SWIFT

Consortium for Sustainable Water, Sanitation & Hygiene in Fragile Contexts

Environmental assessment and risk screening for rural water supply

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Guidance note developed for the SWIFT Consortium

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Key messages

- This report provides a tool to support environmental assessment and risk screening activities for rural water supplies in low-income and fragile contexts.
- It was developed by ODI, with support from Tearfund, for the Sustainable WASH in Fragile Contexts (SWIFT) consortium, providing water, sanitation and hygiene (WASH) services under the DFID WASH Results Programme funded by the UK Government.
- This addresses the following questions regarding shallow groundwater sources (i.e., springs and wells) – both new and existing:
  - Is there enough water of suitable quality to meet demand across seasons for the long term?
  - What are the main environmental risks to ensuring a sustainable supply of safe water?
  - How can these risks be mitigated?
- The tool proposes four main steps to do this:
  1. Understand how much water is available by tapping local knowledge
  2. Determine how much groundwater is needed to meet demand, and how big the catchment (recharge) area of a well will need to be to provide this water
  3. Protect the sites and sources by identifying environmental hazards of, and measures for, site degradation and water supply contamination
  4. Maintain records of the assessment, design and implementation of groundwater projects, so as to inform similar, future projects
- Pages 10 and 11 of this report include a simple flow diagram of the tool that can be used to progress through each of these steps

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This tools draws heavily on work carried out by Roger Calow, Eva Ludi, Seifu Kebede and Andrew McKenzie on similar issues in Ethiopia commissioned by DFID-Ethiopia and supported by the Government of Finland.

Comments and practical insights on ideas for this tool and on an early draft were provided by Tearfund and Oxfam country office staff in Goma and Kinshasa, DRC, and government and non-government partner organisations of SWIFT in Goma, DRC. Andy Bastable, Head of Water and Sanitation at Oxfam GB and Geraint Burrows, Hydrologists Without Borders (HWB), provided extremely valuable comments and critical reflections on early drafts of the tool and provided access to resources compiled by HWB-UK.

Any errors are our own.

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Abbreviations

DRC	Democratic Republic of the Congo
DEM	Digital elevation model
EIA	Environmental impact assessment
GIS	Geographic information system
GW	Groundwater
HH	Household
L/sec	Litres per second
Lcd	Litres per capita per day
O&M	Operation and maintenance
ODI	Overseas Development Institute
m	Metre
mm	Millimetre
m^2	Square metre
m^3	Cubic metre
PD	Person day
SSA	Sub-Saharan Africa
SWIFT	Consortium for Sustainable Water, Sanitation and Hygiene in Fragile Contexts
WASH	Water supply, sanitation and hygiene
WRP	WASH Results Programme
WSP	Water safety plan

Introduction

Extending and sustaining access to WASH services remains vital for poverty reduction in sub-Saharan Africa (SSA), and is the central objective of the DFID-funded WASH Results Programme (WRP). Achieving long-term increases in coverage depends on many factors, including sound financing, community engagement in the design and implementation of schemes, and the training of village mechanics, local government and entrepreneurs in system upkeep and repair. For a scheme to be sustainable, planning also needs to consider the water resources that are available – whether there is enough water, of suitable quality, to meet demand across seasons and between good and bad years. Risks to water systems posed by flooding, land degradation and other environmental hazards also need to be addressed, especially as climate change accelerates.

The guidance presented in this note addresses the resource sustainability and environmental risk elements highlighted above. The aim is to show how WASH organisations, working in partnership with communities, can integrate these concerns into their activities, as a complement to existing approaches such as Water Safety Planning (WSP). The guidance can also be viewed as a contribution to NGO initiatives aimed at mainstreaming community-based water resources management promoted by Oxfam, WaterAid and Helvetas (ICE et al., 2011).

The focus of this note is on groundwater-based, community-managed wells and springs in rural areas that account for most of the SWIFT Consortium's WRP interventions. These systems are potentially most vulnerable to changes in recharge from rainfall, and changes in demand from population growth (Howard and Bartram, 2009).

Why is the guidance important?

Although data on the long-term performance of water supply programmes is patchy across SSA, it is clear that many systems fail to provide safe water on a continuous basis because they deteriorate or fail completely. The causes can be difficult to untangle, but a failure to adequately consider the availability and resilience[1] of water resources, and the risks posed by droughts, floods and other hazards to infrastructure and resources, is an important factor (Calow et al., 2011; Oates et al., 2013).

Systems that depend on shallow groundwater from wells and springs are generally more vulnerable to changes in rainfall (and therefore groundwater recharge) and demand than those exploiting deeper and/or bigger groundwater storage. Over short periods, aquifer storage can even out variations in recharge from rainfall, and variations in discharge, whether natural or from pumped abstraction. But where abstractions exceed recharge and storage is limited, groundwater levels will inevitably fall, and springs and wells may dry up. This makes it important to ensure that new sources are developed with a reasonable understanding of groundwater resources: making sure there is enough water to meet current and projected demand across seasons, and between good and bad years. Steps 1 and 2 of this note therefore focus on the geological and catchment factors that influence groundwater availability and the resilience of groundwater sources. We note that existing sources can also be appraised in terms of their likely vulnerability to changes in recharge and demand if these factors are well understood.

The risks posed to water sources by flooding and land degradation can also be assessed in a systematic manner. Similarly, this can help inform site selection, and be applied post-construction to identify and

[1] Resilience in this context means the ability of groundwater resources to resist or buffer changes in climate and rainfall, and their ability to recover from such changes (MacDonald et al., 2011).

mitigate problems. Risks are both direct and indirect. For example, floods may directly damage water supply infrastructure and contaminate water sources. They may also cause indirect problems by creating gullies that draw the water table down in the vicinity of a water source, affecting their yield.

What does the guidance cover?

The table below provides a summary of the guidance covered in this note. Steps 1 and 2 focus on the availability of water resources, and how to ensure that water supply is sustainable. Step 3 addresses environmental risks, and shows how they can be assessed and mitigated prior to construction as part of the siting process, and also how they can be mitigated following construction. Step 4 offers some suggestions on record keeping so that valuable information collected during the planning and implementation phases of a project/programme can inform future work. The flow diagram (p.10-11) can be used to progress through the main elements of each step.

Guidance	Step
Understanding water availability - tapping local knowledge	**1**
Understanding geology: secondary information and village observations	1.1
Asking about water sources: understanding performance	1.2
Checking sources: measuring yield	1.3
Ensuring sustainability - estimating supply and demand	**2**
Selecting sites: some basic rules of thumb	2.1
Estimating water demand: current and projected needs	2.2
Estimating catchment size: securing sources	2.3
Protecting sites and sources: identifying and mitigating risks	**3**
Assessing direct environmental risks to the water point	3.1
Assessing indirect environmental risks in the catchment	3.2
Addressing risks: developing a catchment protection plan	3.3
Record keeping	**4**

The activities proposed in this tool are most useful where water points are developed that access shallow groundwater, such as hand-dug wells, shallow boreholes equipped with hand pumps and springs. SWIFT partners in DRC and Kenya have developed adapted and simplified forms that can be used in the field, drawing on different steps in the tool.

The tool does not cover all aspects of providing community WASH services and should therefore be used alongside existing guidance and tools:

- The environmental assessment and risk screening tool does not deal with aspects of community mobilisation, design, construction and drilling standards and requirements, water user association establishment, financing and governance or O&M guidelines. For all these aspects, existing country and/or agency-specific guidelines should be consulted. Where they do not already exist such guidelines should be prepared by partner agencies.

- The tool is not a substitute for a more formal Environmental Impact Assessment (EIAs). This is often required and should be carried out routinely where deeper drilled boreholes are planned. In many countries, EIA is compulsory and guidelines have been published by relevant authorities.[2]
- Water quality assessment or sanitary surveys should be carried out alongside the tool. Such water quality assessments form part of developing a water safety plan (WSP) or equivalent country processes, such as the *Village Assaini* approach in DR Congo.

[2] For example, sinking boreholes in Kenya requires an authorization by the Water Resources Management Authority and is subject to fulfilment of special conditions of which one requires an Environmental Impact Assessment (EIA) in accordance with the Environmental Management and Coordination Act of 1999.

Flow diagram of key inputs and expected outputs of the SWIFT / ODI/ Tearfund tool on environmental assessment and risk screening for rural water supplies

This tool is meant to address the following questions regarding shallow groundwater sources (i.e. protected springs, hand-dug wells and shallow boreholes):

1. **Is there enough water of suitable quality to meet demand across seasons for the long term?**
2. **What are the main environmental risks to ensuring a sustainable supply of safe water?**
3. **How can these risks be mitigated?**

You can use this tool by itself or use components of other tools already familiar to you to obtain similar outputs

STEP 1. Understand how much water is available by tapping local knowledge		See section
INPUT	Basic geological map (detailed if available, or simple sketch map) with project water sources superimposed	1.1
INPUT	Expert hydro-geological advice where available (particularly where no mapped data or records exist)	1.1
INPUT	Observation of exposed rock (to compare with summary of typical African geologies and their groundwater potential)	1.1
INPUT	Well records from the surrounding area (including data on geology, seasonal yield, reliability and water quality)	1.1/1.2
INPUT	Local knowledge on behaviour and history of sources in the area	1.2
INPUT	Simple yield measurement of existing sources (using bucket & stopwatch, or weir plate)	1.3

OUTPUT

a) Groundwater potential and average yield estimates based on geology (See Annex, Table A1)
b) Actual yield measurements of sources in the area
c) Short narrative / tabular information on seasonal and long-term reliability of the source, including water quality

STEP 2 Determine how much groundwater is needed to meet demand, and how big the catchment (recharge) area of a well will need to be to provide this water		See Section
INPUT	Annotated sketch map and/ or photos to identify the resilience / vulnerability of the source site in terms of drainage	2.1
INPUT	Measurement of distance of water sources from pollution hazards (contamination control measures needed if hazards are closer than recommended minimum distance)	2.1
INPUT	Estimate of demand for water, currently and in future water (assuming a certain population growth rate e.g. 2.5%)	2.2
INPUT	*For wells:* Estimate of required catchment size by comparing demand with estimated recharge (latter requires agreeing proportion of annual rainfall that is retained at shallow aquifer levels and is accessible. A figure of 1% to 3% is recommended to develop secure water sources in most areas of Africa with over 750mm of rainfall/ year)	2.3
INPUT	Estimate of actual catchment sizes for flat or hilly terrain	2.3
INPUT	*For springs*: It is also possible to compare spring yield (measured during the dry season) to current/ future water demand	2.3

OUTPUT

d) Traffic light assessment of adequacy of catchment size for rainfall and water demand scenario

STEP 3 Protect the sites and sources by identifying environmental hazards of, and measues for, site degradation and water supply contamination		See section
INPUT	Catchment walk / observation to capture sketch map of direct environmental hazards within 150m radius of the water source (direct environmental hazards include features like gully erosion, rill erosion, land slips, cattle tracks, etc.)	3.1
INPUT	Assessment of severity of hazards: e.g. of gullies, flooding risk, and landslides and landslips, and whether they require immediate remedial action or relocation of the water facility	3.1
INPUT	Simple table to identify and outline causes of degradation features in the wider catchment (indirect environmental hazards) based on community discussion.	3.2
INPUT	Assessment of severity / extent of indirect environmental hazards (simple table constructed with community)	3.2
INPUT	Discussion with partners / authorities / experienced local people on management processes for medium to high risk degradation processes (Incorporate community representatives and consider also community-based ideas and solutions)	3.3
INPUT	Construction of table identifying corrective measures	3.3

OUTPUT

e) Remedial measures for direct hazards e.g. to protect against flooding
f) Catchment and water point protection plan with corrective measures and assigned responsibilities, drawn up/ agreed with community

STEP 4 Maintain records of the assessment, design and implementation of groundwater projects, so as to inform similar, future projects		See Section
INPUT	• Geological field notes/ data from geophysical surveys • Digging / drilling logs including all data relating to the drilling, construction and geological/geophysical logging, for dry and successful wells • Pumping test data • Seasonal water level observations • Records on water quality and observations of seasonal quality variations • Information on physical and legal access (e.g., land ownership) • Number of people using the scheme and estimate of amount of water collected per person / household across different seasons • Any incident when water supply system was not functional, reasons and actions undertaken • Records of corrective/remedial measures taken to address direct and indirect environmental hazards • Water level across different seasons • Any chemical, biological and physical parameters from water testing	4

OUTPUT

g) Data records, to be kept at local level and made available to local government WASH / hydrology department, members of national WASH cluster, and to key networks that seek to build national databases

Step 1: Understanding water availability: tapping existing knowledge

Why is this important?

Taking the time to collect existing information on the things that are likely to influence the availability and sustainability (and quality) of water for a village is important. This can help the project team assess (a) what water supply options (e.g. springs, wells, boreholes) are likely to be feasible and cost-effective; and (b) the likely yield and sustainability of water sources. This can save time and money later on, and means that only those options that are likely to be feasible are discussed with communities.

Taking the time to tap community knowledge can provide valuable information on which sources and locations are the most reliable. This information can also be used by the project team, in partnership with the community, to make informed choices on technical choices and siting. For example, older members of the village (particularly women) are likely to know which sources fail seasonally or in particularly dry years, and may be able to 'tell the story' of water development successes and failures in the village.

Comment – geology and groundwater

The underlying geology of an area will determine whether water is stored in underground formations, how much is stored, and the ease with which water can flow to a water point, which determines the yield of an individual source.

Storage, in particular, affects the resilience of water supplies. Storage is a function of rock porosity. The most porous geologies (e.g., alluvial sediments, highly weathered hard rocks) can store large volumes of water, so that when recharge from rainfall or discharge through pumping occurs, changes in water levels are relatively small. However, if the porosity of the rocks is small (e.g., with mudstones, shales, unweathered hard rocks), changes in recharge or discharge will have a bigger impact on water levels and a well or spring can dry up.

Geology will also influence water point construction by affecting digability, the stability of the well wall during digging, well design (e.g. lining requirement) and the periodic requirement for dredging and cleaning.

The reference materials in the Annex provide further information on geological environments and their groundwater potential.

Source: MacDonald et al. (2005); MacDonald and Calow (2010)

What does the guidance cover?

1. Understanding the geology of the area to assess resource potential and inform technical choices (e.g. shallow wells, deeper boreholes, springs).
2. Asking about the performance of existing sources over time (yield, reliability, quality) to help decide on technical choices and sites.

3. Measuring the yield of existing sources to see whether they meet regulatory and/or local needs, and as an input to the catchment sizing process discussed in Step 2.

What activities are involved?

Step 1.1 – Understanding local geology

Knowing 'where you are' in terms of underlying geology is a first step. This can be approached in two ways: (a) looking at secondary information (e.g., maps, well records) to assess groundwater potential and likely yields; and (b) follow-up observation in the project area – looking at rock outcrops and exposed soil/rock profiles – to understand geology and groundwater potential.

> **Hint – when to seek expert advice**
>
> If there is no previous experience of well digging or spring development in the project area, the advice of an experienced geologist should be sought to help decide (a) if well/spring development is feasible; and (b) well siting, if well development is feasible.
>
> If previous wells have failed or do not provide water throughout the year, or if there is evidence of hard rock at shallow depths, alternative options (e.g., a borehole) should be considered.
>
> If a large number of wells in a particular area are planned, it may be cost effective to employ a geologist and possibly geophysical techniques in the siting of wells, since the increased success rate my offset the extra cost of hiring a specialist.
>
> *Source: Republic of Sierra Leone (2014)*

Key questions:

- What is the geology of the area? What is their likely groundwater potential?
- How might geology vary within the village boundary?
- What information or evidence (if any) did previous project teams/drillers leave behind that might help?

How to get answers:

- Consult a geological map of the area. What sort of rocks are likely to be present?
- Visit places where rocks are exposed. River valleys and hills are often good locations
- Look at boulders in the village used for seats, grinding stones, etc. Where did they come from? What kind of rocks?
- Visit wells that have been dug previously and examine soil-rock profiles
- Encourage people to investigate potential sites themselves, e.g., by digging trial pits or using a shallow auger.

Table A1 in the Annex summarises different African geologies and their groundwater potential.

Hint - helping teams to identify geology in the field

Field guidance sheets can be used to help the non-expert identify rocks in the field and place their water scheme in a geological context.

A field guidance sheet can help the user identify rocks they can pick up and look at ('hand specimen' scale), at the scale of larger outcrops in the landscape, and at the wider regional scale. Photographs and block diagrams (pictures showing a three-dimensional 'slice' of the geological formations) can be included as an aid. The photographs of hand specimens can be used to identify colour, texture and mineral composition of rocks for comparison with field specimens.

At outcrop scale a set of features of rocks (e.g., colour, layering, thickness) can be captured in an index of photographs. Such photographs can later be used by practitioners in the field as reference. The same applies to observation of regional geomorphology, which aims to understand the origin and evolution of topographic features. It is much easier to describe geomorphology (such as dome forming, cliff forming, undulating, flat laying, plateau, valley forming, dissected, etc.) than to name rocks, but an understanding of geomorphology can help give clues to the geology.

Figure A2 in the Annex provides an example of a field guidance sheet prepared for project staff in the highlands of Ethiopia. Similar sheets may already be available in country, or could be developed with the help of a geologist.

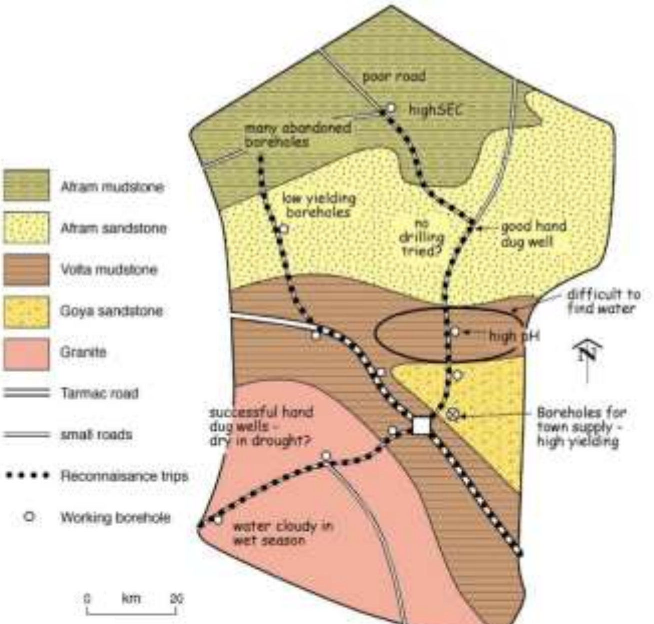
Source: MacDonald et al. (2005)

What next?

The information collected above – from secondary sources and/or field observation – could be used to draw a rough map of the project area showing geology, existing water points and springs (functional and non-functional) and likely groundwater potential. Notes on the performance of existing water points (see tables below) could also be added. This will help focus discussion on which areas and source types are likely to provide the most reliable sources of water.

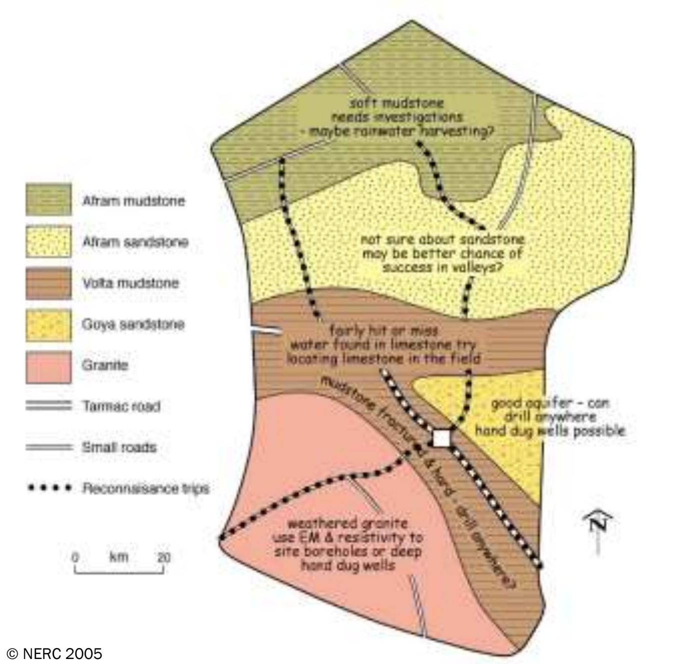
Hint – preparing maps to support groundwater development

Hydrogeological field notes plotted on the geological base map



Source: MacDonald et al. (2005)

A preliminary groundwater development plan developed from the reconnaissance information



Source: MacDonald et al. (2005)

Step 1.2 – Understanding source behaviour

Asking communities about the performance of existing sources can provide useful information on which areas and sources provide the 'best' groundwater – the most reliable, as well as the highest quality and most accessible. This information can be used to inform the selection of new sites and sources, and/or the rehabilitation of existing ones. Note, however, the danger of projects simply developing new sources around existing 'successes': the result may be good on paper (another successful well!), but bad for the community (areas where groundwater conditions are more difficult, but where many people live, are avoided).

Key questions:

- What are the main sources of water available for use by the community, or by groups within it? What sources no longer provide water, and why?
- How does water availability vary between sources? Which are the most reliable, and why?
- How does availability from these sources change over time, e.g., across seasons and between good and bad years?
- What other factors affect the use and performance of sources, e.g., mechanical failures, environmental hazards, etc.?

How to get answers:

The following tables can be used to capture information on the type, number and functionality of existing schemes, and on the reasons for any water supply problems.

Hint – how to get information on source use and behaviour

A good place to begin is with a map, drawn with community members, showing where different water sources are, what they are used for, and by whom. Notes can be added on the characteristics of these sources. If a rough geological map was prepared in Step 1.1, this can be used as the base.

Notes can be supplemented with more detailed water point histories, best conducted at the water sources themselves with women, exploring in detail changes in water levels, yields, recovery times, queueing, etc. The aim is to build up a picture of which sources, in which areas, provide (or are likely to provide) the most reliable groundwater.

Table 1.1: Source type, functionality and access

Source type	Number	Number of fully functional schemes	Number of schemes functional part year (indicate months when functional)	Number of non-functional schemes	Access (Open to all? Restricted to some? Only available to owner?)
Hand-dug well					
Drilled well / borehole					
Protected spring					
Unprotected spring					
Roof catchment					
Open source (e.g., stream)					
Other (specify)					

Table 1.2: Source problems and their causes

Scheme name and type	Not enough water found on drilling / digging	Collapse of wall or sedimentation	Hand pump failure – mechanical	Env hazard e.g., flood, erosion, gullying	Water table decline; decline in spring yield	Other (specify)

Step 1.3 – Measuring the yield of existing sources

As a further step, the yield of different water sources can be measured. Yield requirements within a programme are often standardised, or minimum target yields may be specified in national guidelines. Projected water demand for different numbers of people/households also influences the yield needed from a source (see Step 2, Table 2.3).

Table 1.3: Yield of existing sources

Source	Yield (L/sec) dry season	Yield (L/sec) wet season

Hint – measuring yield

Equipment needed to measure yield: bucket and stop-watch

Measuring yield: How long does it take to fill a bucket of a known volume?

Example:

8 seconds to fill a 10 L bucket. Yield = 10 ÷ 8 = 1.25L/sec

Ideally, yield should be measured during the dry season to assess whether the well or spring is viable (i.e., can meet demand)

If the yield (in L/sec) for different seasons is not available, ask the following questions:

- How do people using this source describe its yield over the year (e.g., fluctuation between dry and wet season, months when source is dry, etc.)?
- Is the source producing enough water throughout the year for all users? If not, where do people get water from during the time when the spring is dry?

What next?

The information collected above will provide an indication of:

- Groundwater availability, groundwater quality, groundwater development potential and the likely cost of developing it (e.g., whether spring sources can be developed or whether shallow groundwater can be accessed via wells)
- The likely resilience of groundwater resources and sources (based on an understanding of groundwater storage and the behaviour of existing sources)
- The kinds of sources that may be feasible to develop or rehabilitate (e.g., do existing technology types and designs provide reliable water supplies? If not, can they be developed/rehabilitated to meet target requirements, or do new sources need to be developed?)

Step 2: Ensuring sustainability: estimating supply and demand

Why is it important?

Building on the initial assessment of groundwater resources carried out in Step 1, for wells, we now ask: How much groundwater is needed to meet current and projected needs, and how big does the catchment (recharge) area of a well need to be to provide this water? For protected springs, where existing yield can be directly measured and there is less choice about siting, we can ask: Is the yield sufficient to meet current and projected needs?

Working through this step will help project staff identify potential sites for a well or spring that can provide water, at the required yield, on a continuous basis for domestic needs. A shortlist of sites, screened for their ability to provide resilient supplies, can then be discussed with communities.

If water sources are likely to be used for minor productive uses as well (see Step 1), then the yields of sources and catchment areas will need to be increased to meet the additional demand.

Note that the guidance provided here can also be applied to completed projects. In other words, an understanding of which sites are likely to provide reliable water can also help project staff identify which existing sites might fail to provide enough water during the dry season, or during drought. Marginal sites could be targeted for extra monitoring, or could be re-visited to develop additional 'back-up' sources.

Comment – catchment areas for wells and springs

If a well is sited without an adequate catchment area, this increases the risk that it will be dry, or that dry season yields will be insufficient to meet community needs. For a spring source, local knowledge is normally used to assess whether dry season flows are adequate, and so springs will not normally be developed if the catchment area can't provide the water. However, in both cases, if catchment areas are marginal in relation to required yield and demand, then any reduction in recharge, whether from climate variability or catchment degradation, will put the source under strain.

What does the guidance cover?

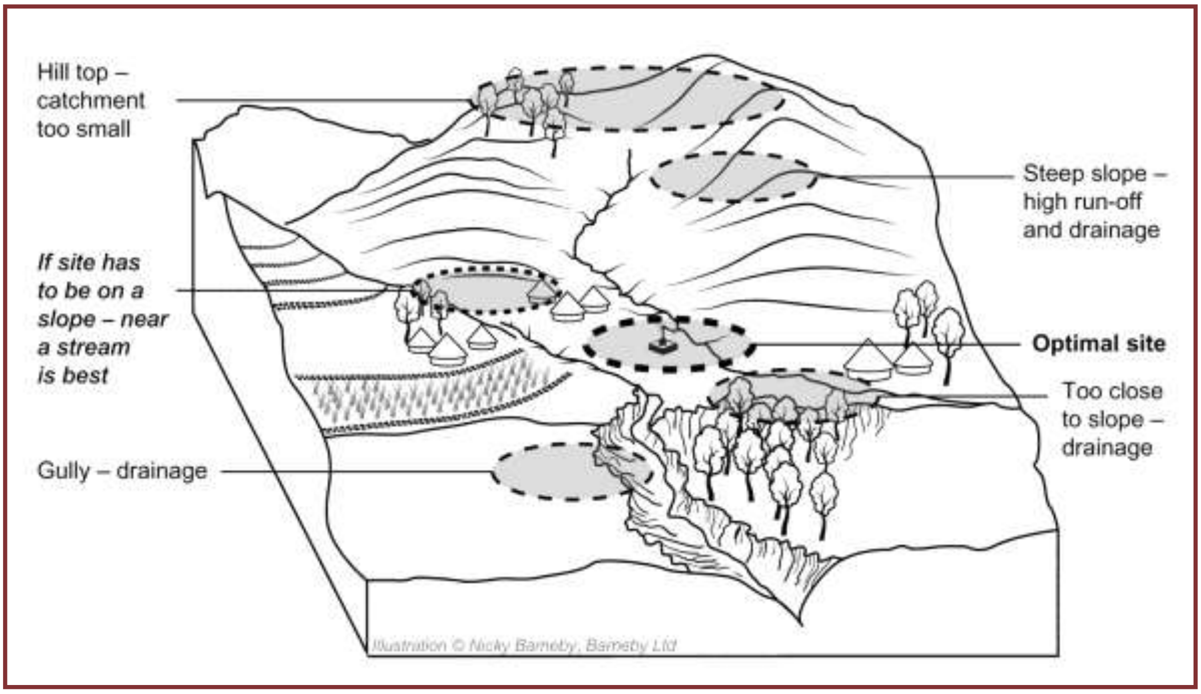
1. Selecting sites – basic rules of thumb
2. Estimating demand – how much water is needed?
3. Estimating the catchment size (wells)/ yield (springs) needed to meet demand

What activities are involved?

Step 2.1 – Selecting sites: rules of thumb

Before looking in detail at the catchment size needed to meet demand from a source, it is useful to look firstly at the topography of the project area – the relief or terrain of the land. Figure 2.1 below highlights some simple 'rules of thumb' for site selection.

Figure 2.1: Scoping the best sites for a water point – the influence of drainage



Source: Calow et al. (2015, forthcoming)

Comment – the importance of drainage

Steep slopes pose a challenge for siting water points. Water within an aquifer will naturally drain to the lower parts of a catchment. In the worst case, an aquifer may have adequate annual recharge, but be unable to sustain dry season yields as recharged water drains down slope. For this reason, both catchment area and topography (drainage) need to assess the vulnerability of a water point to change – from climate variation, environmental degradation or changes in population and demand.

A second important thing to consider is contamination risk. Table 2.1 below provides some similar 'rules of thumb' for minimising the risk of water contamination.

Table 2.1: Minimum distances from sources of pollution

Feature	Minimum distance from water source
Community-level solid waste dump	100m
Storage (or dumps) of petroleum, fertilisers or pesticides	100m
Slaughterhouses / areas where animals are slaughtered	50m
Cemetery	50m
Toilets / latrines (open pit)	30m
Household waste dump	30m
Stables / kraals / animal pen	30m
Main road / railway	20m
River / lakes	20m
Laundry place	20m
Large trees with extensive root system	20m
Dwellings	10m

Source: Collins (2000)

Comment – minimising the risk of contamination

The above recommended distances of sources of potential pollution from water points will not always be possible to achieve. For example, in densely populated areas, latrines might be closer to water sources than the recommended 30m. In such cases, it might be necessary to upgrade latrines from open pit latrines to either sealed pit latrines or latrines with septic tanks.

Step 2.2 – Estimating demand

To assess the catchment area needed to provide sustainable supply, water demand can be estimated based on the number of households a scheme needs to serve and their per capita water needs.

For domestic uses, i.e., drinking, food preparation, and personal and domestic hygiene, a figure of 20 litres per capita per day (Lcd) is often cited in national guidelines. This figure may need to be increased if sources are used for 'productive' water uses such as small-scale irrigation, brewing or brick-making.

Table 2.2: Estimating water needs

Water use (assuming 6 persons per household, demand = 20 Lcd)			
Households	**People**	**Daily needs (m^3)**	**Annual needs (m^3)**
20	120	2.4	876
50	300	6	2190
100	600	12	4380
500	3000	60	21,900
1000	6000	120	43,800
2500	15,000	300	109,500
5000	30,000	600	219,000

Hint – estimating future demand

To build resilience into the estimated number of households that may use the well / spring, consider how the situation might look like in 10 years' time / in 20 years' time. Also consider that a new well / water point might draw in additional people from the vicinity who are currently unserved.

Assume a constant growth rate of the population in the area of approx. 2.5% and use the formula below.

Example:

Current population: 150 people, number of people in 10 years' time: 193

Formula used: $N_t = N_0 * e^{(rt)}$, where:

N_t = Future population after t years
N_0 = Current population
e = Euler's number = 2.718
r = growth rate (e.g., 0.025)
t = Number of years

Step 2.3 – Estimating the required catchment size (wells) or yield (springs)

For water supply systems involving *wells*, the catchment area can be used to assess vulnerability to change (be it climate variation, environmental degradation, or changes in population and demand). If the catchment area is sufficiently large, the water point should, other factors being equal, be resilient to climate variability, and have some capacity to satisfy increases in demand. At the other extreme, catchment areas that are marginal with respect to the required yield are likely to be more vulnerable to change.

Comment – a simplified water balance

A detailed assessment of the water balance of an aquifer in a catchment is complicated, requiring long-term monitoring of rainfall, groundwater recharge, natural discharges (e.g., to base flows in rivers) and human withdrawals. However, simple methods can give reasonable estimates of the recharge area (i.e., catchment) needed to meet demand from a source based on rainfall data, assumptions about how much rainfall recharges groundwater resources, and the required yield of a source.

As a rule of thumb, and based on evidence from numerous empirical studies across Africa, recharge can be assumed as 10% of rainfall in areas with over 750mm of rainfall per year. In areas with less rainfall, the linear relationship between rainfall and recharge breaks down and recharge is related more to extreme rainfall events than averages.

Not all recharged water can be withdrawn from a well, borehole or spring. This is because some recharge is likely to infiltrate deeper aquifers, discharge laterally to rivers, or evaporate back into the atmosphere. *Recoverable* recharge may therefore be only 1 – 3% of rainfall.

Source: Bonsor and MacDonald (2010)

The required catchment area can be calculated as demand (in m^3) divided by recharge (in m), or 'recoverable recharge' if factoring in the limited amount of recharge that can be withdrawn.

Hint – calculating the required catchment area for a source

Demand (in m^3) / recharge (in m)

<u>Demand</u> = 20 HH x 6 members x 20 Lcd x 365 = 876,000 L/year

876,000 L/year ÷ 1000 = **876 m^3/year**

<u>Recoverable recharge</u> = 10% of rainfall of 1300mm = 130mm (optimistic)

130mm ÷ 1000 = **0.13 m/year**

Required catchment area: 876m^3/year ÷ 0.13m/year = **6,740 m^2**

<u>Recoverable recharge</u> = 1% of rainfall of 1300mm = 13mm (cautious)

13mm ÷ 1000 = 0.013 m/year

Required catchment area: 876 m^3/year ÷ 0.013m/year = **67,380 m^2**

Table 2.3 shows the required catchment area for a source under different demand assumptions, for an average annual rainfall of 1300mm, plus the required spring yields needed to meet different demands.

Table 2.3: Estimating the catchment size and spring yield needed to meet demand

Demand				**Approximate catchment area (m²) for well**			**Spring yield**
(assuming 6 persons per household, demand = 20 Lcd)				(assuming 1300mm average rainfall)			
Households	**Persons**	**Daily needs**	**Annual needs**	**Recoverable recharge 10% of rainfall**	**Recoverable recharge 3% of rainfall**	**Recoverable recharge 1% of rainfall**	**L / sec**
		m^3	m^3	m^2	m^2	m^2	
20	120	2.4	876	6,700	22,500	67,500	0.03
50	300	6	2190	17,000	56,000	168,500	0.07
100	600	12	4380	34,000	112,000	337,000	0.14
500	3000	60	21,900	168,500	561,500	1,685,000	0.69
1000	6000	120	43,800	337,000	1,123,000	3,369,000	1.39
2500	15,000	300	109,500	842,500	2,808,000	8,423,000	3.47
5000	30,000	600	219,000	1,684,500	5,615,500	16,846,000	6.94

Hint – interpreting the catchment size table

In Table 2.3 above, the 10% figure gives the required catchment area assuming that 10% of rainfall infiltrates, and that all of this is available (recoverable) to a water point (an optimistic assumption – see comment above). Any existing water point that does not satisfy this criterion is highly vulnerable, and additional sources should be provided. A proposed site that fails to meet the criterion should only be developed if there are no better options, and as one of a number of water sources. More cautious assumptions about recoverable recharge (the 3% and 1% figures above) should produce water points that are relatively secure.

Once the rough catchment area in m^2 is known, the area itself needs to be 'walked out' on the ground.

In flat terrain, the catchment can be viewed as a circle around the water source, and the radius of the circle used to 'walk out' distances from the source to check if there are no other water points (including household wells) or streams or major gullies that might drain water away.

What next?

Hint – measuring out the required catchment area for a source

Example – flat terrain:

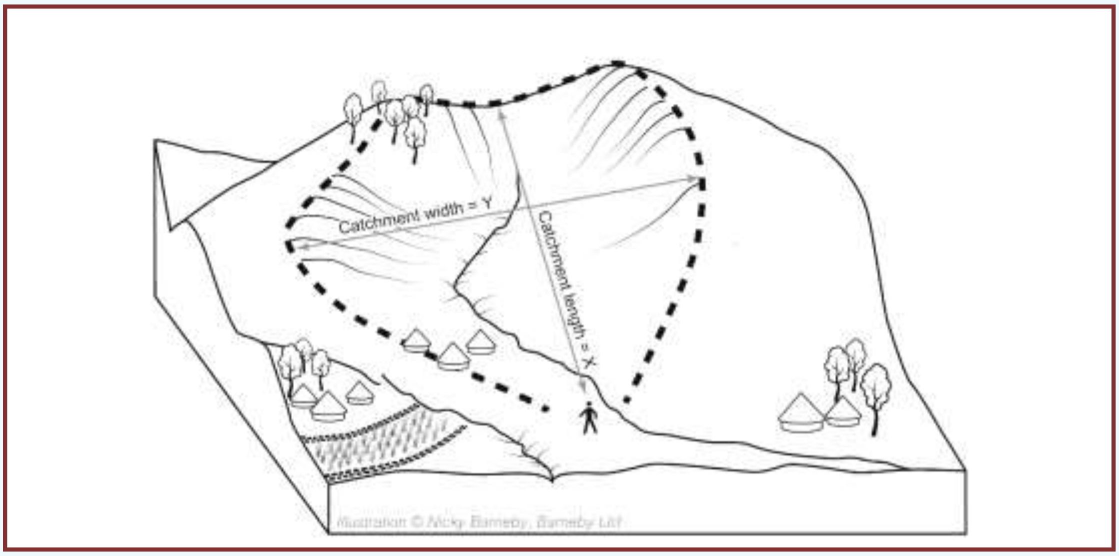
$$r = \sqrt{A/\pi}$$

Required catchment area: **6,740 m²**

⇨ = walk out a circle with 46m radius from source

Example – hilly terrain:

From the selected well site, estimate the length in metres of the catchment either visually or by pacing out upstream to the ridgeline. The width of the catchment is estimated by taking the distance between ridgelines. The catchment area is the two measurements multiplied – see below.



Source: Calow et al (2015, forthcoming)

Project staff with GIS skills and access to digital data on water point locations and terrain (a digital elevation model – DEM) could also plot catchments to assess their size.

Hint – sustainability risks for existing water points

The approach outlined above can also be used to assess whether existing water points are vulnerable in terms of their topography-drainage and catchment characteristics.

Project staff may already have an informed opinion about which sources might be vulnerable. They can apply the tools above to check/confirm and, if necessary, consider developing additional water sources that would help spread risk.

To decide whether it is worth developing a water supply system based on a protected *spring*, a simple assessment can be undertaken, by comparing yield with demand, based on the population served, or likely to be served in future. As a precaution, the yield of the spring during the driest period of the year is used for the calculation.

Hint – comparing spring yield to demand

To assess whether the yield of a spring is sufficient to meet demand, calculate the total water demand of the population to be served annually and compare this to yield. The calculation of total yield should be done based on the lowest yield as measured during the dry season.

Demand: Number of households * number of household members * 20Lcd * 365

Yield: spring yield (L/sec) * 60 * 60 * 24 * 365

Example:

Demand: 245 households * 6 members * 20Lcd * 365 days = 10,731,000 L/year (10,731 m^3 / year)

Yield: Yield during driest period: 1.25 L/sec * 60 sec * 60 min * 24 hours * 365 days = 39,420,000 L/year (39,420 m^3 / year)

Step 3: Protecting sites and sources: hazard assessment and mitigation

Why is it important?

Besides the impacts of well construction and spring protection on the environment (e.g., cutting trees, temporary water pollution, improper disposal of dug out sub-soil), a well-protected and managed environment is crucial for the sustainability and functioning of water points. This is because:

- Direct environmental hazards, such as expanding gullies, floods and landslides can damage water points directly.
- There are indirect environmental aspects to consider as well, relating to degradation processes within the broader catchment that can affect the sustainability of a water system.

Ultimately, the sustainability and resilience of a water system is influenced by how well a catchment of a water source can absorb rainfall through infiltration – water that eventually will feed into the (shallow) groundwater on which the water system depends.

What does the guidance cover?

1. Assessing direct environmental hazards to the water point
2. Assessing indirect environmental degradation processes in the catchment
3. Identifying measures to address direct and indirect hazards via a catchment protection plan

Figure 3.1 summarises the decision-making process in relation to site selection.

Once a site has been identified (Steps 1 and 2 of this note), direct and indirect environmental hazards should be assessed. If there are direct hazards in the vicinity of the proposed water point (Step 3.1), these need to be addressed. If that is not possible – because of the size of the hazard or the lack of financial or technical capacity – alternative sites may need to be considered.

Once a final site has been identified, indirect environmental hazards in the wider catchment of the water source should be identified (Step 3.2) and addressed (Step 3.3)

Figure 3.1: Integrating environmental risk assessment in water point siting

Site pre-selection

Initial pre-selection of water scheme in a community

↓

Hazard assessment

Assessment of the direct environmental hazards that might affect the site

↓

Final site selection

(a) Keep original site and address environmental hazard	(b) Select alternative site if hazards cannot be addressed

↓

Catchment protection plan

Watershed protection plan to address degradation of soils, water and vegetation

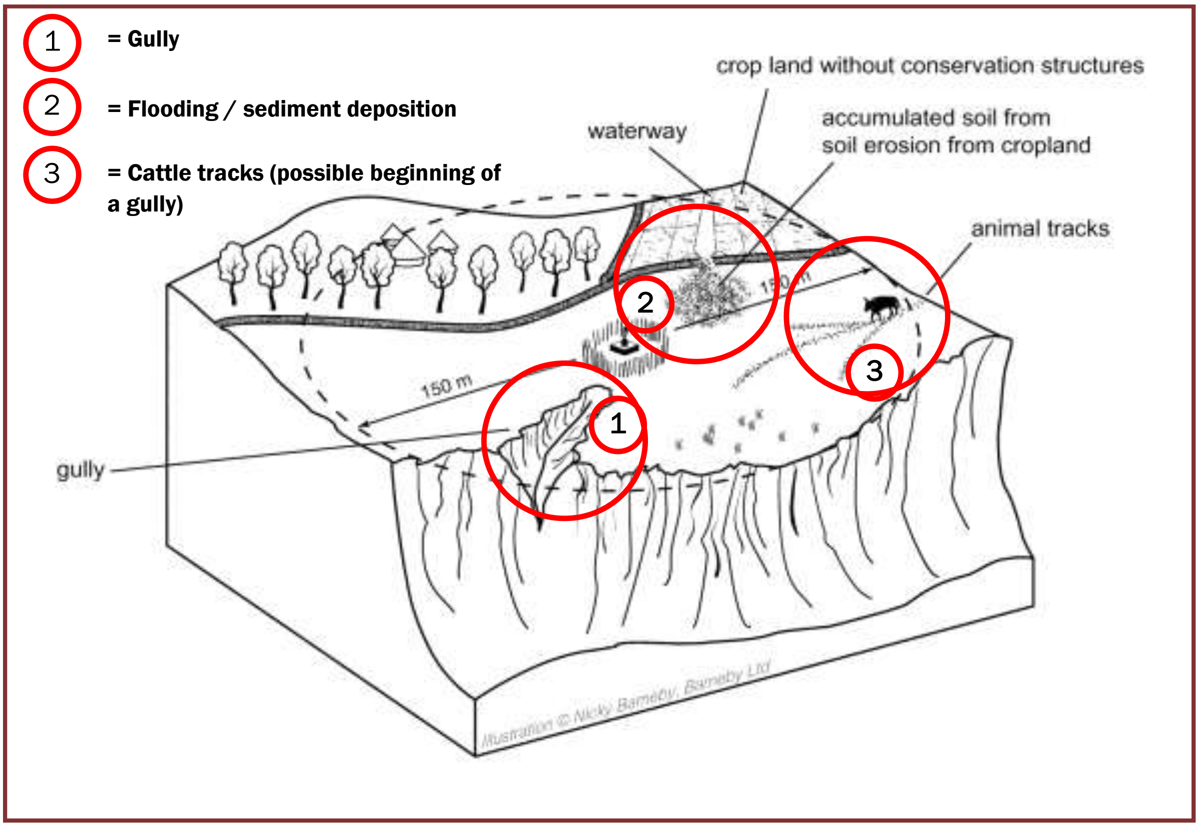
What activities are involved?

Step 3.1 – Assessing direct hazards near a water point

A good place to start is with a map of the vicinity of the water point (approx. 150m radius), whether planned or an existing source, showing the main hazards and degradation features. These may include gullies, areas affected by flooding, landslips or areas prone to landslides. Pollution risks can also be included, such as latrines and waste dumps (see Table 3.3).

Degradation features that might not pose an immediate threat to the water point but left untreated might be a hazard in future (e.g., rills, cattle tracks developing into a gully, etc.) can also be included.

Figure 3.2: Environmental hazards that might affect a water source



Source: Calow et al (2015, forthcoming)

In order to decide whether to go ahead or not with the final site selection, direct environmental threats should be assessed for their severity. If they are so severe that they cannot be resolved within reasonable limits, it might be better to identify alternative sites.

Gullies

The following table provide a simple 'traffic light' system to identify whether gullies might pose a major threat to water points.

Table 3.1: Traffic light assessment for gullies near water points

		Dimension (length x width x depth = m^3)		
		0-10m^3	11-25m^3	>25m^3
Number in vicinity of water point	1		(C)	(B)
	2-3	(C)	(B)	(A)
	4 or more	(B)	(A)	

OK

Low

Moderate

High

Severe

Example: length (25m) x width (2m) x depth (0.5m) = 25 m^3

Hint – what to do about gullies

If there is a gully or gullies in the vicinity of a water point, they need to be treated – i.e., if in a yellow-shaded ('low' or 'moderate' threat) cell.

Consider identifying alternative locations for a water point if you identify several and/or significant gullies – i.e., in a red-shaded ('high' or 'severe' threat) cell.

In both cases, consult natural resource management experts or relevant guidelines for how to do this. In many countries, guidelines have been developed for rehabilitating or protecting watersheds.

If a gully of a given dimension and/or frequency is located downslope of the water point it often poses a more serious threat to the water point than if the gully is located elsewhere. In that case, consider relocating the water point and initiate gully rehabilitation measures. The threat levels identified in the traffic light assessment should all be elevated by one rating. See the letter keys in Table 3.1, i.e.:

- If a gully of the dimension/ frequency labelled 'A' in Table 3.1 is in the *downslope* area of the water point classify as highest ('severe') threat level.
- If a gully of the dimension/ frequency labelled 'B' in Table 3.1 is in the *downslope* area of the water point classify as second highest ('high') threat level.
- If a gully of the dimension/ frequency labelled 'B' in Table 3.1 is in the *downslope* area of the water point classify as third highest ('moderate') threat level.

Area affected by flooding

Regular flooding

If the area where a water point is to be constructed and its immediate environment (e.g., within a radius around the site of the water point of 150m) is regularly flooded (e.g., during the rainy season) then consider the following actions:

- Relocate the site of the water point away from flood prone areas
- Raise the well head and seal the well to prevent any polluted flood water from entering the well
- Manage water flows through cut-off drains, artificial water ways and levees
- Ensure areas from where floodwater originates are open-defecation free and free from other pollutants
- If water point is not accessible during periods of flooding, ensure alternative protected water sources are available

Periodic flooding

- Raise the well head and seal the well to prevent polluted water from entering the well

Hint – thinking about extremes

Also consider flooding that might happen less frequently (e.g., every 5 years, every 10 years) during very heavy rainfall events that might affect a large area and/or create a lot of damage. Consider measures that might reduce the impacts of such extreme events.

Landslips / landslides

Figure 3.3: Image of a landslip

Photo: Frank Greaves, 2015

Landslips may occur because of a variety of natural (geological and morphological structures, such as weak or weathered material, differences in permeability of material) and anthropogenic causes (deforestation, cultivation of steep slopes, road construction). Often they are found on steep hillsides where vegetation is disturbed, for example, along a foot path or where rills have developed as a result of uncontrolled runoff. Landslips can also develop around springs because springs often appear at the intersection of different rock formations

Landslips need to be treated, otherwise there is a danger that they expand and result in more severe damage.

Step 3.2 – Assessing indirect environmental hazards in the wider catchment

Once a potential site for a water point has been identified and deemed safe, i.e., not threatened by environmental hazards, potential indirect environmental hazards should be identified in the wider catchment of the water point. This is important as natural resource degradation in the wider catchment might influence the amount of water that is lost through runoff as opposed to the amount of water that can infiltrate into shallow aquifers.

As a first step, a base map of the catchment of the water point should be drawn, main land cover units mapped and major degradation features identified. An example is provided below.

Figure 3.4: Example base map of catchment

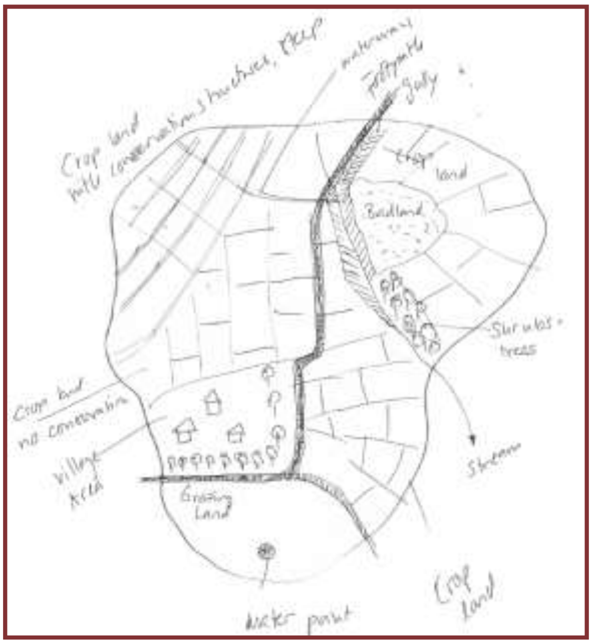
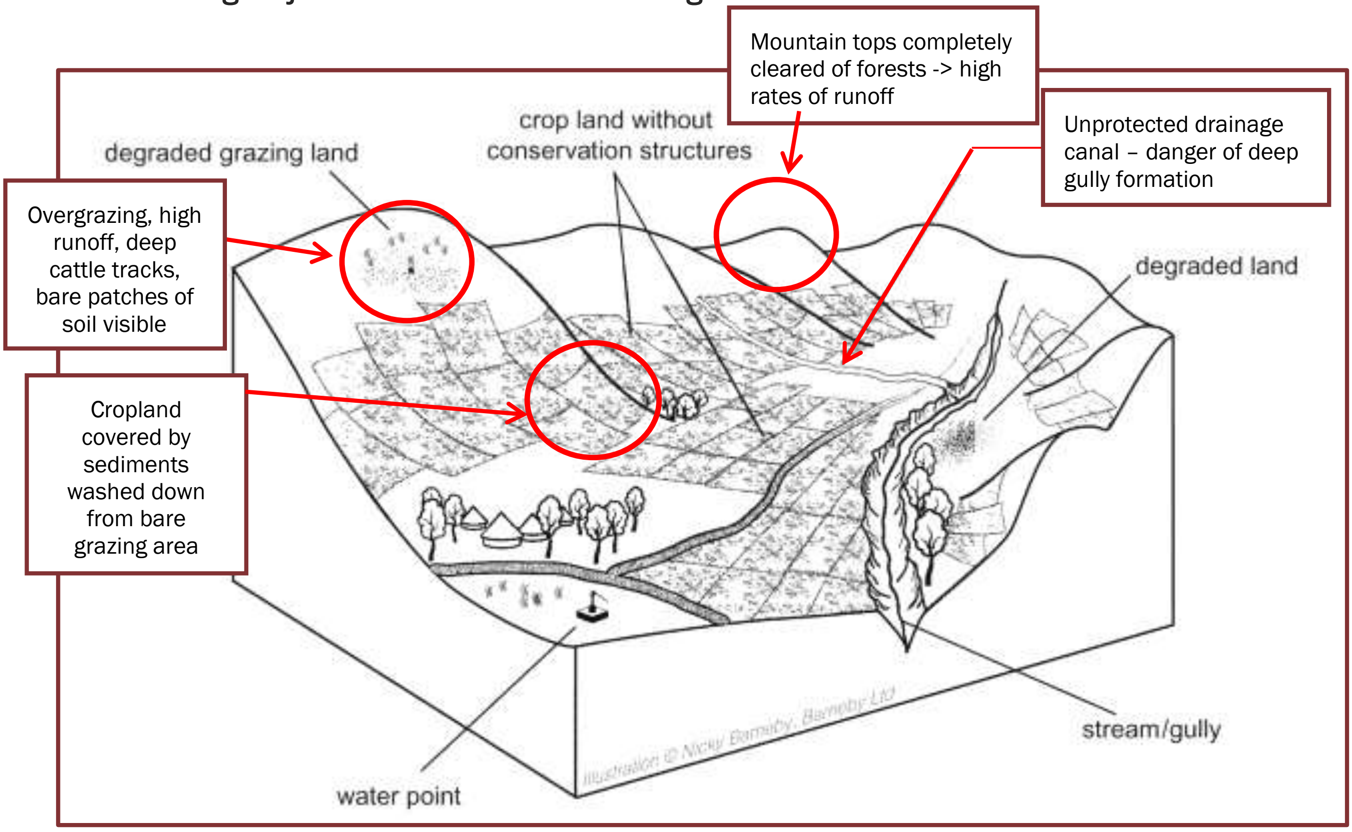


Figure 3.5: Example of a more sophisticated three-dimensional base map showing topography and including major areas of environmental degradation and initial identifications of causes



Source: Calow et al. (2015, forthcoming)

Hint – accounting for perspectives from women and men

Involve both men and women in drawing the catchment map – this might identify special features particularly important for either men or women – for example, accessing water points on a steep slope might be more of an issue for women if they are mainly responsible for collecting water

Table 3.2: Examples of degradation features and possible reasons

Degradation feature	Location	Possible reason
Gully	on grazing land	overgrazing cattle tracks
	on crop land	traditional furrows to drain excess water ploughing up and down the slope
	on bush / forest land	bush / forest clearing
	as a result of foot path / sealed area / cattle track	alignment lacking maintenance
Sheet and rill erosion	on crop land	land management practices
Flooding	on grazing land / on crop land	inappropriate drainage insufficient water infiltration
Landslips	on steep crop and grazing land	land management practices
Landslides	along rivers around springs on steep slopes	deforestation

An assessment of the severity of indirect hazards can also be carried out. This can help establish priorities for action – see Table 3.3 below.

Table 3.3: Assessing the severity of degradation features

Description of degradation features	Severity / extent of degradation				Comments
	none	low	medium	high	
Sheet / splash erosion on crop land					
Rills[3] on crop land					
Gullies[4] on crop land					
Gullies on grazing land					
Gullies on degraded land					
Gullies in forest land					
Sediment deposition					
Cattle step					
Landslip / landslide					
Riverbank erosion					
Deforestation					

Note that gullies or landslips identified in this Step are gullies / landslips in the catchment / watershed area that are **not** a direct threat to the water point. Nevertheless, such environmental degradation features in the catchment / watershed need to be addressed as well.

Step 3.3 – Developing a catchment protection plan

Using the base map and tables prepared during Step 3.2 that helped to identify main indirect hazards and areas where specific natural resource degradation processes are ongoing, identify appropriate mitigation measures.

For all degradation processes classified as medium or high in Table 3.3, seek collaboration with relevant authorities or partners with expertise in natural resource management to identify the most appropriate conservation technology. Table 3.4 below provides some examples of corrective measures depending on the degradation feature and its location. It also provides some ideas what the underlying causes of the degradation feature might be that should be addressed as well.

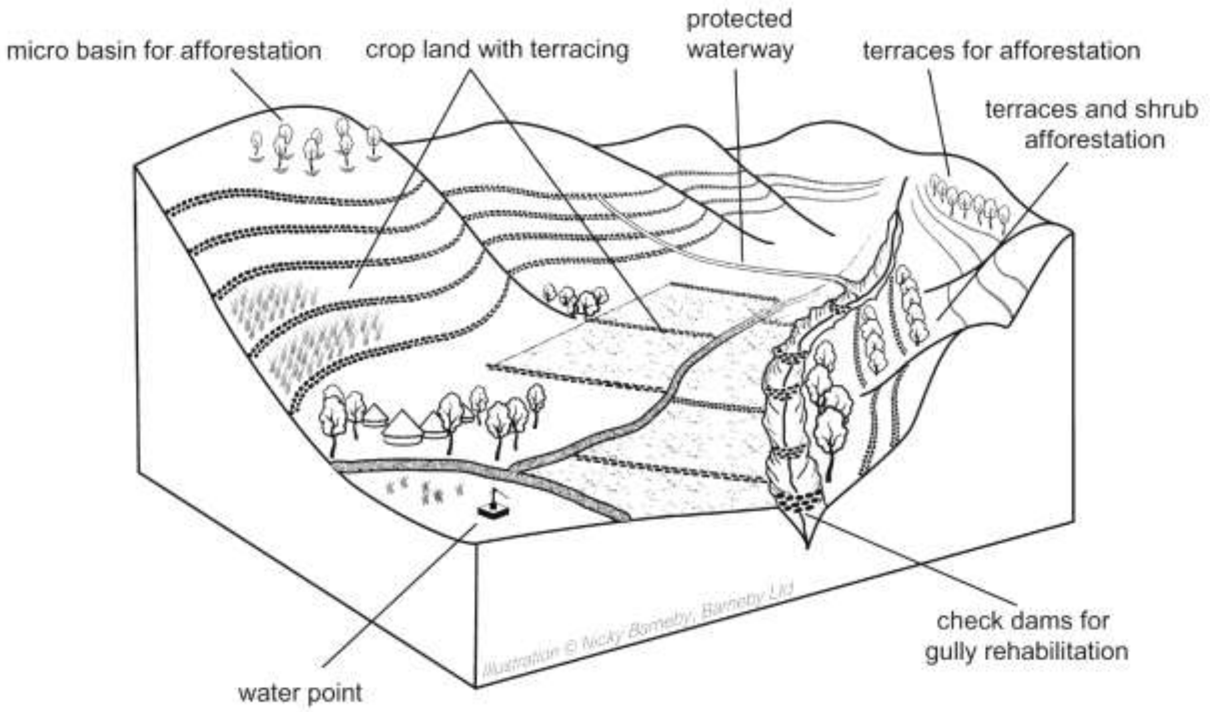
[3] Rills = can be smoothed out completely by normal land management / cultivation practices.
[4] Gully = larger than rills and can no longer be smoothed by normal cultivation practices, persistent.

Table 3.4: Possible corrective measures for main degradation features

Degradation feature	Location	Cause	Correction
Gullies	Grazing land	Overgrazing Cattle tracks	Check-dam Fencing Re-vegetation of gully and surrounding areas
	Crop land	Traditional furrows to drain excess water Ploughing up and down the slope	Ploughing along the contours Cut-off drain and area closures above crop land to reduce run-on and increase infiltration Terracing Check-dam
	Bush / Forest land	Bush / forest clearing	Area closure Cut and carry
	As a result of foot path / sealed area / cattle track	Alignment Inefficient maintenance	Re-alignment Cut-off drains Stone paving and check structures
Sheet and rill erosion	Crop land	Land management practices	Land management practices (e.g., contour ploughing, increasing organic matter content of the soil) Soil and stone bunds Artificial water ways Cut-off drains above crop land
Flooding	Grazing land / Crop land	Inappropriate drainage Insufficient water infiltration	Artificial water ways Cut-off drains Soil and/or stone bunds on crop land to enhance water retention and infiltration Area closures / afforestation on hill tops / steep slopes
Landslips	Steep crop & grazing land	Land management practices	Soil and stone bunds on crop land Area closures or afforestation Retention walls (if serious)
Landslides	Along rivers Around springs	Deforestation	Area closure Afforestation Retention walls Fencing to avoid damage from livestock

Once the main degradation features and corrective measures have been identified and drawn on the base map (Figure 3.5), a catchment protection plan should be elaborated and agreed by all relevant stakeholders. Such a plan should include where which corrective measure is best suited, how much labour needs to be invested and who should provide the labour and what additional material might be required.

Figure 3.6: Base map showing measures to address catchment degradation



Source: Calow et al. (2015, forthcoming)

Step 4: Record keeping

Once the water supply system is completed, it is a good idea to record, store and make available all relevant records. Information gathered from constructing a water point – even if the water point was unsuccessful – can be used to inform future WASH activities.

What data should be kept?

- Geological field notes/ data from geophysical surveys
- Digging / drilling logs including all data relating to the drilling, construction and geological/geophysical logging (including depth and length of well screen, depth and thickness of gravel pack, location of sanitary seal) for dry and successful wells
- Pumping test data
- Seasonal water level observations
- Records on water quality and observations of seasonal quality variations
- Information on physical and legal access (e.g., land ownership)
- Number of people using the scheme and estimate of amount of water collected per person / household across different seasons
- Any incident when water supply system was not functional, reasons and actions undertaken
- Records of corrective/remedial measures taken to address direct and indirect environmental hazards
- Water level (using a dipper, if required) across different seasons
- Any chemical, biological and physical parameters from water testing

Why should data be kept?

This kind of information is helpful in building a picture of the hydrogeology of an area and can help better inform future water scheme developments. For example, it may help governments to develop planning tools, it may help the district hydro-geologist to increase their understanding of the groundwater occurrence in the area and it can help implementing partners in their decisions to develop further water schemes.

Where should data be kept?

Collected data should be kept at local level and a copy should be made available to local and district authorities (e.g., at the office of the district water authority) and to implementing partners.

Hint – drilling logs

A drilling log is a written record of the soil layers and/or geological formations found at different depths. Soil / rock samples should be taken at regular depths (e.g., every meter) and described during the drilling or digging process. The soil / rock description is then recorded in the form of a drilling log. The drilling log will help to determine:

- The right aquifer for installation of the well-screen
- Depth and length of the well-screen
- Depth and thickness of the gravel pack
- Location of the sanitary seal

Source: van der Wal (2010)

Annex: Additional reference material and further reading

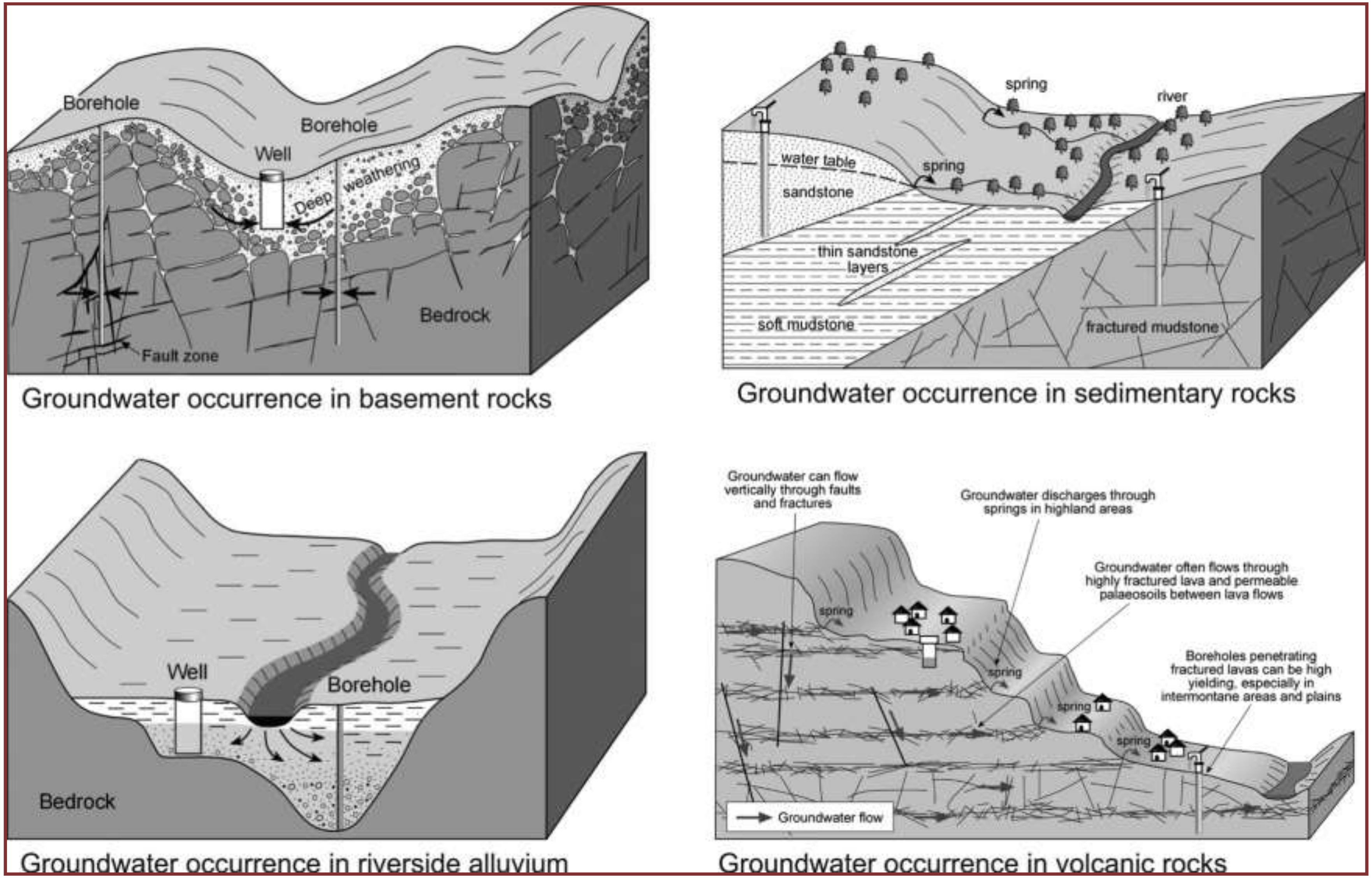
Step 1: Understanding water availability

Table A1: Groundwater potential of major African hydrogeological environments

	Hydrogeological sub-environment	GW potential Average yields (in L/sec)	Groundwater targets
Crystalline basement rocks	Highly weathered and/or fractured basement	Moderate 0.1 – 1 L/sec	Fractures at the base of the deep weathered zone. Sub-vertical fracture zones.
	Poorly weathered or sparsely fractured basement	Low 0.1 – 1 L/sec	Widely spaced fractures and localised pockets of deep weathering.
Consolidated sedimentary rocks	Sandstone	Moderate – high 1 – 20 L/sec	Coarse porous or fractured sandstone.
	Mudstone and shale	Low 0 – 0.5 L/sec	Hard fractured mudstones. Igneous intrusions or thin limestone / sandstone layers.
	Limestones	Moderate – high 1 – 100 L/sec	Fractures and solution enhanced fractures (dry valleys).
	Recent coastal and calcareous island formations	High 10 – 100 L/sec	Proximity of saline water limits depth of boreholes or galleries. High permeability results in water table being only slightly above sea level.
Unconsolidated sediments	Major alluvial and coastal basins	High 1 – 40 L/sec	Sand and gravel layers.
	Small dispersed deposits, such as river valley alluvium and coastal dunes deposits	Moderate 1 – 20 L/sec	Thicker, well-sorted sandy/gravel deposits. Coastal aquifers need to be managed to control saline intrusion.
	Loess	Low – moderate 0.1 – 1 L/sec	Areas where the loess is thick and saturated, or drains down to a more permeable receiving bed.
	Valley deposits in mountain areas	Moderate – high 1 – 10 L/sec	Stable areas of sand and gravel; river-reworked volcanic rocks; blocky lava flows.
Volcanic Rocks	Extensive volcanic terrains	Low – high Lavas 0.1 – 100 L/sec Ashes and pyroclastic rocks 0.5 – 5 L/sec	Generally little porosity or permeability within the lava flows, but the edges and flow tops/bottom can be rubbly and fractured; flow tubes can also be fractured. Ashes are generally poorly permeable but have high storage and can drain water into underlying layers.

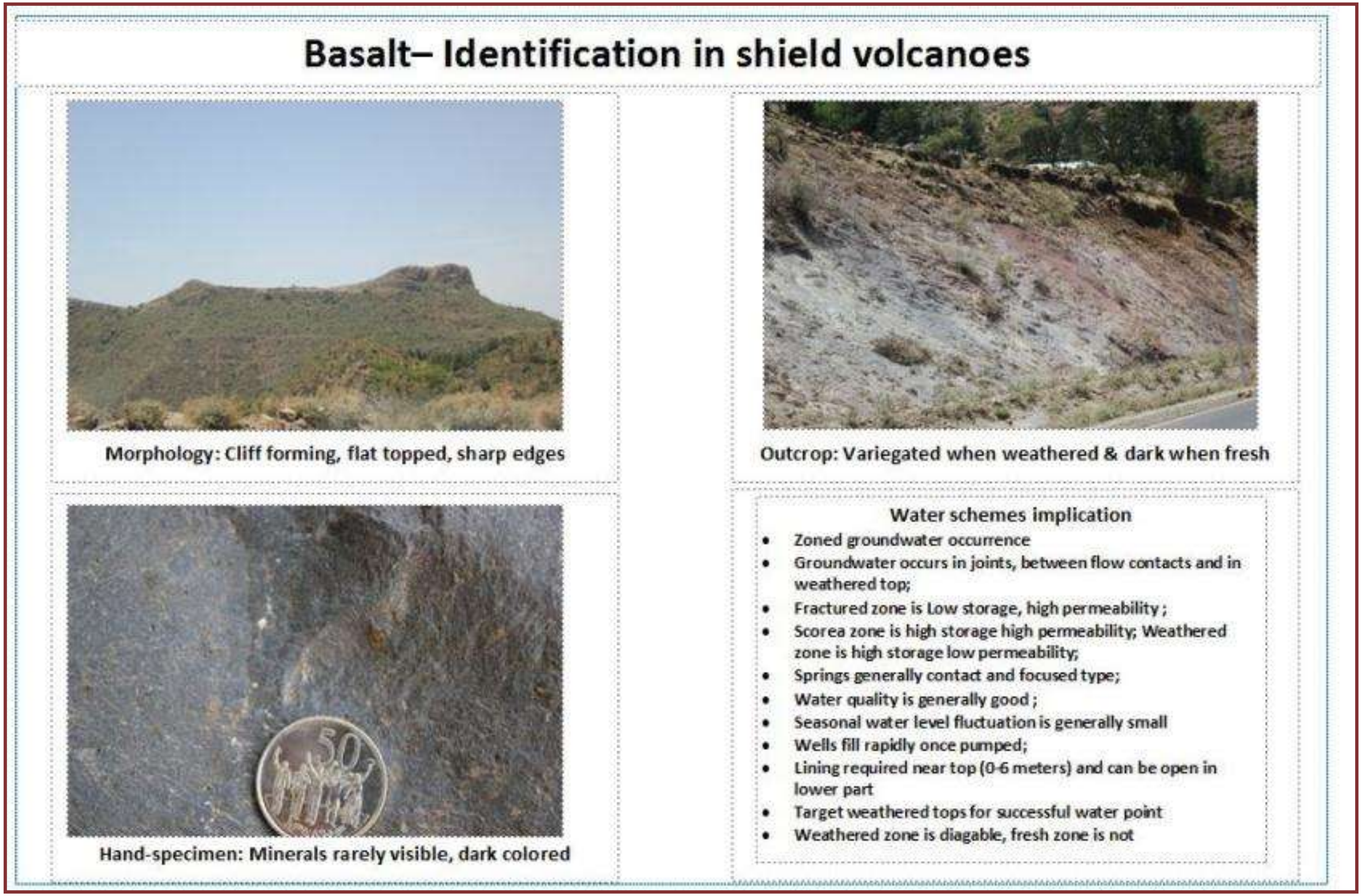
Source: MacDonald et al. (2005)

Figure A1: Geological environments and groundwater availability



Source: MacDonald and Calow (2010)

Figure A2: Example of a geological field identification sheet



Note: this sheet was prepared for field staff in Ethiopia working in an area dominated by different kinds of volcanic basalt rock

Step 3: Identifying and mitigating environmental hazards

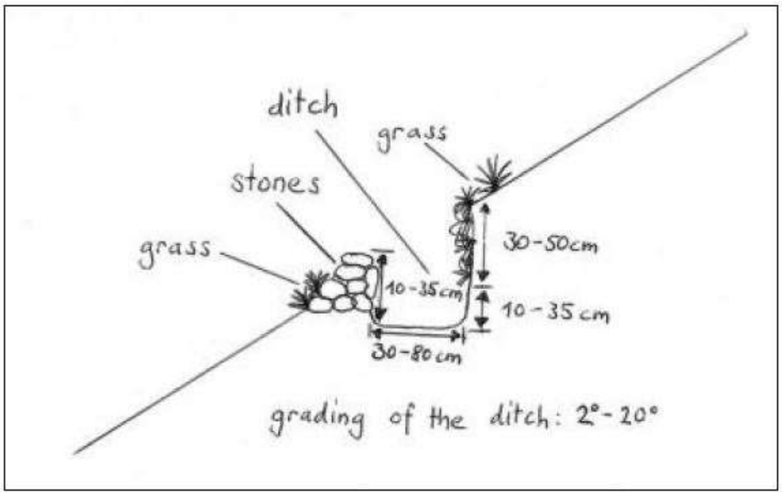
Direct damage to water points

Flood control – additional information

Cut-off drains above water point

A cut-off drain is a graded channel constructed to intercept and divert the surface runoff from higher ground/slopes to a waterway, river, gully, etc, protecting downstream cultivated land or a village. Cut-off drains help to reduce run-on and safely drain excess runoff to the next waterway. If water points are built on heavily grazed and degraded areas (e.g., compacted soil, animal tracks), cut-off drains should be constructed above the water point to protect it from floods. Cut-off drains should be constructed at least 10m above the water point in case contaminated water is collected, and should be deep and wide enough to drain runoff from a major rainfall event.

Figure A3: Diagram of cutoff drain (traditional ditch)



Technical drawing

drawing showing a traditional ditch, Maybar, Ethiopia (Sabina Erny)

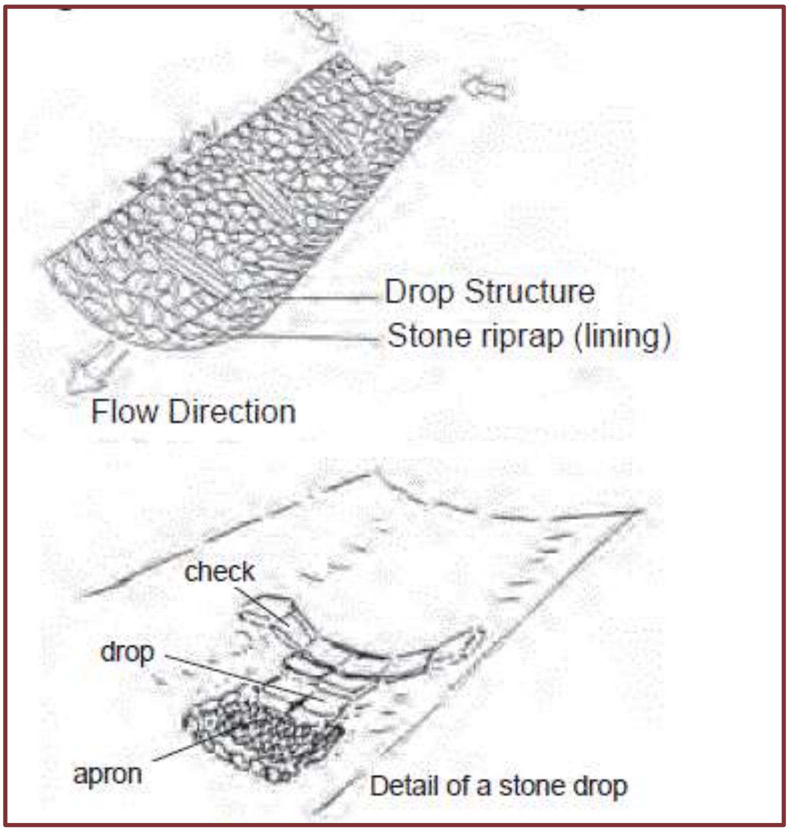
Source: WOCAT Database. Code T_ETH031en. Traditional cut-off drain. Case study compiled by Sabina Erny, Department of Geography, University of Basel, Basel, Switzerland. Technical Drawing: Sabina Erny.

Artificial waterways

If flooding is a recurrent problem in the area where the water point would best be constructed, more sophisticated drainage structures might be necessary. These could include artificial waterways intercepting runoff within the catchment and draining it safely to the nearest natural watercourse. Care needs to be taken to protect the floor of these waterways adequately with grass cover and/or stones and check-dams to prevent them from developing into a gully. Paved waterways are suitable in steeper terrains and areas with large amount of stones.

Protective measures within natural water courses might also be required to prevent further deepening and drawing down the water table.

Figure A4: Diagram of artificial waterway



Source: Lakew Desta, Volli Carucci, Asrat Wendem-Ageňehu, Yitayew Abebe (eds.), 2005. Community-based Participatory Watershed Development – A guide. Ministry of Agriculture and Rural Development (MoARD), Addis Abeba.

Gully protection / reclamation – additional information [5]

If there are rills and gullies near water points or features such as cattle paths / foot paths that may lead to gully formation, these should be addressed. Options include a variety of gully control techniques which are discussed briefly below.

To effectively control gully development, three areas of intervention are required:

1. Improvement of gully catchment to reduce and regulate runoff volume and peak amounts
2. Diversion of runoff water up-stream of the gully area
3. Stabilisation of gullies by structural and vegetative measures

Most important, however, is to avoid gullies from developing – gully rehabilitation can be extremely costly. Preventative measures include:

- Land management practices to reduce runoff and enhance water infiltration (including soil and water conservation practices following a watershed approach, increased vegetation cover / canopy cover, forest / shrubland management, controlled grazing, soil fertility management, stabilisation of large rills / small gullies, etc.)
- Runoff management (including cut-off drains, retention and infiltration ditches, terraces, grass patches above areas where gullies might form, control of runoff from culverts, runoff control from sealed surfaces and paths, etc.)

[5] For further details see Desta and Adugna (2012)

- Diversion of surface water above gully (cut-off drains, diversion ditches, stabilised artificial waterways, etc.).

Figure A5: Photo of a reclaimed gully using check dams and re-vegetation

Photo: Eva Ludi, 2013

Once gullies have started to form, it is important to control them using appropriate structural and vegetative measures in the head area, along the floor and the sides of the gully. There are a range of available physical and biological measures, with a combination of the two achieving best results. Among the most common interventions are the following:

Gully head control

Gully heads are the most difficult part of a gully to treat, especially if the gully is deep because of the erosive power of falling water. First, cut-off drains are required to avoid further erosion and check-dams close to the head should be constructed to trap sediments and raise floor levels. Re-vegetation should follow to further stabilise the gully head.

Gully reshaping

Steep gullies should be reshaped (slope less than 45%) and re-planted. This requires that water flows are entirely diverted away from the gully.

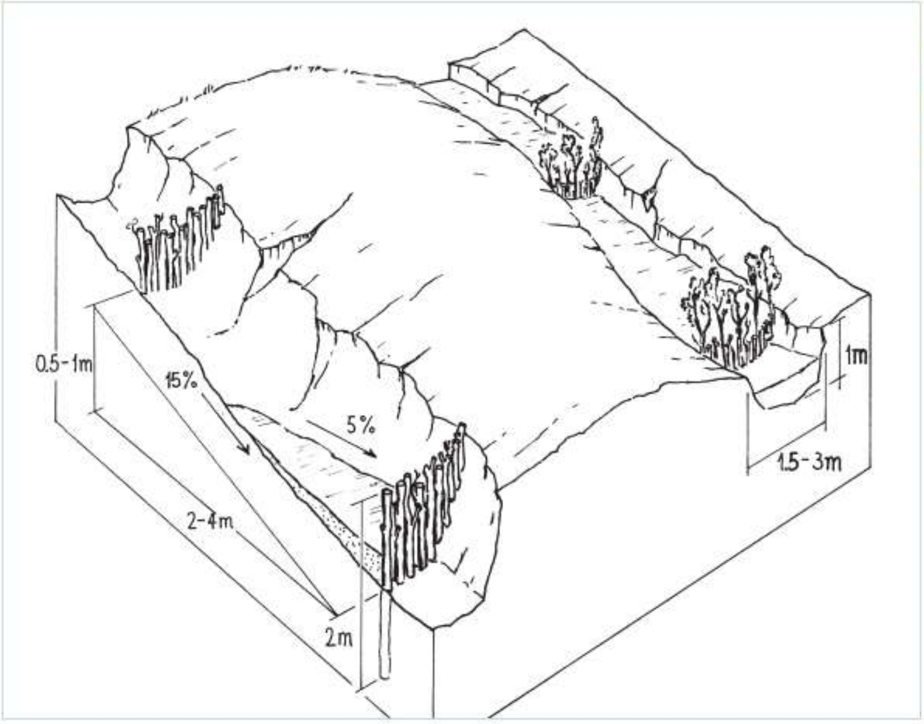
- Reshaping and filling is done to decrease the angle of gully sides, create planting areas and encourage revegetation & stabilization, usually in small to medium-sized gullies where most runoff has been diverted into a stable waterway or drainage line.
- When these gullies are shaped and smoothed, vegetation can be established over the levelled gullies.

Structural check-dams within the gully

Check-dams are constructed across the gully bed to stop channel/bed erosion. By reducing the original gradient of the gully channel, check-dams diminish the velocity of water flow of runoff and the erosive power of runoff. Run-off during peak flow is conveyed safely by check-dams. Check-dams can be constructed using different materials (brushwood, sandbags, loose stones, gabion, organic gabion (bamboo, reed) and arc-weir check-dams).

- Stone check-dams prevent the deepening and widening of the gully and trap sediments. Sediments accumulated behind a check-dam can be planted with crops or trees/shrubs and grass and can thus provide additional income.
- Brushwood check-dams are vegetative measures constructed with vegetative materials, branches, poles/posts and twigs. Plant species which can easily grow vegetatively through shoot cuttings are ideal for this purpose. The objective of a brushwood check-dam is to retain sediments and slow down runoff, and enhance the revegetation of gully areas.

Figure A6: Diagram of vegetative check dams with stem cuttings



Technical drawing
Stem cuttings planted in gullies to form living check dams: recently planted (left) and cuttings that have begun to take root and sprout, resulting in the gully becoming filled with trapped sediment (right).

Source: WOCAT. 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 229ff). Case study compiled by Georg Heim, Langnau, Switzerland and Ivan Vargas, Cochabamba, Bolivia. Technical Drawing: Mats Gurtner.

<u>Vegetative measures for gully control</u>

Vegetation will protect the gully floor and banks from scouring, slows down the velocity of the runoff and encourages deposition of sediments. Depending on soil quality, water availability and steepness of gully sides, vegetation may establish itself naturally if runoff is adequately controlled. If conditions are more difficult, planting of vegetation – grasses, shrubs and trees – might be necessary. Is best done using multi-purpose species (e.g. grasses, leguminous species of trees and shrubs, etc.) on reshaped gully sides and gully bottom for reducing runoff and for erosion control. Best results are achieved when the vegetation cover is dense and covers all gully sides and the bottom of the gully. In all cases, exclusion of all animals is a precondition.

Suggested measures include:

- Bundling or wattle – a technique where fresh stems of plants are bound together, then horizontally planted (across the gully bed or along the sidewall), and covered by soil. Through time, the bundles will grow and serve as a live check-dam.
- Layering – horizontal planting of fresh stems of plants across the gully floor or reshaped sidewall
- Gully bed plantation with water-loving or moisture tolerant trees, shrubs and grasses

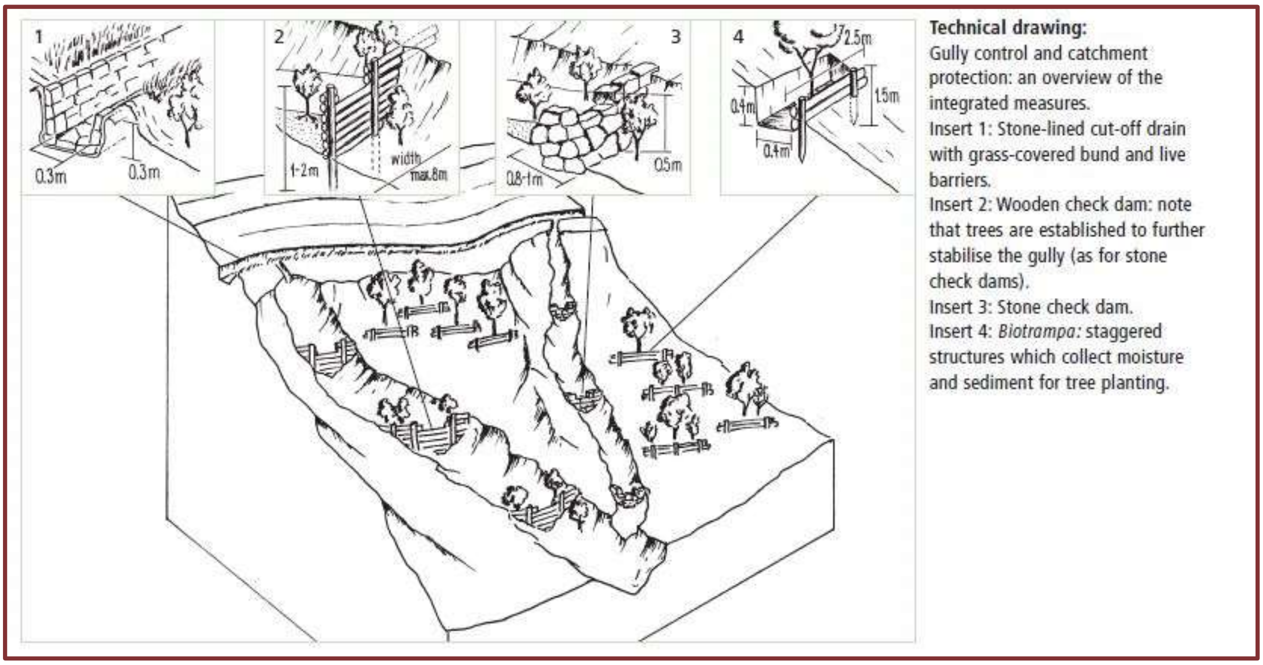
- Retaining walls with bamboo-mat along gully side walls
- Planting of trees, shrubs and grasses on gully sidewalls
- Direct sowing (broadcasting) on gully beds and into cracks on sidewalls during the rainy season
- Off-set plantation in areas adjacent to gullies to prevent sideway extension of the gully and further encroachment of arable land

<u>Maintenance and management arrangements for gully control and rehabilitation</u>

Whether physical or vegetative measures, or both, have been used for rehabilitating a gully, regular maintenance of structures is of paramount importance. Structures should be observed for damage especially during rainy seasons and after heavy storms. Damaged check-dams should be repaired immediately to avoid further damage and the eventual collapse.

Once gullies have stabilised, they can be further used for productive purposes – planting of fodder grasses and trees or fruit trees can offer economic returns. Gullies usually cross land belonging to several farmers (if affecting crop land) or to a group of farmers (if affecting communal grazing areas). A critical component of every gully rehabilitation effort is to establish clear management rules and regulations together with the affected farmers.

Figure A7: Integrated gully control and catchment protection measures

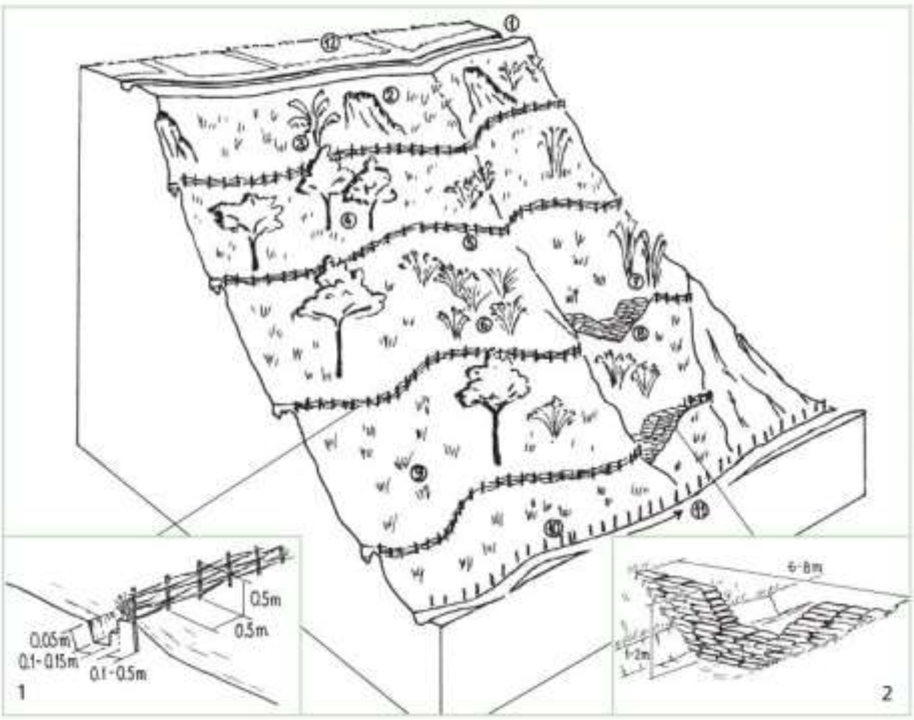


Source: WOCAT (2007) Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 233ff). Case study compiled by Georg Heim, Langnau, Switzerland and Ivan Vargas, Cochabamba, Bolivia. Technical Drawing: Mats Gurtner.

Measures to protect areas vulnerable to land slips / land slides

Natural causes of landslides, such as weak or weathered material, contrasts in permeability or material or shrink-and-swell weathering cannot be directly addressed. It is thus important to protect the wider area where land slips / landslides happened in the past or are likely to happen in future. Such protection is aimed at reducing disturbance through fencing (to avoid animal tracks from developing and preventing further destruction of vegetation cover), as this is vital for enhancing infiltration. Afforestation of a larger area around areas prone to land slips should also be considered as this will help to keep the soil together and reduce the impact of rainfall and runoff. Care needs to be taken, however, in terms of species selection as not all species are equally suitable.

Figure A8: Land slip prevention / rehabilitation



Technical Drawing
Landslip and stream bank protection: an overview of the multiple and integrated vegetative and structural measures: cut-off drain (1); land slip area (2); banana trees (3); alder trees (4); bamboo wattle fences (5); cardamom (6); bamboo planting (7); cement bag check dams (8); broom grass (9); bamboo cuttings (10); stream bank (11), agricultural fields in a flat area (12).
Insert 1: Bamboo wattle fence combined with retention ditch and grassed bund to stabilise steep slopes and gullies.
Insert 2: Old cement bags filled to form checks in gullies.

Source: WOCAT. 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 241ff). Case study compiled by Dileep K. Karna, Department of Soil Conservation and Watershed Management, District Conservation Office, Kathmandu, Nepal. Technical Drawing: Mats Gurtner.

Indirect damage to water points – degradation in the wider catchment of a water point that can result in reduced water infiltration

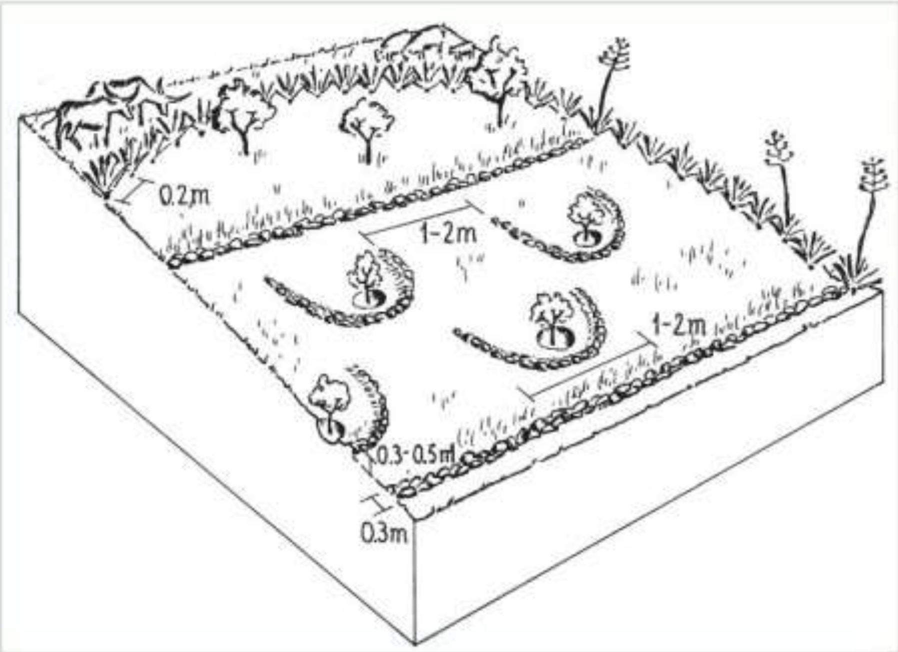
When catchments of water points are degraded, i.e., the infiltration capacity of soils is reduced, water points may be affected and no longer yield water. It is therefore important to invest in appropriate catchment protection to enhance the sustainability of water points.

Depending on the degradation features observed (see above for a short description of the main features), a whole range of measures are available from which the ones that are most appropriate to the bio-physical and socio-economic environment can be selected. The most common ones include:

Area closures

Area closures are a protection system to improve land with degraded vegetation and/or soil through natural regeneration. Area closures with or without additional tree/shrub planting is a common measure on top of hills. Once areas are closed off and livestock and human interference stops, natural vegetation usually recovers quickly. This helps to reduce the impact of rainfall on bare soils, decrease the velocity of runoff and increase water infiltration. After two years, grass can be cut for livestock fodder. Other economic activities can be introduced into closed areas such as special fodder trees, fruit trees, or apiculture. Water harvesting structures such as hillside terraces, micro basins, eyebrow basins, etc., can also be introduced to enhance tree planting and water conservation activities.

Figure A9: Diagram of area closure



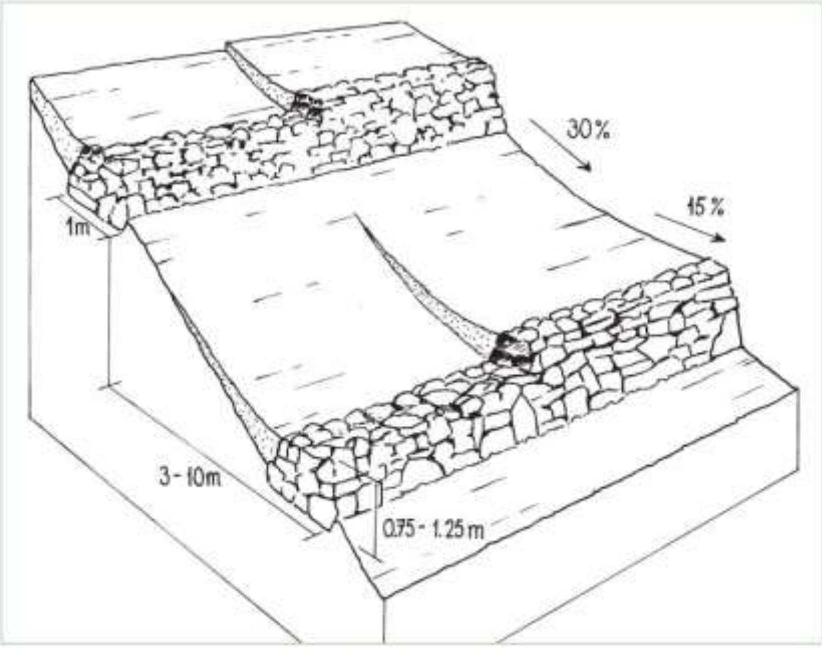
Technical drawing
Rehabilitation of degraded land based on enclosure with live fence. Natural regeneration of vegetative cover is supported by water harvesting structures and planting of nitrogen-fixing/multipurpose shrubs and trees as well as local grass species. On steeper slopes hillside terraces may be established.

Source: WOCAT. 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 317 ff). Case study compiled by Daniel Danano, Addis Abeba, Ethiopia. Technical Drawing: Mats Gurtner.

Physical soil and water conservation on crop land

A range of technologies are available for soil and water conservation on crop land. These include soil and stone bunds and a range of different terraces. Depending on rainfall, structures may be graded (with a gradient of 1% towards the nearest water way or stream) to drain excess runoff. Because they are impermeable structures, stone bunds can retain rainfall for improved soil moisture unless provided with spillways. On less steep slopes, strips of land can be left unploughed for grass strips to develop, which over time develop into terraces. Such grass strips are much cheaper to establish than bunds.

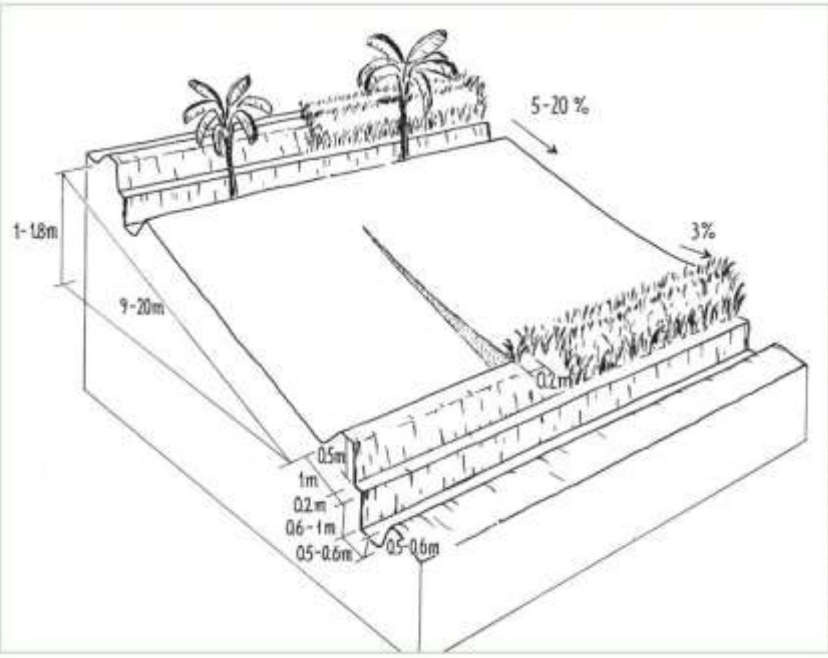
Figure A10: Diagram of stone bund/ terrace



Technical drawing
Layout of stone wall terraces: the walls are built up over time (right) as soil accumulates behind the barriers.

Source: WOCAT. 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 261ff). Case study compiled by William Critchley, Vrije Universiteit, Amsterdam, Netherlands. Technical Drawing: Mats Gurtner.

Figure A11: Diagram of soil bund ('Fanya Juu' in Swahili)



Technical drawing
Fanja juu terraces: newly constructed (left) and mature (right) with bananas planted below the bund and fodder grass on the riser: note leveling occurs over time (right).

Vertical interval and spacing for *fanya juu* terraces

Slope	Terrace spacing	
	Vertical Intervals	Horizontal Distance
(%)	(m)	(m)
5	1.00	20
10	1.35	14
15	1.73	12
20	1.80	9

Formula: Vertical Interval = (% slope / 4 + 2) x 0.3
max vertical interval = 1.8 m
(Source: Thomas 1997)

Source: WOCAT. 2007. Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide. Liniger, H.P. & Critchley, W. (eds.), Centre for Development and Environment, Institute of Geography, University of Bern, Bern. (p. 269ff). Case study compiled by Donald Thomas; Kithinji Mutunga and Joseph Mburu, Ministry of Agriculture, Nairobi, Kenya. Technical Drawing: Mats Gurtner.

Cut-off drains

Cut-off drains above arable land or between grazing land and arable land help to drain excess runoff towards the closest stream. In drier areas, cut-off drains can also be used to divert water to ponds for further use as irrigation water/water for livestock. Cut-off drains are also important structures above gullies to prevent further gully development. See above ('Cutoff drains') for more information on artificial waterways.

Artificial waterways

In areas with high rainfall – or highly concentrated rainfall – artificial waterways might have to be established to drain excess water into the nearest stream. Waterways can be constructed for both very small and large size catchments, thus accomodating individual or communal needs for drainage and evacuation/use of excess run-off. See above ('Direct damage to water points') for more information on artificial waterways.

Table A2: Example of catchment protection plan

Measure	Location	Quantity	Work Norms	Cost (only material, NOT labour)		Material
				Unit	Total	
Soil Bunds	On cultivated fields with slope < 10%	25km	150 PDs/Km			Digging tools, measuring tools, lines for demarcation
Water from roads	From road drains and culverts to reservoir and recharge pits/ponds	2 systems to recharge pits ($500m^3$ each) 350m of waterways 6 gabions structure to deviate water	$1m^3$/PD			Digging tools, gabions, measuring tools, gravel, stones, lining plastic sheets
Gully plugs	On all major gullies on base map	15 systems = $1250m^3$	0.5 PD/m^3			Gabions, stones, digging tools, measuring tools
Cutoff drain	Between cultivated land and closed hillsides above, to intercept runoff	1km = $500m^3$ earthwork (1m x 0.5m)	0.75 m^3/PDs			Digging tools, stones
Waterways	Between fields, to divert excess runoff to stream	2km = $500m^3$ (0.5m x 0.5m)	0.75 m^3/PDs			Digging tools, stones
Recharge pond/pits	Suitable locations	4 systems = $2000m^3$	1 m^3/PDs			Digging tools, measuring tools, gravel, sand
Roof water harvesting	On the roof of School X, on the roof of School Y	Two $50m^3$ ferrocement tanks, gutters				Cement, iron mesh, 80 m of gutters, 20 m of pvc pipe, reinforced iron bars, sand, tools
Seedlings production	In nurseries	100,000	15 PD/1000 seedlings			
PD = Person Day						

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SSWN – Sustainable Sanitation and Water Management
www.sswm.info/content/drilled-wells

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The SWIFT Consortium aims to deliver sustainable access to safe water and sanitation and encourage the adoption of basic hygiene practices in the Democratic Republic of the Congo and Kenya. It is funded with UK aid from the British people.

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