly, but if feasible, weekly or daily) spring discharge, spring water quality, and rainfall data can help in understanding of spring behaviour and aquifer characteristics. Rainfall data is important for establishing relationships between recharge, spring discharge, and the characteristics of the aquifer that feeds the springs. The variations observed through regular testing of water from an individual spring helps in understanding rock-water interactions, travel and residence time of groundwater within the aquifer, and interrelationships between rainfall, recharge, and spring discharge. The local community should be trained in the process of monitoring and recording data as well as drawing simple inferences from the collected data. The following sections describe the methodologies for monitoring different parameters.

Selection of Springs for Long-term Monitoring

The first step in setting up a monitoring system is to select the springs to be monitored in the long term. By long term, we mean at least two years, and if resources allow, then longer. This selection is carried out at two levels. First, a water tower is selected which encompasses a large number of springs from different springsheds and a spring inventory is developed for all the springs in the water tower (Protocol Step 1 above). A number of these springs are then selected for detailed and regular long-term monitoring using the criteria given below. The final number selected will depend on the resources available and the variation. The selection criteria include the following:

- Springs that have recently shown a significant decrease in discharge.
- Springs with seasonal or perennial water quality issues.
- Springs on which a large number of households depend for drinking water throughout the year.
- Springs on which marginalized communities and disadvantaged groups depend.
- Springs with special cultural significance.
- Springs that contribute significantly to the local ecosystem.
- Springs that are shared and managed by the local community.
- Springs that can be measured with a high degree of accuracy (not just measuring the overflow, or what comes out of a single tap) and which are physically accessible (does not unduly endanger the safety of the data collector).

Springs are selected using the data collected in Step 1 and the above criteria. The list of criteria may be modified based on the objective of the project and the resources available. Whatever the selection criteria used, they must be systematically documented in the report.

Selection of Data Collector

Data collection is one of the most important parts of springshed management as the development of plans for augmenting and managing the springs will be based upon the data collected in the initial phase. The community members who will be responsible for collecting, maintaining, and transferring the data are thus very important, and it is important to choose them wisely and train them well. Data collectors need to be trained at least twice and, depending on their skill, it is desirable to re-train them twice a year to ensure that they are collecting data correctly. The following points should be considered when selecting the data collector:

- Should be a local person well acquainted with the local terrain and well accepted by the local community.
- After training, should be able to measure discharge and rainfall accurately.
- After training, should be able to enter collected data properly and accurately in the data entry format provided.
- Wherever possible, preference should be given to women and to members of marginalized and vulnerable communities.
- Should have adequate time available to collect data regularly.

It is advisable to train two people for this task from the same household in order to avoid the chances of data inconsistency and gaps in the event of an emergency. Eventually, the data collectors will also act as ambassadors for the various activities under the programme within the community. Adequate precautions should be taken to ensure the health and safety of the local data collectors. Annex 2 provides a sample Terms of Reference (TOR) for data collectors.

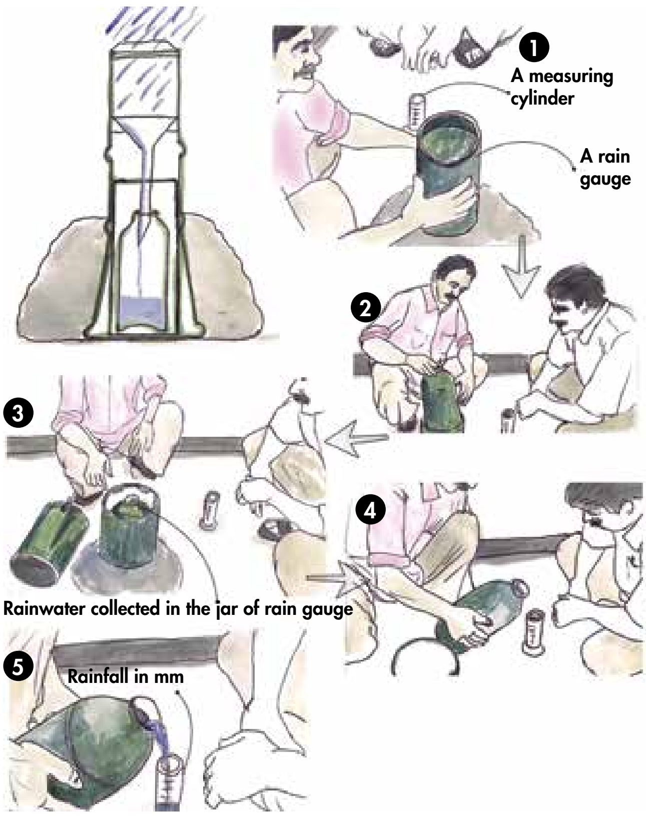
Data Collection

The data collector will collect three types of data – rainfall, spring discharge, and spring water quality. Rainfall should be recorded each day in all months of the year. Spring discharge data should be recorded at least once and preferably twice each month, depending on the human and financial resources available. Water quality data should be collected seasonally and at least three times during the year in the pre-monsoon, peak monsoon, and post monsoon periods. The data collector should understand the process of monitoring the spring discharge and spring water quality and rainfall in the field and should collect data in a timely fashion, store the data in the prescribed format, and transfer the data to the appropriate office.

Setting up Rain Gauges and Measuring Rainfall

Rainfall can be measured using automatic or manual rain gauges. The gauge records rainfall in millimetres (mm) over a selected unit of time. Rainfall should be monitored in every springshed and ideally at two positions – one at the recharge site and one at the spring itself. If only one rain gauge can be installed, it should be set up at a location between the recharge area and the spring. If resources permit, an automated (self-recording) rain gauge should be installed; if they are limited, then a minimum of one standard calibrated manual rain gauge should be installed. In addition, several simple, home-made rain gauges (see below) can be installed at a large number of sites within the springshed to improve spatial coverage over the study area. Normally, rainfall should be measured every day between 8.30 to 8.45 am.

Figure 24: **Rainfall measurement using a manual rain-gauge**



A standard manual rain gauge consists of a collector placed above a funnel that leads into a container where the accumulated water is stored between observations. If the container is a graduated cylinder calibrated to reflect the funnel catchment area, then the rainfall can be read directly in millimetres from the level of water in the cylinder. If the container is unmarked, the accumulated rainwater must be poured into a measuring cylinder to measure the volume, and the rainfall calculated as described below (Figure 24).

A simple rain gauge can be constructed using a one-litre mineral water bottle with a flat base. The top of the bottle is cut off and a funnel inserted. The bottle acts as the rain gauge and the rainfall volume is measured by pouring into a measuring cylinder. Such rain gauges can be installed at a large number of sites and especially in schools and at other community locations. This will enable collection of rainfall data over a much larger area than with the automated or calibrated manual rain gauges alone.

The following method is used to convert volume measurements of rainwater to millimetres of rainfall.

- Measure the volume of rainwater collected in the bottle using a measuring cylinder (in ml)
- Measure the radius of the funnel opening where rain was collected (in mm)
- Calculate the rainfall collection area (funnel opening) A = 3.14* (Radius of funnel in mm)^2
- The rainfall in mm is the total volume of rainwater collected divided by the area of collection of water column in mm
  Rainfall (mm) = volume (ml) *1000 / 3.14* (radius of funnel)^2

Measuring Spring Discharge

Discharge (Q) is the volume of water flowing from a spring per unit time. It is measured in litres per minute (lpm) or litres per second (lps). Discharge is one of the most important parameters for understanding the characteristics of an aquifer. Long-term discharge data will provide information about both the nature of a spring (perennial or seasonal) and the storage and transmission capacity of the aquifer that feeds it. There are various methods available for measuring discharge; the most important are described in the following sections. The method chosen will depend on the volume of flow, the type of spring, and the surrounding infrastructure. In general, measurements should be repeated three times for every reading and averaged to reduce error.

Container (or bucket and stopwatch) method

The simplest method is to hold a container of known volume (bucket or large measuring cylinder) directly under the spring so that all the water from the outlet flows into the container, and to measure the time taken to fill it. This method can be used when the spring is free flowing with no infrastructure like tanks, the spring discharge is significant, and the entire flow can be channelled into the container as shown in Figure 25. The size of the container depends on the amount of discharge. In general, a larger container will provide better accuracy, but it should still fill within a few minutes. The steps are as follows:

Figure 25: **Discharge measurement using bucket and stopwatch method**

- Hold a bucket of known volume under the spring discharge point.
- Start a stopwatch as soon as the spring water starts falling into the bucket and stop as soon as the bucket is full.
- Calculate the spring discharge (Q) in litres per min (lpm) by dividing the volume of the bucket (V) in litres by the time taken to fill it (t) in seconds and multiplying by 60 (as there are 60 seconds in a minute):

$$Q = \frac{V}{t} * 60$$

- NOTE: The measurements should be repeated at least three times and the average value taken as the reading.

Example

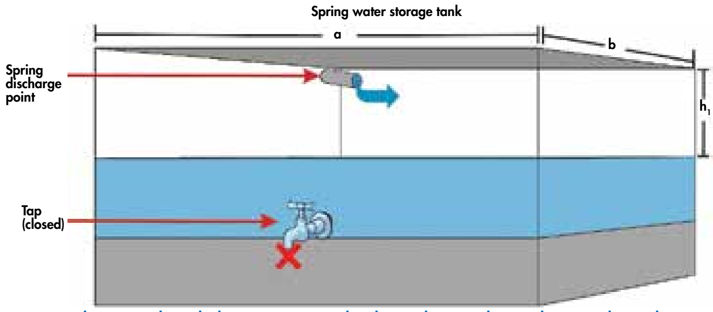
A 5 litre bucket fills up in 45 seconds.

The spring discharge is 5/45 * 60 = 6.67 lpm. In other words, the spring would take one minute to fill a bucket of 6.67 litres.

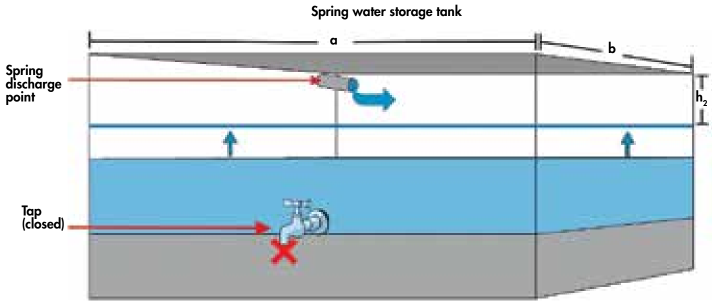
Water level change method

Some springs occur in the form of seepage and a storage tank is constructed to collect the water. It is not possible to measure the discharge of these springs directly; the method of choice is water level change with volume estimation. The discharge is calculated from the observed rise in water level in the tank over a set time; the dimensions of the tank are used to calculate the water volume (Figure 26).

Figure 26: **Using the water level change method in a rectangular spring water storage tank to measure spring discharge**



a) Initial water level (h_1) measured when the outlet valve is closed



b) Final water level (h_2) measured at the end of a fixed time interval

The steps are as follows:

- Close the outlet valve and start a stopwatch. Measure the water level in the tank at the instant of closure (h_1) by dropping a measuring tape or stick through the opening in the top of the tank (Figure 26a).
- Stop the stopwatch after a time interval chosen based on the flow rate of the spring and measure the new level of the water (h_2) in the same way as before (Figure 26b). Choose the time interval such that there is an appreciable (easily measurable) change in water level.
- Calculate the difference between h_1 and h_2 to give the net rise in water level (h) in metres.
- Calculate the water volume using the tank dimensions. For a rectangular tank with sides a, b (metres), the accumulated volume (V) is given by V = a * b * h (m^3). For a cylindrical tank, calculate the volume from the diameter.
- Calculate the spring discharge (Q) in litres per min (lpm) by dividing the accumulated volume with the number of minutes taken (assuming it is 30 minutes in this case) and multiplying by 1,000 (as there are 1,000 litres in 1 m^3)

$$Q = \frac{a * b * h}{30} * 1{,}000$$

- NOTE: The measurement should be repeated three times and the average value taken as the reading.

Example

The initial water level in a rectangular tank 5m long (a) and 3 m wide (b) is 5 m (h_1), the water level after 30 minutes is 4 m (h_2).

The net rise in water level (h) is 5 – 4 = 1 m

The total volume of accumulated water is 5 * 3 * 1 = 15 m^3

The spring discharge is $\frac{15}{30} * 1{,}000 = 500$ litres per minute (lpm)

Water level drop method

Some springs seep into a cavity that is not clearly defined and doesn't have an outflow. Water is withdrawn using a bucket, jug, or other container (Figure 27). The discharge of these springs can be measured by removing a known volume of water and measuring the recovery time. (If resources permit, a pressure transducer can be installed in the spring to accurately measure water level fluctuation, otherwise the manual measurement described here is recommended.)

The steps are as follows:

- Note the depth of the water in the spring cavity using a ruler inserted at the centre and start a stopwatch.
- Extract a known volume of water; the water level will be lower.
- Observe the rise in water level at regular intervals and stop the stopwatch when it reaches the original level.
- Calculate the spring discharge (Q) in litres per min (lpm) by dividing the number of litres withdrawn (V) by the time taken in minutes (t)
  $Q = V/t$
- NOTE: The measurement should be repeated three times and the average value taken as the reading.

Figure 27: **Discharge measurement of spring with no outlet using water level drop method**

Example

5 litres of water is extracted from a cavity with initial water level 12 cm; it takes 10 minutes for the water level to recover.

The spring discharge is 5/10 = 0.5 litres per minute (lpm).

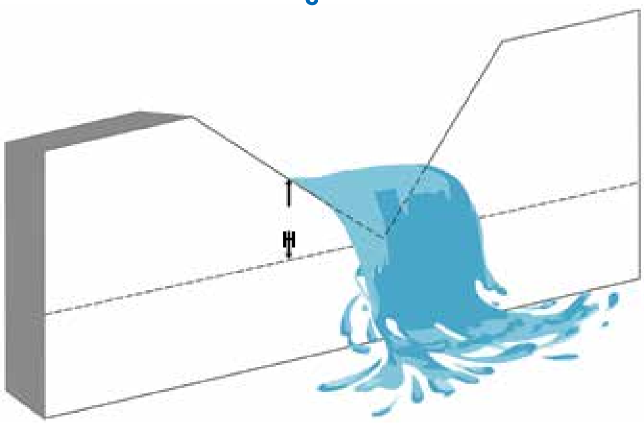
Stream flow method

A few springs occur as seepages forming a stream. Direct measurement of the discharge is a challenge, but the discharge can be calculated using the streamflow. The stream discharge is measured by installing a weir across the stream to channel the flow. There are two types of weir: a V-notch weir for low flow and a rectangular weir for higher flow.

V-notch method

A V-notch weir is used when the stream flow is low. It is simply a 'V notch' in a plate that is placed so that it obstructs the open channel flow, causing all the water to flow through the notch (Figure 28). The weir can be constructed from a metal sheet (GI or hard-bound tin) and should be installed at the narrowest part of the stream close to the springhead. The flow head in the notch is measured and the open flow rate (discharge) calculated using a weir notch equation.

Figure 28: **V-notch arrangement for measuring stream discharge**



H = Head of flow in cm

The steps are as follows:

- Construct a V-notch weir with a 'V' angle of 90°.
- Install the weir in the stream at the narrowest accessible position below the springhead ensuring that all the water in the stream passes through the V.
- Measure the head of flowing water (H) in cm from the bottom of the V using a scale.
- Calculate the spring discharge (Q) in litres per min (lpm) as the flow rate using Thompson's equation:
  $Q = 0.8388 * H^{5/2}$ for a 90° notch

Example

The head measured in a V-notch is 1.5 cm

The spring discharge is $0.8388\ (1.5)^{5/2} = 2.4$ lpm.

Table 3 shows the discharge values for different values of H calculated for a 90° notch using Thompson's equation.

Table 3: **Spring discharge values calculated for different levels of head in a 90° V-notch using Thompson's equation**

Head (H) in cms	Flow in litres per min	Head (H) in cms	Flow in litres per min	Head (H) in cms	Flow in litres per min
	90° notch		90° notch		90° notch
1.0	0.88288	9.5	245.59000	18.0	1213.62060
1.5	2.43293	10.0	279.19117	18.5	1299.66373
2.0	4.99432	10.5	315.40961	19.0	1389.26687
2.5	8.72472	11.0	354.30998	19.5	1482.47783
3.0	13.76273	11.5	395.95540	20.0	1579.34375
3.5	20.23353	12.0	440.40758	20.5	1679.91122
4.0	28.28216	12.5	487.72690	21.0	1784.22621
4.5	37.92564	13.0	537.97247	21.5	1892.33415
5.0	49.35449	13.5	591.20227	22.0	2004.27994
5.5	62.63374	14.0	647.47315	22.5	2120.10794
6.0	77.85379	14.5	706.84092	23.0	2239.86203
6.5	95.10099	15.0	769.36039	23.5	2363.58559
7.0	114.45816	15.5	835.08546	24.0	2491.32154
7.5	136.00498	16.0	904.06912	24.5	2623.11233
8.0	159.81835	16.5	976.36350	25.0	2759.00000
8.5	185.97261	17.0	1052.01996		
9.0	214.53984	17.5	1131.08905		

Rectangular weir

A rectangular concrete weir can be used to measure stream discharge when stream flow is high. A rectangular weir is similar to a V-notch weir but with a level rectangular opening to allow water to flow over the weir (Figures 29 and 30). The flow head in the opening is measured and the open flow rate (discharge) calculated from the length of the opening and the flow head using a rectangular weir equation.

Figure 29: **Rectangular weir arrangement for measuring stream discharge**

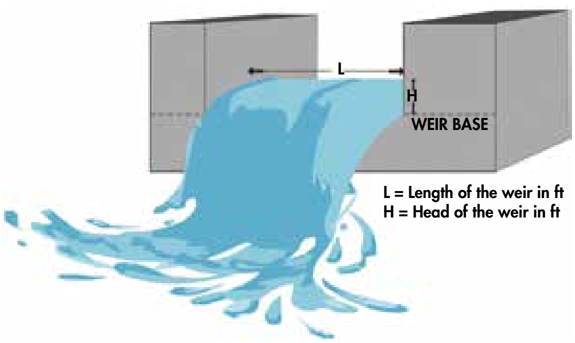


Figure 30: **Discharge measurement using rectangular weir arrangement and measuring the head in the weir**

The steps are as follows:

- Install a rectangular weir in the stream below the springhead ensuring that the base of the opening is uniform and smooth and all the water in the stream passes through it.
- Measure the length of the weir (L) precisely in feet.
- Measure the head of the flowing water (H) in feet from the bottom of the opening using a scale (Figure 29).
- Calculate the spring discharge (Q) as the flow rate using the Francis formula (imperial units):
  $Q = 3.33 (L - 0.2H) H^{1.5}$ ft^3 /sec
- Convert to litres per min (lpm) using 1 ft^3 = 28.32 litres; 1 minute = 60 sec
  $Q = 3.33 (L - 0.2H) H^{1.5} * 28.32 * 60$ lpm

Example

A head of 0.14 ft is measured in a rectangular weir with length 0.69 ft.

The spring discharge is $Q = 3.33 (0.69 – 0.2*0.14) 0.14^{1.5} = 0.114$ ft^3 /sec

$= 0.114 * 28.32 * 60 = 193.7$ lpm

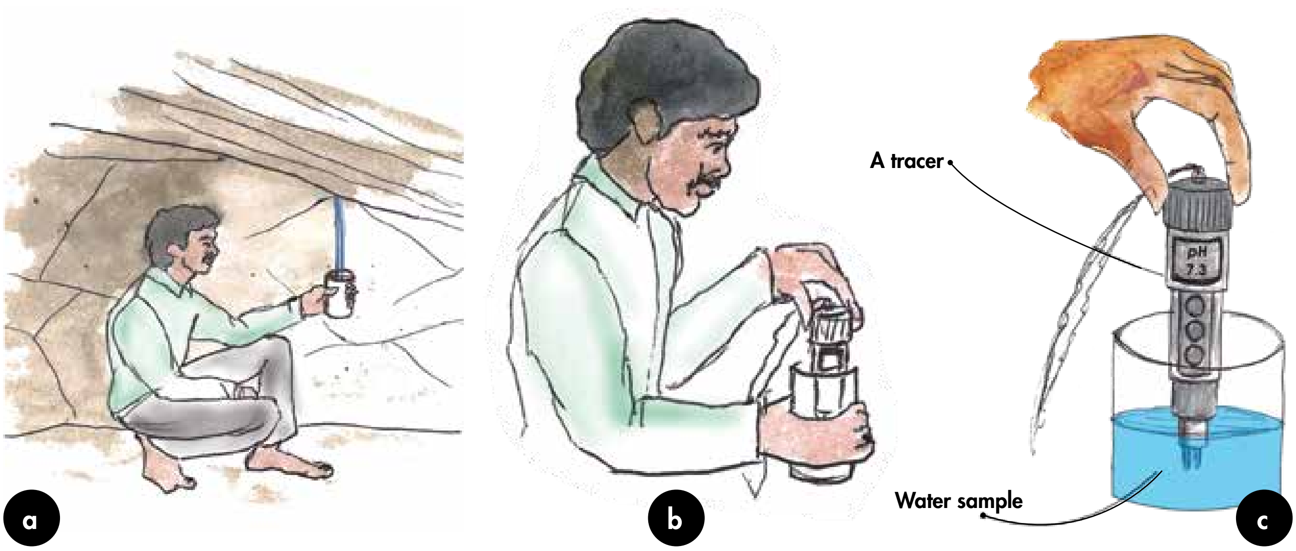
Water Quality Measurement

Spring water quality should be assessed when the initial spring inventory is prepared (Step 1 in the protocol) and then monitored at regular intervals – bi-monthly or monthly if resources permit, but at least three times over the course of a year in the pre-monsoon, monsoon, and post-monsoon seasons.

The initial test is a one-time measurement of water quality for basic parameters carried out as part of the inventory. A hand-held tracer instrument is used to provide instant readings of salinity, total dissolved solids, electrical conductivity, pH, and temperature of the water sample (Figure 31). *E. coli* contamination is tested using H_2S vials.

Field kits can be used for routine water quality assessments in the field. In addition, laboratory water quality tests should be conducted twice during the programme to validate the results obtained from field test kits and in situ testing.

Figure 31: **Water quality measurement using a tracer instrument**



a) Collect the sample directly from the spring into a clean container
b) Immerse tracer probe in the sample
c) Read values for concentrations of selected substances

Data Quality Check, Storage, Management and Transfer

Checking the data quality is of paramount importance. It is also time sensitive – if poor data quality is detected months after the original collection date, little can be done to rectify the problem. Data quality check protocols need to be developed and adhered to. The data collector should submit the data to the project office within one or two days of collection; the project officer should review the data within a day and if there are any doubts, the data collector will be able to go back and repeat the measurements. The project officer should also prepare graphs of spring discharge over time and immediately note any anomalies, and again contact the data collector to rectify any problems.

Several types of data are generated under a spring management programme at different intervals and frequencies. It is important to develop templates and methodologies for recording and storing the data and transferring it from the field level for analysis and storage at a central level.

Data should be maintained at two locations – first with the data collector/field staff in the form of a bound register or notebook (not loose sheets) that includes all the data entries, and second at the project office in the form of a digital database. The project officer should develop a template for the field collector(s). The template should focus on making it easy for the data collector to maintain the data in the given format, while providing sufficient flexibility to modify the format in response to the field collector's inputs without disturbing the structure or quality of the data format/template.

Transfer of data should be the joint responsibility of the project officer and the data collector. Communication methods are likely to be limited in village areas; innovative communication methods can be developed for transfer of data including through telephone, mail, or the use of modern technologies such as the internet, where access is available. Data transfer should be carried out regularly, the frequency should be decided at the outset of the project.

At the office level, the data should be stored in digital databases using software such as Microsoft Excel, Access, or any other database software that allows easy export of data to multiple formats for analysis. A standard format should be used to store data from all the springs in the programme. The examples in this Manual use Microsoft Excel (Annex 1) but can be modified to fit other software as appropriate.

One Excel workbook should be maintained per spring. Within each workbook, different sheets should be used for different types of data – one sheet for data related to the spring information, one sheet for maintaining regular discharge data, one sheet for spring water quality data, one sheet for daily rainfall data for the stations in the springshed, and so on. Consolidated Excel workbooks should be developed that combine similar data from all the springs or gauges within a water tower. For example, a workbook with all spring discharge data, a workbook with all rain gauge data, a workbook with all spring water quality data, and so on. Any discrepancies in the data should be addressed as soon as they are detected. It is essential to carefully maintain backup copies of the data in Excel.

Data Analysis (Software Development, App Development)

Once the data generated through the various monitoring systems has been gathered together in the formats described above, analysis can begin. Data fed into Excel sheets can be used to generate graphs to facilitate interpretation. For example, spring discharge and rainfall data are commonly used to construct a hydrograph which helps in understanding spring behaviour in response to rainfall and aquifer properties and gives an indication of the size and location of the potential recharge area (more details are given in Step 4).

A dedicated app/software based platform can be developed for the springshed management programme, to enable data collection, storage, and processing.

Data Sharing with the Community

Data collection and analysis will provide information and understanding of spring behaviour. The data, the results obtained, and the interpretation in relation to springs should be shared with the local community. This information sharing is especially important at the later phase of developing springshed management activities and protocols during Step 5. The information can be shared with the local community using simple hand drawn graphs and charts.

Training Local Residents in Basic Hydrogeology

Local residents, especially those who directly depend on the springs, should be trained in the basics of hydrogeology so that they can both monitor their springs and also understand the science behind spring recharge and discharge. The training should be carried out when the long-term monitoring system is set up. Training local residents will enable monitoring of spring discharge and other associated variables to continue even after the lifetime of the project.

Resources Needed

Table 4 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 2.

Table 4: **Summary of requirements for Step 2**

Types of skill needed	Objective	Time estimate
Ability and knowledge to set up instruments and take measurements	Setting up a continuous measurement system for precipitation, spring discharge, and spring-water quality	60 person-days/year for measuring spring data at monthly frequency over a springshed area of 100 ha. 365 person hours/year to collect daily rainfall data
Instruments required	Rain gauge, field diary, container of known volume, water quality tester, stopwatch, scale/ measuring tape	

6 Step 3: Understanding Social and Governance Systems Related to Springs

Objective: A comprehensive understanding of current water use patterns and their socio-economic implications, and the institutions and governance systems that are in place for managing springs.

Output: A report that synthesizes the findings from focus group discussions (FGDs), key informant interviews (KII), and a questionnaire survey/interviews and presents various aspects of water use, institutions, and governance.

Understanding the current use of springs and the underlying institutions and governance systems is crucial for devising effective mechanisms for spring revival. This step will yield information on the number of households that depend on a spring, the quantum of water collected from a spring, the uses of the spring water, perceptions of water quantity and quality (now and in the past), ease of water collection, and rules, regulations, and institutions involved in spring management, and conflict management approaches, among others. The data need to be collected at three levels: the overall water tower or springshed level; the level of springs that are being monitored; and at household level from the households that depend on the springs. For ease of understanding, this step in the protocol (Step 3) has been divided into three parts: the instruments needed for data collection, the process of data collection, and the use of the outputs.

Data Collection Instruments

Focus group discussions (FGDs) at springshed and sub-village/ward level

Focus group discussions are conducted at the level of the lowest administrative unit within a water tower or a springshed using a detailed checklist. Annex 3 gives a sample checklist which should be adapted to the local context. The lowest administrative unit might be a ward in Nepal, or specific sub-locality within a village panchayat in India, for example. Three sets of FGDs should be conducted in each unit – one with knowledgeable and influential people in the area (e.g., local leaders, political workers, old men and women); one with a women's group; and one with marginalized communities like *dalits* and minority ethnic communities. For example, if a water tower covers five wards in a village development committee area (VDC) in Nepal, then 15 FGDs will be held, three in each ward (a general FGD, an FGD with women, and an FGD with marginalized groups). Conducting separate FGDs, enables voices from all sections of society to be captured. To be effective, the number of participants in each FGD should be limited to five to twelve. Detailed transcripts should be prepared for each FGD and the information synthesized to yield the following information:

- the sources of water in the study area and a qualitative appraisal of quality and quantity of these sources over time;
- a qualitative understanding of land use patterns, cropping patterns, and land use and land cover changes over time;
- current patterns of management of the springs, such as institutional and governance aspects and conflicts and conflict resolution; and
- the views of women and marginalized sections of the community on various aspects of water use, management, conflicts, and others.

Sub output: A brief report summarizing the findings from the FGDs

Key informant interviews (KII) at spring and tap level

One or two key informants (people likely to have the most information) should be identified for each spring chosen for long-term monitoring (see Step 2). The key informant could be someone who manages the spring, the chairperson or a member of a water users committee, or a person who lives nearby and knows the spring well. A semi-structured interview is held with each informant. Annex 4 gives a sample interview checklist and format which can be adapted to the local context. Where springs are connected to taps, one KII should be held for each tap because taps often have their own institutional arrangements. GPS readings should be made for the water distribution infrastructure – springs, collection tanks, and taps – at the time that interviews are conducted. The KIIs should yield the following information for each spring:

- Ownership, number of dependent households, and type of source (dhara vs. naula/kuwa; perennial vs. seasonal)
- Water distribution system – whether water is collected from source and if so, how, or whether source is connected to collection tanks and/or taps
- Management related institutions – whether there is a water users committee, and if so, the membership and representation of women and marginalized groups, activities of the management committee, sources of finance for the management committee; and norms of participation and decision making
- Rules and regulations for water collection, with a special focus on rules of access for marginalized communities
- Conflicts and conflict resolution mechanisms
- Any awareness about the recharge area and means of spring conservation
- Any other relevant information

Sub-output: One to two-page report summarizing the findings from the KII(s) for each spring and a map showing the water distribution system, if any

Questionnaire survey for individual water users

A structured questionnaire is used to collect socio-economic data from the water users who collect water from the springs chosen for long-term monitoring. Annex 5 shows a generic questionnaire that has been tried and tested in Nepal and the Indian Himalayas which can be adapted to the local context.

The questionnaire survey can cover all water users of a spring or a representative sample. A full census of water users should be held if there are sufficient human and financial resources available and any of the following apply:

- The number of dependent households per spring (identified during the KIIs) is relatively small (20 households or fewer).
- Implementation activities are being planned to revive the spring (Step 5). This is important to provide baseline socio-economic data to compare changes after implementation activities are complete (Step 6).
- Water users collect water at the spring source because there is no distribution system in place (pipelines/ taps).

A representative sample survey of water users is sufficient if

- resources are limited (time, financial, human);
- the number of dependent households is large (50 or more);
- the project is only concerned with generating scientific information (Steps 1–4) and no intervention activities are planned; or
- there is a decentralized piped distribution network, which means that interviewing all users is logistically challenging as the water is fed to several locations.

The questionnaire surveys should generate the following information:

- Demographic information on respondents
- Total water collected per day and total spring discharge per day, i.e., comparison of water availability and demand. This will help categorize springs into those under stress and those not and will help identify seasonal patterns in water availability and demand
- Quantitative data on water use, including ranking of water use according to purpose
- Data on various aspects of water access – such as time taken to collect water, rules for water collection, condition of water sources, and built infrastructure
- Perceptions of water availability, quality, reliability, and dependability, and perceptions of past and future water availability and quality

Sub-output: All data from the questionnaire surveys must be checked and entered into a simple database (Excel workbook). The output is a database with checked data, and a report analysing the data generated.

The Data Collection Process

Designing questionnaires and checklists

Annexes 3–5 provide prototypes of checklists and questionnaires that have been field tested at various locations. However, it is important to adapt these instruments to the local context since socio-economic conditions and institutions vary across the region. A dedicated member of the team should collect relevant socio-economic background information during the reconnaissance survey in Step 1 and use it to modify the instruments accordingly.

Pre-testing and finalizing questionnaires and checklists

At the start of the second visit to set up the monitoring system (Step 2), a member of the team, preferably a socio-economist, should pre-test the instruments and make any necessary changes. In other words, one or two KIIs, FGDs, and questionnaire surveys must be conducted to test whether the instruments yield the required information in a usable form and whether anything needs to be added or deleted. The instruments should then be finalized.

Identifying and training field enumerators

During the first or second visit, the team socio-economists should consult with local partners, to identify a group of five to eight educated youth from the local area (with high school or college education) who can be trained as enumerators for the questionnaire survey. After the questionnaire is finalized and translated into the local language, a manual should be developed in the local language on how to conduct the survey, and the group thoroughly trained. Training a group means that surveys can be held at a number of springs at the same time. A supervisor should be deployed with the enumerator team to check data quality and carry out random quality tests to ensure that data is collected correctly.

Conducting interviews and surveys

FGDs and KIIs

FGDs and KIIs must be conducted by project staff – these qualitative and in-depth interviews cannot be outsourced as they need a consistent interviewer who understands the topic in depth and who can draw conclusions and respond to information given. Great care must be taken in identifying the right respondents for these interviews and in-depth discussions.

Questionnaire surveys

Selecting respondents for the questionnaire surveys is relatively simple. In a full census, one or two enumerators should be present at the selected sources from 5 or 6 in the morning to 5 or 6 in the evening and interview all adults (over 16) who come to collect water. Children should not be interviewed as they may not know all the details, but the number of children who come to collect water should be noted. This approach provides the most realistic estimate of the actual number of people/households who collect water from spring. If resources permit, the exercise should be repeated in the pre and post monsoon seasons to identify seasonal fluctuations in water collection practices. The complete census of water users will take one day.

In a sample survey, a specified number of water users is interviewed from each source. The number of people needed to ensure the sample is statistically representative is determined using the household dependency data obtained in the KIIs for the spring and/or tap. A step-wise process for drawing a sample is given below. The enumerators interview all adults drawing water from a spring or tap until the number required for the sample is reached. They can then move to the next spring. If the water is piped to individual households, the enumerators must visit the number of households required for the sample among those identified as using water from the source.

Determining the sample size

A normal approximation to the hypergeometric distribution is used to determine the sample size for a small population. In the field it is easiest to calculate the sample size required using a sample determination table as shown in Table 5.

Table 5: **Sample size determination**

Population size	Confidence = 95% Margin of Error				Confidence = 99% Margin of Error			
	5%	3.50%	2.50%	1%	5%	3.50%	2.50%	1%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763

Source: https://math.tutorvista.com/statistics/sample-size.html

The sample size is determined for each administrative unit identified for the FGDs (see above) Example: Ward 1 has 100 households, the desired confidence level is 95% with a 5% margin of error. Reading from the table, the sample size is 80 households.

This sample then needs to be allocated proportionally to each spring in the unit area (ward) according to the number of dependent household(s). The number of households dependent on the spring is divided by the total number of households (HHs) in the ward and this proportion of the total sample size calculated to give the number of HHs in the sample for that spring.

If the spring serves a number of separate taps, the same process is used to determine the proportion of the sample to be interviewed at each tap from the proportion of spring households served by the tap.

Data cleaning and entry

All data collected from the FGDs, KIIs, and questionnaire surveys must be recorded properly. For FGDs, detailed transcripts must be written and the information synthesized into a report. Similarly, the KII information should be entered in a database (Excel workbook) and a report prepared. A data entry format should be prepared (in Excel) for the questionnaire survey data and the data entered. If the sample size is large (more than 350 respondents or so), double data entry is preferred with the same data entered by two data entry operators and compared for discrepancies, which are then corrected. Overall, it is very important to clean the data before it is entered into the database and to check that data entry has been done correctly.

Data analysis and report writing

After the data has been entered and quality checks conducted, it can be analysed. Some of the common analysis parameters are demographic composition, types of water use, perceptions of water availability and quality, and presence and types of institutions and governance.

Using the Socio-economic Information for Spring Revival Activities

The socio-economic information gathered through the discussions and interviews will be used in a number of ways:

- For determining which springs should be prioritised for revival based on factors such as the number of dependent households, the proportion of spring water collected as a percentage of total discharge, people's perception of spring water quantity and quality, and whether there is a spring management committee or group that looks after it
- To enforce management and conservation protocols and frame new governance mechanisms for better and more equitable distribution of water
- To measure the impact of revival interventions; the data collected in this step provide the baseline data against which data collected in Step 6 (after interventions) can be evaluated

The final output of this step is a comprehensive report that analyses the socio-economic, institutional, and governance aspects of water use, drawing information from FGDs, KIIs, and the questionnaire survey.

Resources Needed

Table 6 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 3.

Table 6: **Summary of requirements for Step 3**

Types of skill needed	Activity	Time estimate
Social scientist (sociologist, anthropologist, human geographer, economist, social worker)	FGDs, KIIs	1–2 hours for each FGD and KII once FGD participants have been identified
Local village youth (high school or college graduates preferred)	Questionnaire surveys and data entry	Each survey takes 15–30 minutes, but the enumerators need to sit at the water source for 12 hours from morning to evening
Social scientist	Analysis of data and report writing	Up to 2 weeks for a junior professional, plus 2–4 days for a senior professional

7 Step 4: Hydrogeological Mapping, Development of Conceptual Layout, and Identification of Recharge Area

In this step, the recharge area is identified using knowledge of the local hydrogeology. There are three sub-steps: field mapping of the geology; creating a conceptual hydrogeological layout of the springshed; and identifying the recharge area.

Step 4A: Hydrogeological Mapping

Objective: To undertake a detailed study of rocks, rock structures, streams, and springs in the springshed and prepare a geological map (and/or a cross section) of the springshed

Output: A geological map to support development of a conceptual hydrogeological layout

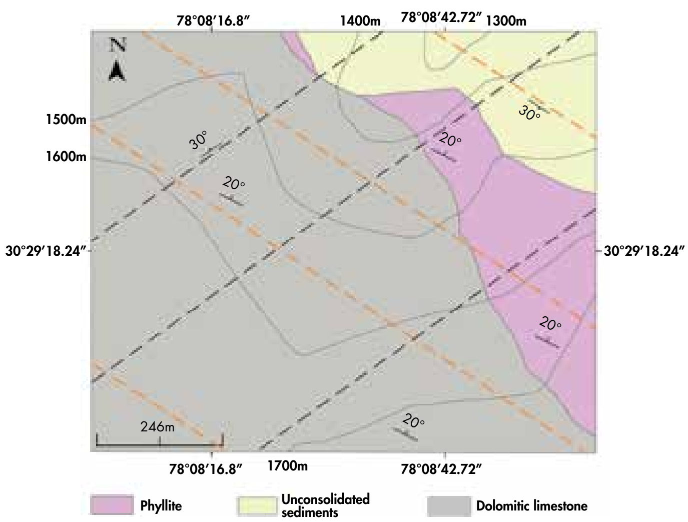
Applying hydrogeological principles through detailed study of the rocks, rock structures, streams, and springs in the springshed can significantly improve demarcation of the recharge zone for spring management and revival. The types of rock, their strike and dip (inclination), presence of openings, and structural features together govern the accumulation and movement of groundwater. The dip and strike of rocks and identification of openings forms the basis of geological mapping, especially in the Himalayan region. The steps involved in detailed hydrogeological mapping of a spring and its springshed are outlined in the following.

Obtaining a geological map of the area

Geological maps (published or unpublished) of the area of interest may be available from different sources; such maps can be used for reference purposes and to gain a first-cut idea about the regional geological conditions. In general, geological maps may be available from the geological survey departments of different countries (e.g., Geological Survey of India, Department of Geology and Mines, Bhutan). Figure 32 shows an example of geological map.

These maps can provide information about the types of rock, their orientation, and broad geological structures present in the area of interest, and can be very useful for understanding the general geology of the area before undertaking detailed hydrogeological mapping of the springs and springsheds.

Figure 32: **A typical geological map**

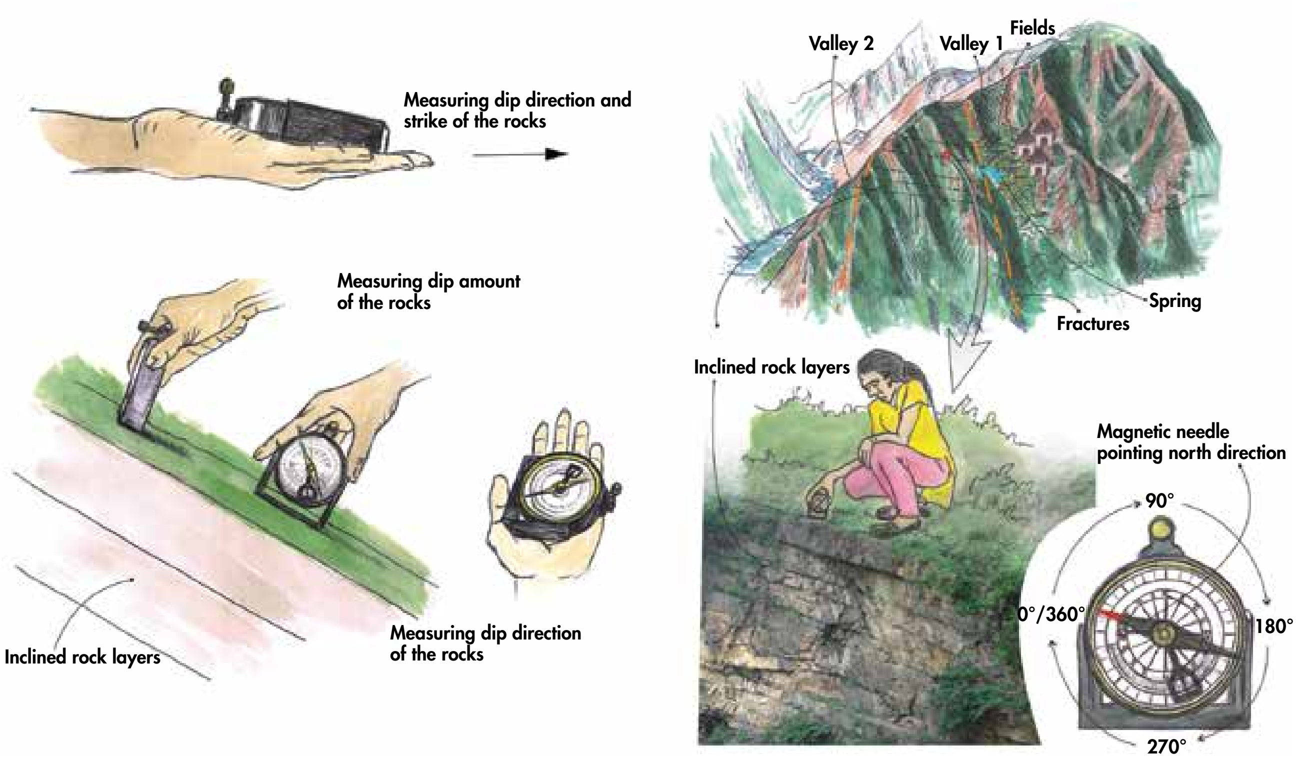


Geological observations during the transect walks

Information on spring location, rock type, and strike and dip values (see Chapter 2 on rocks and structure of rocks), as well as land-use, land-cover, and forest types (broad leafed vs. coniferous), should be collected during the transect walks across the springshed and noted in a field diary, together with values of latitude, longitude, and elevation for every location of interest.

The geological traverses should be planned such that they cover the entire springshed (Figure 33). A geological map and geological cross section are prepared using the information collected. The map and section are essential for the development of a conceptual hydrogeological layout, and ultimately to identify the recharge area or protection zone.

Figure 33: **Measuring strike and dip using a geological compass such as a clinometer or Brunton compass**



Creating a geological map (using Google Earth/Toposheet)

A geological map shows the distribution of different types of rock and their structural relationship with each other in the area of interest. Geological maps can be prepared at various scales, but for the purpose of hydrogeological mapping of a spring and springshed area, it is preferable to prepare the map at a scale of 1:10,000 or 1:25,000, depending on the detailed information required for spring revival activities.

All the information gathered during the transect walk observations is transferred in a specific format to an MS Excel sheet on a computer (Annex 6A). The Excel file is converted to a Google Earth file format (.kml) using an online converter like www.Earthpoint.us which will place all the information in the form of placemarks in Google Earth (Figure 34).

The attitude, i.e., strike and dip, of a particular rock at its place of observation in the field is plotted over the placemark in Google Earth representing its location (Figure 35). In this way, the observations made at the surface are built into a geological map incorporating structural and lithological observations (Annex 6B).

The integration of data on dip and strike with other standard observations made on rocks in the mapping enables interpolation and extrapolation of outcrop data to produce a geological map (Figure 36).

Resources Needed

Table 7 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 4A.

Figure 34: **Geological information locations produced in Google Earth**

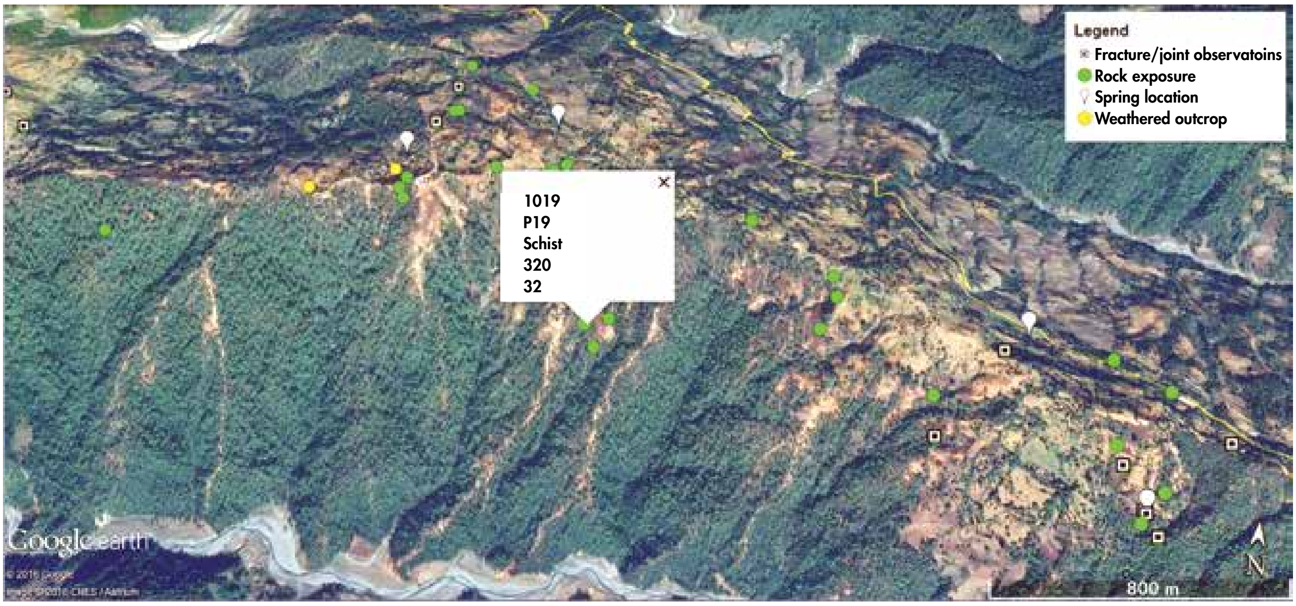


Figure 35: **Plotting of strike and dip**

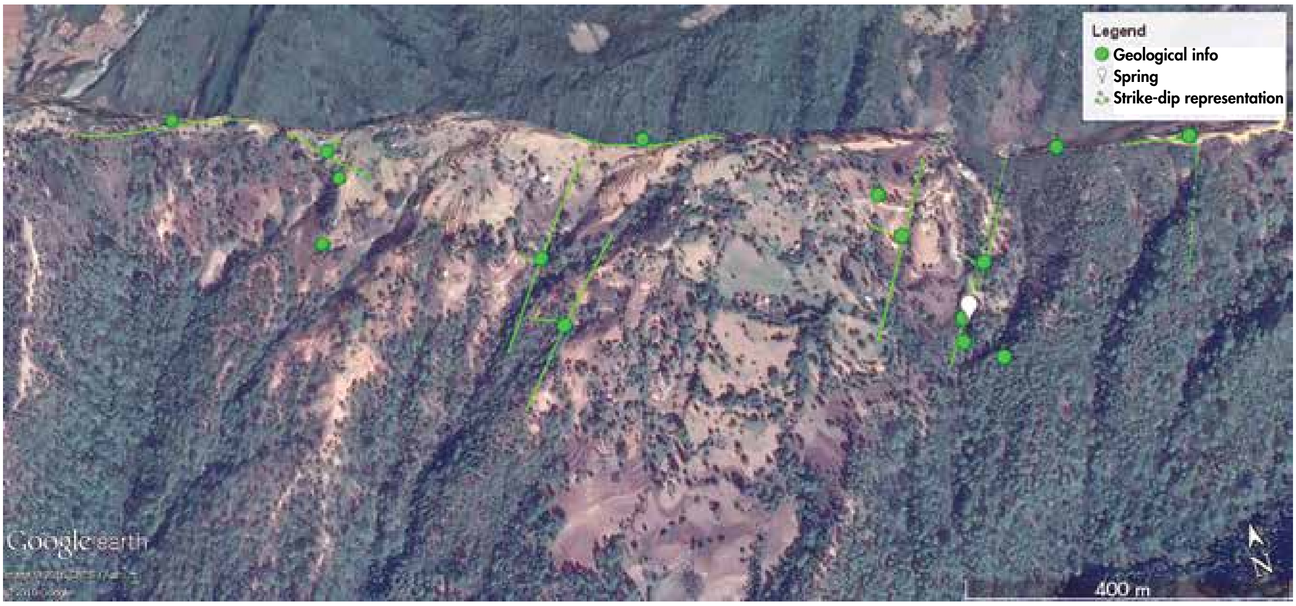


Figure 36: **Geological map in Google Earth**

Table 7: **Summary of requirements for Step 4A**

Types of skill needed	Objective	Time estimate
Basic understanding of field hydrogeology along with hands on experience in using basic software such as MS Excel, Arc GIS, and Google Earth.	Collecting hydrogeological information from the field for developing hydrogeological maps	60 person-days for mapping springshed of 100 ha
Instruments required	Brunton compass/clinometer, hammer, GPS, field diary, base map like toposheet/ geological maps	
Software requirement	Microsoft Excel and Google Earth	

Step 4B: Creating a Conceptual Hydrogeological Layout of the Springshed

Objective: To prepare a geological cross section for the springshed and project it into a three-dimensional (3-D) conceptual hydrogeological layout

Output: A conceptual hydrogeological layout helps in the demarcation of the recharge zone for spring management and revival described in step 4C. It also helps in visualizing the area of interest in 3-D.

A hydrogeological layout of a springshed is actually a geological cross section depicting a spring and its relation to the surrounding geology viewed in 3-D. Thus a geological cross section is first prepared from the geological map and then projected onto a 3-D image. The location of the spring is then marked on the 3-D layout to form a conceptual layout. The base map and geological map prepared using the field data are used to create the hydrogeological layout, including the cross-sectional view of the springs and springsheds. The hydrogeological layout helps in understanding the inclination of rock layers and structures with reference to the spring. These further guide demarcation of the recharge area for the spring. The steps involved in the preparation are described in the following.

Generating a cross section of the springshed

The geological map prepared in step-4A is used as a base for generating a cross section of the springshed using tools in Google Earth together with software support from CorelDRAW. A para-hydrogeologist can also hand-draw a hydrogeological layout and cross section while in the field without the use of computer software.

Using Google Earth, an elevation profile (also called a topography profile) is generated for the springshed of interest. The profile is then transferred to CorelDRAW software where the contrasts in lithology (contacts) are marked together with the locations of the spring and fractures or joints, as noted in the observations (Annex 7). This process yields a two-dimensional (2-D) cross section for the springshed (Figure 37) which is then integrated into CorelDRAW to produce 3-D conceptual hydrogeological layout.

Creating a 3-D conceptual hydrogeological layout

The cross-section profile represents all the geological information in 2-D including rock layers (showing dip direction and dip amount), spring location, and fracture/joint observation points. This section is integrated into a 3-D layout using CorelDRAW tools which displays the fracture trends, strike and dip of the rocks, and location of spring together with any additional observations and information from the field (Figure 38). This 3-D layout helps in developing understanding of the geological setup of the springshed. The aquifer can be represented in the layout itself using the field information on spring typology and aquifer identification, which further helps in demarcating the recharge area for the spring.

Resources Needed

Table 8 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 4B.

Figure 37: **Generating a cross section of the springshed**

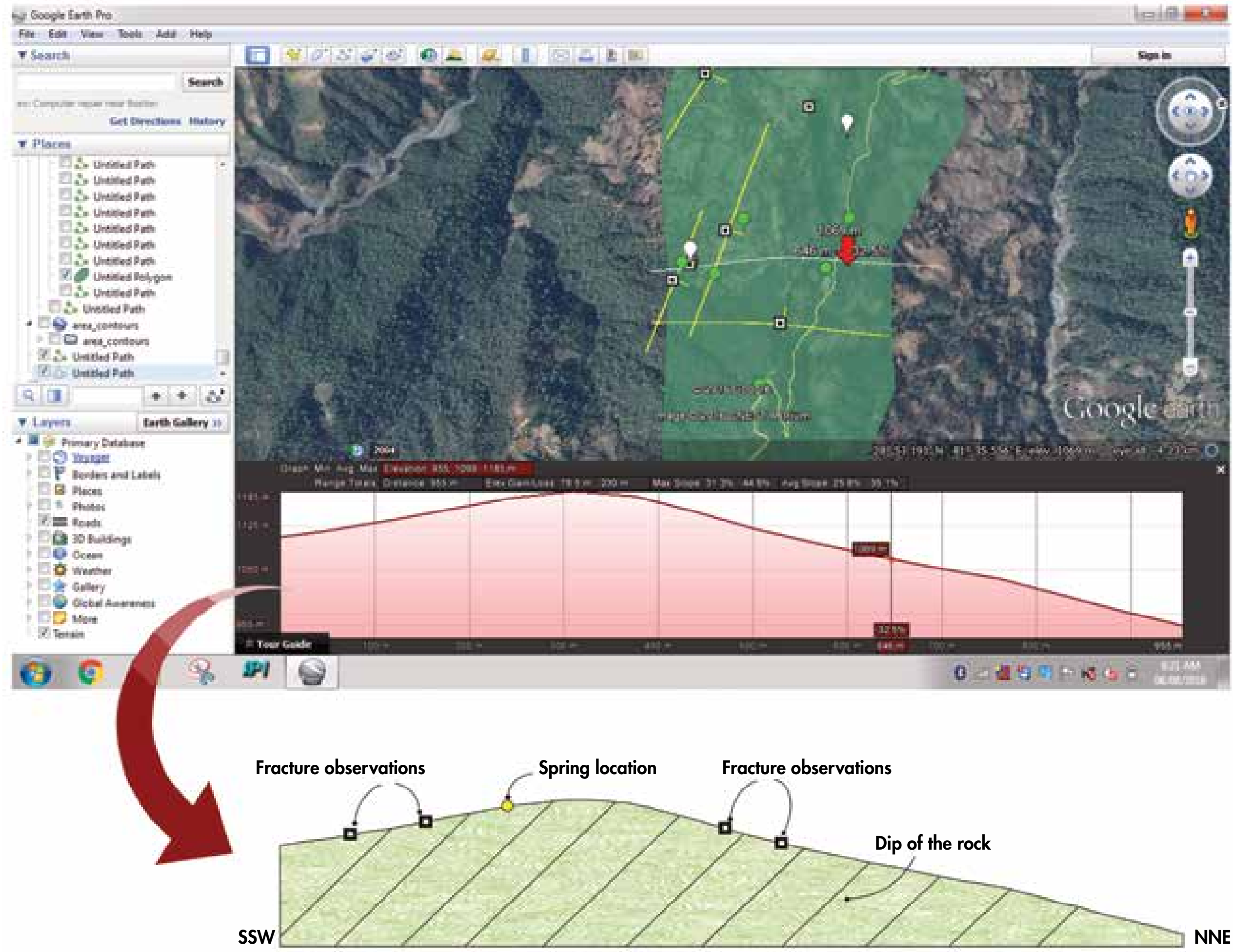


Figure 38: **A conceptual hydrogeological layout**

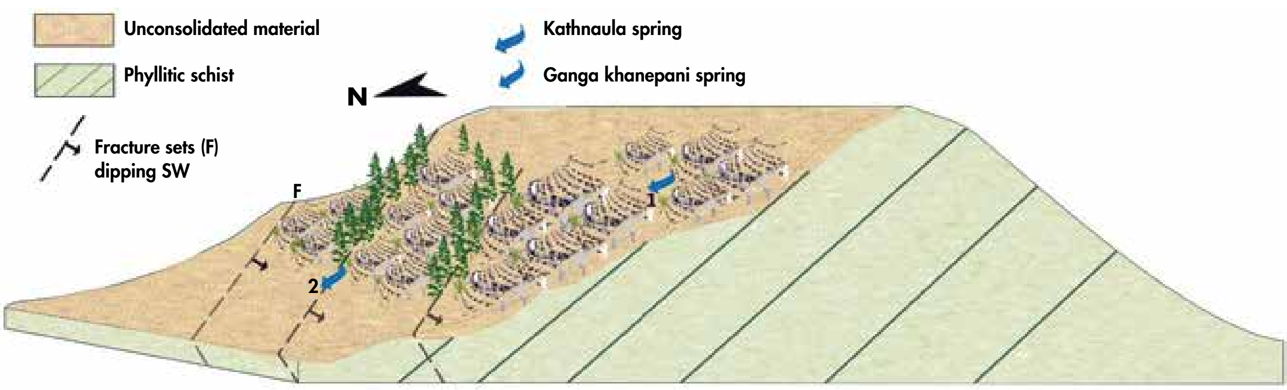


Table 8: **Summary of requirements for Step 4B**

Types of skill needed	Objective	Time estimate
Ability to interpret field data in order to understand and draw the hydrogeological setting of the springshed, together with the capacity to work on various computer aids	Creating a geological cross section and developing a hydrogeological conceptual layout	30 person-days for a 100 ha springshed area
Use of software		Designing software like CorelDRAW and SketchUp, and Google Earth

Step 4C: Classification of Spring Type, Broad Identification of the Mountain Aquifer, and Demarcation and Analysis of the Recharge Area

Objectives: To identify the spring type and the aquifer feeding the spring and demarcate the recharge area for the spring based on various outputs from the previous steps, particularly the hydrogeological layout.

Output: The final output is identification of the recharge area(s), with various sub-outputs from different steps

The hydrogeological layout of a springshed helps in identifying the aquifer and recognizing the type of spring being studied, as well as progressing towards demarcating the recharge area for the spring as part of the springshed management activities. The steps involved are described in the following.

Identifying the spring type and aquifer

The hydrogeological layout described in the previous section is based on field observations and mapping. The broad location of the aquifer, the location of the spring, and other geological features indicate the hydraulic connection between the ground surface, the aquifer, and the spring. Different characteristics contribute to identification of the type of spring and type of aquifer, including the relation to geological features, and the discharge, water quality, and hydrograph.

Identification of spring and aquifer type from the hydrogeological layout

The hydrogeological layout developed from the observations is compared with the diagrams of spring-types and aquifer types given in the concepts section (Chapter 2) in order to identify the basic spring type. Figure 39 shows an example where the spring emerges along a fracture (and mostly due to the presence of the fracture) trending roughly NE-SW from an aquifer defined by phyllite and fractured quartzite layers.

Identification of spring and aquifer type from the hydrograph and groundwater quality information

The type of spring (and aquifer) is also broadly correlated with the rainfall-discharge hydrograph, and with groundwater quality. Thus the preliminary identification can be further confirmed using the data and information on spring discharge, rainfall, and groundwater quality collected during the monitoring activities (Protocol Step 2). It is useful to capture annual and longer-term trends in spring discharge through measurement, but approximate information can also be obtained by talking to the community who can create a narrative about the seasonal and long-term trends in springs that they use. Both types of information are used to help correlate the spring-type. Table 9 provides an indicator matrix for the correlation between spring type and the nature of the hydrograph and groundwater quality which can be used as a rule of thumb. While only indicative, this type of correlation helps strengthen the identification of spring and aquifer(s) type.

Identification of spring and aquifer types from hydrograph typology

The 'type curves' of hydrographs can also be used to further delineate the typology of springs and

Figure 39: **Conceptual layout showing a fracture spring and the aquifer feeding it**

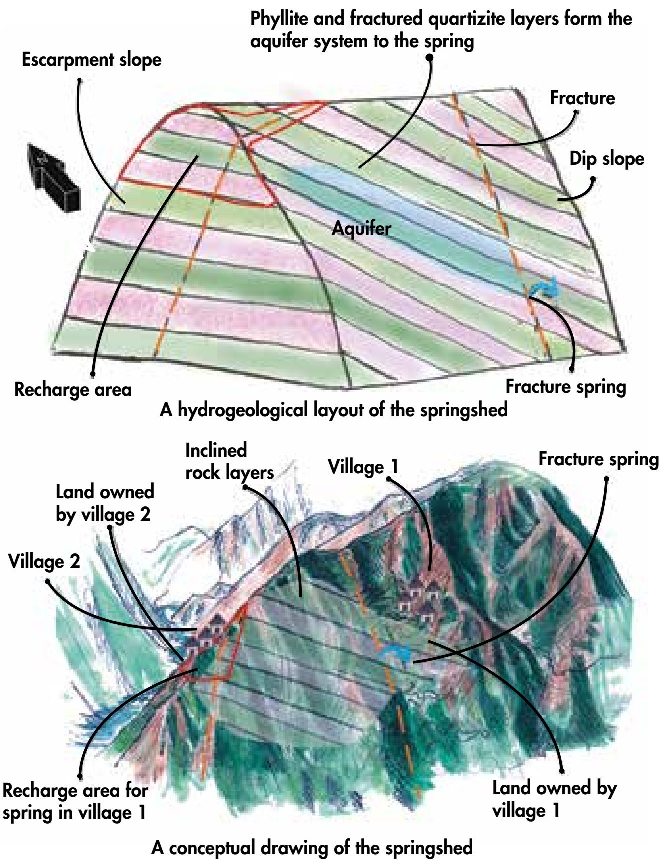
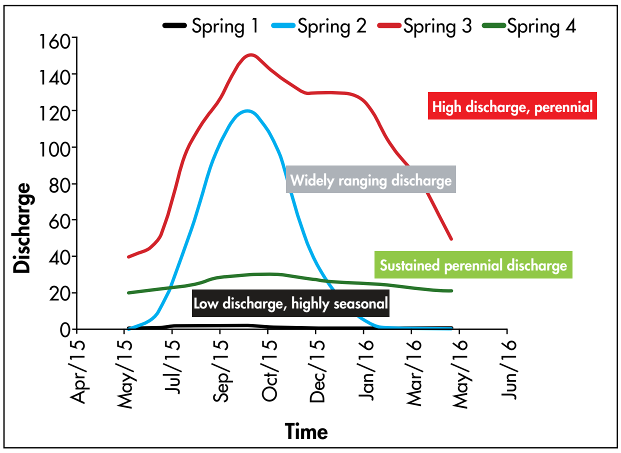


Table 9: **Indicator matrix for spring type, discharge and spring-water quality**

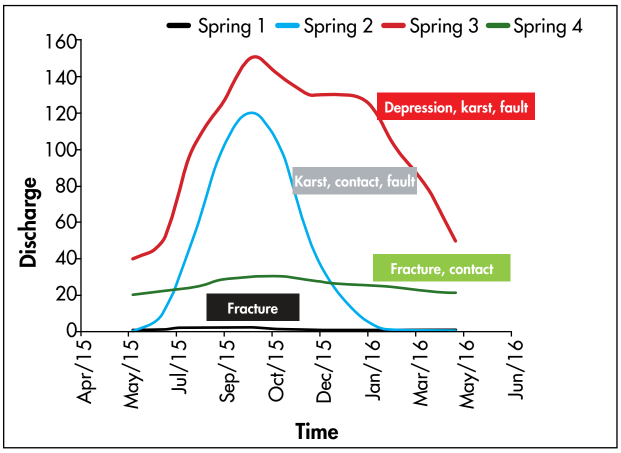
Spring type	Possible nature of hydrograph and groundwater quality
Depression spring	Seasonally high discharge; spring sometimes seasonal but often perennial Groundwater quality changes with season; the concentration of dissolved solids generally increases with drop in discharge
Contact spring	Seasonally high discharge but not as variable as in a depression spring; usually perennial Groundwater quality, particularly the concentration of dissolved solids, generally increases as discharge dwindles
Fracture spring	No major discharge variation, fairly constant, seldom with high discharge; usually perennial Groundwater quality fairly constant, with minor fluctuations
Fault spring	Sometimes with high and fluctuating discharge, particularly when fed by deeper confined aquifers; fluctuation typically doesn't follow the seasons Groundwater quality varies, sometimes with a high concentration of dissolved solids throughout the seasons
Karst spring	Seasonal or perennial with highly fluctuating discharge Groundwater quality is different in karst springs compared to other springs. Usually there is a higher concentration of dissolved solids and seasonal changes in groundwater quality are common.

aquifers, which is then used in the process of identifying recharge zones and management of the recharge process. The sequence of hydrograph type curves shown in Figure 40 illustrates how concepts, data, and hydrogeological interpretation can be used to develop a synopsis of the typology of springs and aquifers in a broad and indicative manner.

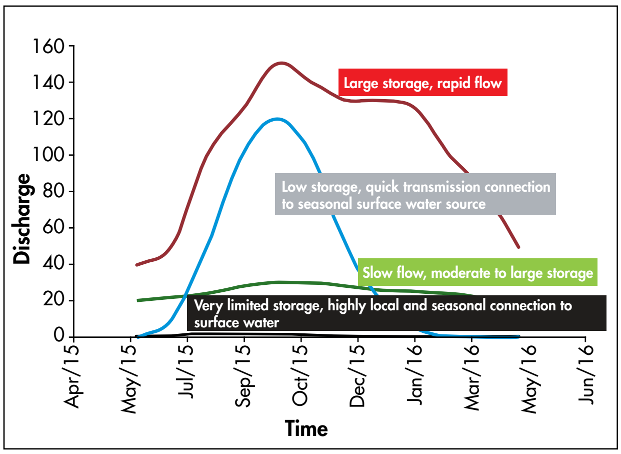
Figure 40: **Sequence of hydrographs illustrating how concepts, data, and hydrogeological interpretation can be used to develop a synopsis of the typology of springs and aquifers**



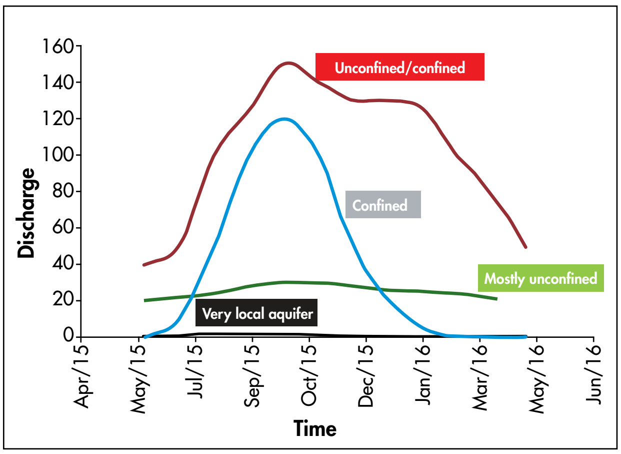
a) Hydrograph with description of the discharge magnitude and fluctuation showing whether the spring is seasonal or perennial



b) Hydrograph indicating the correlation with spring type



c) Hydrograph describing the possibilities for water storage and transmission in the underlying aquifers



d) Hydrograph showing correlation with possible aquifer type

Delineation of the recharge area

Identification and delineation of the recharge area(s) is the most important step in springshed management. It is crucial both for augmenting or restoring spring discharge and quality by increasing recharge to the aquifers feeding the spring, and for managing aquifers and springs by protecting the recharge area. The recharge area is identified from the hydrogeological layout and then located on the map and Google Earth image.

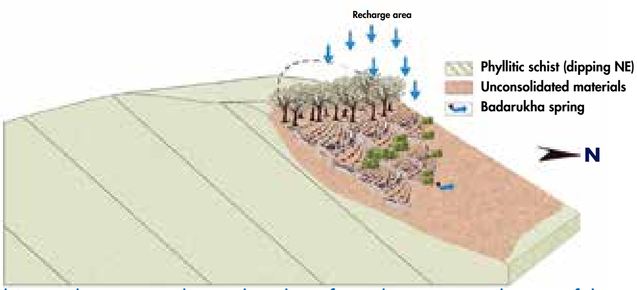
The hydrogeological layout is used to identify the area that supplies water to the aquifer that feeds the spring, i.e., the recharge area, by linking backwards from the spring through potential channels for the water along fractures and other rock formations to the location on the surface. Following careful identification, this area is indicated as the recharge area on the layout (Figure 41).

Once the recharge area has been marked on the hydrogeological layout, it can be located on the geological/ hydrogeological map (Figure 42).

The recharge area is then located on the Google Earth Image to provide a way of identifying the area for recharge interventions in a form that people are accustomed to (Figure 43).

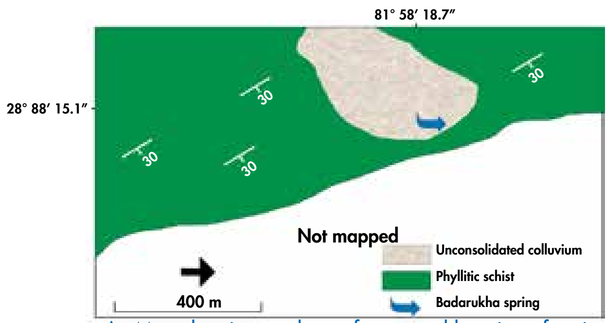
Figure 41: **Hydrogeological layout showing identification of the recharge area for a spring based on the geology**

a) Spring location – a depression spring tapping an unconfined aquifer formed in unconsolidated sediments

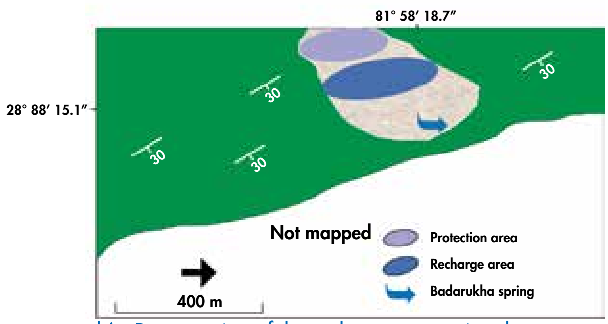


b) Decharge area located upslope from the spring at the top of the unconfined aquifer

Figure 42: **Location of the recharge area on the geological/ hydrogeological map**



a) Map showing geology of area and location of spring



b) Demarcation of the recharge area using the information from the hydrogeological layout

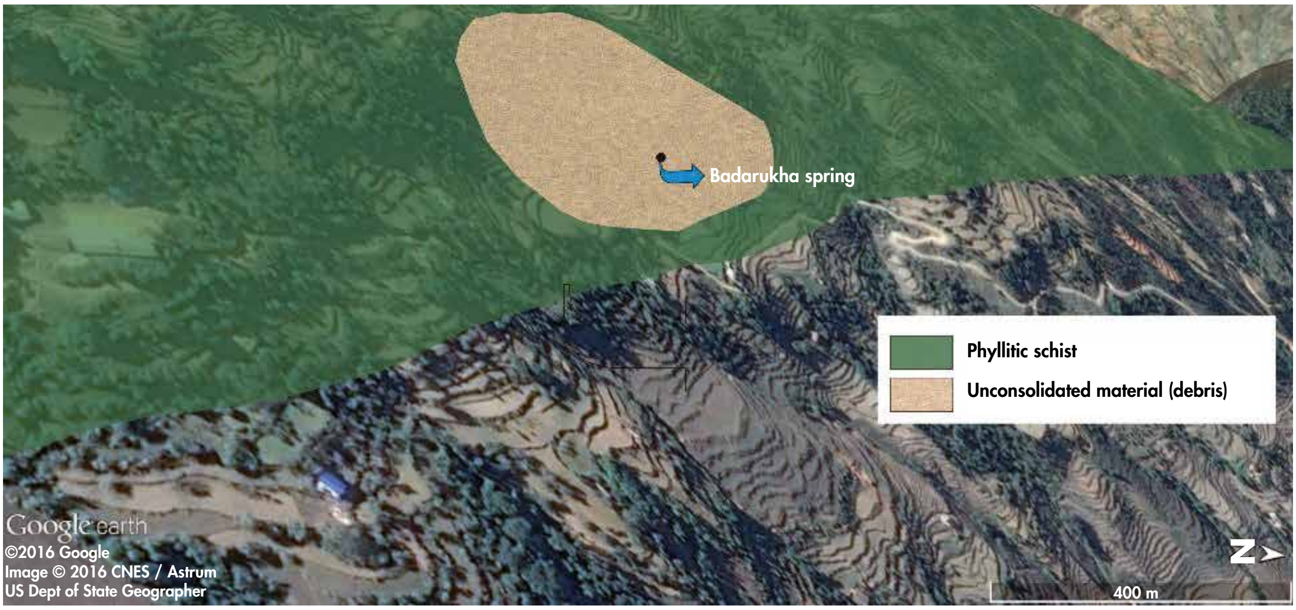
Collecting detailed information about the recharge area

Once the recharge area has been delineated, ground information should be collected on land use and ownership of the site to help in the selection of recharge measures. The type of land cover (forest, agricultural land, settlements, and so on) and land ownership (private vs. communal) will play a significant role in determining what activities are desirable and/or feasible. Table 10 shows a typical format for collecting information about the recharge area. Simple GPS mapping of land ownership and land cover will also help in systematic planning of the recharge activities (Step 5, see next Chapter).

Table 10: **Template for recording land use and ownership in recharge area of springs**

Name of spring	Land use type	Main uses of land	Main users of land	Who owns the land?	Who regulates land use?
[Spring 1]					
[Spring 2] etc					

Figure 43: **Location of the recharge area on the Google Earth image:**



a) Geological map from Figure 42 depicted as an overlay on the Google Earth image in tilt view

b) Demarcation of the recharge area(s) on the Google Earth image in tilt view (the geological layer can be retained or removed)

The identification of spring types and aquifers and demarcation of the recharge area(s) is a prerequisite for the next step of developing the springshed management and governance protocols. The physical aspects of recharge augmentation and protection form a significant part of the protocols. However, implementation depends on community perception and understanding of the process of mapping, measurement, and identification of spring typology. The maps developed in this step provide a basis for helping the community understand the location of the recharge area, the role of recharge in ensuring spring discharge, how spring revival measures can work, and how they can help improve and maintain their water supply. The springshed management plan will link the technical and socio-economic aspects including understanding of the potential impacts of water augmentation. The impacts can include any of the following: increased spring discharge, improved water quality, more sustained discharge during the dry season, better management with more equitable access, and efficient distribution.

Resources Needed

Table 11 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 4C.

Table 11: **Summary of requirements for Step 4C**

Types of skill needed	Objective	Time estimate
Interpreting field hydrogeology and spring discharge hydrographs – geologist and hydrogeologist	Identifying and demarcating potential recharge sites	One person-day for a trained person per spring
Social scientists and forester	Collecting detailed land use and land change information on recharge areas. Remote sensing maps are a good tool	1-4 person days per spring recharge area, depending on the size of the recharge area.
Software requirements	Microsoft Excel, Remote Sensing maps, if available, CorelDRAW and Google Earth	

8 Step 5: Developing Springshed Management and Governance Protocols

Objective: To understand the different ways of enhancing recharge, and develop springshed management and governance protocols. These can be physical measures or governance and social protocols, or a combination of both.

Output: Detailed and context specific spring recharge and governance protocols for implementation activities.

Recharge areas are governed by local geology and often cross village boundaries. This means that management protocols for spring water must be developed by mutual consent among the different villages involved. Management plans are also site specific, developed to meet local needs and taking into account local possibilities and constraints. Land use and ownership play a role in determining what measures are possible. For example, construction of physical structures like pits and ponds or terraces may not be possible on private land and alternative interventions like hedgerows or tree plantation may be suggested. In some cases, the recharge area might be located in a place where activities are not possible, and in others artificial enhancement of recharge may not be needed, with changes in land and spring management sufficient to address any problems. In all cases, it will be useful to organize public meetings to acquaint community members with the possibilities for springshed management, and actions to undertake or avoid. Governance mechanisms will need to be established to ensure that the springshed management protocols can be maintained.

There are two main aspects to springshed management: physical and biological measures, and social measures.

Physical and Biological Measures for Springshed Management

In order to recharge springs, it is important to stop rainwater simply running off the surface and get as much water as possible to infiltrate into the ground. Management measures to increase infiltration are planned at strategic locations in the recharge areas of springs, and are selected based on the land use type, topography, and land ownership. Water infiltration can be encouraged through structural, vegetative, agronomic, or management measures, alone or in combination. A selection of these methods are described in the following section. There are a number of resources available providing more details and more methods such as ICIMOD's Godavari Knowledge Park information sheets (ICIMOD, 2013), Nepal Conservation Approaches and Technologies (NEPCAT) Fact Sheets (www.icimod.org/nepcat), Resource Manual on Flash Flood Risk Management (Shrestha et al., 2012), Global Sustainable Land Management Database of the World Overview of Conservation Approaches and Technologies (WOCAT; https://www.wocat.net/en/global-slm-database), and the Manual on Soil Conservation and Watershed Management Techniques (DSCWM, 2004).

Structural measures

Shallow dugout ponds

Ponds can be used to harvest surface runoff and increase infiltration (Figure 44). They can be round or rectangular and are usually constructed on sloping land where there is a natural depression (ICIMOD, 2008b). The typical size for recharge purposes is around 3 x 3 m, with a depth of 0.75 m. A feeder channel is connected to the pond from both sides to help harvest additional surface flow. The walls should be sloped at 45 degrees to prevent cave in (RM&DD, 2014). It is better to construct a series of small ponds rather than one large pond.

Avoid locations

- where there is slope movement, subsidence, land sliding, or gullying which may affect the area below;
- where the valley side of the pond is not sufficiently stable to hold standing water;
- at the toe of a slope, where the pond may increase the instability of the slope; and
- close to a cliff, where slope-failure may occur due to seepage or water pressure.

Figure 44: **Conservation ponds for spring recharge**

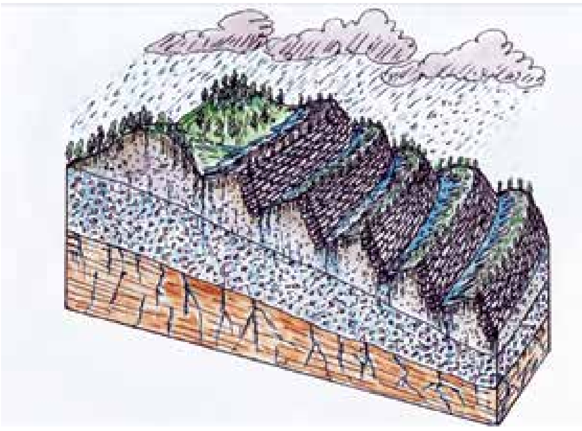
a) Rectangular dugout pond waiting for rain

b) Circular pond – economically efficient but more difficult to construct

Inwardly sloping terraces or absorption terraces

Inwardly sloping terraces guide water towards the hillside rather than down the slope. Level terraces with riser bunds for impounding water for paddy cultivation also facilitate recharge. These terraces are very effective where the soil is fairly rough so that the greatest possible infiltration surface is obtained, but less so where the soil is less penetrable (such as heavy clay). Old terraces can be modified to make them inward sloping with a gentle gradient (Figure 45).

Figure 45: **Typical absorption terraces**



a) Inwardly sloping terraces

b) Level terraces for paddy cultivation with soil bunds at the margins

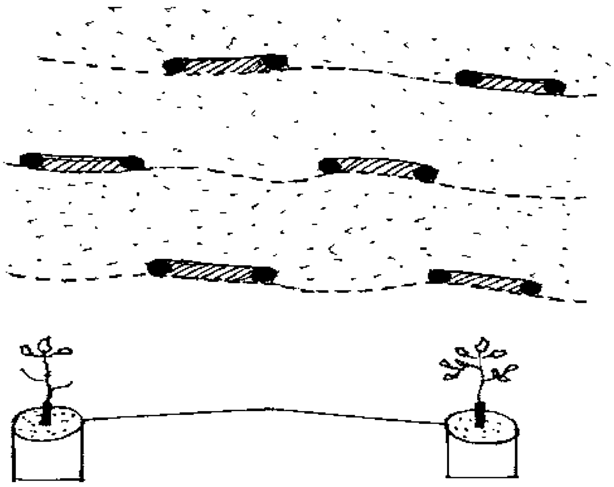
Trenches (continuous or staggered)

Trenches or retention ditches can be dug by hand along contour lines in a staggered (or continuous) pattern (Figure 46). Contour lines can be identified using a simple A-frame (ICIMOD, 1999). The trenches should be trapezoidal, e.g. 40 cm high, 30 cm wide at base, and 50 cm wide at top. The exact size and spacing depends on the slope, with smaller trenches and closer spacing on steeper slopes constructed. The soil excavated from the trench is used to form a compacted berm on the downhill edge of the ditch with a gap of about 10-15 cm, and the berm planted with permanent vegetation to stabilize the soil. Trenches should be maintained before the rainy season and checked after heavy rains. The structure can be unsuitable in areas susceptible to landslides.

Semi-circular bunds or eyebrow pits

Eyebrow pits are small curved trenches around 2 m long and 50 cm wide dug at intervals across a slope to catch water (Figure 47). The soil is piled high to form a ridge on the downslope side which can be planted with grass, fodder, fruit, or non-fruit species to stabilize the pit and further hinder flow. If the fields are levelled, planting pits can also be used. The effectiveness of these water traps can be increased by integrating a layer of mulch (ICIMOD, 2007).

Figure 46: **Construction of staggered trenches for spring recharge**



a) Diagram of layout

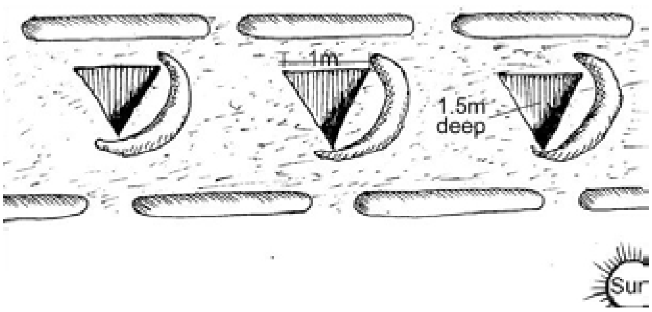
b) Staggered trenches across grassland

Figure 47: **Semicircular or eyebrow pits to hold water and facilitate infiltration**

Triangular pits

Triangular pits are used to trap snow to reduce evaporation and increase percolation. The dug out soil is piled on the sunny side to form a berm or bund in which seeds can be planted (Figure 48) (Bhuchar et al., 2009).

Figure 48: **Triangular pits**



Soil and stone bunds

A bund is a continuous raised mound constructed in a long line to keep back water (Figure 49). Bunds help to increase infiltration and keep back eroded soil. They are easy to build but need more effort to maintain. Bunds can be combined with trenches (Figure 49a) and fodder or other crops can be planted along the top. Stone bunds can be constructed if stones are available (Figure 49b) (WOCAT, 2011).

Check dams

Check dams are small structures constructed from loose stone and gabion masonry across a gully or channel to slow water flow and prevent the gully deepening further (Figure 50). The structures also help increase infiltration along the gullies. Loose check dams can be combined with vegetative measures (bio-engineering) which further increases water retention and infiltration.

Figure 49: **Different types of bund**

a) Soil bund along a contour combined with a trench

b) Stone bunds

Figure 50: **Check dams constructed along gullies to control erosion and increase infiltration**

Vegetative measures

Afforestation and forest management

Deforestation and unsustainable forest management is one of the causes of springs drying up. Sustainable forest management and afforestation of degraded land with appropriate species are important for reducing runoff, increasing infiltration, and enhancing recharge. Species should be selected for afforestation that demand less water, have water saving strategies, and support undergrowth. For example, native deciduous species which shed their leaves during the dry season can further enhance recharge. Intermediate tree cover is generally better than dense tree cover as transpiration is lower. There should be a complete ban on using fire in recharge areas.

Hedgerows

Sloping agricultural land technology – contour hedgerows – can be used to construct terraces naturally that hold back water. Fast-growing nitrogen-fixing tree or shrub species are planted along contour lines to create a living barrier that traps sediment and gradually transforms the sloping land to terraces (Figure 51). The terraces are used to grow crops, fruit, or fodder. The hedgerows reduce runoff and soil erosion and improve infiltration. This approach combines the strength of terracing with the strengths of natural vegetation.

Palisades (live check dams)

A palisade is a fence or wall made from live wood cuttings planted in lines across a slope following the contour in order to trap soil and debris moving down the slope and increase infiltration (Figure 52). The cuttings grow to form a dense, stable wall of vegetation.

Brush layering

In brush layering, live woody cuttings are laid in lines across a slope with soil in between following the contours (Figure 53). As the roots grow, they anchor and reinforce the upper soil layers while the foliage traps debris. Brush layering can be used for well-drained slopes of less than 45°. The structures reduce runoff velocity and increase infiltration.

Agronomic measures (sustainable agriculture)

Organic matter in soil increases the presence of soil cavities and acts as a sponge for water. Soil rich in organic matter preserves moisture longer. There are a range of agronomic techniques that can be used to improve the structure of top soil and increase moisture capacity including mulching, adding compost, and minimum tillage. These techniques also slow the water flow allowing more time for infiltration (Figure 54).

Management measures

Wetlands and grazing land management

If wetlands are present in the recharge area, they must be protected and/or restored. There should be no grazing in the recharge area. Overgrazing leads to soil depletion which reduces soil infiltration. If a complete grazing ban is difficult, options like restricting stocking density and rotational and deferred grazing should be promoted. Simple fencing around the springshed will help to protect it from further deterioration (Figure 55).

Eco-safe roads

Figure 51: **Sloping agricultural land technology with crops in the alleyways at ICIMOD's Knowledge Park**

Figure 52: **Palisades to control erosion and improve infiltration**

Figure 53: **Brush layering across slopes along a contour**

Steep slopes and weak rock are subject to erosion and landslides, which degrade the groundwater recharge capacity. Although erosion and landslides are caused by extreme natural events (e.g. heavy rainfall), they are often aggravated by human activities such as road construction. Eco-safe methods which combine vegetative and low cost structural measures should be used when constructing rural roads (Devkota et al., 2014). Various bio-engineering techniques can be used to hinder landslides such as grass planting, palisades, fascines, and wattle fences, based on a landslide survey and assessment (DSCWM, 2016).

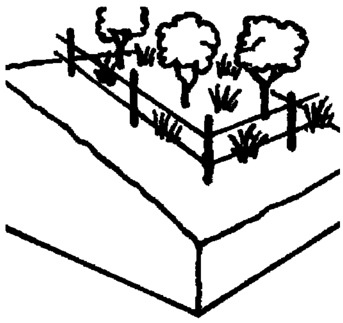
Figure 54: **Agronomic measures promoting infiltration**

a) Minimum tillage

b) Mulching – spreading of plant material or organic matter (here straw) around the base of plants

Figure 55: **Management measures for springshed protection**

a) Rotational grazing, a sustainable land management practice

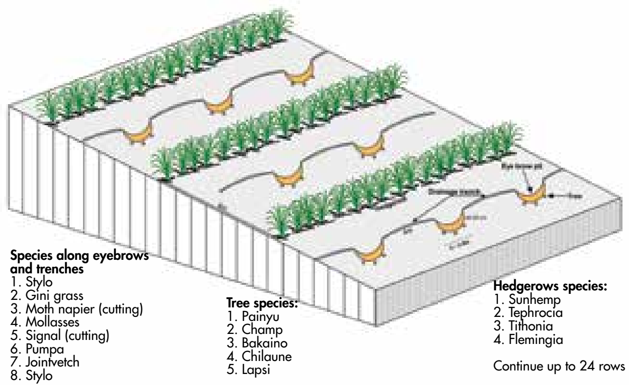


b) Fencing of springshed

Combined measures

The measures described above can be combined in a comprehensive springshed management approach. For example, combining eyebrow pits or trenches with tree plantation in alternative rows can be highly effective to increase infiltration (Figure 56) (ICIMOD, 2008a). These measures can be complemented with other measures like solar energy technologies, improved stoves, fodder cultivation on private lands, and roof rainwater harvesting to reduce the dependence on recharge areas for ecosystem goods and services.

Figure 56: **A combination of trenches, eyebrow pits and tree plantation to harvest surface runoff and increase infiltration**



Social Measures for Springshed Management

Some of the important social protocols for springshed management are as follows:

- Keeping the recharge area and spring surrounding clear of open defecation, garbage, solid waste, and others
- Construction of a spring box to prevent surface water flowing directly into the spring
- Use of clean utensils to draw water from the spring
- No construction of toilets in demarcated recharge area or near springs
- No application of chemicals (fertilizers, pesticides) in the recharge area or near the spring; replace with eco-friendly methods like composting and integrated pest management
- No cutting of trees in the demarcated 'Protection and Recharge' area
- Keeping the area around the spring clean and green

Ways to Improve Springshed Management Governance

It is important to have local systems based on good governance principles that facilitate and control decision making with regards to spring water use and spring resource management. The local systems may comprise the following:

- Formation of spring water user groups for springs and recharge area management. All castes and groups of different social/economic status should be included in the group, and women's participation encouraged.
- Spring water user groups should have written rules and regulations for spring water management, and penalties for violations of rules.
- A community fund should be established with a nominal monetary contribution once every three months from each household. This is important to ensure that the recurrent costs for maintenance and management of springs and recharge structures can be covered in a sustainable manner.
- Spring discharge, water quality, and rainfall should be monitored regularly to assess the impact of springshed management protocols.
- A yearly water balance should be calculated based on spring discharge and rainfall data to facilitate equitable distribution of spring water.

Planning and Implementation

The planning and implementation of springshed management and governance protocols requires good community mobilization for motivating and convincing land users to invest in, and maintain, spring recharge measures. Social mobilization is also necessary for ensuring gender and social equity and for conflict resolution during the process of designing and implementing protocols. Moreover, the effectiveness and efficiency of the recharge measures are ensured if the technical measures are selected and applied based on proper survey, design, and cost estimations, and when there is coordination between the relevant programmes of agriculture, horticulture, forestry, animal husbandry, infrastructure development, soil and water conservation, and others. Therefore, the implementation of Step 5 demands an interdisciplinary and gender balanced team of social and technical persons with knowledge of the local contexts.

Resources Needed

Table 12 gives a summary of the skills (human resources) and instruments (hardware, software) required to carry out the tasks outlined in Step 5.

Table 12: **Summary of requirements for Step 5**

Types of skill needed	Objective	Time estimate
Soil and water conservation expert	Selection of appropriate measures for different land use types, technical inputs to field technician	3–4 hours per site during selection of measures 1–2 hours per day per site to provide technical inputs to field technician during implementation
Soil and water conservation field technician	To supervise and provide technical inputs to communities and implementers during establishment of recharge measures, and arrange tools and material	7–10 days per site
Community mobilizer	To discuss with farmers and local authorities to acquire land where measures are to be implemented, to arrange tools and material	3–4 days per site
Unskilled labour (about 10–15)	To work on the ground	Usually around 7–10 days per site (but depends on area of recharge zone to be covered and measures to be implemented)
Tools and material (Number/amount of tools and material required depends on size of intervention area and measures adopted)	Tools for technician: measuring tape, clino-compass (one per site) Tools for structural and vegetative measures: A-frame to make contour lines, rope, white powder or ash; spade, shovel, hoe, pick Material for vegetative and agronomic measures: planting material (seeds/plant cuttings, seedlings), locally available biological mulching material such as straw, plant residues, stones, empty sacks	

9 Step 6: Measuring the Impact of Spring Revival Activities

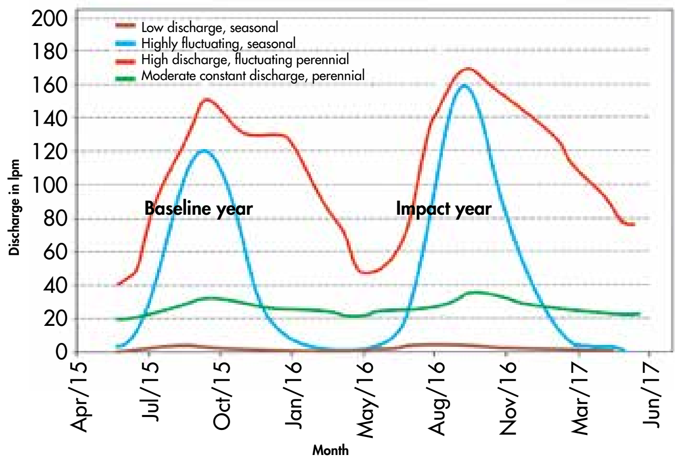
Types of Impact of Spring Revival Activities

The impacts of springshed management are manifested in various forms. They range from a simple increase in spring discharge to improved equity and efficiency in the use of spring water. Continued monitoring of the springshed activities described in the various steps above is necessary to correctly gauge and understand the impacts of a springshed management programme. Springshed management impacts can be broadly categorized into changes in:

- the resource (aquifers) feeding the spring system
- the supply of spring water to users
- the demand for spring water

Figure 57 shows a typical example: the impact on spring discharge after a year for different types of spring in an area with a spring management programme.

Figure 57: **Hydrographs reflecting spring discharge for different types of spring and the change following completion of springshed management work at the end of the baseline year**



Impacts on resource (aquifers)

The impacts on the resource result from changes in the quantity of water available to the spring from the aquifer due to improvements in one or more of the following:

- The quantity of water stored in the aquifer which is reflected in an increase in spring discharge
- The quality of water stored in the aquifer which is reflected in improved spring-water quality
- Better management of the recharge area – it is protected, litter free, and rules and norms for land use in the recharge area are well laid out

Improved supply of spring water

Supply, including access to spring water and/or distribution, can be improved through appropriate engineering systems, improved access points, and better protocols for managing spring tanks and distributing water equitably and efficiently to communities. Adequate attention should be paid to both engineering design and social equity when constructing any civil engineering structures, in order to ensure that socially marginalized populations also benefit from these investments.

Improved demand management for spring water

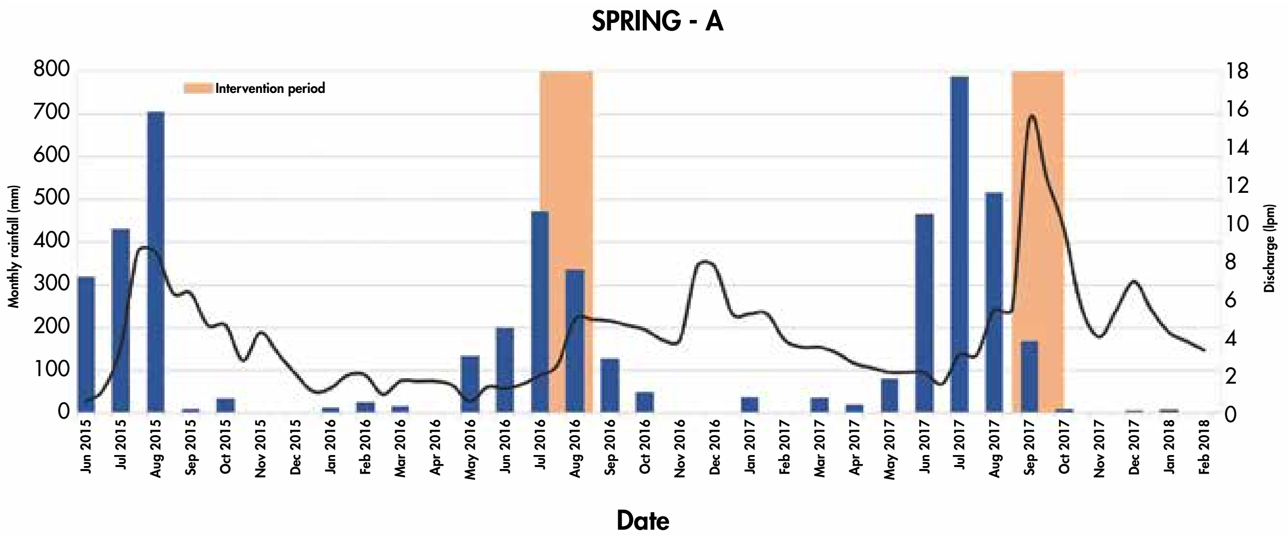
Social norms can be established regarding conservation measures, protection of recharge zones, and rules in accessing spring water, as well as practices that reduce wastage and contamination at the source.

Measuring Impacts

Measuring hydrological impacts

Step 2 (Chapter 4) describes the setting up of a long-term monitoring system for selected springs. The data from this system should be used to measure the hydrological impacts of the spring revival activities. The impact is measured by comparison with the baseline situation as well as comparison with a comparable 'non-intervention' situation. For example, 20 springs are being monitored in a programme, but only four have undergone intervention for spring revival. The discharge of these four is plotted before and after intervention, together with rainfall, to identify any increase in discharge giving a 'before-after' comparison. Figure 58 shows a typical hydrograph plot for 'Spring A' illustrating an increase in discharge during the dry season after an intervention.

Figure 58: **Hydrograph of Spring A showing an increase in discharge after intervention**



A few of the other non-intervention springs with similar hydrogeology and typology and in a similar area (especially in terms of rainfall) are selected ('control springs'), and their hydrographs compared with those from the springs with intervention. This provides an approximate 'with-without' comparison. For example, Figure 59 shows the hydrographs from two springs situated in a similar hydrogeological setting and located on the same topographic slope: treated Spring B and control Spring C. The discharge from Spring B has risen noticeably, while that from Spring C has not. These examples show the importance of hydrological data for monitoring impacts.

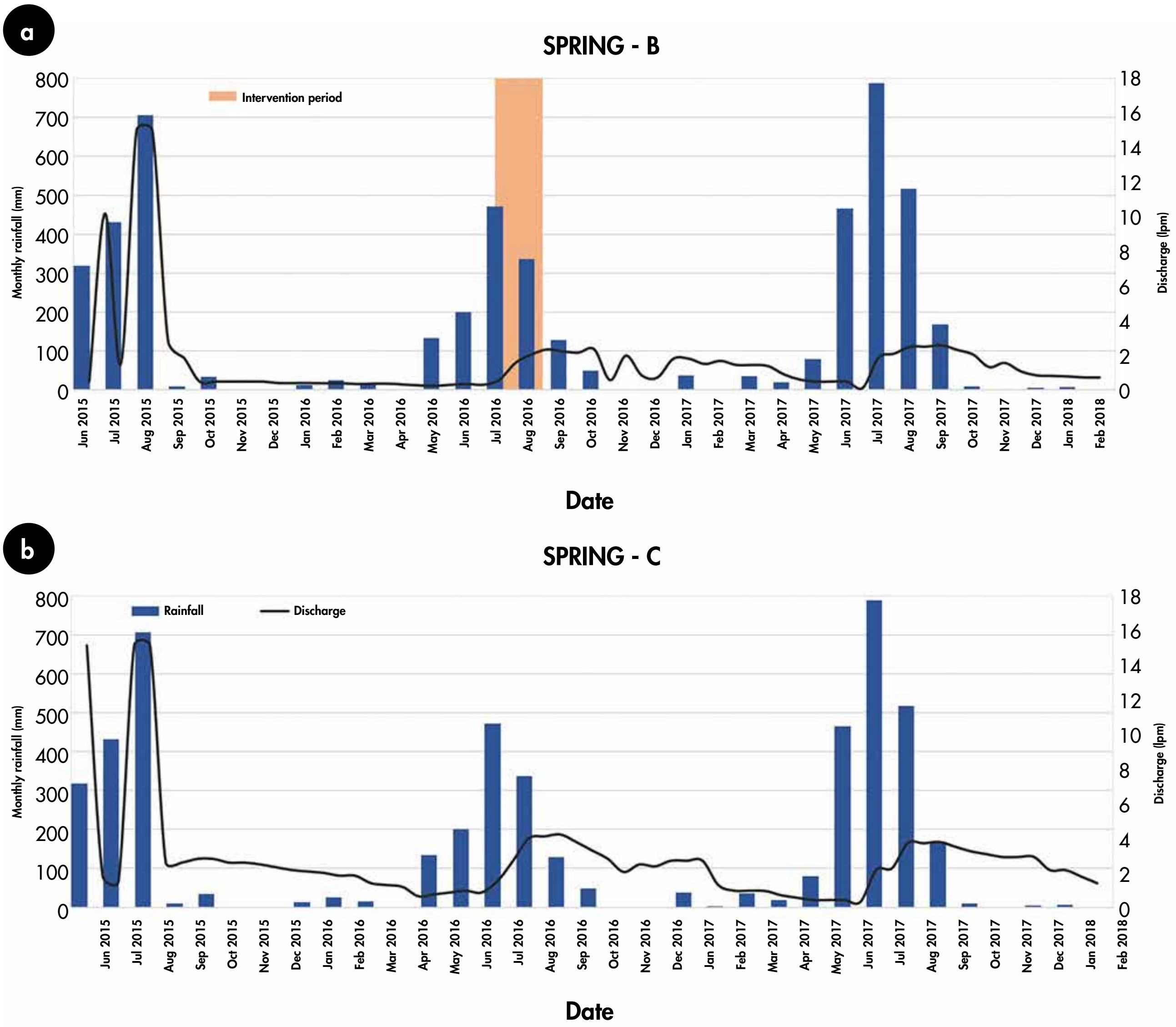
Measuring socio-economic impacts

Step 3 (Chapter 5) describes the collection of various types of socio-economic data through instruments like FGDs, KIIs, and questionnaire surveys. The data collection exercise should be repeated post-intervention in Step 6 to gather evidence about the impact of the intervention on water access for local people. Again, this analysis can be carried out in terms of a 'before-after' and 'with-without' comparison.

Resources Needed

Resources needed are same as in Step 2 where spring discharge and water quality are monitored and Step 3, where we conduct socio-economic surveys, FGDs and KIIs to understand people's perception on various issues, including that of adequacy and reliability of spring water availability and its quality.

Figure 59: **Hydrographs of (a) treated spring (Spring B) and (b) control spring (Spring C)**



10 The Way Forward

Hydrogeological science should form the basis for any work related to watershed or springshed management, in fact for any work on groundwater. The location and extent of recharge areas are governed purely by the local hydrogeology and not by administrative or socioeconomic boundaries. The complex geology, spring discharge locations, and site specific recharge areas force a shift in perspective in studies dealing with spring water away from the classical 'ridge to valley to contiguous valley' approach. It requires a paradigm shift in the way we think about watersheds and springsheds. It is essential to raise awareness in the local community about the role of hydrogeology in governing recharge areas, the importance of protecting recharge areas, and the importance of collecting data on spring water to inform planning. Both the spring source and the underlying aquifer should be considered as 'common pool resources' and managed accordingly.

In terms of implementation, there are two proven ways of moving forward. The first is the government led implementation model. So, far, several states in India have taken up programmes for spring revival. Sikkim has been a pioneer and most of the other states have followed the Sikkim model, whereby a nodal government agency (RM&DD in Sikkim) is in charge of implementation of the spring recharge programme, in collaboration with a host of other civil society and scientific organizations. For example, ACWADAM in partnership with People's Science Institute (PSI) and Central Himalayan Rural Action Group (CHIRAG), has provided basic training in hydrogeology to all such state government implementing agencies. Work on similar lines to Sikkim has commenced in the Indian states of West Bengal and Meghalaya. These states have, in turn, leveraged funds from other national programmes, such as MGNREGS, for involving communities in digging recharge structures and paying them based on national wage norms. Bhutan also plans to embark on a national spring revival programme along similar lines, whereby it will impart training to field staff in its watershed management and forestry divisions to identify recharge areas using field geology, and then implement recharge interventions in identified recharge areas through existing government programmes. This state-led model of implementation, when done in conjunction with other knowledge and implementing partners, has proved to be both successful and scalable. However, the majority of these programmes do not maintain long-term databases on spring discharge before and after intervention, and it is difficult to carry out a rigorous evaluation of project impact in terms of actual volume of enhanced recharge and improved quality.

The second model is the NGO led model implemented in Uttarakhand state of India, in which NGOs train their field staff and local communities in basic hydrogeology using donor funding, and then carry out recharge area demarcation and field implementation work together with the communities. This model is quite successful in building up a long-term evidence base (as most NGOs do a good job of monitoring and data management), but without explicit government support, scaling up remains a challenge.

Therefore, an ideal combination is a model that combines the strength of government-led models in terms of scalability and of NGO-led models in terms of monitoring and evaluation of impacts. Knowledge and scientific organizations like ICIMOD and ACWADAM can play an important role in creating a scientific evidence base for the efficacy of spring revival programmes in the HKH region. It is expected that as water scarcity issues in the mid hills of the HKH become more acute, more and more countries in the region will adopt a similar methodology for reviving springs. This manual is designed to serve these various stakeholders – be it technical staff of government agencies or relevant NGOs.

In terms of the way forward in scientific methods and knowledge generation, it is possible to supplement the identification of recharge areas based on field geology (as outlined in this manual) with stable isotope methods, which can help confirm the recharge pathway and the size and storage capacity of spring aquifers. While basic isotope analysis tools are now available in many scientific agencies and universities, the main challenge remains the relatively high cost and time taken for the analysis. We suggest that in the interests of scalability, the field geology method that this manual espouses remains the main method for identification of recharge areas, but wherever resources and technology permit, stable isotope analysis be carried out for additional verification. Further details about this method can be found in IAEA (2004) and Dhakal et al. (2014).

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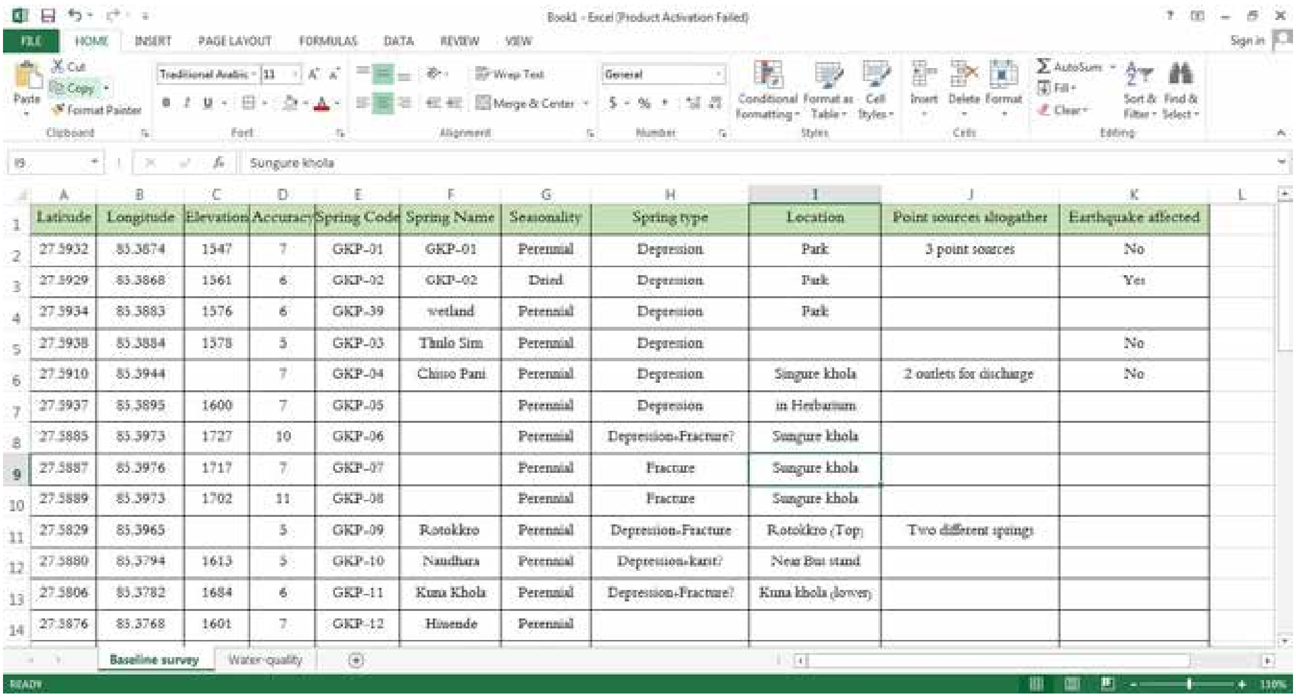
Annexes

Annex 1: Sample Template in Microsoft Excel for Entering Baseline Data

Microsoft Excel is used to store data collected in the field. One Excel workbook should be maintained to feed in all the data related to springs mapped in a particular region. The spring location (latitude, longitude, elevation), spring code, and spring name, should go into the first columns followed by other related data (Figure A.1).

Multiple sheets can be created within one workbook to keep data segregated. For example, baseline socio-economic data in the first sheet, discharge data in the second, water quality in the third and so on. This helps in understanding and retrieving data for later analysis.

Figure A.1: **Example of an Excel Workbook showing location of the spring (Latitude, Longitude, Elevation), and spring code, name and type**



Latitude	Longitude	Elevation	Accuracy	Spring Code	Spring Name	Seasonality	Spring type	Location	Point sources altogather	Earthquake affected
27.5932	85.3874	1547	7	GKP-01	GKP-01	Perennial	Depression	Park	3 point sources	No
27.5929	85.3868	1561	6	GKP-02	GKP-02	Dried	Depression	Park		Yes
27.5934	85.3883	1576	6	GKP-39	wetland	Perennial	Depression	Park		
27.5938	85.3884	1578	5	GKP-03	Thulo Sim	Perennial	Depression			No
27.5910	85.3944		7	GKP-04	Chiso Pani	Perennial	Depression	Singure khola	2 outlets for discharge	No
27.5937	85.3895	1600	7	GKP-05		Perennial	Depression	in Herbarium		
27.5885	85.3973	1727	10	GKP-06		Perennial	Depression+Fracture?	Sungure khola		
27.5887	85.3976	1717	7	GKP-07		Perennial	Fracture	Sungure khola		
27.5889	85.3973	1702	11	GKP-08		Perennial	Fracture	Sungure khola		
27.5829	85.3965		5	GKP-09	Rotokkro	Perennial	Depression+Fracture	Rotokkro (Top)	Two different springs	
27.5880	85.3794	1613	5	GKP-10	Naudhara	Perennial	Depression+karst?	Near Bus stand		
27.5806	85.3782	1684	6	GKP-11	Kuna Khola	Perennial	Depression+Fracture?	Kuna khola (lower)		
27.5876	85.3768	1601	7	GKP-12	Himende	Perennial				

Annex 2: Terms of Reference (TOR) for Data Collector

The data collector will carry out the following tasks.

Measure spring discharge weekly/ bi monthly/ monthly, as per the requirement of the project.

Total number of springs to be monitored: ....

Number of wards covered by the research site: ....

Number of springs covered in each ward: ....

Measure rainfall data

Measure daily rainfall.

Standard time for measurement: 8:45 am

Measure in-situ water-quality parameters like pH, EC, TDS, and salinity using water-quality tester

Enter data into standard format as provided

Report the updated records to focal person or local facilitator.

Send monthly data to agency office concerned

Qualifications

Should measure discharge and rainfall accurately.

Should enter collected data into the data entry format properly and accurately.

Preference should be given to women/dalits.

Should be a local or locally-based working person.

Annex 3: Focus Group Discussion Checklist

1. General

Area:	
VDC/Panchayat:	
Ward Nos:	
Village/settlement:	
No. of households:	
Average family size:	
Total population:	
Male/female ratio:	

2. Water Resources by Type

2.1 Rivers

2.1.1 What are the major rivers and streams in the area?

River/stream name	Location and ward/name of the place	Water availability (seasonal, permanent)

2.1.2 For what purpose is the river water used?

Drinking:

Livestock:

Irrigation:

Other:

2.1.3 Have the flows of rivers changed over the past 10 years? (increased, decreased, or remained the same)

2.1.4 If water availability has decreased, how do you cope with it?

Drinking:

Washing, cleaning:

Irrigation:

Livestock:

Other:

2.2 Ponds

2.2.1 How many ponds exist in the area (ward number wise) and how are they distributed geographically?

Name/ Location*	Permanent	Seasonal	Completely dry
* Location can be up or down or east, west, north, south, etc. depending on the cluster			

2.2.2 For what purposes are the ponds used (religious, recreational, watering animals, fishery, washing, cleaning, and groundwater recharge)?

2.2.3 Which of the ponds mentioned above have performed well in terms of water availability and what is the reason for this?

2.2.4 Please give the location of those ponds that may be contributing to recharge of springs downstream.

2.2.5 How have ponds changed in the past 10 years in terms of number, water depth, quality, etc.? And why?

2.2.6 Do you think there is a connection between ponds and springs? Please give examples.

2.2.7 Do you plan to build ponds (types) for the purpose of recharging springs in your locality?

2.2.8 Where are suitable areas located for this purpose? (History, community…..)

2.3 Dug wells and bore wells

2.3.1 Are there dug wells in your ward/VDC, if so how many and since when? What is the water used for?

2.3.2 Do you use deep borings for water? If so, how many, when was the first deep boring drilled, who owns it, how much does it cost, what is the water used for?

2.3.3 If yes, how many are in use and how are they distributed geographically?

- Dugwells

Name/ Location*	Permanent	Seasonal	Remarks
*Location can be up or down or east, west, north, south, etc. depending on the cluster			

- Deep bores

Name/ Location*	Permanent	Seasonal	Remarks
*Location can be up or down or east, west, north, south, etc. depending on the cluster			

2.3.4 Are they reliable sources of water for drinking? Which is better?

- Dugwells:
- Deep borings:

2.3.5 How does the depth of water fluctuate between dry and wet seasons? (Unit: foot, metre, haat, bitta, other specify…)

- Dugwells:
- Deep borings:

2.3.6 What is the quality (for drinking) of water from these sources?

- Dugwells:
- Deep borings:

2.3.7 Do you get sufficient water for all your needs? If not, how do you prioritize?

- Dugwells:
- Deep borings:

2.3.8 Have the number increased or decreased in the past 10 years? What about the water table? Why?

- Dugwells:
- Deep borings:

2.4 Rainwater harvesting:

2.4.1 Do you harvest rain water in your locality? When was the first rainwater harvesting scheme introduced? Who brought that idea for the first time? (Institutions or someone from the community)

2.4.2 How many households use this practice now?

2.4.3 How has the number of households using this practice increased (or decreased) over the past 10 years

2.4.4 What kind of water harvesting system is commonly used (collection in drums and buckets, open storage tank, closed storage tank, plastic pond, groundwater recharge, etc.)?

2.4.5 Does any HH have any permanent rainwater harvesting structure (with all components of rooftop water harvesting scheme)? If yes, how many HHs have them?

2.4.6 What is the average capacity of household level rainwater collection systems?

2.4.7 What are the preferred uses of water from this source?

2.4.8 For how many months is the harvested water sufficient?

2.4.9 What is the level of acceptance for rainwater harvesting? Do you think this is a sustainable source of water for household use?

3. Sources of water for specific uses

3.1 For domestic use

3.1.1 What are the major sources of water for domestic use?

System	Number	Beneficiary households	Quality	Change in past 10 years	
				Quality	Quantity
Tap water (government)					
Tap water (private)					
Spring water (mul, dhara, kuwa)					
Dug well and bore well					
River/stream					
Tanker					
Rainwater harvesting					
Pond					

3.1.2 Is the quantity of water sufficient (from above sources) for all your domestic needs (including drinking, cleaning, washing, sanitation)?

3.1.3 What changes in quantity and quality of water from different sources (mentioned above) have you noticed in the past 10 years?

3.1.4 If there has been a decline, how do you cope with it?

3.2 Sanitation

Type	Volume of water used	Source of water	Number of households
Pit latrine			
Pakka latrine			
No latrine			

3.2.1 Is sufficient water available for all your sanitation needs? If not, how do you cope with it?

3.3 Irrigation

3.3.1 Major sources for irrigation:

Source	Type (permanent, seasonal)	Irrigated area (ropani)	Beneficiary households	Trend (Increasing/ decreasing)
River/stream				
Spring (mul, kuwa, dhara)				
Ponds				
Canal/channel/raj kulo				
Rainwater harvest				
Inar/deep boring				
Other				

3.3.2 Methods of irrigation:

Method	Trend (increasing/ decreasing)	Source	Remarks
Flooding			
Polythene pipes			
Sprinklers/drip			
Others			
Ridge furrow (eg: potato)			
Pitcher			

3.3.3 Is the quantity of water sufficient for all your agricultural needs (including irrigation and livestock)?

3.3.4 How are the irrigation systems managed (in terms of institution – formal/informal such as user groups; rules and regulations)?

3.3.5 What changes in quantity and quality of water for agricultural use have you noticed in the past 10 years?

3.3.6 If there has been a decline in quantity, how do you cope with it?

3.4 Other users:

3.4.1 Who are the other users of water in this area (e.g., hotels, industry)?

Number of hotels:

Number of industries:

3.4.2 What are the sources used for this and what is the situation regarding sufficiency, quality, etc.?

3.4.3 Impact on water availability for locals/community due to other users?

4. Land use and land related activities

4.1 Land use

Land use	Estimated area (%)	Notes and remarks
Agriculture		
Forest		
Grazing		
Settlements		
Degraded lands		
Other, specify		

4.2 Agricultural practices

4.2.1 What are the proportions of khet and bari land? (*In %*)

Khet:

Bari:

4.2.2 What are the major crops and cropping patterns?

Khet:

Bari:

4.2.3 What changes have taken place in the past 10 years in:

Land use?

Crops?

Cropping patterns?

Production and yields?

4.3 Forests

Forest name	Type*	Condition	User/ beneficiary households (no.)
*government, private, community, leasehold, religious, national park/reserve, others			

4.3.1 What are the natural forest species?

4.3.2 What are the species used in afforestation? History of past 10 years.

4.3.3 How have forests changed over the past 10 years in terms of:

Area under forest?

Forest condition?

Species of trees and other vegetation?

4.3.4 Any changes observed in water availability after planting any particular plants/ species in the locality? History of 10 years?

4.3.4 In your experience, which species of plant are good and bad for water restoration?

4.3.6 What are the water resources available within the forests?

Rivers/streams:

Springs (mul, kuwa, dhara):

Ponds:

4.3.7 How are the water resources in the forests utilized?

5. Water collection and allocation for domestic use (Preferably ask women)

5.1 Who fetches water for household use (men, women, children)?

5.2 How much water does one person collect per day?

5.3 How many times does one person have to collect water per day?

5.4 How much water does one household use per day?

5.5 How much time does it take to fetch water for household use?

5.6 How is water allocated for household use?

Drinking and cooking: ....%

Dishwashing..........................%

Washing clothes........................%

House cleaning...........................%

Toilet..%

Other (specify)... ....%

6. Institutional and Governance aspects

6.1 Which institutions are involved in managing water resources?

Springs:

Ponds:

Wells:

Deep boring:

Irrigation canals:

6.2 Have you noticed any conflicts regarding water use/distribution in your locality?

6.3 How are conflicts resolved?

7. Upstream areas

7.1 What is the condition of upstream areas of water resources used by the community?

4.2 Have there been any major changes over the past 10 years in terms of infrastructure, housing, land use?

4.3 Are there any plans for development and land use changes in the upstream areas in the near future?

8. Climate change

8.1 Over the past 10 years, have there been any major changes (in terms of amount and timing) in:

Temperature:

Rainfall:

Extreme events e.g., floods, droughts, hailstones, landslides, cloudbursts:

8.2 How did they impact on the water sources in the area?

8.3 How did people cope with impacts?

9. Groundwater recharge practices?

9.1 Are you aware (directly/indirectly) of concept of groundwater recharge?

9.2 Have you ever implemented any techniques?

9.3 What kind of techniques have you practised so far?

10. Migration

10.1 Has anyone migrated outside from your area/village?

10.2 If yes, then what was the reason for migration? How many HHs have migrated? Where did they migrate to?

10.3 Has any household or community migrated due to water shortage in your locality?

List of participants

Sn.	Name of participant	Age	Sex	Ward number (residence)	Caste/ethnic group	Phone number/ postal address (if applicable)	Signature	Occupation
1								
2								
3								
4								
5								
6								
7								

Annex 4: Checklist for Key Informant Interviews

(The person or persons who manage the spring, or are most knowledgeable about the spring, should be interviewed)

1. Name of the tap/spring :	2. Date of interview (Nepali):
3. Time of interview: start: / finish:	
4. Name of interviewer:	
5. Name of respondent:	6. Phone number of respondent, if any:
7. GPS location of tap: N E Elevation: m	
8.Ward no. where tap is located:	9. Landmark identification for tap, if any:
10.Name of the village/gaun where tap is located:	11. Ownership of spring/ tap from a spring (private = 1; community = 2; any other specify = 3):
12. Number of households dependent on spring/ tap from a spring:	13. When was tap constructed (year)?
14. Who provided financial support for construction of the tap?	15. Name of spring from where water is supplied to this tap:
16. Type of spring (dhara = 1, kuwa = 2, kholsa = 3, other = 4):	
17. GPS location of spring: N E elevation: m	
18. Distance of tap from spring (metres):	
19. Name of the village/gaun where collection tank is located:	20. Capacity of collection tank (in ltr)
21. GPS location of collection tank: N elevation: m	
22. Distance of collection tank from tap (m):	23. From how many additional sources is water being collected in the collection tank? (1 = just one; 2 = two; 3 = three; 4 = more than four): Note: ignore, if the respondent collects water directly from the spring source.
24. If more than one, can you please name additional sources? Note: ignore if respondent collects water directly from the spring source	25. If more than one, why did you collect water from additional sources? (1 = not enough water; 2 = low pressure; 3 = not reliable (not delivered on time/frequent breakdowns/dried up); 4 = poor quality/dirty; 5 = due to frequent landslides around source; 6 = physically challenging; 7 = any other, specify______) Note: ignore if respondent collects water directly from the spring source.
26. How is the quality of water from tap/collection tank? (very good = 1; good = 2; fair = 3; poor = 4; very poor = 5):	27. Is there anyone responsible for management and maintenance of this tap/collection tank? (yes = 1; no = 2; everyone is responsible = 3):
28. If yes, name and contact number of that person or any formal/informal management committee, if any?	
29. Are there any operational rules for tap/collection tank: (Clues: what happens when there is less water in tap, for how long is tap open, anyone who takes care of closing and opening the tap, any rules on connecting loose pipes from tap)	30. Is there any specific rule for collecting water from tap/collection tank? (Clues: first come first serve; rationing in dry season; open for specific time; based on family size; only allowed for people from this village/ward; no rule etc.)
31. Is there any charge taken for maintenance and repair of the tap/collection tanks? (yes = 1; no = 2):	32. If yes, how much per year?

Annex 5: Questionnaire Survey for Spring Water Users

Instruction: In a sample survey, interview the specified number of respondents (adults who come to fetch water) for the tap/spring/collection tank. When the required number of surveys is complete, move to another tap sourced to the same spring or the spring source itself. When conducting the survey, make sure that each respondent represents a unique household.

Part 1: General information

1.1 Tap/spring code. # : ☐☐☐☐☐☐☐☐☐☐☐ District/Ward/Spring no./Tap no./Respondent no			
1.2 Date of interview (Nepali):			
1.3 Time of interview: Start: /Finish:		1.4 Name of interviewer:	
1.5 Name of supervisor who has checked the questionnaire:		1.6 Village name:	
1.7 Ward number:		1.8. VDC name:	
1.9 Telephone/mobile no. of respondent (if any):			
1.10 GPS locations of :			
Spring:	N-	E-	Elev.(m)-
Tap:	N-	E-	Elev.(m)-
Collection Tank:	N-	E-	Elev.(m)-

Part 2: Household information (Household means people who eat from the same kitchen)

2.1 Name of head of household:	2.2 Age of head of household (years):
2.3 Sex of head of household (1 = M; 2 = F):	2.4 Caste of household: (1 = Brahmin; 2 = Chhetri; 3 = Dalit; 4 = Newar; 5 = Tamang; 6 = Sherpa; 7 = Gurung; 8 = Sanyashi; 9 = other, specify_______)
2.5 Level of education of head of household (1 = non-literate; 2 = just literate; 3 = primary school; 4 = lower secondary; 5 = secondary; 6 = higher secondary; 7 = graduate and above):	2.6 Name of respondent (if different from head of household. If same, repeat the name)
2.7 Age of respondent in years (if different from head of household. If same, repeat same age):	2.8 Sex of respondent (if different from head of household. If same, repeat same sex) (1 = M; 2 = F):
2.9 Relationship with head of household (1 = self; 2 = father; 3 =mother; 4 = son; 5 = daughter; | 6 = wife; 7 = husband; 8 = daughter-in-law; 9 = other, specify______):	2.10 Years of education respondent (if different from head of household. If same, repeat same level of education):
2.11 Total number of household members:	2.12 Sources of income for the entire household for whom water is collected (1 = crop cultivation; 2 = livestock; 3 = remittances; 4= business; 5 = government service; 6 = private service; 7 = agricultural labour; 8 = non-agricultural labour; 9 = other, specify______) [You can choose more than one option]:

2.13 Of the sources of income mentioned, which is THE MOST important:	2.14 Total household income of all household members (monthly): (1 = < Rs. 999; 2 = Rs. 1,000 to Rs. 4,999;3 = Rs. 5,000 to Rs.9,999; 4 = Rs.10,000 to Rs.19,999; 5 = Rs. 20,000 to Rs. 49,999; 6 = > Rs. 50,000)

Part 3: Tap/ spring source specific questions

Seasonal water collection data				
Season	Dry season (Falgun- Jestha)		Wet season (Asar– Magha)	
3.1 No. of times in a day when water is collected?				
3.2 No. of days in the week when water is collected (1-7)?				
3.3 No. collected per trip?	gagri		gagri	
	drums		drums	
	buckets		buckets	
	jerkins		jerkins	
	cans		cans	
	bottles		bottles	
	other specify___________		other specify___________	

3.4 How long (in minutes) does it take to fill up your gagri/vessel/ drum/bucket etc?			3.5 For how many years have you been collecting water from this tap/ spring source?	
Type of vessel	Capacity of vessel (ltr)	Time taken (minutes)		
Gagri				
Drum				
Bucket				
Jerkin				
Other				
3.6 How far (metres) is your home from this tap/ spring source?			3.7 How long (in minutes) does it take to fetch water (two-way travel time and waiting time)?	
3.8 For what purposes do you use this water? (1 = drinking; 2 = washing clothes; 3 = other domestic use such as washing utensils; 4 = livestock; 5 = irrigation; 6 = making raksi/jand; 7 = religious purposes; 8 = karesha bari irrigation; 9 = other, specify_________) you can choose more than one :				
3.9 Are you allowed to collect as much water as you want in a day? (1 = yes, always; 2 = no, never; 3 = sometimes):			3.10 If your answer to Q. 3.9 is, no, never (=2) or sometimes (=3), then how many gagris can you collect at a time in	
			Dry season	Wet season
3.11 Do you have to stand in a queue to collect water? (1 = yes, always; 2 = no, never; 3 = sometimes):				

<table>
<tr><td colspan="2">3.12 List all rules for water collection, if any? (Clues: first come first serve; rationing on dry seasons; open for specific time; based on family size; only allowed for people from this village/ward; no rule, etc</td></tr>
<tr><td>3.13 Perception of quantity of water from the spring source?
(1 = always sufficient; 2 = usually sufficient; 3 = sometimes sufficient; 4 = rarely sufficient; 5 = never sufficient):

Note: here spring source means the main source/mool from where water is collected.</td><td>3.14 Has the volume of water in the spring source changed over the past 10 years? (1 = increased; 2 = decreased; 3 = no change):

Note: here spring source means the main source/mool from where water is collected.</td></tr>
<tr><td colspan="2">3.15 If volume (quantity) of water has changed in the source (increased or decreased), what were the reasons?</td></tr>
<tr><td>3.16 Perception on quality of water from spring source?
(1 = very good; 2 = good; 3 = fair; 4 = poor; 5 = very poor):

Note: here spring source means the main source/mool from where water is collected.</td><td>3.17 Has the quality of water in the spring source changed over the past 10 years? (1 = improved; 2 = declined; 3 = no change):

Note: here spring source means the main source/mool from where water is collected.</td></tr>
<tr><td colspan="2">3.18 If quality of water has changed (improved or declined), in the source what were the reasons?</td></tr>
<tr><td>3.19 Perception on water source's reliability (dependability)?
(1 = always reliable; 2 = usually reliable; 3 = occasionally reliable; 4 = rarely reliable; 5 = never reliable):

Note: here spring source means the main source/mool from where water is collected.</td><td>3.20 On a scale of 1-5, how dependent are you on this specific tap/ spring source? (Scale 1 = no dependence; 2 = very low dependence; 3 = low dependence; 4 = moderately dependent; 5 = high dependence)</td></tr>
<tr><td colspan="2">3.21 On a scale of 1-5, what is the condition of the following (1 = very good; 2 = good; 3 = fair; 4 = poor; 5 = very poor)
Source:
Collection tanks:
Pipes:
Tap:</td></tr>
</table>

Part 4: Information on additional and other available sources of water:

4.1 In the past 10 years have you changed the source from which you collect water? (1 = yes; 2 = no):	
4.2 If the answer to question 4.1 is "Yes" why? (1 = insufficient water in previous source; 2 = more water in the new source; 3 = tap water available at or near home; 4 = easy to use seasonal springs in monsoon season; 5 = other, specify_____________) You can write more than one reason:	4.3 Apart from this primary spring source do you also get water from other spring sources? (1 = yes, 2 = no)
4.4 If yes to Q 4.3, can you name those springs? Note: this is a specific question. Ignore if respondent collects water from non spring source	4.5 Name the source from which you used to collect water before this tap/water supply system was built? Note: if water is fetched directly from spring source, then ask for the spring source.
4.6 How far was that source from your house (metres)? Note: if water is fetched directly form spring source, then ask for the spring source.	4.7 Do you also collect water directly from 1. Loose pipes connected to collection tanks, taps or spring source: 2. Collection tank without pipe: 3. Any other spring: (eg: seasonal springs or any other springs besides the primary spring)

(Rank according to importance):

Instruction: Ask questions vertically by purpose for which water is used…….

Choose ALL available water sources used for household needs and agricultural needs: **(MENTION ALL)	Purposes for which water is used and water sources ranked according to their importance											
	Drinking water		Domestic water (other than drinking water)		Water for livestock		Water for irrigation		Type of irrigated land (Tick)		Water for other purposes	
	Tick	Rank (1 = most imp)	Tick	Rank (1 = most imp)	Tick	Rank (1 = most imp)	Tick	Rank (1 = most imp)	Karesha Bari (kitchen garden)	Khet	Tick	Rank (1 = most imp)
4.8 Dharas (springs)												
4.9 Kuwas (springs)												
4.10 Kholas (rivers)												
4.11 Kulos (canals)												
4.12 Kholsa (streams)												

Choose ALL available water sources used for household needs and agricultural needs: **(MENTION ALL)	Purposes for which water is used and water sources ranked according to their importance											
	Drinking water		Domestic water (other than drinking water)		Water for livestock		Water for irrigation		Type of irrigated land (Tick)		Water for other purposes	
4.13 Piped water supply (from springs)												
4.14 Piped water supply (from sources other than springs)												
4.15 Rainwater harvesting (unorganized/ organized with system components)												
4.16 Rainwater for irrigation												
4.17 Other (specify)												
4.18 After obtaining water from ALL of your different water sources, how well are your household's water needs met? (1 = always meets our needs, 2 = usually, 3 = occasionally, 4 = rarely, 5 = never):												

Part 5: Water scarcity and water crisis perception

5.1 List all problems faced while collecting water?	
5.2 Overall, do you think there is a water crisis/problem in your locality? (1 = yes; 2 = no):	5.3 On a scale of 1-5, how concerned are you about the possible drying up of this source? (scale 1 = not concerned; 2 = hardly concerned; 3 = less concerned; 4 = moderately concerned; 5 = very concerned)
5.4 If yes to Q 5.2, What are the best practices you/ your community has adopted to cope with water scarcity? (Clues: rainwater harvesting; collect water from nearby sources; control in distribution in season of scarcity; lock taps/pipes to control open flow etc)	
5.5 Any suggestions on how to improve water supply from the existing distribution system? :	

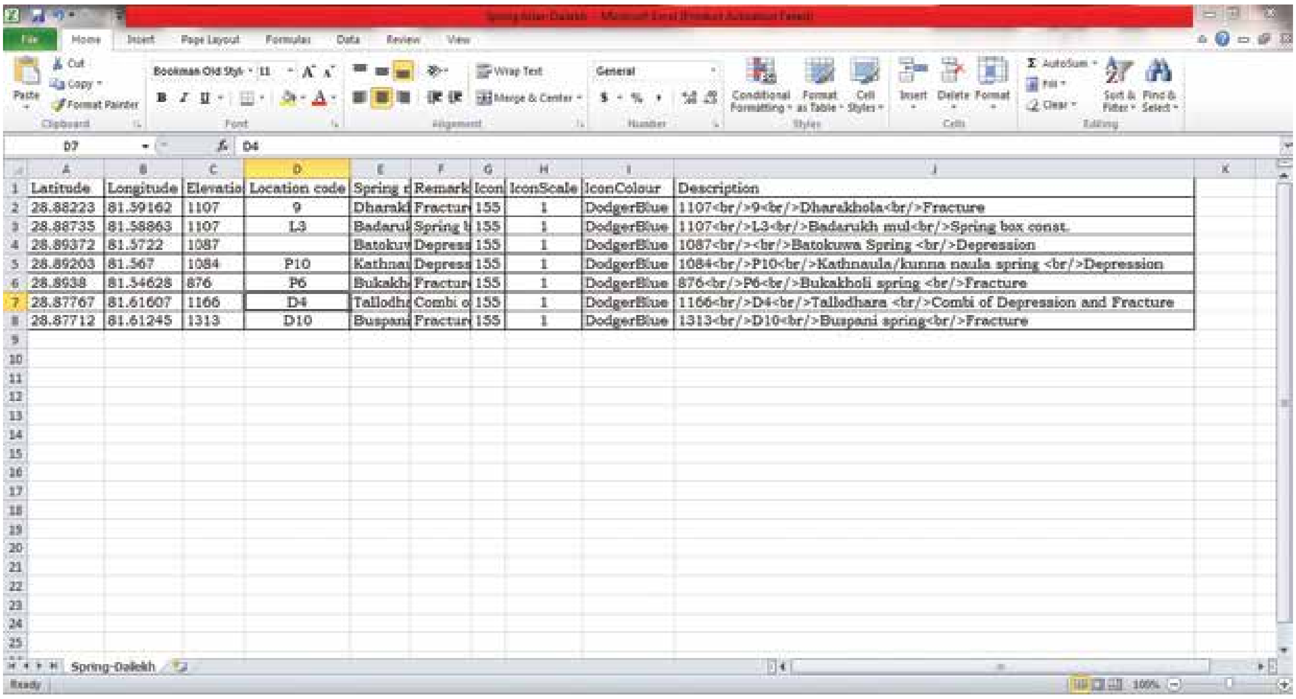
Annex 6: Field Data Compilation to Produce Collected Information in Google Earth

Annex 6A

1. Data compilation in MS Excel.

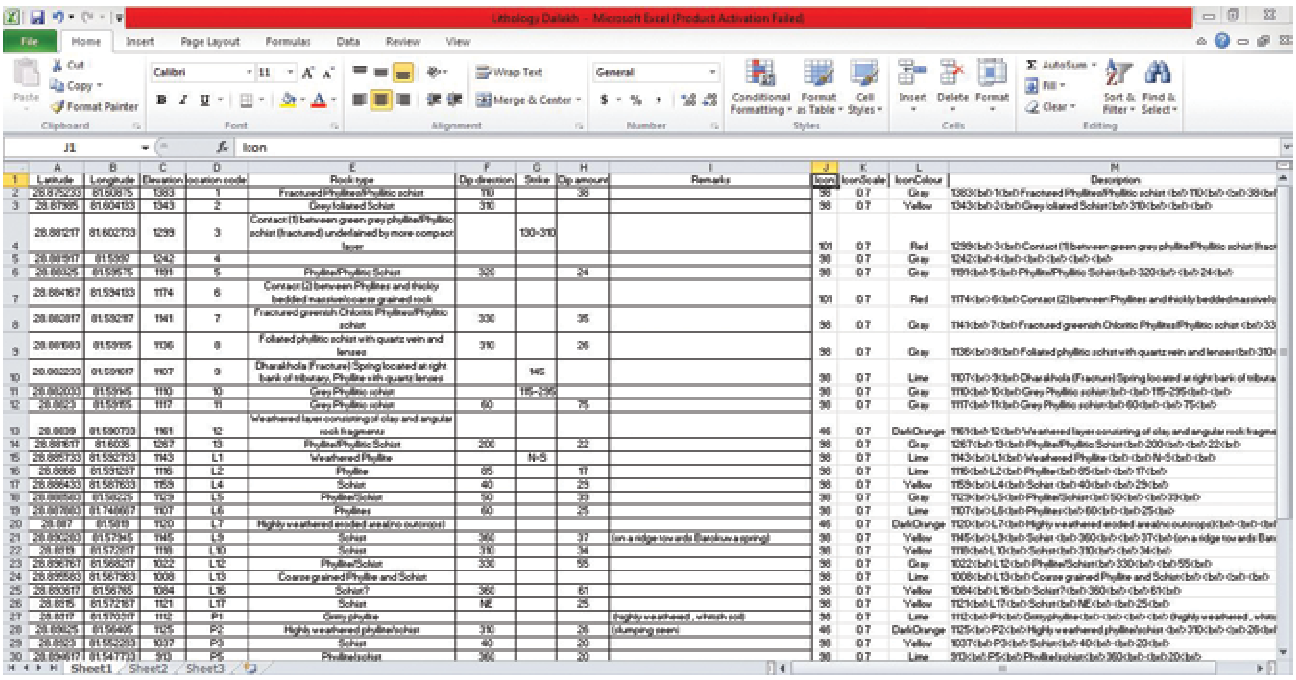
- Field data need to be fed into Excel sheet in the format given in the figures below.
- Make three separate workbooks for spring locations, rock formation, and fracture/joint readings.
- Using simple formula (& "
"&) all the information for a particular location can be clubbed and viewed in Google Earth. (Figures A.2, A.3)

Figure A.2: **Excel sheet with spring details**



Latitude	Longitude	Elevatio	Location code	Spring r	Remark	Icon	IconScale	IconColour	Description
28.88223	81.59162	1107	9	Dharakl	Fractur	155	1	DodgerBlue	1107 9 Dharakhola Fracture
28.88735	81.58863	1107	L3	Badarul	Spring b	155	1	DodgerBlue	1107 L3 Badarukh mul Spring box const.
28.89372	81.5722	1087		Batokuv	Depress	155	1	DodgerBlue	1087 Batokuwa Spring Depression
28.89203	81.567	1084	P10	Kathnau	Depress	155	1	DodgerBlue	1084 P10 Kathnaula/kunna naula spring Depression
28.8938	81.54628	876	P6	Bukakh	Fractur	155	1	DodgerBlue	876 P6 Bukakholi spring Fracture
28.87767	81.61607	1166	D4	Tallodh	Combi o	155	1	DodgerBlue	1166 D4 Talladhara Combi of Depression and Fracture
28.87712	81.61245	1313	D10	Buspani	Fractur	155	1	DodgerBlue	1313 D10 Buspani spring Fracture

Figure A.3: **Excel sheet with lithology data**



2. Converting Excel data into Google .kml file

Open www.earthpoint.us website and go to the "Excel to kml" tool available on the website as shown below.

- Using the "Browse" option, choose the Excel file created for various data sets.
- Press "View file on web page, Check for errors" to find any errors in the Excel data.
- Using the "Browse" option, again select the file and choose the "View on Google Earth" option which then exports the Excel data as .kml format in downloads which can be accessed using Google Earth Pro (Figure A.4).

Importing the .kml file in Google Earth yields information in the form of a placemark for every location mapped which is then further integrated to produce a geological map (Figure A.5).

Figure A.4: **www.Earthpoint.us website outline gallery**

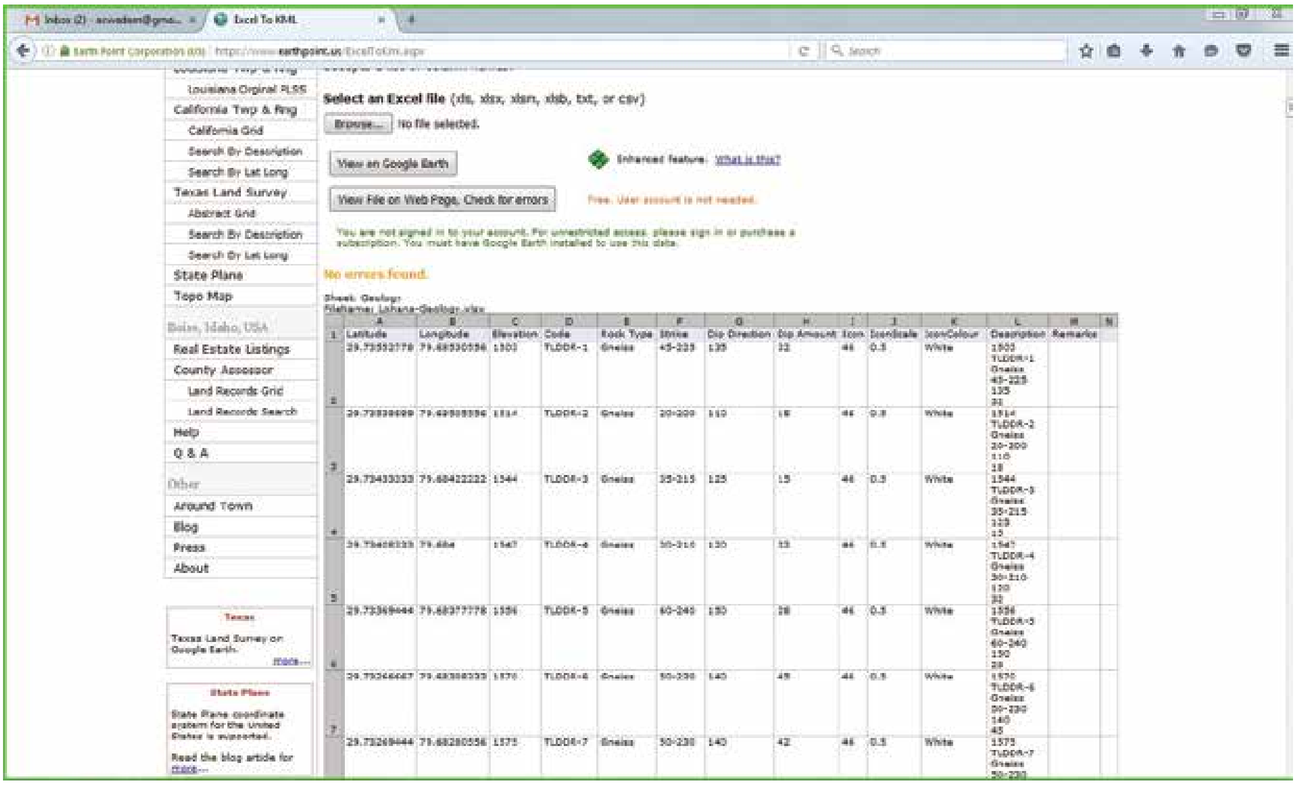
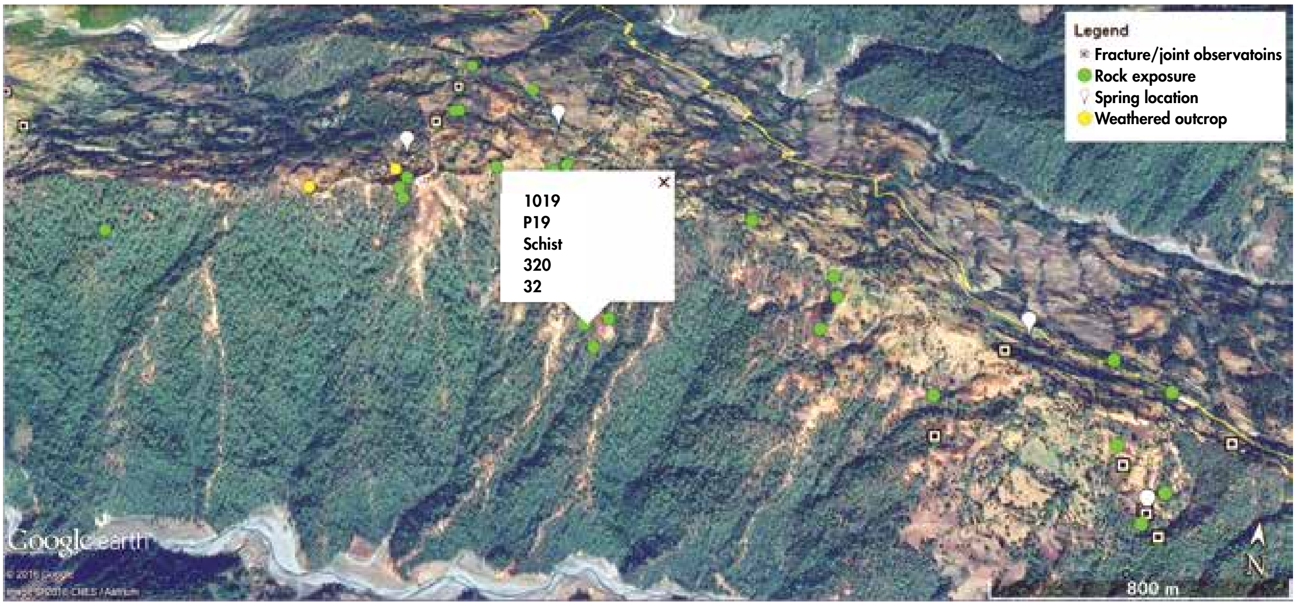


Figure A.5: **Observation points displayed on the Google Earth platform**



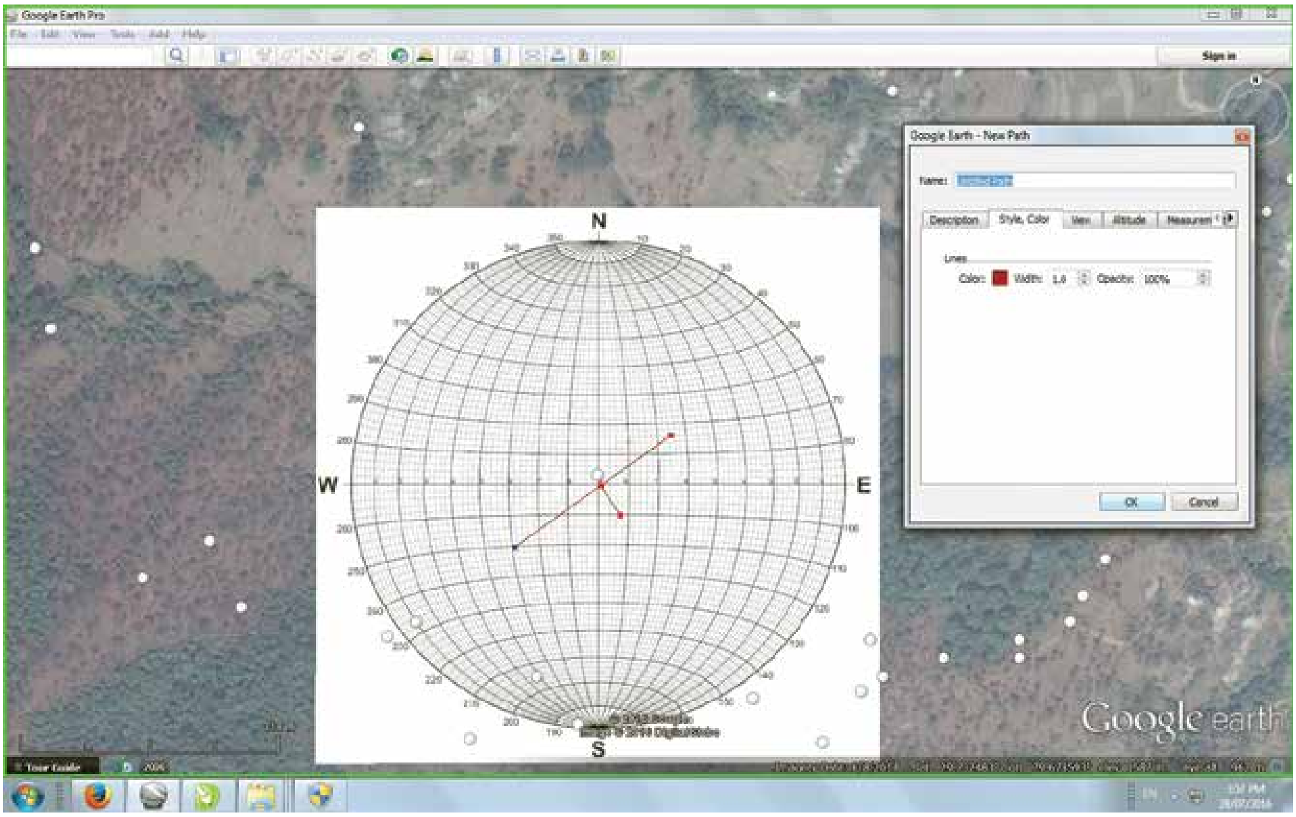
Annex 6B – Producing a Geological Map

1. Plotting strike and dip of lithology and fracture/joints in Google Earth

- Keeping Google Earth aligned to North, overlay stereo-net using image overlay tool and resize it accordingly.
- To plot strike and dip for a particular location, stereo-net is made to lie over that particular location in such a way that the location placemark lies at its centre.
- Using the "Add path" tool, plot strike and dip as per the geological information collected.

Strike and dip is plotted for all the locations which help in interpreting rock layers and their disposition in the field (Figure A.6). A geological map is prepared by collating all the additional information together with strike and dip for rocks, using the step described below.

Figure A.6: **Plotting strike and dip**



2. Interpolating lithology and structural data to produce a map

- Rock layers are delineated using "Add polygon" tool in Google Earth, taking into account the lithological information together with their plotted strike and dip.
- Assign colours to polygons as per lithology, mark fractures/joints with a particular colour to distinguish them from the strike and dip of rocks (Figure A.7).

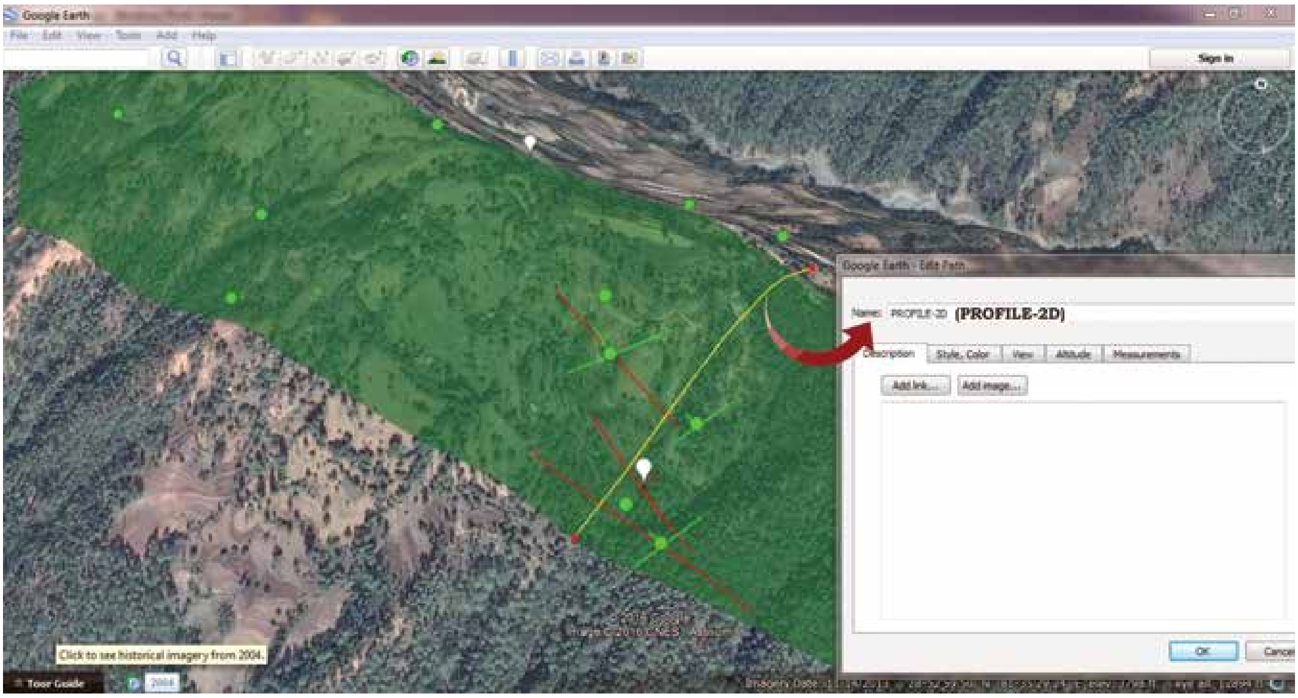
Figure A.7: **Geological map**

Annex 7: Developing a Cross Section of the Springshed Using Google Earth

1. Obtaining a 2-D profile of the springshed from Google Earth

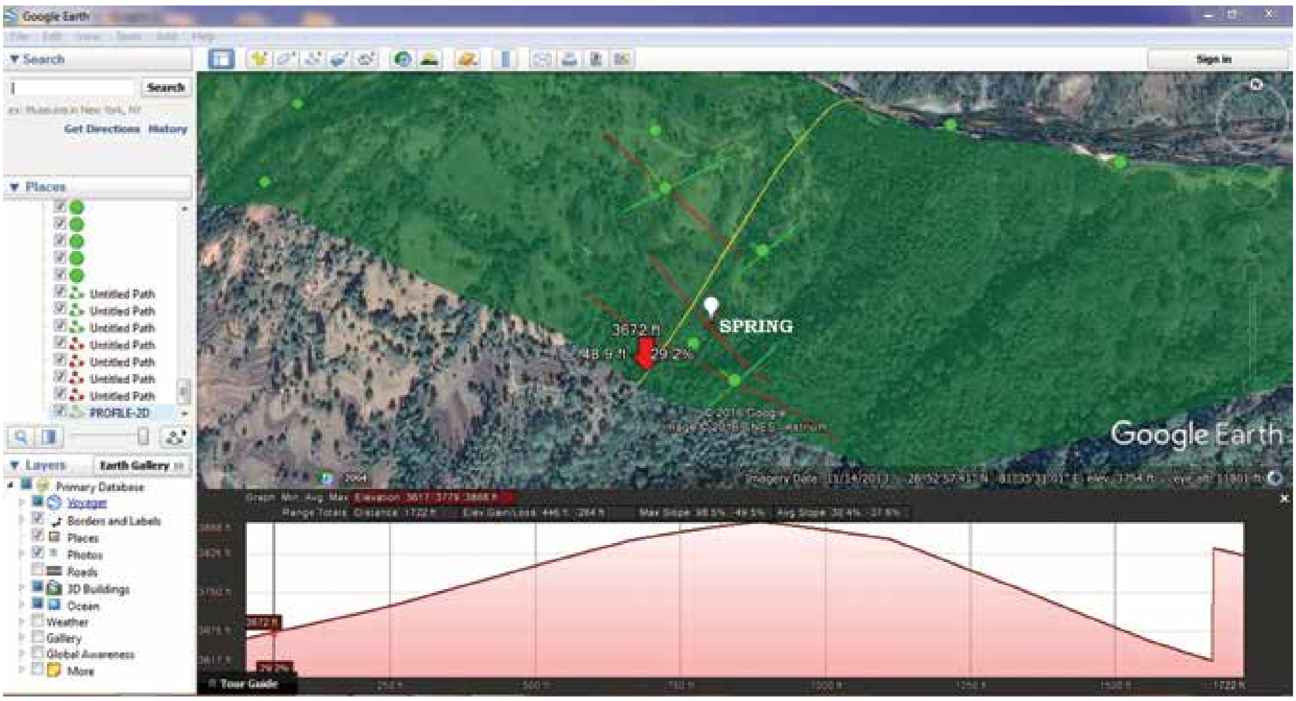
- The geological map prepared in Step-4A, is used as a base to produce a cross section for any particular spring and its springshed.
- Draw a profile line using the “add path” tool in Google Earth for the identified springshed, this will help build an elevation profile for it (Figure A.8).

Figure A.8: **Process of adding a path to generate a 2-D profile**



- After saving the profile line, an option asking for ‘show elevation profile’ is available on the right click dropdown. The elevation profile of the desired profile (section) line is generated, this helps produce the cross section of the springshed (Figure A.9).

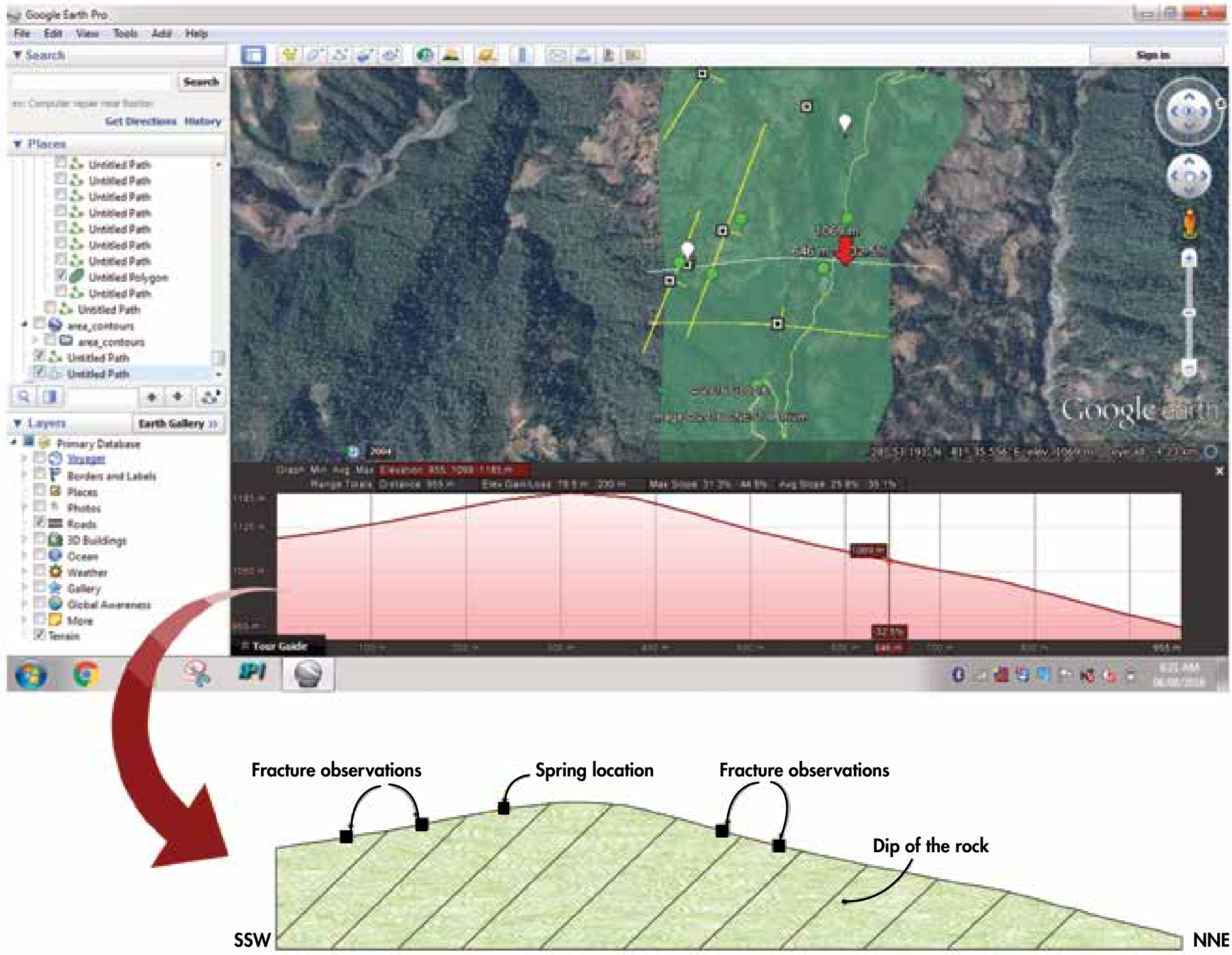
Figure A.9: **Generating an elevation profile from the profile created**



2 Preparing a cross section of the springshed using designing software

- Using CorelDRAW, trace out the complete profile by adding all the geological observations to it at their respective locations.
- Once all the information and observations are in the profile, the cross section is ready (Figure A.10) for developing further into a 3-D conceptual layout.

Figure A.10: **Preparing a complete cross section of the springshed using CorelDRAW**



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