Government of Nepal

Ministry of Forest and Environment

Department of Forest and Soil Conservation

Federal Watershed Management Resource Centre

Kulekhani, Makwanpur, Nepal

एकिकृत जलाधार व्यवस्थापन प्रदर्शन स्थल निर्माणका लागि Baseline सर्भे

Submitted by:
Kiru Consultant Pvt Ltd.
Shantinagar, Kathmandu

Abstract

Kulekhani watershed area consist of 124.67 km^2 area and lies on Thaha Municipality and Indrasarovar Rural Municipality of Makwanpur district of Bagmati Province. Kulekhani Reservoir (Indrasarobar) is one of the first reservoirs made by damming the Kulekhani river and its tributaries at an elevation of 1427 masl in 1982. The Indrasarover watershed was built by the construction of 114 m tall and 10 m wide rock fill (stone and soil mixed dam) dam in Kulekhani with the purpose of generating the electricity which was located in Bagmati province, Makawanpur district. The watershed of the region is prone to different natural and man-made hazards.

Kulekhani is the first storage project in Nepal and backbone of power supply during dry season. So, it is very crucial to preserve the watershed region of the Kulekhani. So, baseline survey was done to locate the region that are vulnerable to watershed degradation. These included landslides in the Kulekhani watershed and all water resources on the region. The landslide region were marked and their characters were studied. These landslides includes Mahabhir landslide, Dhodeni pakha, Chitlang Kharga, Chitlang Kharga 2, Dada Gaun 1 and dada gaun 2. The present condition and dimension of these landslides were noted. Various control measure such as bio-engineering, retaining wall construction, gabion wall and mechanical scaling off the rock slope were recommend for the prevention of the landslides.

Various water sources were mapped and methods to preserve the resource were studied. Box spring method was recommended to protect the quality and quantity of the water.

Different appropriate methodologies to control the landslide and water source degradation was recommended such that it can be set as demonstrated as component of integrated watershed management system for future studies.

Contents

Table of Figures

1. INTRODUCTION

1.1 Background:

In the recent years, the concept of watershed has become increasingly popular in many development programs across the nation because of the synergistic relationship between land and water resources within a watershed. An area in which all the water or snowmelt drains to a single streams, river, lake or reservoir is known as watershed or drainage basin (Goodman, 2011). The holistic approach can be applied forthe management of watershed by integrating the forestry, agriculture, pasture and water for sustainable management of natural resources (Pandit *et al.*, 2007). In broader sense, the watershed management is an effort for ensuring hydrological, soil as well as biotic regime based on which the water development projects are planned, maintained or even enhanced to prevent it from deterioration. Water and soil regimes of any watershed are mostly affected by the changing in landuse pattern of that site (Biswas, 1990). Water and soils are the vital components of the ecosystemthat support the production of ecosystem goods and services, such as: food, fibers and energy provision, water storage and purification, irrigation, aquatic environment, neutralization, filtering and buffering of pollutants, natural hazard regulation, bio-geochemical cycle and climate regulation (Biswas, 1990). The sub-watershed is considered as an important unit for the management of watershed, this management approach has been followed by the government of Nepal since ninth five-year plan (from 1997/98 to 2001/02) in which the sub-watershed needs to be ranked by erosion severity (DSCWM, 2015).

Watershed development and watershed management are frequently used as the interchangeable term. The watershed management is a science and an art of land management with reference to hydrological cycle (Swallow et al., 2002). Watershed management refers to managing hydrological relationships between land and water, which may involve protecting certain resources from degradation rather than making physical investments in their productivity (Kerr, 2007). The holistic and integrated management approach can be applied for the management of watershed by integrating the forestry, agriculture, pasture and water for sustainable management of natural resources in the watershed (Pandit et al., 2007). In broader sense, the watershed management is an effort for ensuring hydrological, soil as well as biotic regime based on which the water development projects are planned, maintained or even enhanced to prevent it from 2 deterioration. Water and soil regimes of any watershed are mostly affected by the changing in land use pattern of that site (Biswas, 1990).

Watershed management is the process of guiding and organizing land and other resources use in a watershed to provide desired goods and services without adversely affecting land resources (K. R. Tiwari et al., 2009). It integrates various aspects of hydrology, ecology, soils, physical climatology and other sciences to 3 provide guidelines for choosing acceptable management alternatives within the socioeconomic context taking into consideration the interactions and implications among land resources and the linkages between uplands and downstream area (Sen et al., 1997). However, in the present context, watershed management is not only for managing or conserving natural resources in a holistic manner, but also to involve local people for betterment of their lives. Thus, modern watershed management is more people oriented and process based, unlike many of the programs in the past, which were physically target oriented. It is meant to fit into the farmers, lifestyle rather than merely fulfilling the purposes of donors, governments, or non- government agencies (Sen et al., 1997).

Reservoirs are essential for storing water and providing necessary head to run turbines for a conventional hydroelectric power (Bodaly *et al*., 2004). The siltation of reservoirs is one of the most important off-site impacts of soil erosion (Sharma, 1998) that are closely linked to desertification problems like reservoir sedimentation, flooding problems, the loss of fertile foot slopes and floodplains, nutrient loss, eutrophication and the destruction of ecological habitats (Vanmaercke *et al*., 2011). The crucial ecosystem services (e.g., ecotourism, biodiversity, food production, and sediment retention) would be affected by land-use changes (Liang *et al*., 2017). The processes of soil erosion, sediment retention, and sediment transport are the key componentsand functions of the watershed area (Morgan, 2005).

landslides degrades the quality of a watershed and hence should be controlled to manage the watershed area. By implementing effective landslide control measures, watershed managers can mitigate erosion, protect water quality, and ensure the sustainable use of land and water resources.

Introduction to Kulekhani Watershed:

Kulekhani watershed is located 50km southwest of Kathmandu and is the source of water for reservoir which supplies water to 2 hydropower plants located further downstream.

.Kulekhani hydro electricity plant (KHEP) is the first reservoir based hydropower plant in Nepal, which was accomplished in 1980s. This reservoir is human made constructed by erecting 114 m tall and 10 m wide rock fill (stone and soil mixed dam) dam in the Kulekhani river which is also the main tributaries of Bagmati basin. Hence, conservation and management of reservoir is crucial. For this, detail investigation of the factors i.e. land use, soil, rocks, agricultural land, settlements inthe upstream of the sub-watershed could provide the details of landslide, soil erosion, soil and water quality. Hence, there will be high probability of landslides, soil erosion, debris flow and floods thereafter increased sedimentation level, the water level of this reservoir to be increased though the precipitation has been observed declining (Ghimire *et al.*, 2019b). So, it is crucial to preserve the

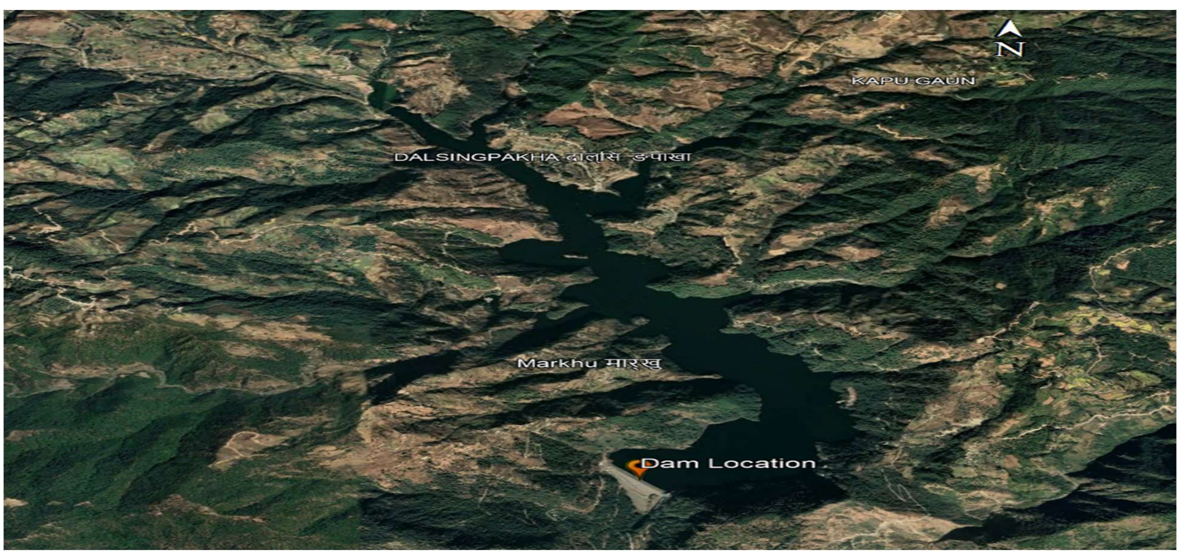


Figure 1 Kulekhani Reservoir (source google earth)

watershed of the Kulekhani area through the various effort of various parties

1.2 Problem Statement:

Kulekhani watershed area is an important source of Kulekhani Hydroelectric project. It is also famousfor biodiversity, fishing, boating, scenic beauty and as a recreational place. The tributaries of Kulekhani reservoir are Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola. Due to the various causes such as unmanaged and unscientific road construction, human settlement, unstable sources and other various causes the watershed arera is prone to landslide, debris flow and other naturalhazars.

Kulekhani watershed consist of is multiple rivers and rivulets, which also contribute to the soil erosion,landslide and other hazards which harm the watershed area of the region. Water resources are integral part of watershed, so the water source conservation is also essential for the preservation of watershed. The landslide is major issuein the region which causes various harm to society environment and kulekhani hydropower project thatis ultimately fed by the watershed. The conservation of the watershed is vital for local community, environment and the hydropower project. Hence, the study is necessary for the watershed management. Since, there are very less studies in sector of watershed management in Nepal, the conservation of the watershed of the region is also important to demonstrate the watershed conservation method in Nepal and for the future references.

1.3 Objectives:

General Objective

- To do the baseline survey for integrated watershed management display location.

Specific Objective:

- To locate various place that are prone to watershed degradation.
- To locate the landslide prone zone and recommend the mitigating measures.
- To recommend conservation methods that can be demonstrated for the future references as illustration of watershed management system.

1.4 Limitations of the Study:

- Technical and geographical difficulty to obtain the primary data.
- Unavailability of sufficient data for the study.
- Reliance on the various secondary data for the calculation.
- Lack of Nepalese code and guidance for the design purpose.
- Insufficient pervious study for comparison.
- Dependence on the empirical relations for the calculation.

2. Literature Review

2.1 Watershed :

watershed is defined as any surface area from which runoff resulting from rainfall is collected and drained through a common point.

It is defined by the topography of the land, where the high points form the boundaries that separate one watershed from another. Watersheds come in various sizes, ranging from small ones that cover only a few acres to large ones that span thousands of square miles.

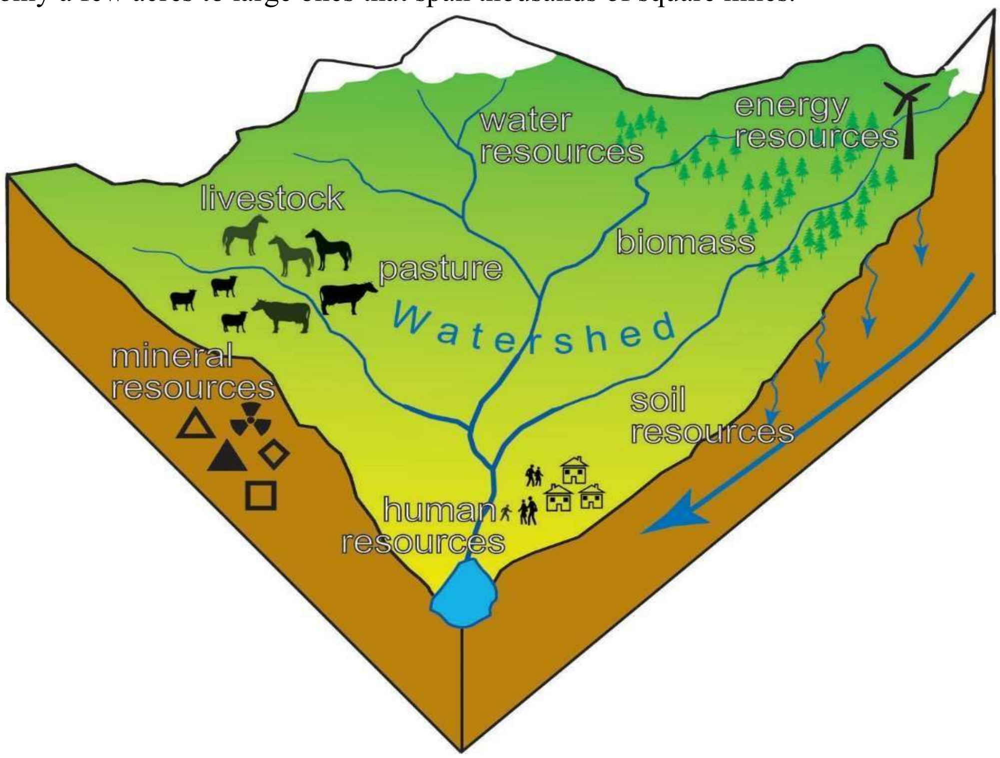


Figure 2 Schematic diagram of watershed (Ellen Leinner after Oktiabr Topbaey 2015)

2.2 Integrated watershed management system :

Integrated Watershed Management is a holistic and integrated approach for sustainable management of a watershed area. Integrated watershed management (IWM) is the process of managing human activities and natural resources on a watershed basis, considering social, economic and environmental issues, as well as local community interests and issues such asthe impacts of growth and climate change.

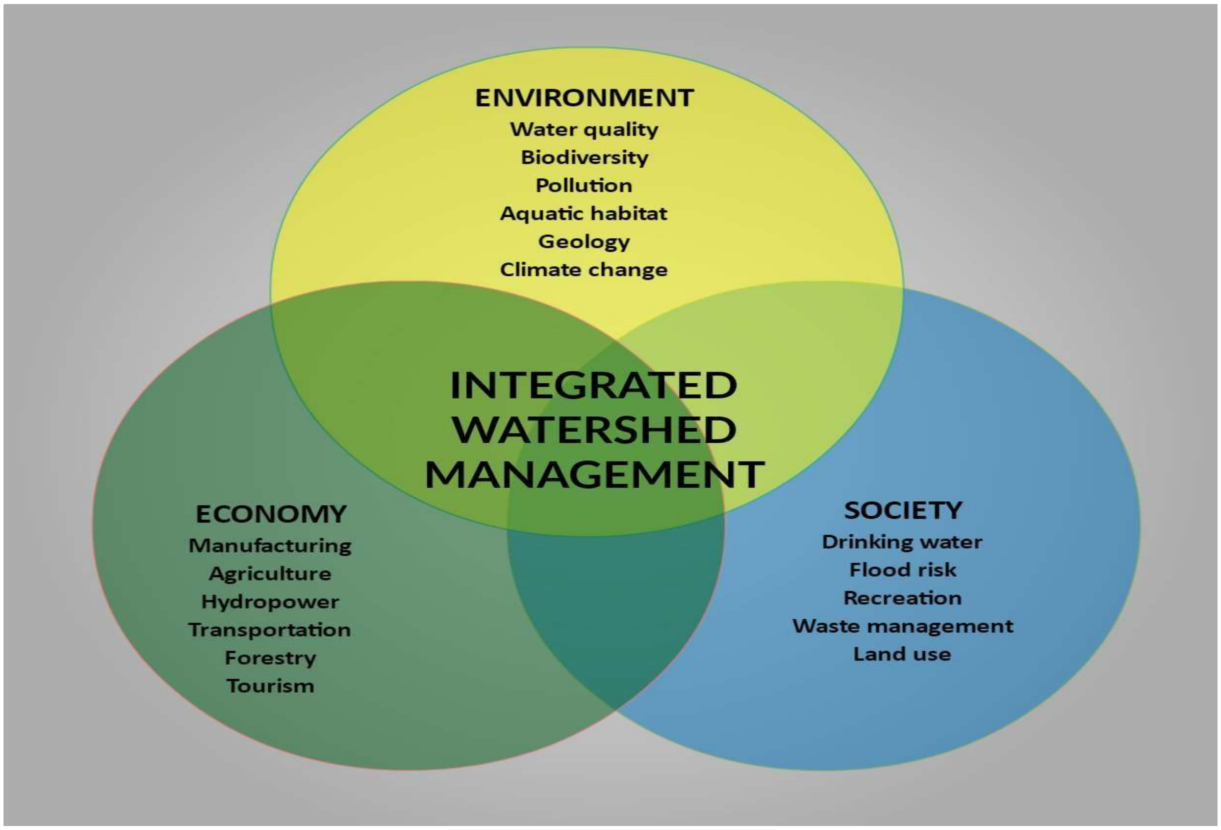


Figure 3 integrated watershed management system

An IWMS typically involves the following key components:

1. Stakeholder Engagement: IWMS emphasizes the involvement of various stakeholders, including local communities, government agencies, NGOs, and private sectors. Collaborative decision-making processes allow for the integration of diverse perspectivesand local knowledge.
2. Watershed Assessment: A comprehensive assessment of the watershed is conducted to understand its physical, ecological, and socio-economic characteristics. This assessment helps identify existing challenges, opportunities, and potential impacts on water resources.
3. Land Use Planning: An important aspect of IWMS is the development and implementation of land use plans that consider the ecological integrity of the watershed. It aims to balancecompeting land uses, such as agriculture, forestry, urban development, and conservation, while minimizing negative impacts on water resources.
4. Water Resource Management: IWMS focuses on managing water resources sustainably. This involves monitoring water quantity and quality, implementing water conservation measures, and ensuring equitable access to water for various users within the watershed.

5. Ecosystem Conservation and Restoration: The protection and restoration of natural ecosystems within the watershed are essential for maintaining water quality, biodiversity, and ecosystem services. This includes measures such as reforestation, wetland restoration,and the preservation of riparian areas.
6. Soil and Water Conservation: IWMS promotes soil and water conservation practices to prevent erosion, sedimentation, and nutrient runoff. Techniques such as terracing, contourfarming, and vegetative buffer strips are employed to reduce soil erosion and protect waterquality.
7. Integrated Flood and Drought Management: Effective IWMS includes measures to mitigate the impacts of floods and droughts. This may involve the construction of reservoirs, floodplain zoning, water storage and management, and early warning systems.
8. Capacity Building and Education: IWMS emphasizes capacity building and education programs to enhance the knowledge and skills of stakeholders involved in watershed management. This includes training on sustainable farming practices, water conservation methods, and community-based natural resource management.
9. Monitoring and Evaluation: Regular monitoring and evaluation are crucial components of IWMS. It helps assess the effectiveness of management strategies, identifies emerging challenges, and guides adaptive management approaches.

By adopting an integrated approach, IWMS aims to balance socio-economic development with environmental sustainability, enhance water security, and promote the resilience of watersheds in the face of climate change and other challenges. It recognizes the interconnectedness of various components within a watershed and promotes collaborative efforts to ensure the long-term healthand sustainability of water resources.

Landslide:

The term "landslide" describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing. Figure 1 shows a graphic illustration of a landslide, with the commonly accepted terminology describing its features.

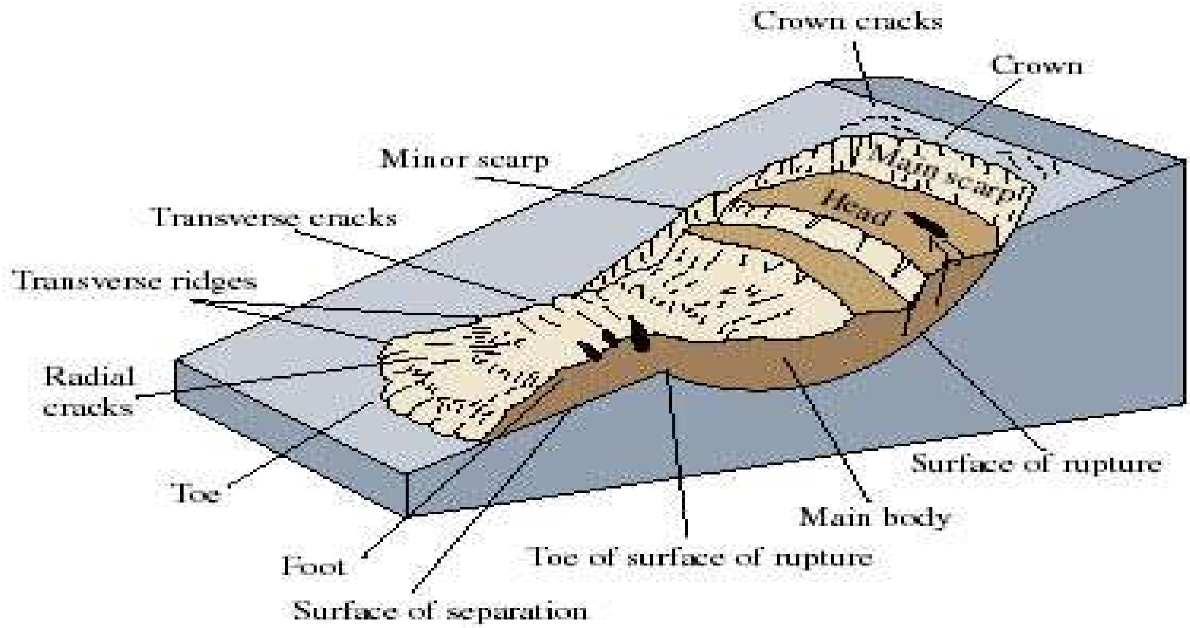


Figure 4 parts of landslides

The various types of landslides can be differentiated by the kinds of material involved and the mode of movement. A classification system based on these parameters is shown in figure below. Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

Bio-Engineering:

Bioengineering refers to the use of living organisms, primarily plants, in combination with engineering techniques to address environmental challenges and promote sustainable solutions. It involves the application of biological principles and processes to create or restore ecosystems, enhance natural resource management, and provide ecological benefits.

In the context of environmental conservation and restoration, bioengineering focuses on utilizing the inherent properties of plants to stabilize slopes, control erosion, improve water quality, restore habitats, and mitigate the impacts of natural disasters such as landslides and floods. It involves the strategic selection and use of plant species, along with appropriate engineering techniques, to achieve specific environmental objectives.

Bioengineering finds application in various environmental contexts to address challenges such as slope stabilization, erosion control, habitat restoration, and water resource management. In slope stabilization, bioengineering techniques involve the strategic selection and planting of native plant species with robust root systems to reinforce the soil and reduce erosion, providing long-term stability. For erosion control, vegetation is used to slow down water flow, trap sediments, and prevent the loss of topsoil, complemented by techniques like coir logs or geotextiles. Bioengineering also plays a vital role in habitat restoration by utilizing plant species that enhance biodiversity, improve ecological functions, and restore degraded ecosystems.

2.3 various Studies on Watershed Management:

- Asian development bank conducted a study on 'Sustainable Rural Infrastructure and Watershed Management Sector Project: Report and Recommendation of the President' project number 50236-002 for the improvement of rural incomes from market-driven diversified farm output, watershed health, and community nutrition in the four northern provinces of Houaphan, Louangphabang, Xaignabouli, and Xiangkhouang.
- Clark and Howell (1992) have focused their study on the role and principles of soil bioengineering for the develop-ment of soil bioengineering strategies in rural mountain areas of Nepal.
- "Assessment of Watershed Management Approaches: A Comparative Study" by Rajendra P. Shrestha et al.: This study compares different watershed management approaches in the Nepalese Himalayas, focusing on their effectiveness in addressing water-related challenges. It assesses the outcomes of community-based watershed management, government-led initiatives, and donor-funded projects, providing valuable insights for policy and practice.
- "Evaluation of Watershed Management Practices for Sustainable Development: A Case Study of the Masinga Watershed, Kenya" by Joy Obando et al.: This case study evaluates the impact of watershed management practices on the sustainable development of the Masinga watershed in Kenya. It assesses the effectiveness of measures such as afforestation, soil conservation, and water harvesting in enhancing water availability, reducing soil erosion, and improving livelihoods.
- "Landslide Risk Reduction in Nepal: Recent Advances and Future Directions" by Hari Prasad Pandit et al.: This study provides an overview of recent advances in landslide risk reduction in Nepal. It discusses various approaches and techniques, including engineering measures, early warning systems, and community-based approaches. The study also highlights the need for interdisciplinary research and collaboration to enhance landslide control in Nepal.
- "Assessment of Landslide Risk and Mitigation Strategies in the Koshi River Basin, Nepal" by Nabin K. Baral et al.: This study focuses on the assessment of landslide risk and the development of mitigation strategies in the Koshi River Basin. It incorporates remote sensing, GIS analysis, and field investigations to identify high-risk areas and recommend appropriate control measures. The study emphasizes the importance of integrated watershed management for effective landslide control.
- "Effectiveness of Bioengineering Measures for Slope Stabilization in Nepal: A Case Study" by Bhanu Neupane et al.: This study evaluates the effectiveness of bioengineering measures for slope stabilization in Nepal. It assesses the performance of various techniques, including vegetative measures, check dams, and gabion structures, through field monitoring and analysis. The findings contribute to the understanding of bioengineering techniques for landslide control in the Nepalese context.
- "Application of Remote Sensing and GIS for Landslide Hazard Mapping in the Central Development Region of Nepal" by Krishna P. Kafle et al.: This study focuses on the application of remote sensing and GIS technologies for landslide hazard mapping in the Central Development Region of Nepal. It combines satellite imagery, topographic data, and field surveys to identify landslide-prone areas and develop hazard maps. The study highlights the potential of these technologies for effective landslide control and management.

3. Methodology:

a. Study Area:

The Kulekhani Watershed area of the Kulekhani Reservoir was selected for the study area. It is located in the Makwanpur district of Bagmati Province. The reservoir (also known as Indrasarbar)synonymously known as Kulekhani Hydropower. Various river such as Chitlang khola, Bisenkhelkhola, Palung khola, Thado khola, Chalkhu khola contribute to the sediment and water flow to thereservoir. The total area of the watershed is 124.67 km^2. Geographically it is extended from 27^0 34' 54" N to 27^0 40' 59" N and 85^0 01' 21" E to 85^0 12' 20" E.

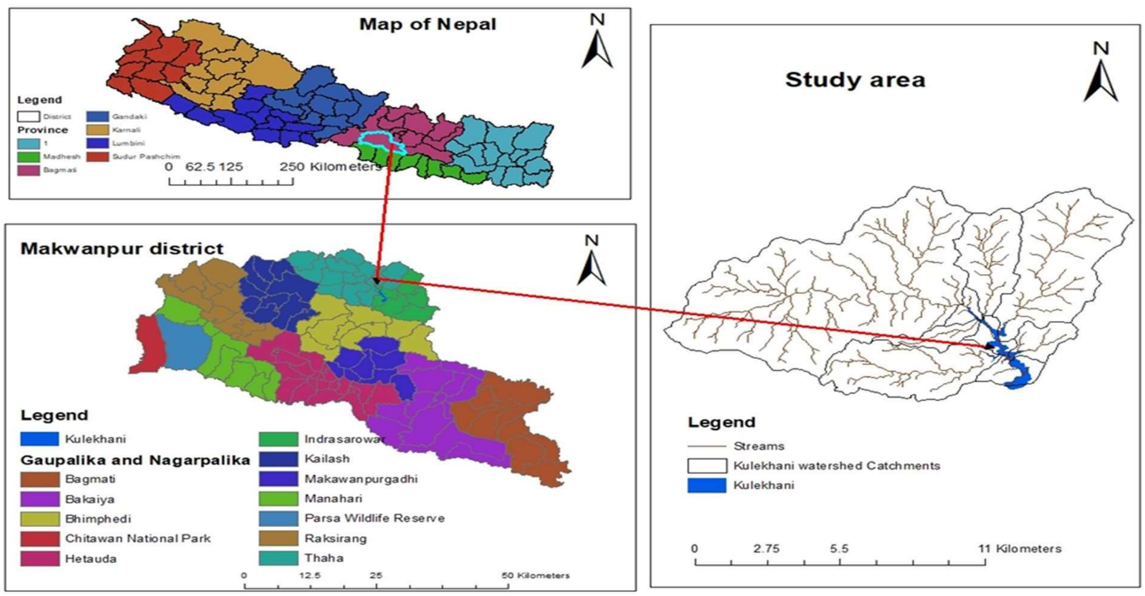


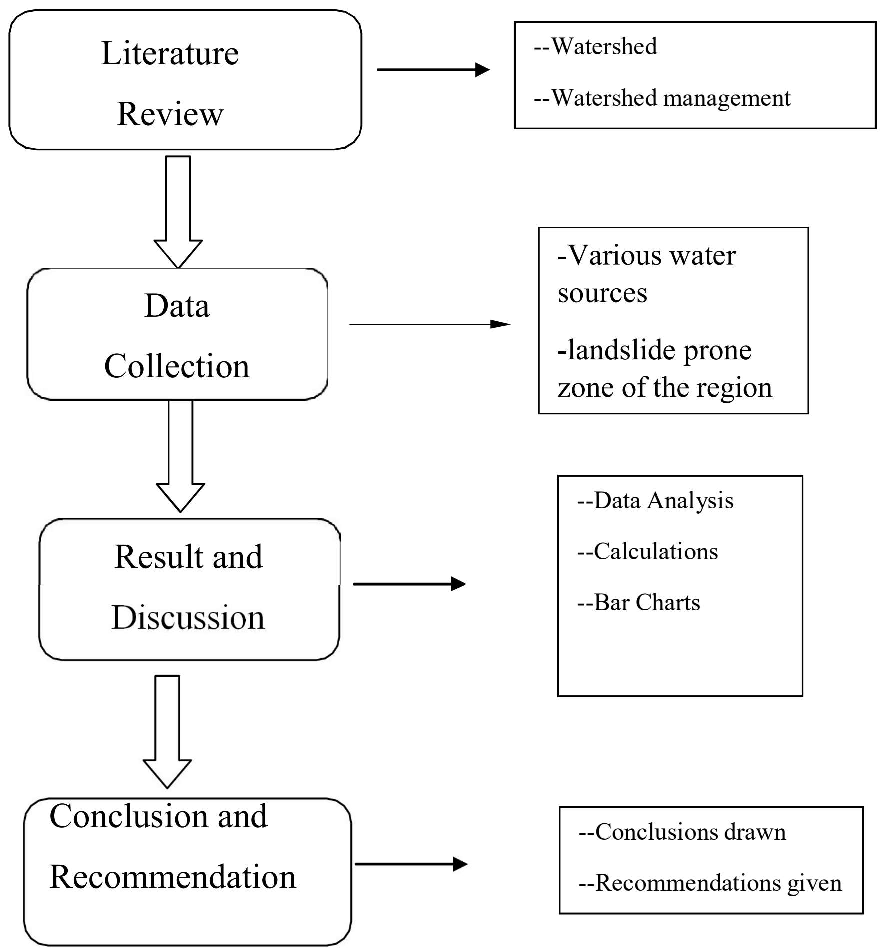
Figure 5 project area

Table 1 sub watershed of Kulekhani

S.N	River	Area (km^2)	Stream_density
1	Bisinkhel Khola	9.654	19.648
2	Chitlang Khola	22.639	8.378
3	Chalkhu Khola	2.681	70.756
4	Seti Khola	3.356	56.525
5	Palung Khola	62.622	3.029
6	Salma Kulekhani Khola	5.966	31.796
7	Thado Khola	14.875	12.751

b. Work Flow Chart

The work flow chart for the analysis include the following:



The Research Methodology includes Literature Review, Data Collection, Result andDiscussion and Conclusion and Recommendation which are described below in detail:

c. Field Visit:

The field visit was carried out on Ashad 1st to Ashad 5th .Various data were collected fromthe previous studies of the region.

d. Data Collection:

Various survey data required for the landslide condition were measured. Various features of the power plant were considered. The data collection was mix of primary and secondary data. Primarydata were collected from the site. For secondary data, different research articles were referred.

e. Data Management and Analysis:

Area prone to landslide in the region:

An article published on Bulletin of Nepal geological society 2018) mapped the regions that are prone to the landslide in the region.

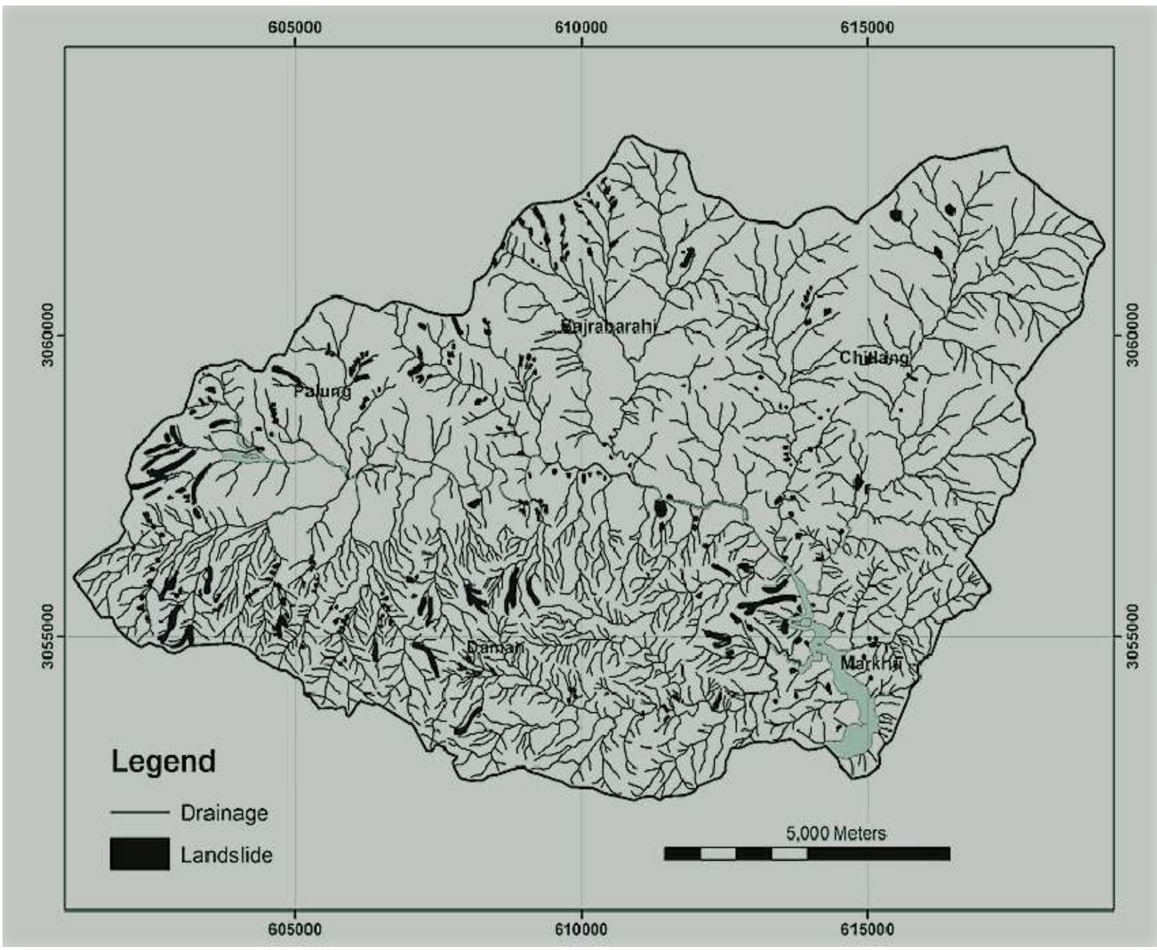


Figure 6 Landslide prone zone in Kulekhani watershed (Bulletin of Nepal Geological society 2018, vol 35)

Classification of the Landslides:
The landslide were classified on the basis of Indian code IS 14680:1999 . The classification basis table is as shown as follow:

IS 14680 : 1999

Table 1 Landslide Classification System
(*Clause* 4)

Type of Movement		Type of Material			Recommended Control Measures
		Soils		Bed Rock	
		Predominantly fine	Predominantly coarse		
Falls		Earth fall	Debris fall	Rock fall	Geotextile nailed on slope/spot bolting
Topples		Earth topple	Debris topple	Rock topple	Breast walls/soil nailing
Slides	Rotational	Earth slump	Debris slump	Rock slump	Alteration of slope profile and earth and rock fill buttress
	Translational	Earth block slide	Debris block slide	Rock block slide	Reinforced earth or rock reinforcement in rock slope
		Earth slide	Debris slide	Rock slide	Biotechnical measures
Lateral Spreads		Earth spread	Debris spread	Rock spread	Check dams along gully
Flows		Earth flow	Debris flow	Rock flow	Series of check dams
		(Soil creep)		(Deep creep)	Rows of deep piles
Complex		Combination of two or more principal types of movement			Combined system

Figure 7 Landslide classification system based on IS code

The landslides were inspected and there dimensions were measured for the recommendation of retaining structure. The soil type and nature of the fall were noted, The basic pattern of the landslide were also considered. The retaining structure were recommended based on the IS code 14680: 1999 also considering the following aspect:

1. Type and Characteristics of Landslide: The specific type of landslide and its characteristics, such as the slope angle, height, and geometry. This information helped us determine which control measures were suitable for stabilizing the landslide.
2. Triggering Factor and Stability Condition: The factors that triggered the landslide were taken into consideration and the slope of the site was also noted.
3. Site Conditions: We had evaluated the site conditions, including soil type, geological condition, and groundwater conditions & susceptibility to erosion.
4. Environmental Factors: We had considered the environmental conditions surrounding the site. This included rainfall patterns, climate conditions, vegetation cover, and potential impacts on nearby ecosystems. The control measure needed to be compatible with the environmental context and minimize any adverse effects.
5. Suitability and Feasibility: We had assessed the suitability and feasibility of the control measure in terms of technical requirements, construction methods, and available resources. We considered factors such as cost, time, and accessibility for implementation.

6. Long-Term Effectiveness: We had evaluated the long-term effectiveness of the control measure. Would it have provided a sustainable solution to mitigate the landslide risk over an extended period? We considered factors such as maintenance requirements, durability, and adaptability to changing conditions.
7. Safety Considerations: We had prioritized the safety of people, structures, and infrastructure in the affected area. We ensured that the recommended control measure minimized the risk to human life and property. We considered potential hazards during construction and maintenance activities

3.6 Landslides Taken in considerations:

6 landslides were considered for the study, the landslide that are near to the kulekhani were given the priority for the study. All the landslide lies inside the Kulekhani watershed region. The muck and debris generated from the landslide mixes to the reservoir of the Kulekhani. The landslides that were considered for the study are given in the google map below:

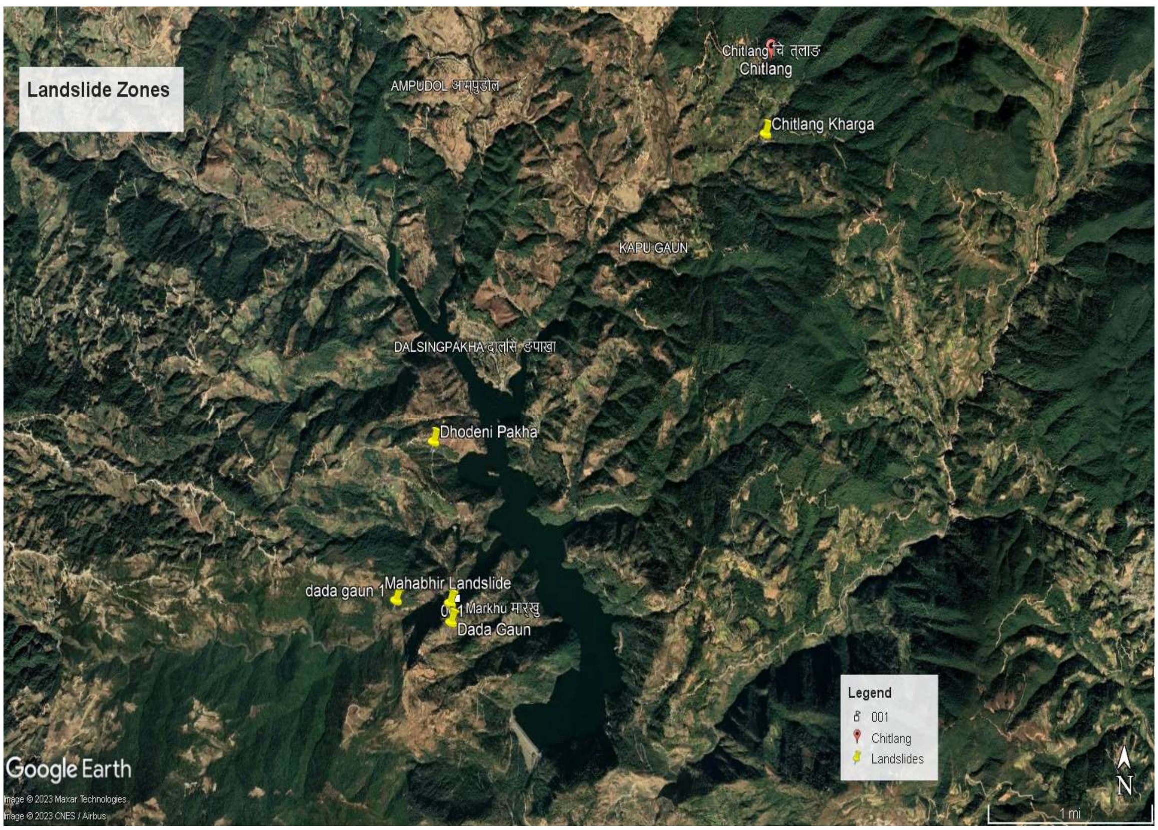


Figure 8 Landslides considered for study.

These landslides along with the methodology to mitigate them are explained below:

1.Mahabhir Landslide:

Location: Near Mohini Jharna

Co-ordinate: 27 35 59.44 N 85 08 52.09, elevation 1700 meter

Dimension: length 57 meter height 150 meter

Landslide type: **Translational Slide**

Triggering factor: Road Construction

Soil Type: granular form of Quartzite and schists

Vegetation Type: pine forest

Figure 9 Mahabhir Landslide

Recommended control measures:

Stepped gabion wall along with bio engineering is suggested.

Bio-Engineering:

Various bio-engineering technique is suggested for the stabilization of the soil of the landslide region. The bio engineering guideline given by a study conduct by Asian development bank titled ‘Sustainable Rural Infrastructure and Watershed Management Sector Project’ suggested given guidelines for the bio-engineering.

Work Phase	Activities
Site Preparation	Develop a plan to coordinate all parties involved in the bio-engineering process. The plan must be flexible in response to the weather conditions at the time.
	Establish clear objectives for the bio-engineering project.
	Calculate all of the works quantities and materials required.
	Schedule all work items and the responsible party.
	Identify any timing conflicts with other project work.
	Collect seeds at the appropriate time and prepare for storage.
	Arrange for the sourcing or propagating of the required plant materials.
	Plan any required earthworks well in advance.
	Select all the appropriate good quality tools before starting.
	Identify and remove any works hazards.
	Identify and salvage existing vegetation or topsoil for later use.
	Locate suitable storage areas for plant material and topsoil.
	Plan worker access routes on the rehabilitation site to minimise disturbance across the site.
	Divert surface water flows to reduce erosion on site, and install sediment control measures, if required.
Implementation Phase	Arrange site visit with all persons involved prior to the commencement of works to avoid any misunderstanding of the process and the flow of materials.
	Commence collection of all live materials for use on the site
	Ensure that the plant material source delivers quality plant materials at the onset of the implementation work. Have a quality management plan for all materials developed in a nursery
	Arrange suitable storage for each vegetation type.
	Monitor potential slope failure or soil erosion sites before and during the implementation phase.
	Contract the workers required and train them as necessary.
	Undertake the preparation work for planting, e.g. clearing the surfaces and digging planting trenches.
	Undertake the actual bio-engineering planting works.
	Monitor the effectiveness of the works and take any remedial action that is necessary.

Plant selection:

The plants that should be used for the bio engineering on various region of Nepal is recommended by yam Prashad dhital and the team. The elevation of the landslide zone is around 1700 meters, So, the plantation should be done accordingly.

Table 2 Popular plant species of Nepal used in soil bioengineering (Howell 1999b; Devkota and others 2006)

Species	Local name	Botanical name	Characteristics	Best propagation	Alt.(m)
Grasses	Amliso	Thysanolaena maxima	Large clumping	Slip cuttings	100–2,000
	Babio	Eulaliopsis binata	Medium-sized clumping	Slip cuttings/seeds	100–1,500
	Kans	Saccharum pontaneum	Large clumping, spreading	Slip cuttings	100–2,000
	Khar	Cymbopogon microtheca	Medium-large clumping	Slip cuttings/seeds	500–2,000
	Narkat	Arundo clonax	Large clumping, spreading	Stem/slip cuttings	100–1,500
Shrubs/small trees	Bains	Salix tetrasperma	Tree up to 15 m high	Hardwood cuttings	100–2,700
	Bhujetro	Butea minor	Shrub up to 4 m high	Direct seeding	500–1,500
	Dhanyero	Woodfordia fruticosa	Shrub up to 3 m high	Seeds/polypots	100–1,500
	Namdi phul	Colquhounia coccinea	Shrub up to 3 m high	Hardwood cuttings	1,000–2,000
	Tilka	Wendlandia puberula	Tree up to 10 m high	Seeds/polypots	100–1,500
Large trees	Chilaune	Schima wallichi	Large, evergreen tree	Seeds/polypots	900–2,000
	Khayer	Acacia catechu	Large, thorny tree	Seeds/polypots	100–1,000
	Lankuri	Fraxinus floribunda	Large deciduous tree	Seeds/polypots	1,200–2,700
	Sisau	Dalbergia sisso	Large broad-leaved tree	Seeds/polypots	100–1,400
	Utis	Alnus nepalensis	Large broad-leaved tree	Seeds/polypots	900–2,700

The retaining structure that is suitable for the location includes:

- Gabion walls
- Retaining walls such as breast wall
- gravity Wall
- Anchored Retaining wall
- Stone masonry Wall

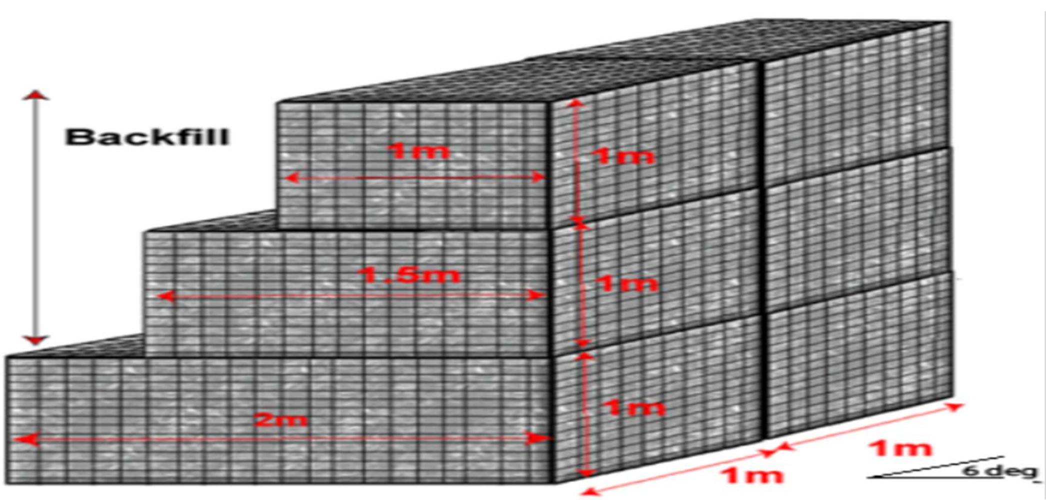


Figure 10 Representative figure of gabion wall

2.Dhodeni Pakha:

Length= 37 meter

Height= 16 meter, slope: 30-45 degree

Co-ordinate: 27 36 42.26 N, 85 08 44.98 E, 1666 m elevation

Landslide type: **Translational Slide**

Triggering factor: Road Construction

Rock Type: Quartzite and schists

Vegetation Type: Pine Forest

Figure 11 Dhodeni pakha Landslide

Recommended control measures:

- **Breast wall**
- **Gabion wall**
- **Stone Masonry Walls**

Breast Wall:

The allowable bearing capacity should be calculated in accordance to IS 6403 on the basis of soil test data. Since, there were no soil test datas, for preliminary design, table 1 from code IS 14458 part 2 1997 was taken:

For fine sand, silty or clayey medium to fine sand

Consistency of place: Medium to compact

So, Recommended Bearing Capacity of soil: 25 t/m^2

The design of wall foundation should meet the requirement of IS 1080 and IS 1904.

Minimum depth of breast wall = 0.5 meter below the side drain

For the wall less than 8 meter and 120 m^2 area.

Considering, Good back fill From table 3 of IS 14458 part 2.

Height= 6 meter

top width in meter= 0.75 meter

bottom width in meter= 3.92 meter

So, 2 walls of length 18 meter is recommended.

Gabion Wall:

2 layer of gabion wall is recommended for the length of 36 meter. They should be tilted towards backfill at 6 degree.

3.Chitlang Kharga:

Co-ordinate: Latitude 27 35 59.68 N, Longitude 85 7 33.82 E

Location: Machuni Community forest, Thaha Nagarpalika (12 km from Chitlang)

Dimension: 45 m height 30 meter width

Landslide type: **Complex**

Triggering factor: Road Construction

Soil Type: Rock form of Quartzite and schists

Vegetation Type: pine, oak, alder forest

Figure 12 Chitlang Kharga Landslide

Recommended control measures:

Since, the land is highy unstable and there is high settlement possibility. Gabion retaining wall is recommended for the control of this landslide.

4.Chitlang kharga 2,(kab gaupakha)

length =25.7m, height =25m approximately

Location: Location: Kharga, Thaha Nagarpalika (10 km from Chitlang)

Landslide type: **Translational Slide**

Triggering factor: Road Construction

Soil Type: granular form of Quartzite and schists

Vegetation Type: Agricultural Crops

Recommended control measures:

Bio engineering with retaining wall is preferred for this landslide.

For Bio Engineering:

Various bio-engineering technique is suggested for the stabilization of the soil of the landslide region. The bio engineering guideline given by a study conduct by Asian development bank titled 'Sustainable Rural Infrastructure and Watershed Management Sector Project' suggested given guidelines for the bio-engineering. The methodology for bio-engineering in the landslide region includes the following steps:

Work Phase	Activities
Site Preparation	Develop a plan to coordinate all parties involved in the bio-engineering process. The plan must be flexible in response to the weather conditions at the time.
	Establish clear objectives for the bio-engineering project.
	Calculate all of the works quantities and materials required.
	Schedule all work items and the responsible party.
	Identify any timing conflicts with other project work.
	Collect seeds at the appropriate time and prepare for storage.
	Arrange for the sourcing or propagating of the required plant materials.
	Plan any required earthworks well in advance.
	Select all the appropriate good quality tools before starting.
	Identify and remove any works hazards.
	Identify and salvage existing vegetation or topsoil for later use.
	Locate suitable storage areas for plant material and topsoil.
	Plan worker access routes on the rehabilitation site to minimise disturbance across the site.
	Divert surface water flows to reduce erosion on site, and install sediment control measures, if required.
Implementation Phase	Arrange site visit with all persons involved prior to the commencement of works to avoid any misunderstanding of the process and the flow of materials.
	Commence collection of all live materials for use on the site
	Ensure that the plant material source delivers quality plant materials at the onset of the implementation work. Have a quality management plan for all materials developed in a nursery
	Arrange suitable storage for each vegetation type.
	Monitor potential slope failure or soil erosion sites before and during the implementation phase.
	Contract the workers required and train them as necessary.
	Undertake the preparation work for planting, e.g. clearing the surfaces and digging planting trenches.
	Undertake the actual bio-engineering planting works.
	Monitor the effectiveness of the works and take any remedial action that is necessary.

Plant selection:

The plants that should be used for the bio engineering on various region of Nepal is recommended by yam Prashad dhital and the team. The elevation of the landslide zone is around 1700 meters, So, the plantation should be done accordingly.

Table 3 Popular plant species of Nepal used in soil bioengineering (Howell 1999b; Devkota and others 2006)

Species	Local name	Botanical name	Characteristics	Best propagation	Alt.(m)
Grasses	Amliso	Thysanolaena maxima	Large clumping	Slip cuttings	100–2,000
	Babio	Eulaliopsis binata	Medium-sized clumping	Slip cuttings/seeds	100–1,500
	Kans	Saccharum pontaneum	Large clumping, spreading	Slip cuttings	100–2,000
	Khar	Cymbopogon microtheca	Medium-large clumping	Slip cuttings/seeds	500–2,000
	Narkat	Arundo clonax	Large clumping, spreading	Stem/slip cuttings	100–1,500
Shrubs/small trees	Bains	Salix tetrasperma	Tree up to 15 m high	Hardwood cuttings	100–2,700
	Bhujetro	Butea minor	Shrub up to 4 m high	Direct seeding	500–1,500
	Dhanyero	Woodfordia fruticosa	Shrub up to 3 m high	Seeds/polypots	100–1,500
	Namdi phul	Colquhounia coccinea	Shrub up to 3 m high	Hardwood cuttings	1,000–2,000
	Tilka	Wendlandia puberula	Tree up to 10 m high	Seeds/polypots	100–1,500
Large trees	Chilaune	Schima wallichi	Large, evergreen tree	Seeds/polypots	900–2,000
	Khayer	Acacia catechu	Large, thorny tree	Seeds/polypots	100–1,000
	Lankuri	Fraxinus floribunda	Large deciduous tree	Seeds/polypots	1,200–2,700
	Sisau	Dalbergia sisso	Large broad-leaved tree	Seeds/polypots	100–1,400
	Utis	Alnus nepalensis	Large broad-leaved tree	Seeds/polypots	900–2,700

Retaining walls:

- Gabion walls
- Retaining walls such as breast wall
- gravity Wall
- Anchored Retaining wall
- Stone masonry Wall

5.Dadha Gaun 1

Location: Dadha Gaun (4 km from the kulekhani Dam)

Co-Ordinate: Latitude 27.59411, Longitude: 85.1509

Dimension: Height =60m Length= 44.9 m (presence of 22 meter Gavin wall)

Landslide type: **Translational Slide**

Triggering factor: Road Construction

Rock Type: Quartzite and schists (Kulekhani Formation)

Vegetation:

Figure 13 Dhadha gaun 1 Landslide

Check dams along with Bio-engineering is recommended for the control of landslide of this location. The area of landslide is very long so, step wise check dams is required at certain interval. For the bio engineering, Since Chitlang Kharga 2 and this location has similar geographical and vegetation condition, Chitlang Kharga 2 can be taken for reference for the bio engineering studies.

Various Check dams that can be used in this landslides are as follow:

- Gabion walls
- Retaining walls such as breast wall
- gravity Wall
- Anchored Retaining wall
- Stone masonry Wall

6.Dada Gaun 2

Location: Dadha Gaun (3 km from the kulekhani Dam)

Dimensions: Height =17m Length= 50 meter

Co-ordinate: 27.58861 Latitude, 85.14903 Longitude

Landslide type: **Topples**

Triggering factor: Road Construction

Rock Type: Quartzite and schists (Kulekhani Formation)

Vegetation: Pine Forest, Uttis

Methods of Control:

Mechanical rock scaling method is suitable for the stabilization of the soil.
Rock bolting and anchoring can also be used to join the the rock surface to the strong base.

3.7 Water Sources Of Kulekhani:

All the water resources that lies inside the Kulekhani watershed area were marked and the resources that are most vulnerable were noted.

Altogether 60 water sources were identified and mapped in the Setikhani Khola Sub-watershed, Kali khola Sub-watershed, Chitlang khola Sub-watershed, Bisinkhel khola Sub-watershed, Tistung khola Sub-watershed, Palung khola Sub-watershed, Chnakhu khola Sub-watershed and Thado khola Sub-watershed) of Kulekhani Watershed.

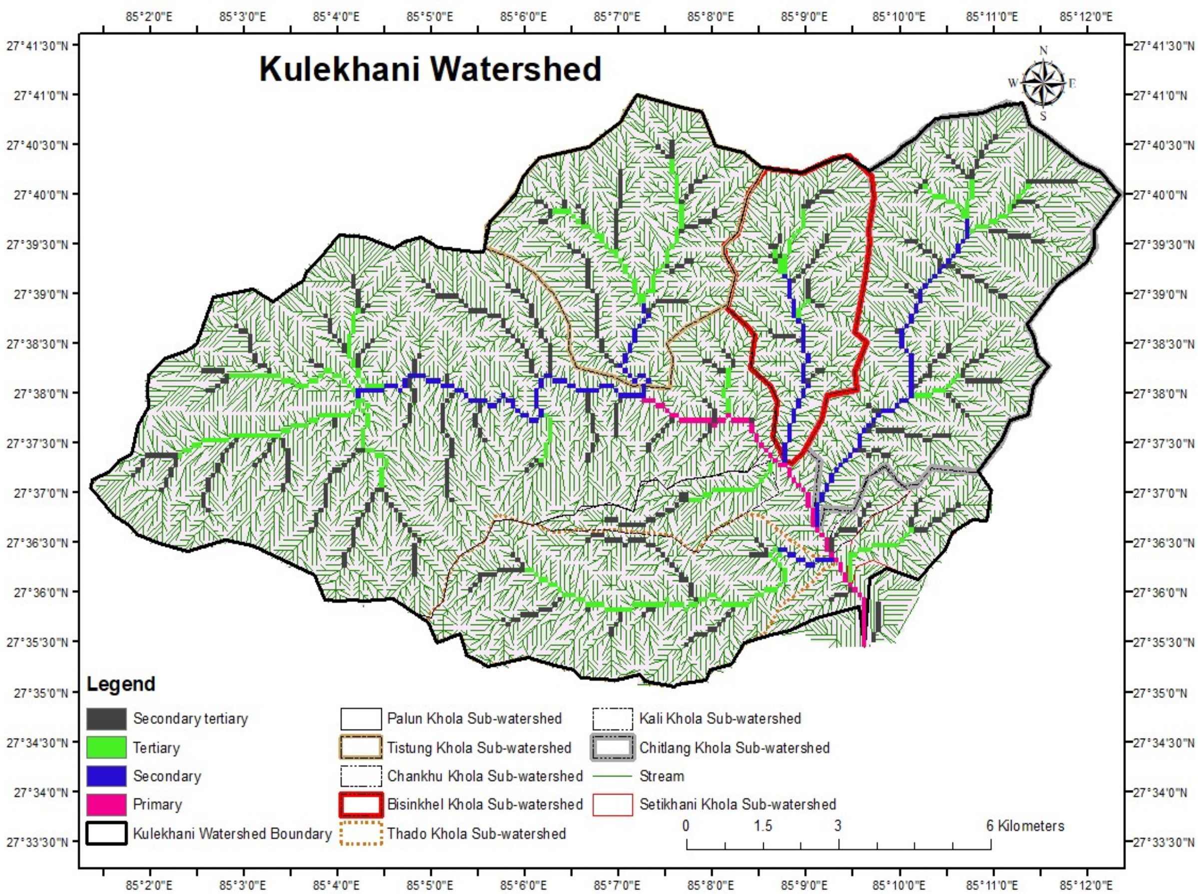


Figure 14 Kulekhani watershed area

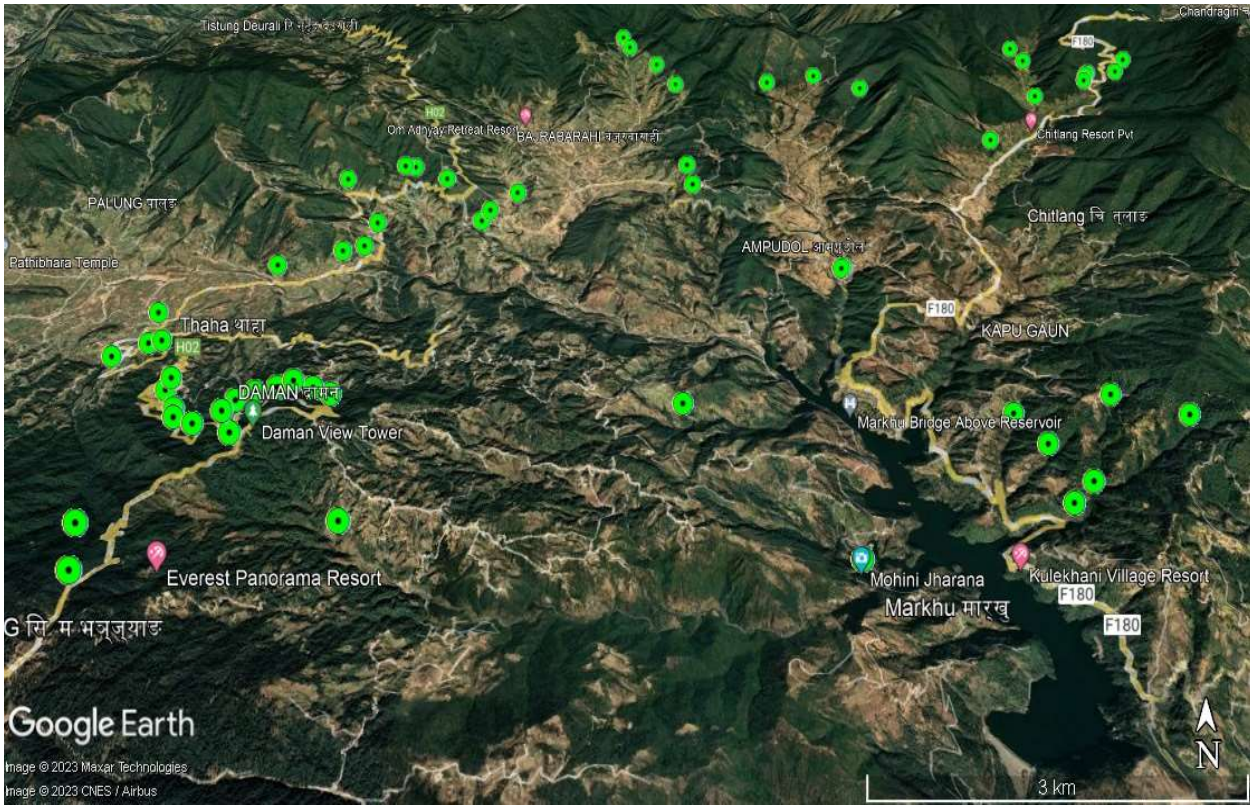


Figure 15 water resources of kulekhani watershed

Water resources of Kulekhani watershed region were studied and the water originating sources were marked. They are the spring water sources from which the river and rivulates that fed the kulekhani reservoir is fed. The 3 representative sources that are vulnerable to degradation and destruction that are considered in the study are as follow:

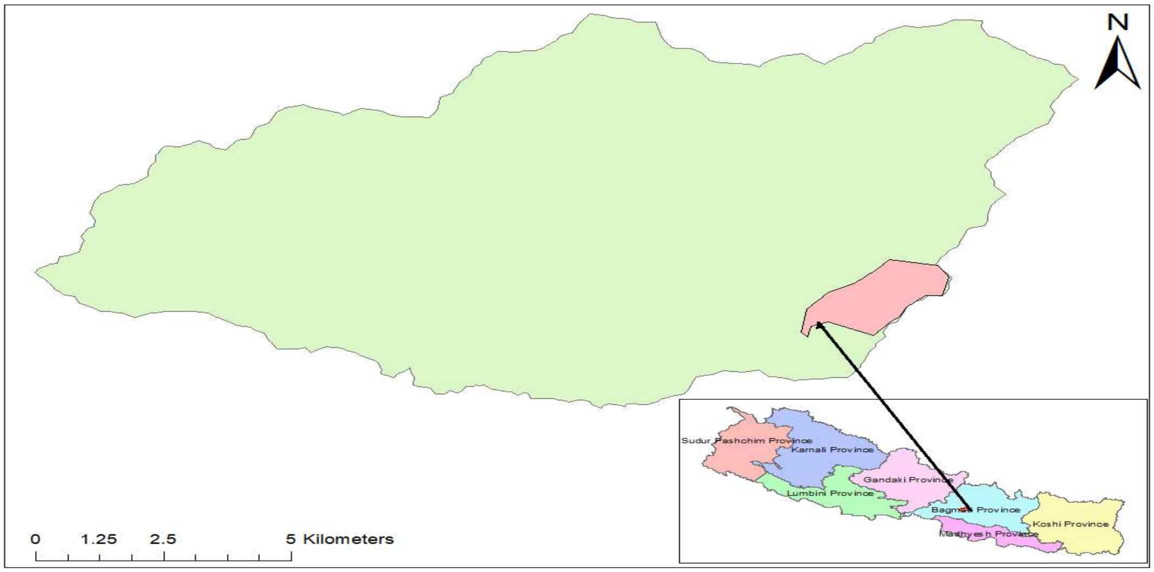
1. Seti khola Water sources
2. Kalikhola Water Sources
3. Bisinkhel Water source

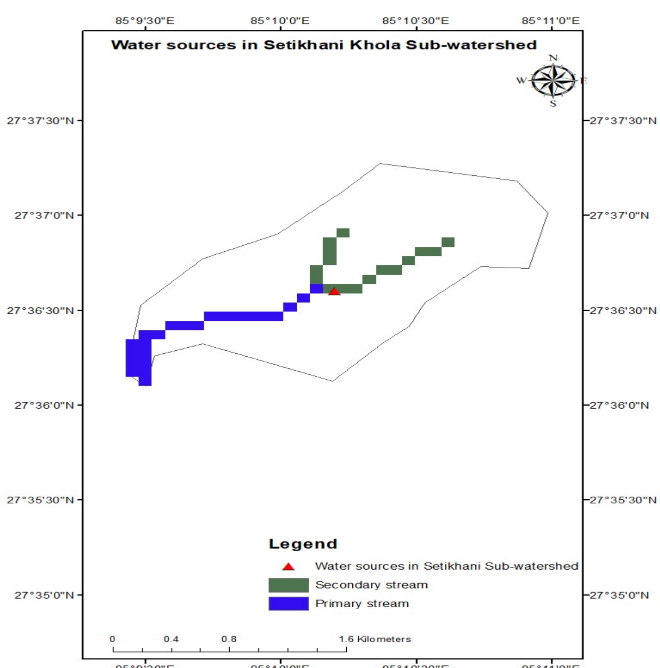
1. **Setikhani Khola Water source:**

Loation: Thaha Municipality, ward no. 9; Indrasarovar Rural Municipality, ward no. 1

Type: Open Spring Water Resource

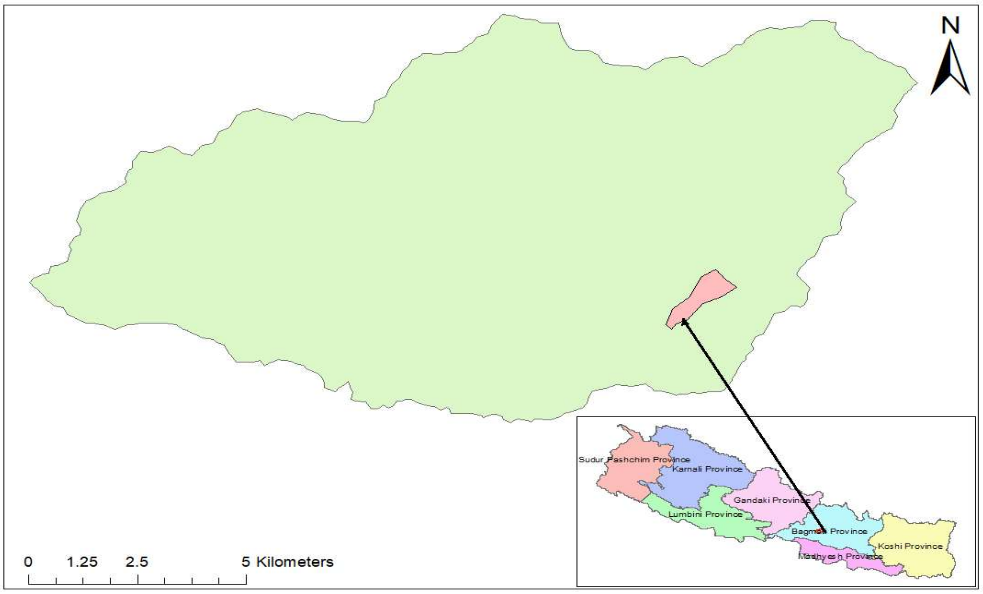
Physiological Region: Mid-Hill

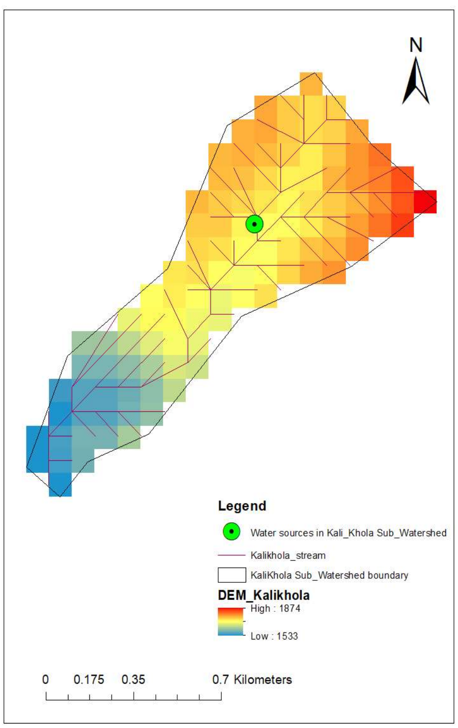




2. Kalikhola water Source:

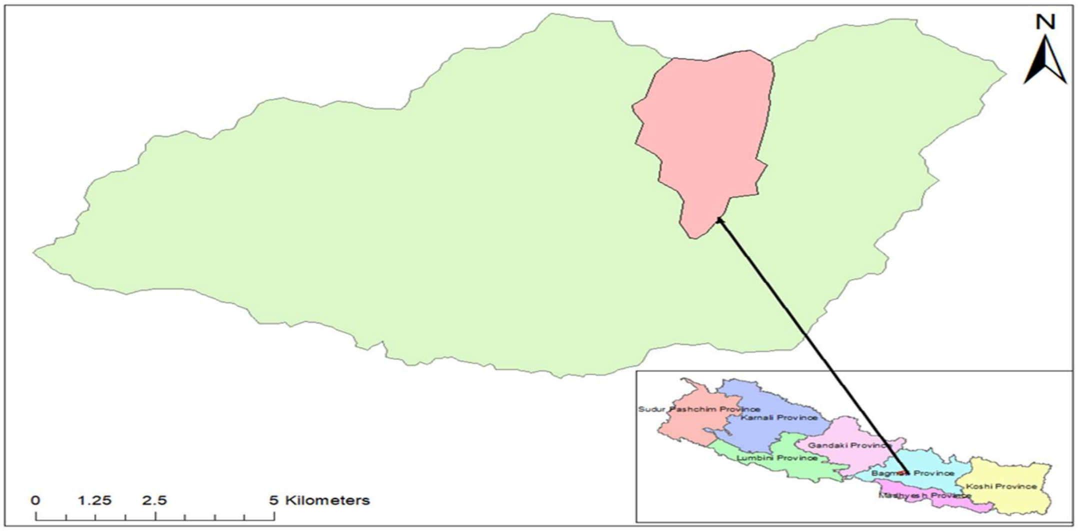
Location: Kali khola sub-watershed, Thaha Municipality, ward 9
Region: Mid hill
Precipitation on the region: 1500 mm annually
Geology: Tistung Formation

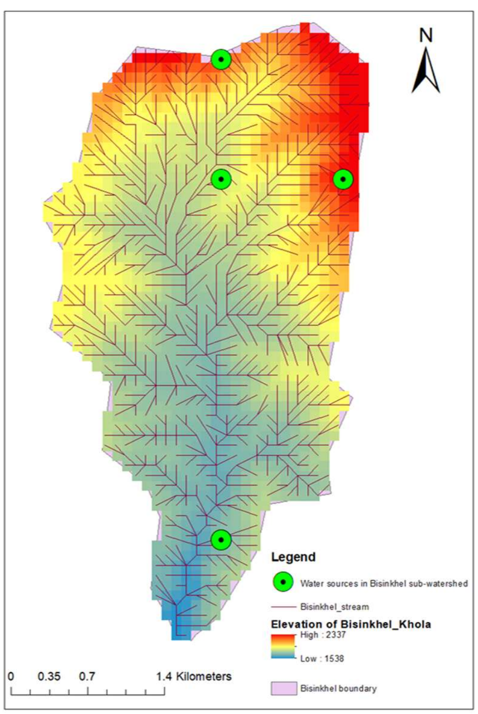




3. Bisinkhel Water Source:

Location: Thaha Municipality ward no. 5
Physiographic Region: Mid hill
Geology: Chandragiri Formation
Rocks: White Quartzite, argillaceous limestone
Vegetation of surrounding: Uttis, salla, Setikath, Katus, Guras





Protection Methodology:

Setikhani Khola water source, Kali Khola water source and Bisinkhel water source are vulnerable to human encroachment and water pollution.

All the water sources should be protected for proper management of the watershed of the area. All the springs are the origin point of the rivers. So, it is crucial these water sources must be protected. The set up for the spring conservation are demonstrated on the figure below.

The various technical aspects of a protected spring are designed to prevent contamination, improve access or both. Unlike boreholes or gravity-flow water systems, springs can be improved in stages, with each element providing another contamination barrier or better access. The catchment area above the spring captures the rainwater that feeds the spring. Polluting activities in this area must be limited, especially close to the spring. Building toilets and using agricultural chemicals should be banned. Livestock and people can be prevented from going uphill from the spring by fencing off the area. Surface runoff from the wider catchment area needs to be diverted away from the area above the spring with a ditch and/or a bund (raised mound). Trying to scoop up water as it seeps into a pool is difficult and it will quickly get muddy. Digging into the hillside allows the water to be captured and channelled into a pipe.

A retaining wall will hold back the soil and a platform will stop the area becoming muddy. The pipe needs to be set so it is slightly higher than water containers used locally. Too low and the containers will not fit, too high and water will be wasted. The platform should drain excess water back to the original stream.

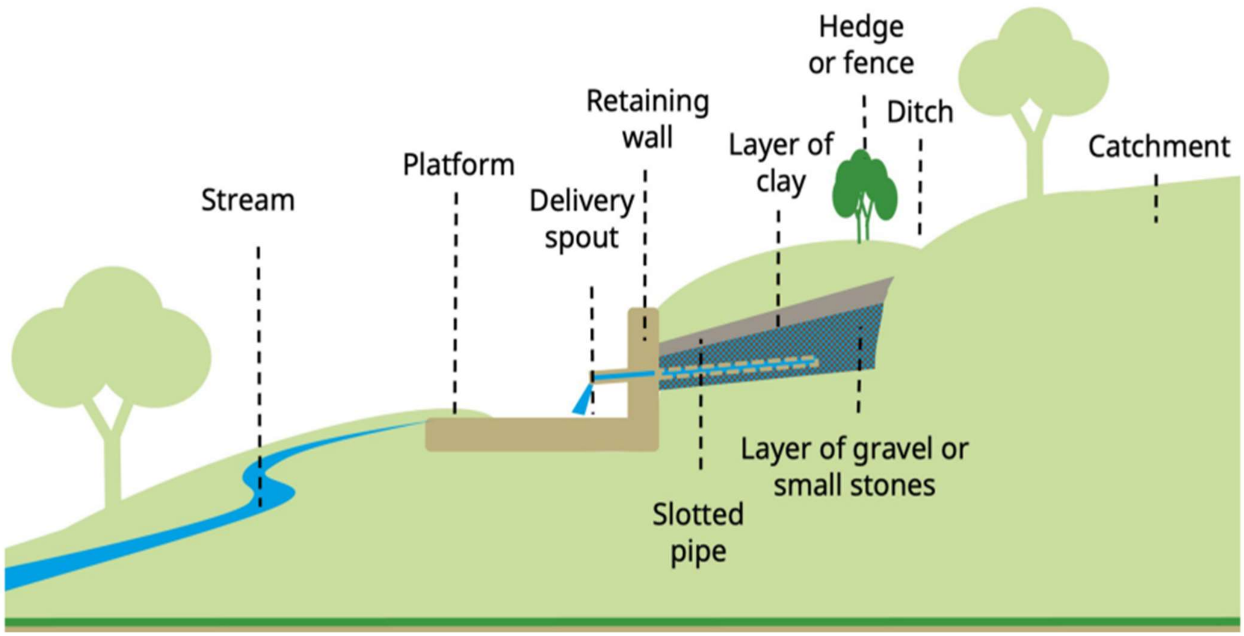


Figure 16 schematic diagram of spring proctection

The retaining wall and platform may appear to be protecting the spring, but the really important part is behind the wall. When the hole is dug to expose the spring, the area is carefully excavated. The water is allowed to flow to clear away the silt until the eye of the spring is found. The area around the eye is filled with small stones or gravel. This acts as a reservoir and allows the water to flow easily into a slotted pipe. This pipe has lots of holes in it to let the water through but keep the stones out. On top of this is a layer of clay or plastic sheeting. This is the main protection for the spring. It stops water from the surface reaching the eye of the spring. A sheet of plastic or layer of sand might be laid between the clay and gravel to stop the clay being washed down into the spring.

Spring Box: The structure which is required to catch the water from a spring is called spring box. A typical layout of the spring box is as shown below:

Source: USAID

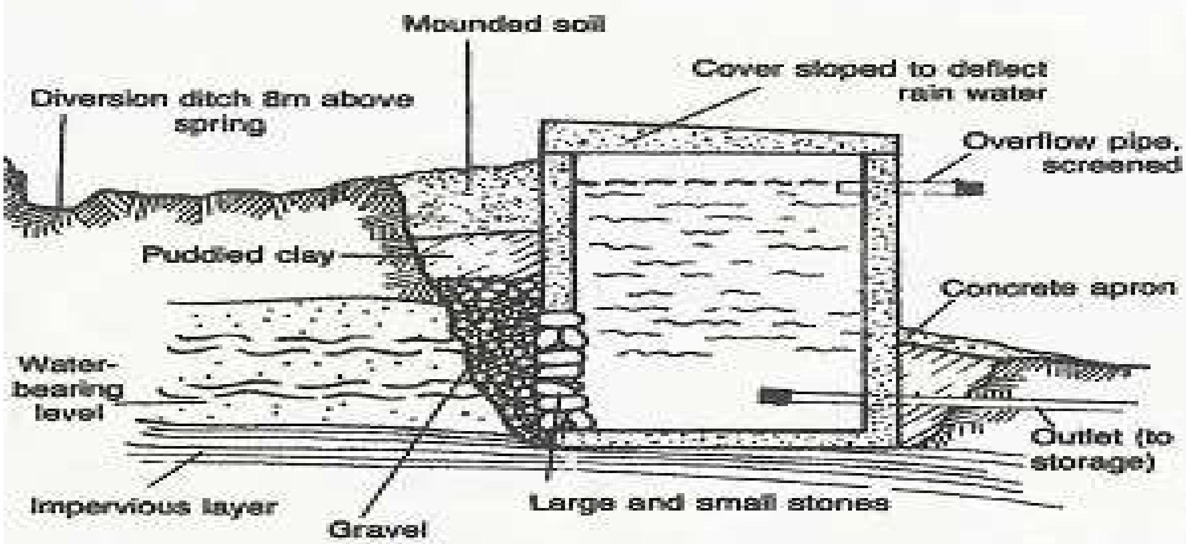


Fig. 1. Spring Box with Pervious Side

Source: USAID

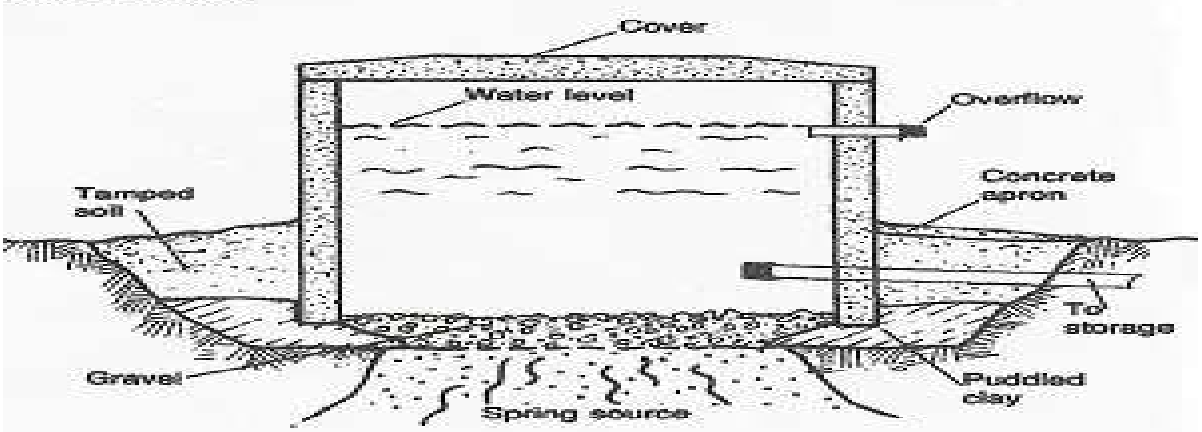


Fig. 2. Spring Box for Single Source

Figure 17 spring box section

Additional protection:

To further improve water quality, activities around the spring should be limited. Bathing and laundry should take place downstream. This can be encouraged by building bathing shelters or laundry slabs close by – but downhill of the spring. Livestock watering should take place even further downhill. If the spring is located close to the community, access to it can be improved. Steps and a path encourage people to approach the spring from below, reducing the chance of contamination. This makes access easier, especially in the wetter seasons, in the dark, and for people with limited mobility.

If the flow rate is low (especially in the drier seasons), queues will form. This wastes people's time and can reduce the amount of water used for hygiene practices. One way to increase the flow is to ensure all the spring water is captured when the eye is excavated. This is why this stage of construction needs careful observation. If the water is flowing from several eyes or seeps out along a line, then a long trench might be needed. This is filled with gravel as before and slotted pipes are put in. These form a Y shape with the arms of the Y going along the trenches and the base of the Y leading to the spout. Adding a tank Another way to increase yields is to build a tank. This fills up at night when water use is low. An overflow is needed for when the tank is full. The stored water is then used in daytime. Taps are included to stop the water draining away, and people need to know these taps should be turned off when not being used. Sometimes a tank with a porous rear wall is built instead of a retaining wall. Water then seeps in over a wide area. This is called a spring box. Treating water The water should not need treating if protection is in place. However, this protection is only as good as the weakest part of the system. The collection of water is a likely point of contamination. Hygiene education helps promote safe storage of water. If the quality is poor in the wetter months or people in the household have health issues, then household water treatment may be needed.

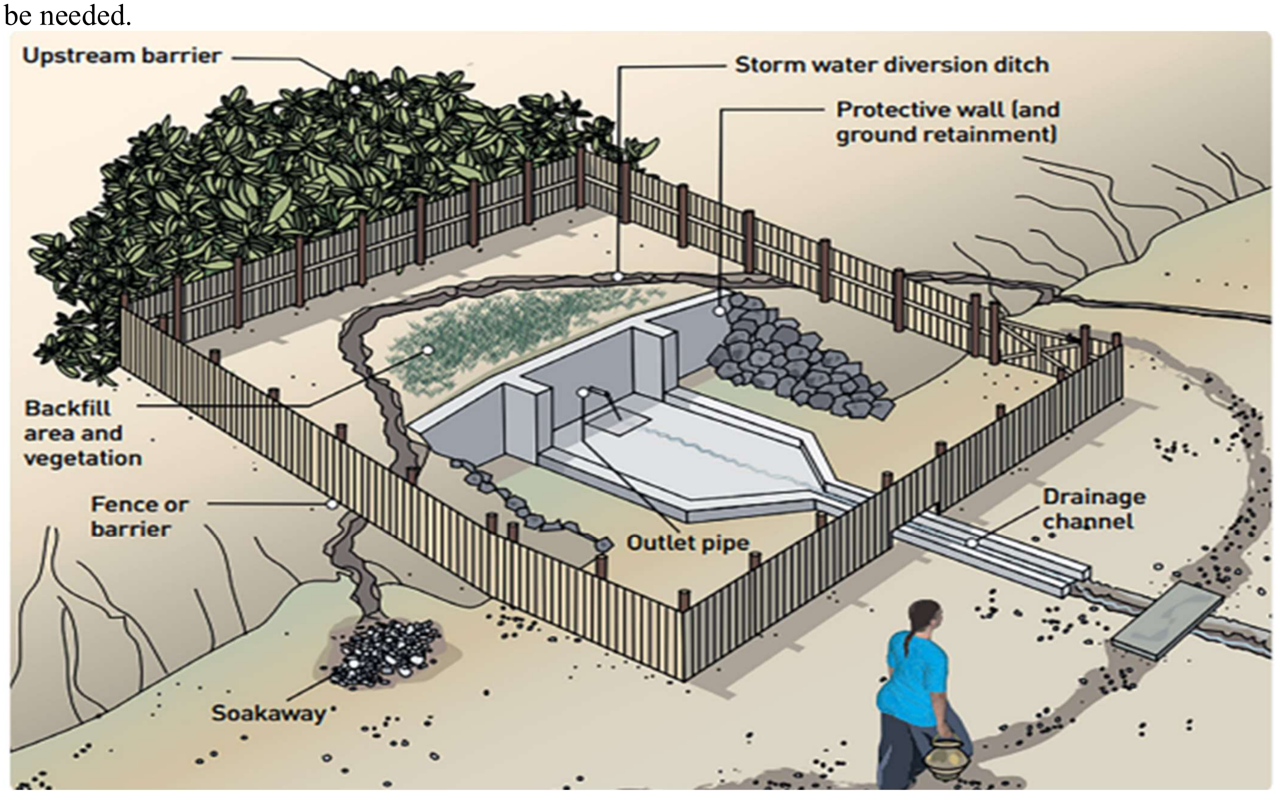


Figure 18 additional protection for water source

4. Results and Discussion:

There were many vulnerable sites in the watershed of Kulekhani reservoir. Landslides control and water sources management were considered major components for integrated watershed management. Various landslides in the kulekhani watershed were located. Six major landslides were marked and named as Mahabhir landslide, Dhodeni pakha, Chitlang Kharga, Chitlang Kharga 2, Dada Gaun 1 and dada gaun 2. The present condition and dimension of these landslides were noted.

these studied showed Mahabhir landslide and Dada gaun Landslide region requires the bio-engineering technique along with other retaining structure for the prevention.

The Chitlang Kharga 1 and Dhodeni Pakha requires retaing structures such as breast wall and gabion wall for the landslide control. Dada gaun requires mechanical scaling for the rock stability.

In case of water source management for kalikhola, Setikhola and Bisinkhel water source, spring management using spring box is recommended.

These water source and landslides can be effectively managed so that they can be developed as a demonstration location for the watershed management system.

Discussion:

The prevention methods are based on the dimension and nature of the landslides. There are other various parameters that should be considered for the landslide control such as ground water conditions, landslide history, geomorphological parameters. The chemical and physical properties of rock such as density, porosity, shear strength etc also dictates the landslide control methodology. So, due to unavailability of in depth characteristic of the landslides parameter. Basic guidelines were only used for the recommendation of control procedure. All recommended procedure are commonly practiced in Nepal and are cost effective and easy to carried out.

For water sources protection, the spring box system is scientific and cost effective in context of Nepal. It can preserve both quality and quantity of water so that local community is benefitted by it and it helps in proper management integrated watershed management.

5. Conclusion and Recommendation:

Hence, the baseline survey was conducted for demonstration of the watershed management of the area. There is requirement of proper watershed management in the Kulekhani region. The region is prone to watershed degradation because of the various landslides which disturbs the natural water system balance. The regions also requires the proper protection of the water sources in watershed so that the reservoir watershed system is well managed. In order to demonstrate the integrated watershed management of Kulekhani reservoir, the management of landslides and proper protection of the water source in the watershed area is necessary.
Following recommendation were made from the study:

1. Detail Study of the Landslides:
   There are many landslides prone region which can be controlled and demonstrated as the site for the watershed management system. The sites should be studied and various mitigating measures should be implemented pre-planning for landslides control.

2. Further Study of Mahabhir landslide and Dadha gaun landslides:
   These landslides are big in size and are identical to many big landslides that occurs in the country. They also directly contribute to the sedimentation in Kulekhani reservoir. In depth study of these landslides is necessary so that these landslides can be controlled and they can be demonstrated as pioneer project for the further studies.

3. Water source protection Program:
   The water sources inside the Kulekhani reservoir is prone to degradation. So, it is recommended to assess the present scenario of the water resources and various protection program should be conducted for the most vulnerable resources.

4. Watershed Management guidelines:
   Nepali guidelines regarding various water resource management technique such as landslide control, water resource protection, bio diversity management is recommended to be developed as various studies in Nepal always have to rely on various foreign guidelines which might not be effective to present situation.