GUIDELINE

on

Protecting & Developing Springs in Hill and Mountain areas

Local Road Development

Government of Nepal

Ministry of Federal Affairs and General Administration

Department of Local Infrastructure (DoLI)

Pulchowk, Lalitpur

GUIDELINE

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Preface

After federalization, responsibility of formulating technical documents that are applicable for implementation of Local infrastructures at local level is assigned to Department of Local Infrastructure (DoLI) as DoLI is the only one engineering department within Ministry of Federal Affairs and General Administration (MoFAGA) which take care of maintenance, construction, and upgrading of Local Road Network (LRN).

This mandate has triggered to the revision of the Nepal Rural Road Standards, 1999. In 2014, revised version of Nepal Rural Road Standard (NRRS) was published, and that proved to be a milestone for LRN initiatives.

However, springs and seeps formed while constructing roads in hill and mountain terrain, on several occasions, are completely omitted. In this context, the mandate to safely dispose or drain off this induced water to minimize damage that to road body requires addressing judiciously. Lacking the intervention, it will damage roads directly by forming depressions in the road surface and grow during monsoon causing uncontrolled and erosive runoff on the road surface. To tackle such nuisance, water from road springs and seeps can be tapped for domestic water supply and agriculture use in hill and mountain areas of Nepal, which is equally pertinent in the context of changing climate and managing roadside springs by including the seeps and springs integral part of road construction. This has prompted the development of a guideline to protect and manage springs and seeps in local road development.

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I am confident that this guideline shall be beneficial for proper management of springs along the road. Any comments or suggestion will be highly appreciated.

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1. Introduction

The guide is meant to make the use of very important source of water in hill and mountain areas of Nepal i.e., springs and seeps that are developed along the roadside and that need protection while constructing roads. To provide ideas and intervention for protection and management of such water sources.

In this guideline we describe the importance of springs and seeps in hill and mountain areas of Nepal. We first explain how springs and seeps can be protected and managed, the tools or techniques to manage such resources to improve livelihood of people living along roadside. This guideline also touches upon the techniques to use spoil from road construction that helps to recharge groundwater and roadside bioengineering to protect road slopes. The guideline is written for different stakeholders related local roads and water management along roadsides. It gives an idea on what steps to take to protect springs and seeps along roadside, techniques to make use of such resources.

1.1 Mountain aquifer: basics – recognizing water bearing strata

The natural springs represent the groundwater storage within the catchments, which form an important component of the Himalayan water budget (Andermann et al. 2012). Groundwater springs in the mountain areas are poorly understood and insufficiently mapped, and the potential occurrence of groundwater springs in the Himalayas are not well studied (Chinnasamy and Prathapar 2016; Sharma et al. 2016). Lack of adequate data on geology and structure, soil, geomorphology, and groundwater hydrology make spatial prediction or mapping groundwater spring potential zones even more difficult.

Geology controls occurrence, movement, and storage of groundwater. The petrography, stratigraphy, structure, lithology, and thickness of a given rock type control the porosity and permeability that define the storage capacity of an aquifer (Higgins et al. 1985; Winter 1998; Crawford and Kath 2005; Chinnasamy and Prathapar 2016). The shape, sorting and packing of grains layer in the rocks during their formation determine primary porosity. Secondary porosity, such as joints, fractures, and solution opening, is formed after the rock has been deposited. The number and arrangement of fracture openings and the degree to which they are filled with fine-grained material control secondary porosity.

Highly sheared and fractured rocks of gneiss, schist, and quartzite beneath the soil and saprolite in these geological unit favor high infiltration rates and groundwater storage, which yield to discharge of ground spring water (Kerrich 1986; Florinsky 2000). Moreover, geological contacts, faults, joints, soil, and other deposition characteristics (Higgins *et al.,* 1985; Marklund and W¨orman, 2007; Younger 2007) intersecting the topographic features control the recharge and discharge of groundwater.

Another phenomenon influencing the potential occurrence of groundwater is the presence of lineaments in crystalline hard rock (Nag 2005; Kolawole *et al*., 2016). The presence of lineaments generally represents the major joints and faults in the tectonically active areas, where bedrock is intensely deformed (Dhital *et al.,* 2002; Dhital, 2015). These lineaments act as a conduit for groundwater movement, which result in increased secondary porosity and can serve as the groundwater potential zone.

Although knowledge and study of mountain aquifers are especially important for sustainable water resources management and build climate resilience in mountain areas, there are limited studies on mountain aquifers. These mountain aquifers come out from surface as a spring from weathered, jointed, or fractured rock aquifers in the high-grade metamorphosed rocks. Some of the influencing factors for assessing the groundwater spring potentials are altitude, slope gradient, slope shape, relative relief, flow accumulation, drainage density, geology, lineament density, land use and vegetation density (Ghimire *et al*., 2019).

1.2 Importance of springs/ seeps in mountain areas

Springs and seeps are the primary and often the only accessible sources of water and is lifeline for millions of people living in the hills and mountain areas of Nepal (Gurung *et al*., 2019). Both rural and urban communities depend on springs and seeps to meet their drinking, domestic and agricultural water needs. Villages sit far above streams and rivers and the cost of carrying or pumping water to the hill settlements from rivers are not necessary as springs emerge all around the hill slopes close to the villages (Tambe *et al*., 2012; Sharma *et. al*., 2016). Most of the drinking water supplies the hill and mountain areas are through gravity flow system from natural springs, which represent the groundwater storage within the catchment, and form an important component of the Himalayan water budget (Andermann *et al*., 2012).

The ultimate source of the springs is rainwater and snowmelt. Rainwater infiltrates in the soil and seeps through cracks and fissures in the rock before accumulating above impervious layers. Water is stored both in the soil and rock fissures creating a water tower. The water emerges where impermeable material blocks the groundwater flow and intersects the sloping ground, or where groundwater flows along a rock fracture and the fracture intersects the hill slope. The resultant springs are found on slopes of all angles and with different types of geology and land use.

Springs can be seasonal (relatively short-lived) or perennial (year-round discharge of water). The amount of discharge from springs depends on the water availability of the water tower depending on local recharge. Rainfall in Nepal is highly seasonal, as about 80% of the total rainfall occurs during the monsoon season (June-September). So, during the monsoon season the main groundwater recharge takes place and this can also provide water for a certain period of time after the monsoons. However, in the dry season (October-May), there is often water scarcity, as rainfall is negligible during these months.

Springs used to provide sufficient water to meet the modest requirements of the villages, but since the early 1980s, people have started to face increasing shortages of water. The study of springs in the Tanahun district of Nepal shows that 63% springs had reduced flow by an average of 21% between 2004-2014. The preliminary analysis of 693 springs over ten districts of the Far West showed 187 springs had their average discharge decline by 60% between 2013-2016 (Dixit, 2019[1]). There are many factors involved, including anthropogenic activities like degradation of catchments, land use changes (deforestation, agricultural development, etc.), infrastructure development such as road network disrupting the hill slope hydrology in middle mountains (Ghimire *et al.,* 2019), and climate change factor (Alcamo *et al*., 2008; Du Plessis, 2017). This led to drying up of spring sources and the reduction of regular flow regimes, especially during the dry season (ICIMOD, 2015; Chapagain *et al.,* 2019; Ghimire *et al.,* 2019).

Climate change has brought changes in weather patterns. Winter rain and snow are deficient when compared to 10 years back. Rainfall comes in bursts, is erratic and the steady, relentless rain of the past is a fading memory. The decreasing winter and pre-monsoon rainfall have negatively affected the springs recharge, and thereby the water volume of springs has gradually decreased. In a research study made in Melamchi, local people in the study area have also perceived increasing temperature, late and less rainfall, and a more frequent cloudburst. Apart from a decrease in winter rainfall, the amount of snowfall in winter has also drastically decreased which has directly affected the water volume in springs as well. More than 80% of communities have experienced increased water stress and decreased rainfall and a corresponding delay in the monsoon season along with high intensity and uneven rainfall distribution over the last 10–15 years. Tambe *et al*. (2012) study from the Sikkim Himalayas has revealed a 50% decline in spring discharge in drought-prone areas in the last 50 years and a 35% decline of discharge in other areas due to decreasing winter rainfall and anthropogenic activities. However, there are no studies on how the anthropogenic activities like road development and other construction activities have affected the springs in the hills and mountain areas of Nepal.

Though climate change and change in bio-physical landscape (land-use and vegetation) are widely implicated in the drying of the springs, there is very little systematic knowledge to effectively link these two phenomena to spring discharge, especially due to large data uncertainties (i.e. data and knowledge

1 Nepal's silent emergency: springs going dry by Ajaya Dixit published in Nepali Times on January 4, 2019

of local meteorology, hydrology, geology, and surface-water/groundwater dynamics, imperative to designing climate resilient interventions for spring management, are scarce for the Nepalese mid-hills). The lack of understanding of fundamental processes in governing springs in the Himalayan catchments is a key reason for limited impact, or even failure, of watershed interventions (Sharma *et al*. 2000; Vashisht 2008). Rapid socio-economic and demographic changes and infrastructure like roads and dams have also impacted springs. But the exact nature of change is difficult to understand.

In Nepal, research on groundwater is very limited and hence little known, both in the Terai plain or hilly mountain areas. Until recently, very little research work has been done to map spring sources in the middle mountain areas of Nepal. To address the issue related to water availability, water supply and distribution, having a longer-term impact database would be required inclusive of geology and structure, geomorphology and groundwater and hydrology. Generating knowledge on mapping of water resources and monitoring water flow and factors associated with change in water availability are prerequisites for effective management of scarce water resources.

1.2.1 Spring types

A spring is the point at the land surface where groundwater discharges from an aquifer creating a visible flow. When the flow is not observed, but the area has become wet it is a diffuse discharge of water. This is called seep. The discharge of groundwater is created by the difference in elevation of the hydraulic head and the elevation of the land surface where the discharge takes place. (Kresic & Stevanovic, 2009)

There are of lot different spring types which can be distinguished by different factors. Looking at the hydraulic head of the underlying aquifer, there are two main groups of springs: gravity springs and artesian springs. Gravity springs are a result of descending water where the water table of an aquifer intersects the land surface. Artesian springs are a result of ascending discharge, as the water is under pressure due to confined conditions in the underlying aquifer such as an impermeable layer. (Kresic & Stevanovic, 2009)

There are several types of springs. Geomorphology, rock type, and tectonic history determine the type of spring that occurs. Two broad categories of springs are namely 1. springs with concentrated discharge through one or more clear orifices, and 2. springs with more diffuse discharge. Different from a spring, a seep does not have a clear orifice and water exits over a localized area or the entire water bearing strata.

Moreover, springs can be distinguished by the way they are formed as a result of geomorphology and geological factors. A fracture, joint or tubular spring will be formed when the groundwater flowing along an impermeable layer meets a fracture (crack) or joint in the rock (USDA, 2010). Springs can also form on faulting rock. Due to geotechnical movement a permeable layer is moved on top of an impermeable layer, which causes the water to discharge. This is called a fault spring (Kresic & Stevanovic, 2009). A contact spring occurs mostly in sloping areas where a water-bearing permeable layer overlays an impermeable layer (USDA, 2010). This forces water to come out. A depression spring is formed by a topographical low or cutting in the surface. The land surface will be cut out, giving the water freedom to flow out (Kresic & Stevanovic, 2009). A special kind of spring is a karst spring which is formed in karst landscapes where water erodes calcium. Water can discharge at places where the erosion has formed openings in the land surface. Karst springs often have a high discharge rate, because carbonate rock (the main type of rock in karst areas) has a high hydraulic conductivity, forming large groundwater reservoirs. Karst springs can be categorized into warm and cold, based on their water temperature. (Shah et al., 2018). Ebb-and-flow or periodic springs are often present in limestone areas. These springs have a uniform time interval of discharging water, as the system works as a siphon (discharge will happen when the tube or reservoir overflows after being filled) (Kresic & Stevanovic, 2009). An estavelle is a spring which forms during high hydraulic heads or when there is sink hole in the land surface during a low hydraulic head (Kresic & Stevanovic, 2009). Finally, a seep is a type of spring which has a diffuse discharge of water, which mostly happens in unconsolidated sediments (sand, gravel) or loose soil.

The time the spring discharges depends on the weather and climate, but also on the type of spring. A spring is perennial when it constantly discharges. Springs with a perennial flow are fracture, fault, contact, depression, and karst springs (USDA, 2010). Warm karst springs have a steadier flow than cold karst springs. However, cold springs show a faster hydraulic response to hydrological events and seasonal variability, whereas warm springs have a weak response to input signal, which can be explained by the deep circulation of the aquifer connected to warm springs (Shah et al., 2018).

When the discharge is not constant a spring has an intermittent flow. Depression, ebb-and-flow and estavelle springs are intermittent. These springs are mostly dependent on the recharge of the aquifer by precipitation (LaMoreaux & Tanner, 2001).

Table 1: Summary of different springs

Spring Type	Description
Springs with concentrated discharge (through one or more orifices)	
Fracture springs	Fault, fractures, and cleavage in semi-permeable and permeable formations connected with a water source (seepage, flow shallow or deep aquifer)
Contact spring	Permeable layer overlays an impermeable layer, forcing water to come out – often in a line of springs
Fault spring	Due to geotectonic movement a permeable layer is moved on top of an impermeable layer
Depression springs	The groundwater table reaches the surface in topographical low
Karst springs	Relatively large flow from large openings – typically in karst areas where water erodes the calcium formation
Ebb-and-flow or periodic springs	Uniform time interval of discharging water as system work as siphon and present in limestone areas.
Estavelle Spring	forms during high hydraulic heads or when there is sink hole in the land surface during a low hydraulic head
Springs with diffuse discharge	
Seep	Diffuse direct discharge of water usually from soils or unconsolidated sediments (sand or gravel)
Secondary springs	Water issued from a primary spring that is typically covered by debris or rockfall

1.3 Understanding small stream crossings

Nepal is a part of the Ganga Basin. It is estimated that there are altogether over 6000 rivers (including rivulets and tributaries), with cumulative length of 45000 km, in Nepal and its drainage density is about 0.3 km/km^2. Rivers in Nepal are classified in three broad group based on their origin.

i. Snow fed.
ii. Rivers originate from mountains and hilly region.
iii. Rivers originate from Siwalik zone.

The third type of river is majorly dependent on monsoon rain and their flow level could deplete

significantly low during non-monsoon period.

Majority of Nepal's total precipitation occurs during the monsoon (June-September). The south and east of Nepal generally receives 80% of the total precipitation during monsoon while north and west of Nepal receives 55-80% of the total precipitation (Shrestha, 2000)

In mountainous and mid-hill regions, due to steep slopes, that promote rapid runoff resulting in a sense network of small, steep streams that drain into major tributaries (Bricker et al. 2014). Water streams are common in the mid-hills and mountain areas in Nepal. The main characteristics of mountain streams is their steep gradient, sharply varying rates of flow within a short period of time and high-speed flow down a mountain side. Streams can have different sources. The water can come from precipitation runoff, seepage, and groundwater (also including springs). In the high mountains, the source is likely a location where snow collects in the winter and melts in the summer. In the mid-hills several streams which form from rain can be observed. They are seasonal and form during the rainy season.

Another source could be groundwater. There are two different types of groundwater streams: a losing stream and a gaining stream. The channel of a losing stream lies above the water table and loses water into the unsaturated zone through which it is flowing. This water then migrates down which can induce the local water table to rise. In drier climates a losing stream may disappear underground as its water content becomes progressively diminished downstream (Houghton Mifflin Harcourt, 2020). A gaining stream is a stream from which groundwater flows from the saturated zone. The channels of gaining streams are usually at or below the level of the water table. Bodies of water and marshes form when the water table intersects the land surface over a broad, fairly flat area (Houghton Mifflin Harcourt, 2020).

It is important to understand mountain streams, as they can damage the roads by causing erosion for instance. Road construction changes the hydrology of the mountain area. This also includes the flow direction of mountain streams. Streams are interrupted by the road, which can lead to road damage, or they will flow in another direction to a point where water might not be wanted. Therefore, it is important to have cross-drainage practices to protect both the flow of the streams and the roads.

2. Protecting and developing springs and seeps as part of road development

2.1 Improved Road planning and road development

Road development in mountain regions presents many engineering, logistical, and financial challenges. If done carelessly, the development of roads in these environments can have a heavy negative impact on the surrounding environment and undermine climate resilience. Road development can change runoff patterns and cause areas to further dry out. They can transfigure the face of mountain regions, leaving behind huge erosion scars and accelerate the rate of sedimentation.

It is unavoidable that the development of a road changes the environment of mountain areas, mainly the hydrology, microclimate, and sedimentation patterns. The changes in hydrology concern several dimensions. First important consideration in selecting the road alignment is that it should not disturb natural runoff patterns. The high speed of runoff on steep slopes commonly found in mountain regions can create havoc in unstable slopes. The Nepal Rural Road Standards (NRRS) uses 7 percent as the ruling gradient (for a maximum of 300 meters). The recommended limiting longitudinal gradient in mountain roads is 10 percent. Beyond that, the road will act as a drain, collecting water during rainfall events, resulting extensive cutting in road surface that increases erosion.

(a) (b)

Figure 2.1: (a) Increased air-surface exposure of hill slope; (b) Interrupted subsurface flow due to road openings along Mugu Humla Road (West Nepal**)**. Source: MetaMeta (www.roadsforwater.org).

The development of a road typically changes surface runoff patterns. Rather than flowing down a smooth gradient, the runoff is interrupted once or several times while descending from the newly cut hillside. As the runoff touches the road surface it may concentrate and accumulate along the road surface, effectively changing the natural drainage pattern. Runoff pattern changes can be minimized by outward sloping road (camber cross slope) a criterion developed by the NRRS, good water exit at hairpin bends, using frequent road-surface cross-drainage, and ensuring that each natural drainage has a structure crossing (i.e. causeways) the road to keep the flow in its natural channel. These are the part of good road alignment and design. Secondly, in a similar fashion the subsurface flows are interrupted in road construction (see figure 2.1.). The degree to which water travels in the upper soil layers and geological formations differs from place to place and from road section to road section. Roads disrupt these shallow moisture flows and, in many areas, cause new springs and seeps to emerge.

2.2 Preventing damage to aquifer systems

2.2.1 Spring protection and preservation

In mountain areas, the development of roads—either though the removal of unconsolidated material or the cutting of rock formations—will affect the occurrence of seeps and springs (see figure 2.2). The management of such springs and seeps is important: in many hilly and mountain regions they are the main source of domestic water supply and small-scale irrigation, especially in dry periods.

(a)

(b)

(c)

(d)

Figure 2.2: (a) Road opening a seep that next damages the road surface (Mugu, Nepal); (b)&(d) seep from road construction in Mugu and Kathmandu respectively; (c) spring at roadside formed after road construction in Mugu; (d) water from seep in the upstream side of road is tapped and collected in the bucket (Kathmandu, Nepal). Source: MetaMeta (www.roadsforwater.org).

Table 2.1 shows the effect of opening of new road alignment on different spring types. The development of roads may distort existing springs but may also create new ones. Given the importance of springs for domestic water supply and agricultural use, the management of hill and mountain springs in road development should be an integral part of road construction. On the other hand, these springs and seeps are also main sources of road damage (figure 2.2 a), either by affecting the road surface directly or by creating (minor) depressions in the roads that grow during the monsoon and cause uncontrolled and erosive runoff from road bodies.

Geomorphology, rock type and tectonic history determines the type of springs that occur. Two broad categories are springs with concentrated discharge through one or more clear orifices, and spins with more diffuse discharge. Table 2 shows the effect of road development on the different types of springs

.

Table 2: Effect of Road development in different type of springs

Spring Type	Description	What roads development will do to springs
Springs with concentrated discharge (through one or more orifices)		
Fracture springs	Fault, fractures, and cleavage in semi-permeable and permeable formations connected with a water source (seepage, flow shallow or deep aquifer)	Road development may expose the spring; rock cutting may change the location of the orifices – either blocking old or creating new ones
Contact spring	Permeable layer overlays an impermeable layer, forcing water to come out – often in a line of springs	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent on the geological faulting
Fault spring	Due to geotectonic movement a permeable layer is moved on top of an impermeable layer	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent on the geological faulting
Depression springs	The groundwater table reaches the surface in topographical low	Road may create new depression springs where the roads are made in cut or dry existing one by lowering the groundwater table
Karst springs	Relatively large flow from large openings – typically in karst areas where water erodes the calcium formation	Roads may expose new springs and expose new cavities
Springs with diffuse discharge		
Seep	Diffuse direct discharge of water usually from soils or unconsolidated sediments (sand or gravel)	Road development may create many seeps, especially where roads are developed in areas with deep soil profiles
Secondary springs	Water issued from a primary spring that is typically covered by debris or rockfall	Road development may expose springs or change the outlet, particularly where unconsolidated material is removed

Source: MetaMeta (www.roadsforwater.com).

Managing the springs along mountain roads is important for safeguarding road quality and ensuring water supply for domestic and agricultural use. It is recommended that before the road is built, the route should be investigated, the geology must be understood and the areas where springs occur or are likely to occur should be mapped. Unstable areas should be avoided, both because they are often associated with groundwater, and because of problems and costs created for the road. When roads are being constructed, they affect the location of the spring if not handled carefully. The use of bulldozers or excavators in areas of potential springs should be avoided and manual labor should be used to excavate the road in such sections.

Once the road is developed, the presence of springs and seeps will be evident (figure 2.3). A choice must be made whether the spring or seep will be used or not. The table 3 suggests methods for managing different types of springs in different circumstances.

(a) (b)

Figure 2.3: (a)spring from weep hole at roadside; (b) collecting spring water through pipe at Mugu, Nepal.
Source: MetaMeta (www.roadsforwater.org).

Table 3: Recommended practices for spring management along roads.

Spring Type	Description	Spring management
Spring with concentrated discharge	Not used	Retaining wall with weep holes or with longitudinal drain to collect excess water and traverse drains (French mattresses) underneath the road
	Used for agriculture	Retaining wall with longitudinal drain to collect excess water and traverse drains (French mattresses) underneath the road
	Used for domestic water supply	Spring box (capture) and conveyance to benefit community, or tap fitted on protected spring
	Used for domestic water supply and storage	Spring box (capture) and conveyance to benefit community. Include possibility of spring closure (tap) to store water inside the mountain aquifer (especially in karst areas)

Spring/ seep with diffuse dis-charge	Not used	Develop road drainage in up-road section to collect seepage and convey to safe place, such as a pond
	Used for agriculture	Use gravel section in road with underdrain to convey water to agricultural land
	Used for domestic water supply	Develop a seepage spring to capture the water in a safe place (spring box or pond)

Source: MetaMeta (www.roadsforwater.org).

By controlling the outflow of the springs, water can be better retained in the area. Equipping the orifice of a spring with a gated outlet and even a tap makes it possible, in some cases (especially karst springs or fracture springs), to store water in the mountain aquifer and prolong its availability.

To ensure that water quality is not threatened and that roads are not damaged, springs need to be protected. The following tasks should be considered when a potential spring source is investigated:

- Understand the nature of the spring.
- Ensure that the spring is not a stream that has gone underground and is reemerging.
- Ensure that the source and the collection area are not likely to be polluted by surface runoff.
- Check that there are no latrines within 30 meters, particularly upstream of the spring.
- Fence the area around the spring tank to prevent pollution.
- Make sure that if the spring is to be connected to a piped water system, it is on higher ground than the area to be supplied so that the water will flow with gravity.
- Take care that the spring tank is not built on swampy ground or on land that is subject to erosion or flooding, and that the flow from the protected spring will not cause erosion or damage the road.
- Develop a collecting structure to collect the water from the spring.
  (Source: van Steenbergen et al. 2021)

2.2.2 Techniques for capturing Springs and seeps

2.2.2.1. Spring box in a spring catchment

Protecting the catchment of the spring and the spring head from pollution is crucial, as is arranging for the spring water to be delivered at an appropriate height so that water falls with gravity directly into the container. Springs can be protected by installing a spring tapping, a spring box, and a drainage system. Moreover, a surface water drainage ditch should be dug above and around the spring area to keep surface water runoff from polluting the source. If the area around a spring intake is unstable or exposed to erosion, gabions or dry-stone masonry can be used to stabilize the area.

Protection boxes (figure 2.4) for newly opened springs collect the spring water, which can either be diverted to infiltration structures (such as soak ways) or used directly in storage structures such as open ponds or cisterns. Estimating the spring's flow rate is important for properly determining the dimensions of the collection tanks and creating spillover structures.

The function of spring box is for regular control of water quality and quantity and can function as a sedimentation tank. It is mostly part of a spring protection zone (figure 2.4), which include:

- water bearing layer
- coverage of source
- catchment dam

- filter package
- spring box
- impermeable coat if concreting
- (concrete) supply pipe
- overflow pipe
  (Source: Meuli & Wehrle, 2001)

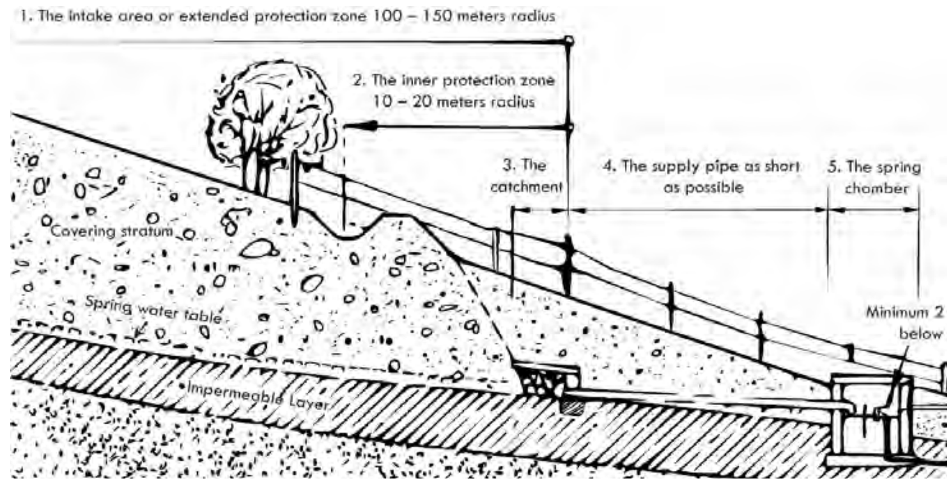


Figure 2.4: A schematic overview of a spring protection area. Source: Meuli & Wehrle, 2001, as adapted by MetaMeta (www.roadsforwater.com).

It is important to know the characteristics of the source before designing the spring box. This includes the discharge of the spring and land use characteristics surrounding the spring, such as vegetation.

Before designing a spring catchment, the area should be excavated, which means cleaning, digging a furrow following the flow spring above the impermeable layer, implementing drainage, and refilling it again when the earth cover is thick enough to provide protection.

A barrage (catchment dam) is necessary to prevent the spring box from flooding (figure 2.5). It is constructed to an in front of the water flowing into the catchment.

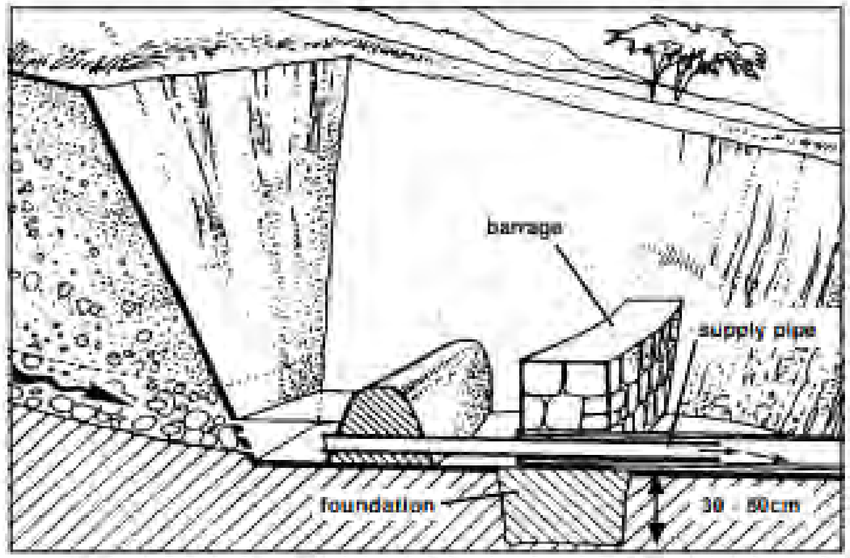


Figure 2.5: A schematic picture of a barrage dam in a spring catchment. Source: Meuli & Wehrle, 2001.

A permeable construction is needed to be able to drain the maximum yield of a spring without obstructing its natural flow. It consists of a filter package using dry stone masonry and gravel or a perforated pipe with a gravel filter package.

There are different types of spring boxes, but the most easy and common one is a simple inspection chamber (figure 2.6). It can yield a few thousand liters per day, and it can be built with a second basin as collection chamber. However, it is important to use watertight covers to prevent contamination. A sketch/drawing of spring chamber of spring yield 2-20 liters per minute is presented in ***Annex 2.***

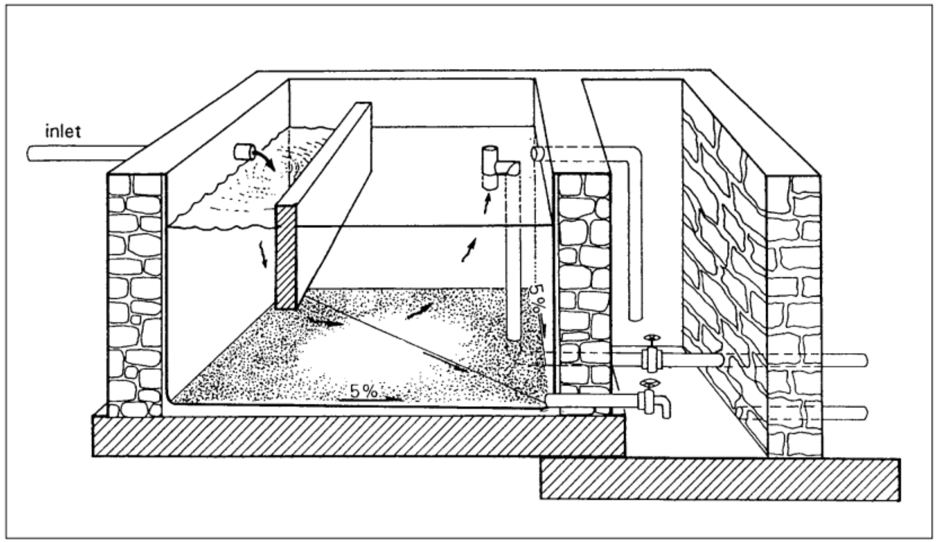


Figure 2.6: A schematic picture of the spring box/spring chamber. Source: Meuli & Wehrle, 2001.

2.2.2.2. Seepage spring

(Jennings, 1996)

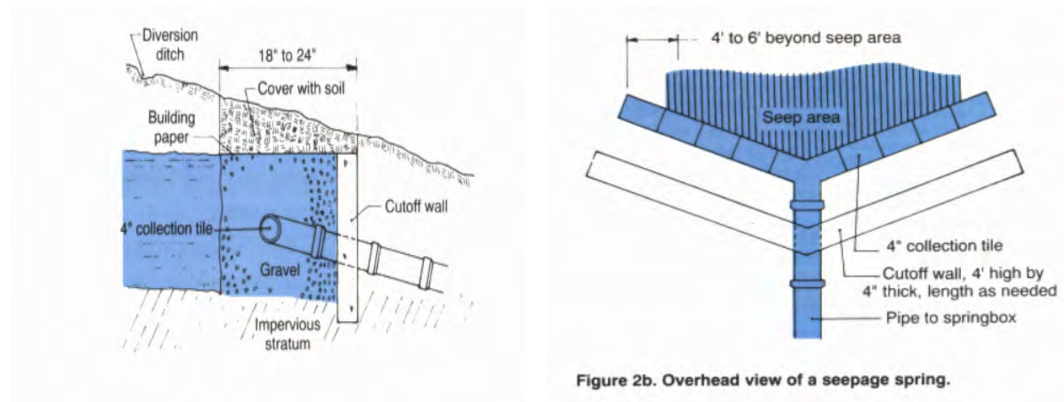
A seepage spring is a practice to capture water from seeps. More seeps are being formed because of the road construction, which makes collecting water from seeps even more important.

The following steps are important in the developing of a seepage spring (see also figure 2.7).

1. Dig test holes uphill from the seep to find a point where the impervious layer below the water-bearing layer is about 3 feet (90 cm) underground. Water flows on top of this layer in sand or gravel toward the surface seep.
2. Dig a 2-foot-wide (60 cm) trench across the slope to a depth of 6 inches below the water-bearing layer and extending 4 to 6 feet (120-180 cm) beyond the seep area on each side. Install a 4-inch (10 cm) collector tile and surround the tile with gravel.
3. Connect the collector tile to a 4-inch (10 cm) line leading to the spring box. The box inlet must be below the elevation of the collector tile.

The collection box (also a spring box here) should be watertight (most are made of reinforced concrete) and have a tight-fitting "shoebox" cover. The size of the spring box depends on the amount of storage needed.

The spring box should have and outlet pipe and an overflow pipe. The overflow pipe should be screened and located below the collector pipe or tile so that water will not back up behind the spring. The overflow may be a floating device connected to the outlet pipe. Install a drain for cleaning the box.



a) b)

Figure 2.7: a) a cut-away view of a seepage spring and b) an overhead view of seepage spring. Source: Jennings, 1996.

2.2.2.3. Ponds

Spring-water ponds can also be used as a practice to collect spring water (figure 2.8). Barrage ponds are the most common in capturing spring water. The pond is directly fed from a nearby spring (or stream) and the water enters from a point called the inlet. When the water is needed, it can flow out from an outlet, or the water can be collected directly from the pond.

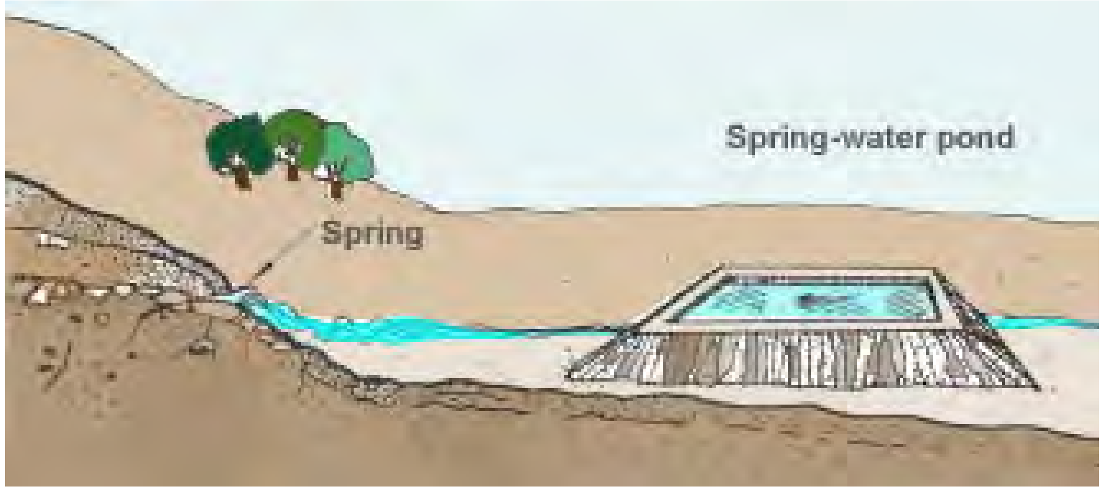
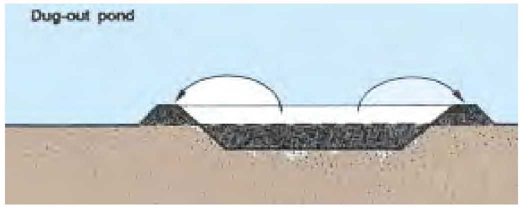


Figure 2.8: Schematic picture of a spring-water pond. Source: FAO.

The pond can be constructed by different methods and with different materials. There are different types of ponds based on the constructed method (figure 2.9). These are a) dug-out ponds, b) embankment ponds and c) cut- and-fill ponds.



a)

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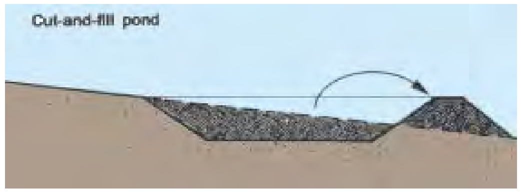


c)

Figure 2.9: Pond types based on construction methods: a) dug-out pond, b) embankment pond and c) cut- and-fill pond. Source: FAO.

Ponds can also be made of different materials. The most common ones are earthen, walled, and lined ponds. Earthen ponds are purely made of soil materials. Walled ponds are surrounded by blocks, bricks, stone or a concrete wall. Lastly, lined ponds are lined by impervious material such as plastic or a rubber sheet.

2.2.2.4. French Mattress

French mattress is a structure under a road consisting of clean coarse rock wrapped in geotextile

through which water can freely pass. They are used in saturated soils, such as in wetlands to support the roadbed while allowing unrestricted water movement. French mattress stabilizes the road base in the areas where road is weakened by the water saturation. It also allows the free movement of water through road base. Further it effectively insulates the road surface from water under the road, keeping the travel-way high and dry.

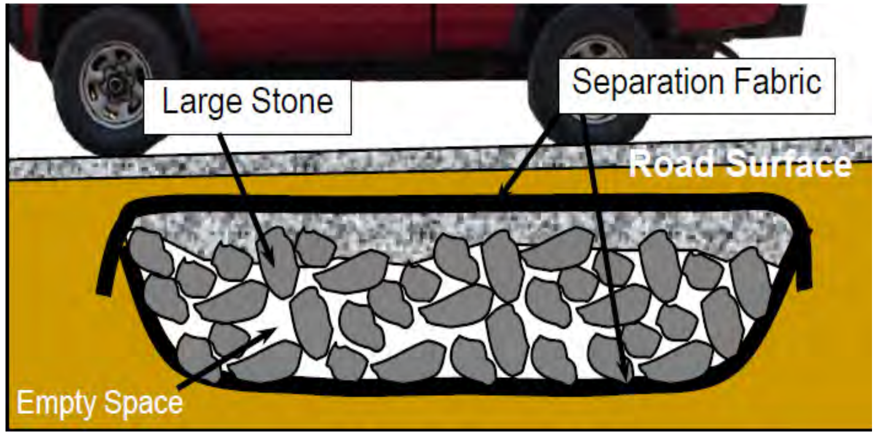


Figure 2.10: A schematic picture of French mattresses.

Figure 2.11: A drainage blanket or French Mattress using perforated geocells or aggregate/gravel wrapped in geotextile.

<u>Criteria for French Mattress use</u>

- Areas where roadside springs and low gradient road ditches result in road base saturation.
- Areas where springs under the road saturate the road base or come to the surface in the road.

<u>Important consideration for French Mattress</u>

- French mattress should be covered by a minimum of 12” of compacted fill material.
- It should provide unrestricted flow through the road.

- Mattresses are not suitable replacements for road drainage pipes and underdrains, or anywhere concentrated overland flow carries sediment. These flows will clog the mattress over time and are able to be handled by drainage pipes.
- The mattress or underdrain rock should be wrapped in a geotextile to provide for filtration, letting the water in but keeping soil out. Without other testing, a 6 ounce/square yard needle punch-nonwoven fabric is recommended. A slit film woven fabric, commonly used in grain sacks, should not be used since they have very little permeability and ability to pass water.

Construction steps

- Excavate to make a trench. Make a trench along the width of road in such a way to allow minimum of 12 inches of compacted cover over the mattress. Place geotextile fabric in the trench. Allow enough fabric on the end s to overlap the top piece of geotextile in the finished mattress.
- Place porous stone on the top of the fabric and spread into uniform bed of the desire depth.
- Place a piece of fabric overtop of the installed stone. Make sure that the overlap fabric joints by at least 12 inches. Leave the stone exposes along the road edges.
- Shape and compact fill overtop of the finished mattress. Place enough fill to ensure a minimum of 12 inches of compacted cover once to fill and surface select material or aggregate are installed.

2.2.3 Application of Spring Water Management along LRN

We provide a menu of techniques which can be used to implement protection and management of springs and seeps along the roadsides (Table 4). The table provides techniques for spring water management for different situation. You can pick and choose, based on your local issues, needs, and conditions. These techniques form the backbone for spring protection and management and provide idea regarding the measure to take.

Table 4: **Roadside spring water management**

Context		Techniques	Advantages	Technical Requirements
Roadside spring near settlement area for domestic use		- Spring box - Conveyance means (pipe) - Water storage tank	+ Easy to construct + Easy and increased access to domestic water supply + water available at community/household level + Cascades of storage tank depending on the water discharge in spring, whereby surplus of storage 1 flows into storage 2 + reduce uncontrol runoff on road surface + increase durability of road surface	- Measure discharge of Springs - Depending upon the discharge from springs, number of water storage tank at community level or household level can be determined. - Storage tank should be closed to maintain good water quality
Roadside spring near agriculture area.		- Retaining wall with weep hole - longitudinal drain - French mattress (traverse drain) - Conveyance means (pipe) - small storage pond/tank nearby farm area	+ easy access to agriculture water + provide good amount of water for agriculture during the dry season from water stored in the pond + reduce uncontrol runoff on road surface + increase durability of road surface	- Measure discharge of Springs - The size of the pond(s) depends on the discharge of the spring and available land plots. - Use of impermeable layers such as plastics or clay material (which one easily available) at the base and side of the pond to interrupt infiltration.
Roadside spring in forest area		- Retaining wall with weep hole - longitudinal drain - French mattress - cascades of recharge pits at downstream	+ Strengthens aquifer recharge + reduce uncontrol runoff on road surface + increase durability of road surface	- The slope of the downstream side of springs is important to determine recharge. - Recharge pits/trench are good for slope less than 45-50 degrees
Roadside spring not in use		- Retaining wall - Longitudinal drain - French Mattress	+ safe drain of spring water. + reduce uncontrol runoff on road surface + increase durability of road surface	

2.3 Techniques for Groundwater Recharge and spoil heaps management

The different changes that come with the road construction are changed hydrology, opened up hill slopes and more exposure to sunlight and wind. They add up to a severe effect on the micro-climate that could affect the forest stands or the quality of the pasture. The impact on the microclimate will be less water retention, hence loss of moisture, an increase in temperature and more dissipating effects.

To counterbalance this effect, the capacity of the affected area to retain moisture should be increased. This will also reduce the risk of erosion and degradation of forest hill slopes. This will contribute to the regreening of the area, including the compensation of those trees removed during the road construction. The presence of large quantities of spoils (rocks and boulders) from the road construction again presents the material for these measures. Proposed is the use of eyebrow/ half-moons and stone strips/rock bunds for groundwater recharge and spoil heap management.

1. Eyebrows/half-moon terraces

Eyebrows or half-moons are small, semi-circular, and stone-faced structures that open in the direction of the run-off (figure 2.12). They can be built on steep slopes, usually with a maximum preferred slope of 50 degrees. Steeper gradients are possible, especially when rainfall is not torrential, as in the project area. On a slope also the steepest sections should be avoided where the eyebrows may be reconstructed.

The steeper the gradient, the more the bunds have to be reinforced (by stone) in the downward toe and the higher the downward toe section becomes. The typical diameter of the eyebrow should be between 1.4-2.5m with an infiltration or planting pit of size 40 cm wide by 50 cm deep. The suggested size of eyebrows with different gradients are given in table 5 below.

Figure 2.12: Eyebrows in Ethiopia . Source: MetaMeta (www.roadsforwater.org).

Table 5: Sizes of Eyebrows with gradient

Gradient	Stone ring diameter	Inner cross width	Backwall height	Reinforced backwall
30	30 cm	220 cm	70	-
45	30 cm	180 cm	120	10 cm
60	30 cm	140 cm	180	20 cm

Abundant spoil material can be used to build up the semi-circular eyebrows. The topsoil that was removed whilst making the road can be used to fill the inner side of the semi-circular stone structure. This can be used for tree planting and can contribute to the regreening of the area. Around the eyebrows/, controlled grazing is essential if the area is regreened. In the forest areas, it is good to have high density of eyebrows (see figure 2.13). The preferred distance between lines of eyebrow terraces is given in table 6.

Table 6: Preferred distance between lines of eyebrows terraces

Gradient	Distance between lines of eyebrow terraces (meter)
30	15-20
45	10-15
60	8-10

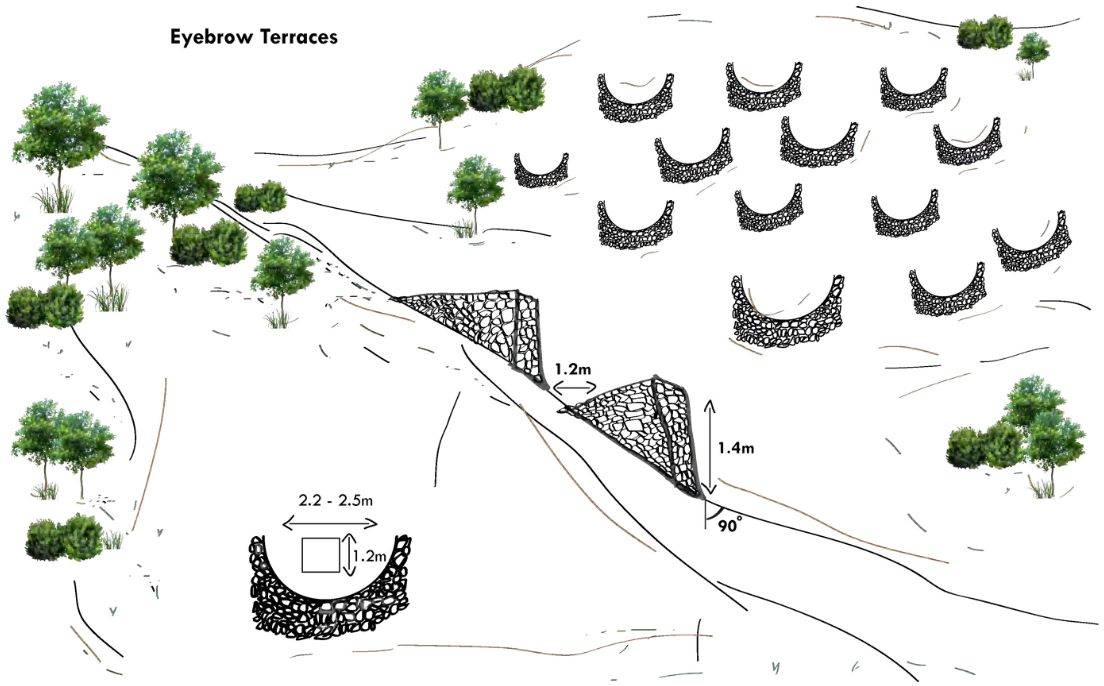


Figure 2.13: Schematic of Eyebrows in the hill slope. Source: MetaMeta (www.roadsforwater.org).

2. Stone strips

The eyebrows can be complemented by stone strips or rock bunds, on slopes that are relatively even and not too steep. They are built from coarse stones and boulders. These stone strips will slow down run-off, intercept sediment and built-up soil layers. They will stretch over the width of the slopes, allowing water to filter through as they are permeable. See figure 2.14 and table 7 for layout and design of the stone strips for different gradients.

The minimum criteria of the stone strips are:

Table 7: Basic Parameters for Stone at different gradients

Gradient	Heigth (m)	Vertical Interval (m)	Distance between stone strips (m)
30	1	2.8	6
40	1	2.8	5
50	1	2.8	4

Note: Though the table shows the possibility to build stone stripes even in 50% slope, the field situation needs to be observed carefully when the slope increases.

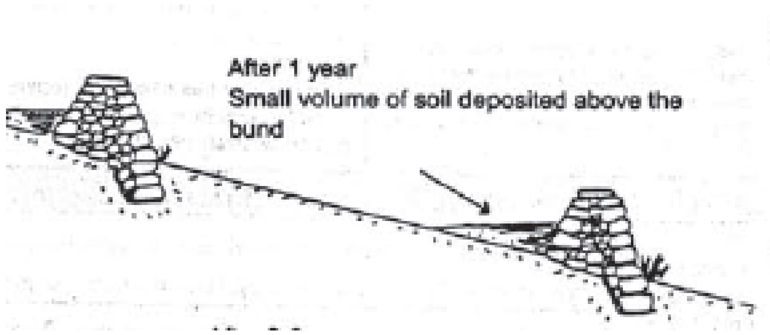


Figure 2.14: Side view of stone strips. Source: Lakew et al., 2015.

2.4 Roadside Bioengineering

Bioengineering is the use of living plants for engineering purposes. Vegetation is carefully selected for the functions it can serve in stabilizing roadside slopes and for its suitability to the site. It is used in combination with civil engineering structure.

- Bioengineering is used to protect slopes against erosion
- It can be used to improve surface drainage and reduce slumping.

The engineering function of vegetations are catch eroding materials like debris, armour, reinforce, anchor, and support the soil in the slope. Some of the bio-engineering techniques for roadsides are.

i. **Brush Layering**:

Woody cuttings are laid in lines across the slope following the contour. These form a strong barrier, preventing the development of rills, and trap material moving down the slope. In the long term, a small terrace will develop. The main engineering functions are to catch debris, and to armour and reinforce the slope. This technique can be used on wide range of sites up to about 45 degrees. It is effective on debris site and fill slopes. Avoid using this technique in poorly drained sites.

Material

- Woody materials (6-10 months) of 20-40 mm in diameter and 400 to 600 mm long,
- shovels and pickaxes to make the trenches for planting,
- hessian and water to keep the cuttings moist until planting,
- string,
- measuring tape,
- forest topsoil in gravel areas

Spacing

Spacing between brush layers depends on the steepness of the slope.

Slope below 30 degree – 2 m interval

Slope 30 to 45 degree – 1 m

Within the brush layers, cuttings should be at 50 mm center to center (c/c)

Construction Steps

- Mark the planting lines, from 500 mm above the base of the slope
- Install brush layers starts from bottom of the slope and work upward
- Form a 400 mm wide with 20% terrace into the slope
- In gravel fill road embankment, lay 50 mm thick forest soil along the terrace
- Lay the first layer of cuttings 50 mm c/c with one bud and 1/3rd protruding outside the slope
- Lay 20 mm thick soil in between the cuttings to provide a loose cushion,
- Lay the second layer of cuttings on top of it– staggered with first layer

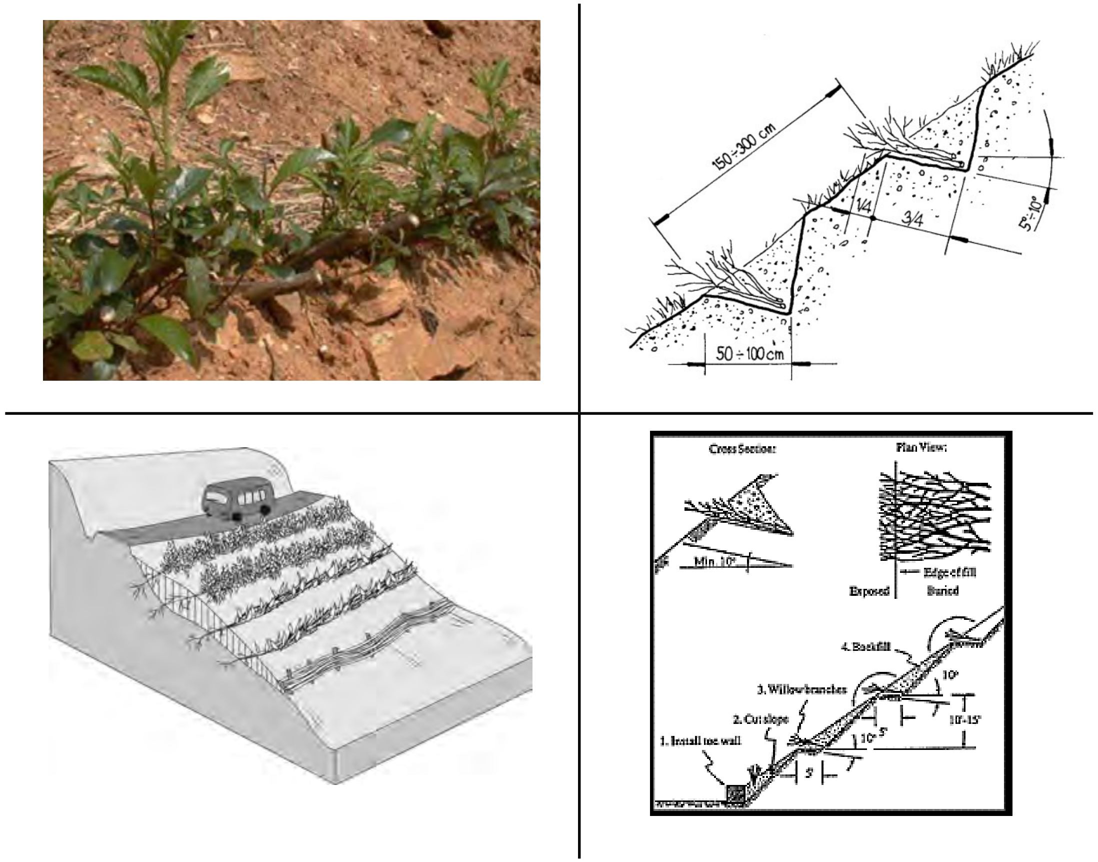


Figure 2.15: Schematic of Brush Layering. Source: DoR, 1999.

ii. Live Check Dams

Large woody cuttings are planted across a gully, usually following the contour. A strong barrier is formed and trap material moving downwards. In the longer term, a small step will develop in the floor of the gully. The main engineering function are to catch debris and to reinforce and armor the gully floor.

This technique can be used on a wide range of gully sites, on slopes of up to 45 degrees. This method cannot be used for large and very active gullies.

Material

- Large woody material (2m long and 20 to 50 mm in diameter) of 6 to 30 months old
- Truncheon cuttings 2m long and 30 to 80 mm diameter, preferably Simali, Dabdabe and Phaledo.
- shovels and pick-axes
- Hessian and water to keep cuttings moist until planting

Spacing

Spacing between check dam depends on the steepness of the gully and the profile of the gully floor. Normally, 3 to 5m interval along the slope. The cuttings should be about 30 to 50 mm apart, depending on the slope. A double offset line also possible if required for much stronger check dam.

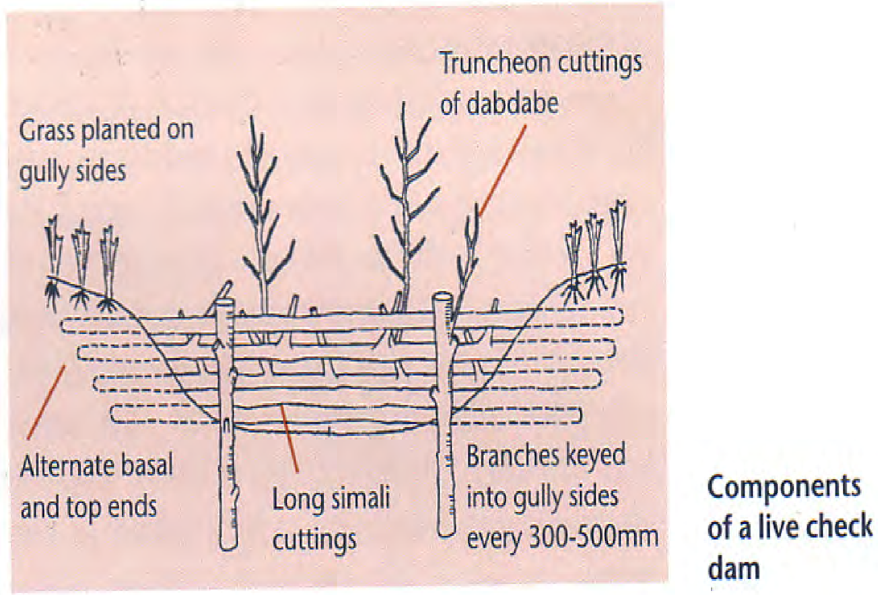


Figure 2.16: Components of live check dam. Source: DoR, 1999.

Construction steps

- Choose a location for the live check dam so that the maximum effect can be achieved in terms of gully stabilization
- Make a hole deep and big enough to insert vertical hardwood cuttings of the largest size available
- Insert the vertical cuttings into the holes and firm the soil around them; try not to damage the bark; they should protrude about 300 mm above the ground surface
- Place fascines or long hardwood cuttings on the uphill side of the vertical stakes
- Key these horizontal members into the wall of the gully

iii. Fascines

Fascine means a bundle of sticks. In this techniques, bundle of live branches is laid in shallow trenches. They put out roots and shoots after burial forming strong line of vegetation. It is also called live contour wattling. The main engineering function is to catch debris, and to reinforce, and armor the slope. Facines are best suited on consolidated debris or soft cut slopes. Growth will be very slow if the materials is too hard. The maximum slope is about 45 degrees with preferably well drained

Material

- Large woody materials at least 1 m long and 20-40 mm diameter
- Hessian and water to keep the cuttings moist until planting.
- Tools to dig trenches
- Jute string or wire to bind the fascines

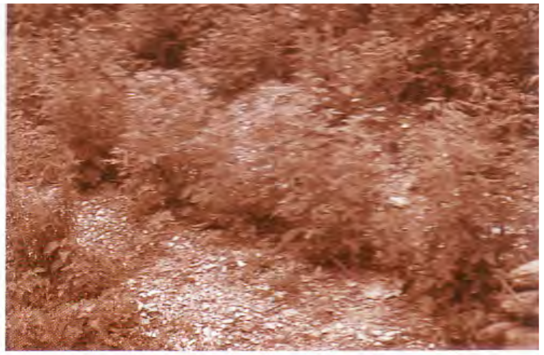
Spacing

For less than 30-degree slope, the spacing between fascines laid is 4m and for slope 30 to 45 degree, 2m spacing need to be maintained.

Orientation: On well drained materials, contour fascines are used. On poorly drained materials, a herringbone pattern is used to improve drainage.

Construction steps

- Prepare the site, clear loose material, and firmly infill depressions.
- Mark the lines on the slope so that they follow the contour or desired angle precisely.
- Work from the bottom of the slope and work upwards.
- Dig about 5 m trench (100 mm deep and 200 mm wide) at a time
- Lay the cuttings together with their ends overlapping
- Bind the fascines with string to keep the cuttings together (optional)
- Backfill the trench as soon as possible, lightly covering the cuttings, and tamp the soil down firmly around it
- For slopes greater than 25 deg, peg the fascine by placing a large cutting at right angles into the slope immediately below the slope at 500 mm c/c



Fascines are effective on consolidated debris. They put out roots and shoots which develop into a strong line of vegetation, catching falling debris as well as armouring and reinforcing the slope

Figure 2.17: Fascine. Source: DoR, 1999.

3. Protecting and improving small streams as part of road development

When a road is opened up, many new road water crossings are created. These may be of regular streams that are interrupted or of torrents that only flow during the rainy season and now descend on the road body. Where a road crosses a natural watercourse, provision must be made to carry the water under or across the road. The selection of the best and most appropriate stream crossing design depends on several factors. Moreover, a poor design choice can result in a costly installation that is subject to failure and significant environmental damage. If not managed properly, streams crossing the roads can degrade roads very rapidly and aggressively.

3.1 Optimized cross drainage

Road drainage structures include those features of a road, other than road shape, designed to drain the road surface and cutbank runoff off or away from the road prism. The purpose of drainage structures is to get water off, and away from, the roadbed as quickly as possible so roadbed materials do not become saturated, and roadbed/ditch erosion is minimized. During the monsoon season, streams are formed and create extensive wet road sections which are easily damaged under traffic impact. Moreover, erosion may easily extend to the land alongside the roads. To reduce the damage from the water crossings or streams, some good practices are listed below.

1. Dissipation blocks
2. Tilted Causeways
3. Check dams and down-road protection.

3.1.1 Practices for optimized cross drainage

3.1.1.2. **3.1.1.1. Dissipation blocks**

Streams and torrents during the rainy season, especially where rain concentrates and flows, have a high tendency to erode the surface. In steep slopes, the eroding capacity of torrents increases rapidly, as the velocity is very high. Where the minor stream descends on the road, the use of dissipation blocks is recommended (figure 3.1). The block may be created by stacking up stones and rocks that become available when a mountain road is opened. If placed where the streams and torrents hit the roads, these stockpiled stone blocks will dissipate the force of the water flows. This measure comes at no extra costs, as the stone blocks are available during road construction and are stockpiled for use in future repairs. These blocks are best placed 30-40 cm away from the upstream side-slope. Flat stones may be placed in between the torrent coming from the hillslope and the dissipation block in order to break the velocity impact of the descending water. The stockpiled stones will further baffle the force of the mountain stream After this, the stockpiled stones will further ‘baffle’ the force of the mountain stream.

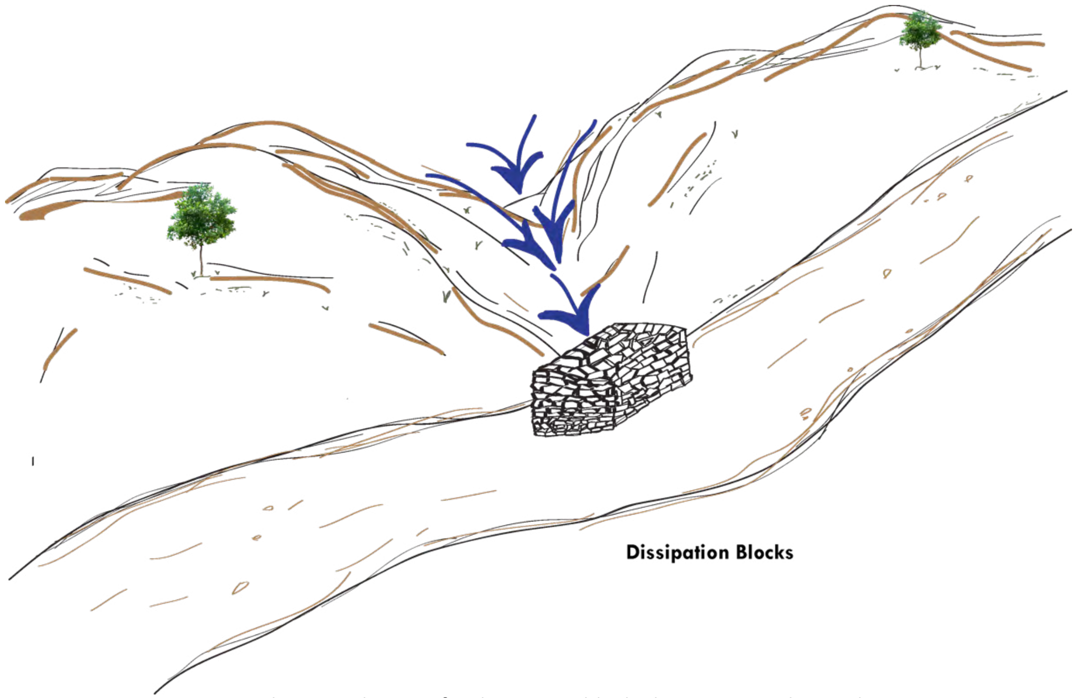


Figure 3.1: Schematic diagram for dissipation block placement on the road.

3.1.1.2. Reinforced tilted causeways

Roads are traversed by several streams. Prior to the construction of the road such a stream followed their natural course. With the construction of the roads the stream flows are interrupted, and the gradient is broken. Depending on the local topography and the nature of the stream, a hydraulic impact is created on the road surface. The streams differ – some are perennial, some seasonal -, but they will all increase their discharge, velocity, and erosive/ torrential power during monsoon season.

Another practice to reduce damage of roads because of streams are reinforced tilted causeways. The reinforced causeways made of flat stone, – like the entire road – are tilted at a slight angle (max 4 to 5 degrees[2]) towards the downhill side to facilitate the drainage of the water from the stream. Such technology supports using locally available material or the spoil formed, especially stone, during road construction and it is easy to maintain.

To improve and guide the water, it is proposed to make a depression in the middle of such a causeway. This depression should be modest. In case the causeway has a width of 25 meter, the lowered section should be 25 to 50 cm. This will have two main benefits:

- It forces the stream and torrent flows towards the middle of the causeway and continue their flow – among others avoiding erosion of the banks of the down road part of the water course.
- It will reduce the chance of side-spills from the causeway during high discharges that may damage the road body.

2 As per the Nepal Rural Road Standard (NRRS), the maximum cross slope is different for different on the road types. For, earthen road: 5%, Gravel road: 4% and Bituminous seal coat road: 3%

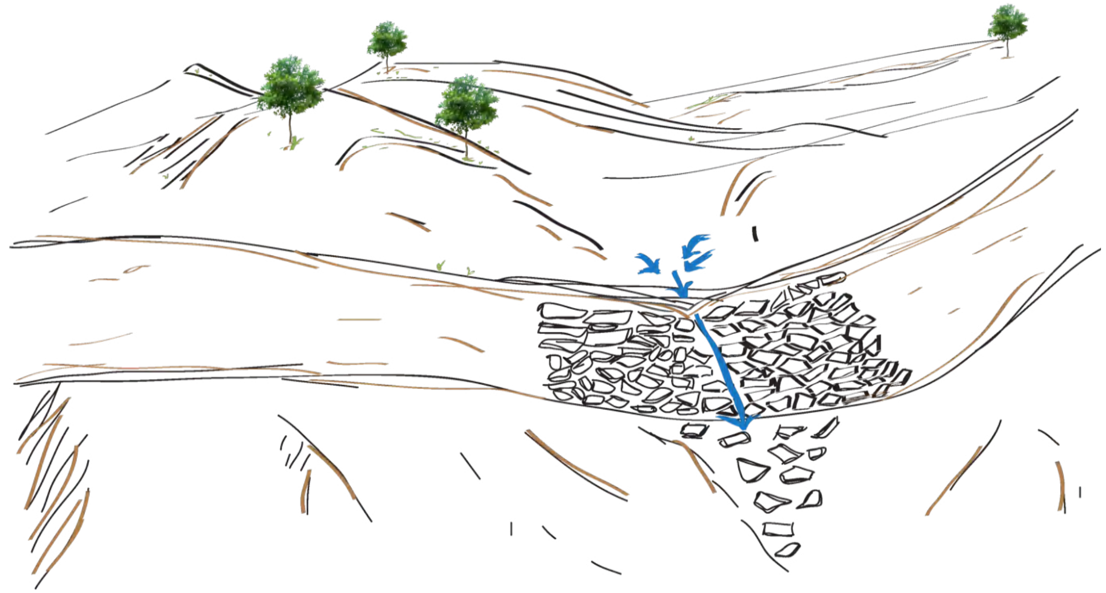


Figure 3.2: Schematic picture of a reinforced tilted causeway.

The depression should be at angle of maximum 5 degrees so it will not be able to interfere with the road. Where the road water exits the tilted causeway, it may be useful in many places to armour the downstream parts of the stream.

3.1.1.3. Check dams and downstream protection

In the accented terrain most, streams will flow at high velocity. The development of a road section creates chutes that can do considerable damage to the road surface and side slopes. Placing check dams in the upstream section of these road streams reduces the velocity of water crossing the road. The spoils i.e. spare stone blocks from road construction may be used to build up small check dams in the upstream (figure 3.3). The excess material may also be used to armour the down road part of the stream by placing some stones there. This technique will prevent damage from erosion to the landscape and avoids upward gully development that could affect the road body. The general criteria (Desta et al., 2005) for such check dams are:

- Spacing between check dams = height * 1.2/ slope of stream in decimals
- Side key of check dams 0.7-1 meter each side
- Bottom key and foundation 0.5 meter deep
- Height of check dams 1 m (maximum excluding foundation)
- Stone face vertical to horizontal ratio 1:3 to 1:5
- Spill way (preferably in trapezoidal shape) width 0.75-1 m; depth/ freeboard 0.25 m
- Using rock rubble for apron immediately downstream: length 1 m and width 0.5 m

4. Role and Responsibility of different stakeholders

4.1 Department of Local Infrastructure (DoLI)

The objective of DoLI is to undertake infrastructure development programmes in accordance with decentralization policies for attaining the goals set forth by the GON's National Strategy for local Infrastructure Development by making the local authorities technically capable and competent and ensuring their accountable participation.

4.1.1 Role of DoLI

1. Dissemination of the guidelines to the municipalities.
2. Organizing workshops or trainings for municipalities to make them better understand how the guideline works, how to implement it, and how to own it.
3. Monitoring: policy level monitoring to observe the implementation process and practicality of the guidelines in the given context along with the municipality and community.

4.2 Municipality

The municipality is a local government unit which is responsible for the overall development in the municipality. Development activities such as road construction, in a large scale, are done by excavators, dozers and do not meet the basics such as the mass balancing methods, slopes, use of free drainage road surface. The impacts of such construction on the surrounding landscape in many cases are negative.

4.2.1 Role of Municipality

1. To raise awareness about spring protection and conservation among the people and community.
2. To disseminate the guideline.
3. Municipalities conduct trainings, workshops, and programmes to technicians and communities with the technical support from DoLI.
4. To create environment for the easy dissemination of guideline among the communities.
5. Monitoring: A periodic monitoring.

4.3 Community

Communities are important stakeholders and their engagement in the conservation and protection of springs and seeps, developing roads for socioeconomic development and livelihoods, environmental rehabilitation and climate resilience are crucial. Local communities have good knowledge of the water sources and water management practices in the locality. The whole process of the implementation if made, community centric, would create more livelihood opportunities, integrate indigenous and good techniques and easy to access opportunities in the community. A group or committee from the community can be formed for protection and management of the springs and spring-shed. This may include a member from the existing committee or groups like Road Maintenance Groups (RBGs) or Water Users' Group (WUGs) etc. Those committees will also have a representative from the municipality.

4.3.1 Role of Community

1. Support in every step of the process from springs mapping to spring-shed conservation work.
2. Frequent monitoring and maintenance of the spring conservation intervention.
3. Frequent communication with the municipality on the issues and progresses. If prescribed interventions are not possible at community level or if the damages are big, the community or the committee need to interact with the municipality for funds or support.

4.4 I/NGOs

Internationals and national NGOs working in development sector focusing on road and water sectors are important stakeholders.

4.4.1 Role of I/NGOs

1. Support in up taking or upscaling of the work.
2. Implement it in their programs or projects.
3. Replicate the actions in their projects.

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Annex 1: Summary of technologies recommended for springs/seeps, streams, recharge, and spoil management

<table>
<tr><th>SN</th><th>Technology</th><th>Detail</th><th>Condition to fulfill</th></tr>
<tr><td></td><td>Spring/Seep</td><td></td><td></td></tr>
<tr><td>1</td><td>Spring box (Spring Chamber)</td><td><table>
<tr><th rowspan="2">Q max in lit/sec</th><th rowspan="2">Area of surface in m²</th><th colspan="3">Inside measurement for the water basin in m1</th></tr>
<tr><th>width</th><th>length</th><th>depth</th></tr>
<tr><td>0.5</td><td>1.0</td><td>0.65</td><td>1.50</td><td>0.5 - 0.6</td></tr>
<tr><td>1.0</td><td>1.5</td><td>0.75</td><td>2.10</td><td>0.6 - 0.75</td></tr>
<tr><td>2.0</td><td>3.0</td><td>1.00</td><td>3.00</td><td>0.8 - 0.95</td></tr>
<tr><td>3.0</td><td>4.6</td><td>1.00</td><td>4.60</td><td>0.9 - 1.15</td></tr>
<tr><td>4.0</td><td>6.2</td><td colspan="3" rowspan="2">combination of chambers from above</td></tr>
<tr><td>5.0</td><td>7.7</td></tr>
</table></td><td>- Protection around the spring and spring box is required.
- From the spring box water can be transported to water tank</td></tr>
<tr><td>2</td><td>French Mattress</td><td>• Overlap of geotextile at joint: 12 inches
• Minimum 12 inches compacted material overtop of finished mattress.</td><td>- Area where roadside springs result in road base saturation.
- Area where springs under the road saturate the road base or come to the surface in the road.
- use of clean coarse rock from the spoil develop during road construction.</td></tr>
<tr><td></td><td>Recharge and spoil management</td><td></td><td></td></tr>
<tr><td>5</td><td>Eyebrows/half-moon terraces</td><td>maximum preferred slope is 50 degrees typical diameter= 1.4-2.5 m;
For 30-degree gradient:
• Stone ring diameter: 30 cm
• Inner cross width: 220 cm
• Backwall height: 70 cm
• Distance between eyebrows: 15-20m</td><td>- Use of coarse stones and boulders available from spoil.
- The steeper the gradient, the more the reinforcement in the downward toe.
- Topsoil removed while making road can be used to fill inner side of structure.</td></tr>
<tr><td>6</td><td>Stone Strip</td><td>maximum preferred slope is 50 degree
For 30-degree gradient:
• Height: 1m
• Vertical interval: 2.8m
• Distance between stone strips: 6m</td><td>- Use of coarse stones and boulders available from spoil.
- Help to slow down runoff, and intercept sediments and soils.</td></tr>
</table>

<table>
<tr><th></th><th>Small Streams</th><th></th><th></th></tr>
<tr><td>7</td><td>Dissipation Block</td><td>Place 30-40 cm away from upstream side-slope</td><td>- It breaks the speed and erosive power of the streams or torrents.
- Use of stones from the spoil generated during road construction.</td></tr>
<tr><td>8</td><td>Reinforced tilted causeways</td><td>• Where natural streams meet road section.
• Causeways gradient towards downhill= 4-5 degrees.
• Depression in the middle: if causeways width is 25 m, the lowered section should be 25-50 cm</td><td>- Use of locally available material (stones) during road construction.
- Stream and torrents flow towards the middle of causeway.
- Reduces damages of road body.</td></tr>
<tr><td>9</td><td>Check dams</td><td>• Height of check dam: 1 m excluding foundation
• Foundation: 0.5m
• Rock rubble apron in the downstream: L=1m & B= 0.5m</td><td>- Use of stone blocks that generate from spoil from road construction</td></tr>
<tr><td></td><td>Roadside</td><td></td><td></td></tr>
<tr><td>10</td><td>Brush Layering</td><td>• Maximum slope: 45 degrees
• Wood material: L=40-60 cm & dia-20-40mm
• Spacing between layers: 2m (30 degree gradient)
• Cutting spacing: 50 mm c/c</td><td></td></tr>
<tr><td>11</td><td>Live Check dam</td><td>• Maximum slope: 45 degrees
• Wood material: L=2m & dia: 20-50mm
• Truncheon cutting: L=2m & dia: 30-80 mm
• Spacing between check dam: 3-5m
• Cutting spacing: 50 mm c/c</td><td></td></tr>
<tr><td>12</td><td>Fascine</td><td>• Maximum slope: 45 degrees
• Wood material: L= 1m & dia: 20-40mm
• Spacing between layers: 4m (30 degree gradient)
• Dig 5m trench (100 mm deep & 200 mm wide)</td><td></td></tr>
</table>

Annex 2: Design and Dimension of spring chamber

For the springs with the yield roughly between 2-20 liters per minute.

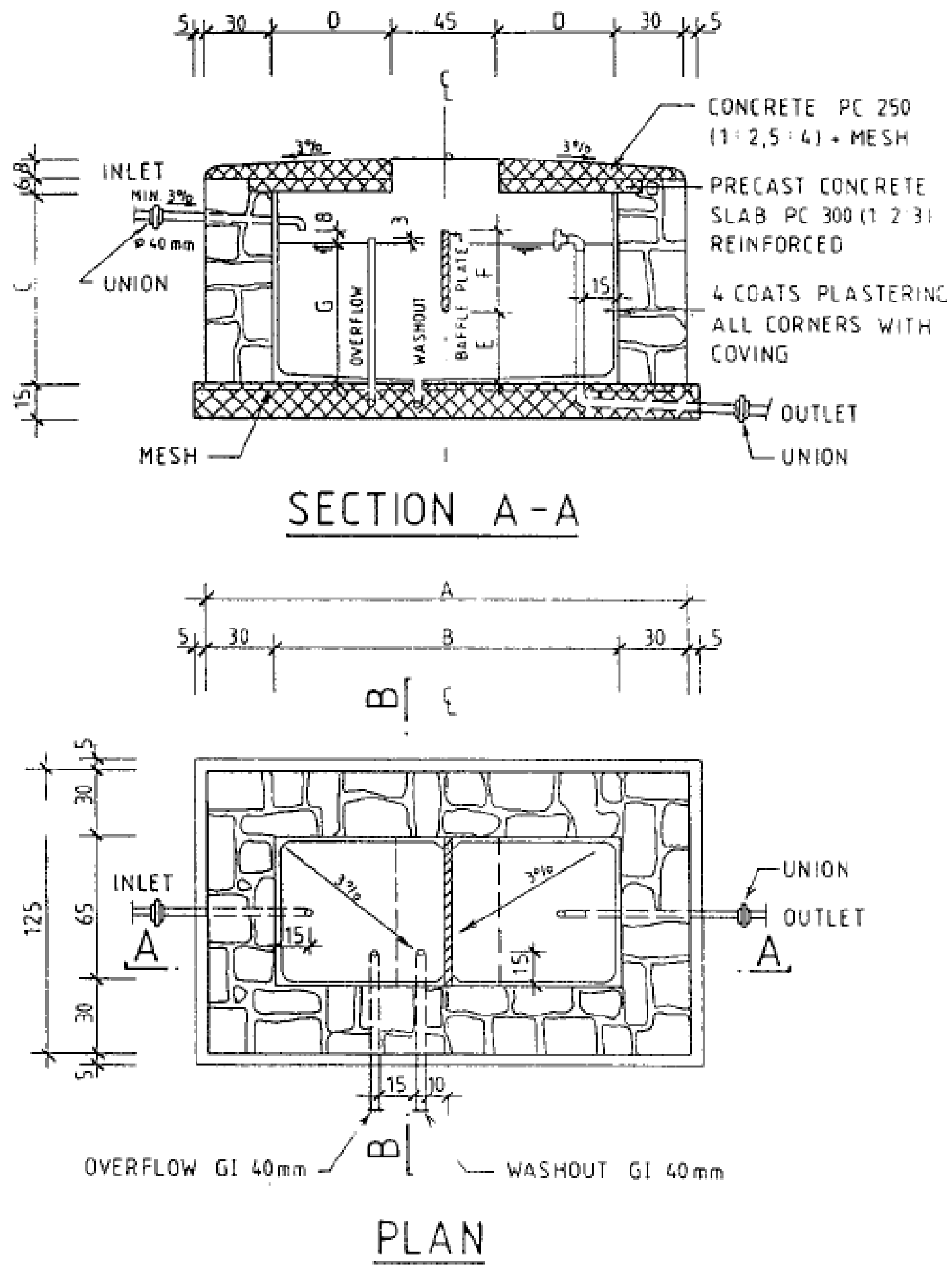

Figure: Simple spring chamber (Source: Meuli & Wehrle, 2001)

Table: Measurement of spring chamber for different discharges. Source: Meuli & Wehrle, 2001.

Q max in lit/sec	*Area of surface in m²*	*Inside measurement for the water basin in m1*		
		width	*length*	*depth*
0.5	1.0	0.65	1.50	0.5 - 0.6
1.0	1.5	0.75	2.10	0.6 - 0.75
2.0	3.0	1.00	3.00	0.8 - 0.95
3.0	4.6	1.00	4.60	0.9 - 1.15
4.0	6.2	combination of chambers from above		
5.0	7.7			

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