How Tough is WASH Climate Resilience Framework

A field guide to assess climate resilience of water supplies

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INTRODUCTION

Background

Building the resilience of water supplies to climate change will be critical in improving and maintaining access to safe drinking water, sanitation and hygiene (WASH). This will require an understanding of how current climate variability affects services and the strength of WASH institutions to manage these, and other threats. Robust assessments of resilience that cover multiple aspects of service delivery can strengthen monitoring and aid decision-making to improve resilience in the WASH sector.

This document is a field guide for practitioners and researchers to assess the climate resilience of drinking water supplies using the *How Tough is WASH* framework. The *How Tough is WASH* framework considers resilience along six interconnected domains of service delivery – environment, infrastructure, service management, institutional support, community governance & engagement and supply chains. These domains, sometimes referred to as WASH building blocks, collectively affect the quality of services and the ability of service providers to deliver safe and reliable water.

The framework is operationalised through a set of six indicators. These indicators describe conditions corresponding to different levels of resilience and are scored by collecting and analysing relevant information on each domain of water supply services. The output of this assessment is a single resilience score for a system, found by adding scores of each of the six indicators.

System scores can be used to identify the least resilient systems in a community or region and monitored over time. Individual indicator scores also allow teams to identify specific weaknesses in the system and recommend improvements. The application of this framework in field settings is the focus of this field guide. Examples from previous applications of this framework are provided throughout the guide. The framework avoids

BOX 1 CLIMATE RESILIENCE OF WASH

The IPCC (2021) defines resilience as

'The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.'

being prescriptive and encourages assessment teams to modify it to suit their specific context. While we suggest a range of tools to support field assessments, teams are encouraged to rely on their judgement and local knowledge to assess resilience.

Structure of this document

This document provides practical guidance on the use of the *How Tough is WASH* framework to assess the resilience of drinking water supplies. It begins with definitions of terms used in the field guide, an overview of the indicators, data collection methods, and indicator scoring. The following sections provide detailed information on collecting data on each indicator, sample questions for community discussions and key informant interviews and guidance on analysing the data to score each indicator. These can be used to identify weaknesses in particular aspects of service delivery, assign overall system resilience scores and prioritize systems for improvements. This guide is accompanied by surveys and site inspection forms.

Target audience

This field guide is intended for WASH professionals undertaking assessments of resilience of drinking water supplies to understand their strengths and weaknesses through a climate lens.

The framework has been tested on rural community-managed water supplies and local government-owned piped-water supplies in small towns in Ethiopia, Mozambique, Nepal and South Africa. As such, this guidance is ideally suited for systems in similar settings. For larger, utility-operated piped water supplies, the sub-indicators and resilience conditions may need to be modified by assessment teams.

Table 1 Definitions of terms used in the field guide

Term	Definition
Domain	Aspects of a water supply system that affect the quality of services and their resilience, also referred to as building blocks
Indicator	A measurable metric that can be assigned a score
Sub-indicator	Elements within each indicator that provide indicative features of what each level of resilience of that indicator may look like
WASH	Water, sanitation, and hygiene

Figure 1 Climate resilience is based on multiple aspects of service delivery

The six indicators

Table 2 The set of indicators and sub-indicators in the *How Tough is WASH* framework

Indicator	Sub-indicators
Environment	Topography and land-use in the catchment
	Exposure to flooding
	Population density in the catchment and risk of fecal contamination
	Competition for water source
Infrastructure	Sanitary protection
	Yield
Service management	Strength of management
	Understanding of climate change and adaptive management
	Gender and social representation
Institutional support	Risk management program and support for adaptation
	Support after emergency
	Inter-sector coordination
Supply chains	Access to spare parts and consumables
	Robustness of supporting infrastructure
	Availability of spare parts locally
Community governance & engagement	Civic engagement and participatory behaviour (for community-managed supplies)
	Inclusivity (for community-managed supplies)
	Reporting mechanisms and engagement (for utility-managed supplies)

BOX 2 INDICATOR WEIGHTING

Each indicator and sub-indicator are considered equal in the framework. There is insufficient evidence from field applications of this framework to support a different weighting system. However, indicators may eventually be weighted after validation using sufficiently large datasets.

How is resilience scored?

Each indicator contains a set of sub-indicators, as shown in Table 2. These can be scored on two different scales, depending on the goal of the assessment.

If the goal of the assessment is to obtain resilience scores for individual water supplies to identify weaknesses and monitor them over time, and there is limited capability in undertaking resilience assessments, then it may be easier to score the sub-indicators on a three-point scale from low to high.

On the other hand, if the goal of the assessment is to develop aggregate resilience scores of water supply systems to allow regional or national comparisons, then it is recommended that the sub-indicators are scored on a 5-point scale from very low to very high resilience. A wider scale helps to preserve detail when resilience scores from a large number of systems are aggregated, and use of this scale is more likely to identify trends in domains and between different types of water supply. Both 3- and 5-point scales are presented in this field guide.

Each point contains criteria describing varying degrees of resilience. The resilience of a sub-indicator should be selected based on which criteria most closely describe the system being assessed. The criteria are designed to provide indicative features of what each level of resilience may look like. Assessment teams may wish to add or modify them to suit local context.

The indicator should be assigned the resilience score corresponding to the majority of the sub-indicator scores, e.g., if more than 50% of sub-indicators have Low resilience, that indicator should also have Low resilience.

Data to score each sub-indicator are collected through a range of methods which are briefly described in Table 3 and detailed in the rest of this field guide.

Table 3 Overview of data collection methods

Indicator	Method of data collection
Environment	Geospatial analysis using Google Earth™ Visual inspection, transect walks
Infrastructure	Visual site inspection, transect walks
Service management	Stakeholder interviews
Institutional support	Stakeholder interviews
Supply chains	Stakeholder interviews
Community governance and engagement	Focus group discussions

ENVIRONMENT

Objective To collect data on the natural and human-made features in the catchment of the water supply and score the environment indicator.

This indicator (Table 4) is structured to cover multiple catchment typologies. Each sub-indicator may not apply to every source or catchment. Assessment teams should pick which sub-indicators apply to their system and include only those in the assessment.

If the water source is in a hilly or mountainous area users need to evaluate only the first sub-indicator that deals with the steepness of the slope and the land cover. Together, these represent the risk of erosion and rapid stormwater runoff and landslides damaging the infrastructure during heavy rainfall. For sources in flat regions, this sub-indicator can be removed from the analysis.

If the source is close to a river or coast, the water supply infrastructure could be at risk of flooding or inundation unless there are flood protection measures present, which is covered by the second sub-indicator. For water supplies in such areas, the risk of landslips does not exist, and the first sub-indicator is not applicable.

If the source is not in hilly areas and is not in proximity of a river or coast, assessment teams should consider if there are risks of heavy faecal loading in the catchment. Shallow groundwater sources in densely populated areas with open defecation or pit latrines that are prone to flooding are susceptible to frequent contamination from faeces and with increasing intensity of rainfall with climate change, this risk may increase. The third sub-indicator is applicable in such environments.

Methods Geospatial analysis can be done by importing GPS coordinates of water points and overlaying on satellite or aerial images using programs with GIS capabilities. Google Earth™ (https://earth.google.com/web/) can be used to visually assess catchment characteristics relevant tothe assessment. Landscape features like mountains, surface waters and forests, built-up areas, roads,communities, and farmland can be identified using Google Earth. Household surveys with users of the water supply can be used to collect additional information on risks in the catchment. For these surveys, it is recommended to select participants familiar with the community and surrounding areas, who can provide information about changes in long-term weather patterns, extreme events and land-use in the catchment. Sample survey questions are provided at the end of this chapter.

Indicator scoring on the 5-point scale

Table 4 The environment indicator scored on a 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Environment	Topography and land-use in the catchment	Source is downhill of steeply sloping built-up land/bare soil	Source is downhill of steeply sloping managed or cultivated land	Source is downhill of moderately sloping managed or cultivated land	Source is downhill of gently sloping cultivated or managed land	Source is downhill of gently sloping natural land
	Exposure to flooding	Annual river or coastal flooding, with no flood protection measures for infrastructure	Regular (e.g., once every 3-5 years) river or coastal flooding, with partial flood protection measures for infrastructure	Occasional (e.g., once every 10 years) river or coastal flooding, with partial flood protection measures for infrastructure	Rare (e.g., once every 20 or more years) river or coastal flooding, with partial or robust flood protection measures for infrastructure	No river or coastal flooding, with robust flood protection measures for infrastructure
	Population density in the catchment and risk of fecal contamination	Dense population with open defecation and on-site sanitation at high risk of inundation	Dense population with no open defecation and on-site sanitation at high risk of inundation	Dense population with no open defecation and on-site sanitation at medium risk of inundation	Low to medium population density, no open defecation and on-site sanitation at low risk of inundation	Low to medium population density, no open defecation and on-site sanitation at no risk of inundation
	Competition for water source	Other users severely impact water availability throughout the year	Other users severely impact water availability in some seasons only	Other users have moderate impact on water availability throughout the year	Other users have moderate impact on water availability in some seasons	Other users have no impact on water availability

Note: Slope (expressed as %) = elevation change/horizontal distance. Gentle: 0-12% slope; Moderate: 12-30% slope; Steep: > 30% slope

Indicator scoring on the 3-point scale

Table 5 The environment indicator scored on a 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Environment	Topography and land-use in the catchment	Source is downhill of steeply sloping built-up land/bare soil	Source is downhill of moderately sloping managed or cultivated land	Source is downhill of gently sloping natural land
	Exposure to flooding	Annual river or coastal flooding, with no flood protection measures for infrastructure	Occasional (e.g., once every 3-5 years) river or coastal flooding, with partial flood protection measures for infrastructure	Rare (e.g., once every 10 or more years) river or coastal flooding, with partial or robust flood protection measures for infrastructure
	Population density in the catchment and risk of fecal contamination	Dense population with open defecation and on-site sanitation at high risk of inundation	Dense population with no open defecation and on-site sanitation at medium risk of inundation	No open defecation and on-site sanitation at no risk of inundation
	Competition for water source	Other users severely impact water availability	Other users have moderate impact water availability	Other users have no impact on water availability

Google Earth™ based analysis

Step 1 Access Google Earth web at https://earth.google.com/web/ using Google Chrome and sign-inwith a Google account.

Step 2 From the menu on the left-hand side, click on the search button and input the GPS coordinates of your water source. This will create a placemark of the location on the map.

Step 3 Describe the features of the environment around each water source that can act as potential hazards. More details on features of interest, and an example with screenshots ofeach step, are provided below.

Catchment features of interest:

The catchment features of interest will depend on the region, location, and type of technology used.

For systems at high elevations and hilly areas

- List the elevation of the water source and identify whether the water source lies on a steepslope or flat terrain.
- Identify communities, agricultural or pastoral land without terracing, and animal husbandryuphill of a water source.
- Identify whether there is pristine forest uphill of the source.
- Identify the distance between the source and the nearest road.
- Look for bare soil or rock uphill of the source. Water supplies and latrines downhill of such areas can potentially be damaged after a rainfall triggered landslide.
- Look for landslip or landslides scars left by the movement of soil or rock down a slope. These are generally lighter coloured than their surroundings, with a coarse surface.

Drinking water sources at lower elevations are exposed to different risk factors from different climatic conditions and topography compared to those at higher elevations. Infrastructure in low-lying areas near a river or coast is especially vulnerable to flooding and saltwater intrusion. Shallow groundwater sources in densely populated areas with widespread open defecation and pit latrines that flood frequently, are at risk of microbial contamination.

For systems at lower elevations and plains, identify

- densely populated communities with low sanitation coverage or on-site sanitation systems prone to flooding
- farmland or animal grazing/husbandry activities
- distance between the source and the nearest road
- elevation and proximity to a river or the coast

A worked example of identifying catchment risks on Google Earth™ is provided in Annex 1.

Step 4 Score each sub- indicator based on which set of conditions describe the catchment i.e., the wider environment around the water source most closely.

Step 5 After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

Survey-based analysis

The following survey questions can be used to supplement geospatial analysis to identify catchment risks:

Question	Response			Comments
Does the catchment include:		**Yes**	**No**	
	Farmland	1	2	
	Is Terracing used?	1	2	
	Forest	1	2	
	Animal pastures	1	2	
	Roads	1	2	
Are there significant areas of bare rock or earth uphill of the source?	Yes ----------1 No ----------0			
Are landslides or rockfall common around the source?	Yes ----------1 No ----------0			
Is the source at risk of river/coastal flooding?	Yes ----------1 No ----------0			
What is the population density in the catchment?	Low--------- 1 Medium----------2 High----------3			
Is the open defecation practised in the community?	Yes ----------1 No ----------0			
Do people use latrines in the community?	Yes ----------1 No ----------0			0 → end
If yes, what type of latrine is most common?				
If yes, what is the risk of latrine flooding?	Low--------- 1 Medium----------2 High----------3			
If yes, are latrines less than 1.5m from the water table where groundwater is used for drinking?	Yes ----------1 No ----------0			
If yes, are latrines located on higher ground than the water source?	Yes ----------1 No ----------0			

INFRASTRUCTURE

Objective To identify potential risks at the water supply infrastructure and its immediate vicinity and score the infrastructure indicator

Methods The resilience of infrastructure will be assessed through the use of site inspection forms and from a review of data on source yields (in the case of water supplies). Site inspections should be used to determine whether there are protection measures around the water source or latrine to prevent damage to the infrastructure from flooding, falling debris or landslides. If the source or latrine is near a flood-prone stream or downhill of a steep hill that is not covered with vegetation, it may be at risk of damage unless there are flood protection measures around it. These can be in the form of diversion ditches, plinths, platforms to elevate the infrastructure above the flood line, or other barriers such as a wall. Site inspections will also be useful in identifying sources of faecal pollution (in the case of water sources) from nearby latrines or animal or human faeces on theground near the source, and risk of faeces coming in contact with the environment and humans (in the case of latrines).

In the case of water supplies, an analysis of long-term data on source yield (typically measured as litres per minute) can be used to determine its response to changes in seasonal precipitation. Ideally, long-term records should be reviewed to detect seasonal and annual variation in yield. This can indicate whether the water source is likely to be resilient to long dry spells or drought. In the absence of such data, information around seasonal changes in availability of water should be collected from water supply managers.

Step 1 Conduct site inspection to identify risks at the infrastructure and in its immediate vicinity. Site inspections can be done using WHO sanitary inspection packages for water supplies, but these may need to be modified. These forms allow for risk assessment through visual assessment of the water supply scheme or point source, while also giving an idea of missing protection measures. They usually consist of yes or no questions, each assessing a specific risk. A risk can exist either because of inadequate or poorlymaintained infrastructure or because there is a potential source of pollution nearby. The response toeach question is assigned a score of 0 or 1 depending on whether the risk is absent or present. The total risk score can be assigned to a low, medium or high-risk category according to criteria listed in the form.

The teams should add or modify the existing inspection forms to suit the local context and ensure that all relevant points in the water supply are covered during the inspection. The field team should walk around the sources, especially in areas uphill of the source, to assess potential risks.Some risks might not be immediately obvious, and the field team should consult locals such as user management groups/operators in such a case.

Step 2 Collect and review data on source yield from water supply operators,if available. The teams should ask for records of quantitative data on yield to detect any seasonal or annual changes. If this is not available, ask the operators if they have noticed changes tothe amount of water supplied by the source, and if so, by how much. Does the source dry up during a particular time of the year? Has the volume of available water changed since the source was first developed?

Step 3 Score each sub- indicator based on which set of conditions describe the infrastructure the most closely.

Step 4 After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

BOX 3 MEASURING YIELD

For a one-time measurement of yield, collect water in a bucket or container of known volume, and measure the time it takes to fill it. In case of a handpump, record how many strokes it takes to fill the bucket or container.

Daily water availability can be calculated from the yield measurement as follows:

Daily water availability (litres/day) = Yield measured in litres per minute ÷ 3600

BOX 4 EXAMPLE OF SCORING THE INFRASTRUCTURE INDICATOR

The following information was collected on the condition of a borehole (or tube well) with a handpump and the risks in its immediate vicinity:

Sanitary risk score: 7/12 (high), no data on trends in yield. Faulty drainage causing ponding around the handpump, missing or inadequate fencing, handpump loose at the point of attachment with apron, apron cracked and less than 1 m around the handpump, unsanitary well cover, animal excreta or rubbish within 10 m of the source.

The infrastructure indicator was given a score of Low resilience because there are high sanitary risks and no data on yield.

Indicator scoring on the 5-point scale

Table 6 The infrastructure indicator scored on a 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Infrastructure	Sanitary protection	No protective measures and very high sanitary risks along the water supply	Some protective measures in place and high sanitary risks along the water supply	Some protective measures in place and intermediate sanitary risks along the water supply	Most protective measures in place and low sanitary risks along the water supply	Robust protective measures in place and low sanitary risks along the water supply
	Yield	No data available on seasonal or long-term trends in yield	Qualitative evidence shows seasonal or long-term reduction of yield (from users)	Quantitative evidence shows major seasonal or long-term reduction of yield (from operator records)	Quantitative evidence shows minor seasonal or long-term reduction of yield (from operator records)	Quantitative evidence shows no reduction of yield (from operator records)

Indicator scoring on the 3-point scale

Table 7 The infrastructure indicator scored on a 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Infrastructure	Sanitary protection	No protective measures and high sanitary risks along the water supply	Some protective measures and intermediate sanitary risks along the water supply	Robust protective measures and low sanitary risks along the water supply
	Yield	No data on trends in yield, or qualitative evidence of seasonal or long-term variability in yield (from users)	Quantitative evidence shows moderate to low seasonal variability in yield (from operator records)	Quantitative evidence shows no seasonal or long-term variability in yield (from operator records)

SERVICE MANAGEMENT

Objective To conduct key informant interviews with water supply managers and operators to assess their awareness and responsiveness regarding climate change

Methods

Step 1 Develop a set of questions for key informant interviews (KIIs) with service providers of water supplies. These may be members of user committees of community-managed water supplies, or managers and operators of professionalized services. Interviews should capture their understanding of current climate variability and its impact on their systems in terms of changes to water quality and availability, or damage to infrastructure. Additionally, service providers should be asked about their knowledge of climate change scenarios projected for the region; participation in trainings and risk assessments related to climate change, knowledge of sanitary protection measures, water quality testing and water treatment (for water supply), skills related to repair of infrastructure, and the role of women in management.

Below is a topic guide with sample questions for the KIIs. Assessment teams should modify these/develop further questions to suit the local context and use specific terms to get appropriate, context-specific responses. The responder should be encouraged to give as much detail and personal experience as possible. Additional follow-up questions may be needed to gather more detailed information.

Responder: Service providers, user committees, managers or operators

Sample questions

1. Awareness or perception of climate risks and impact on water supply
    a. Which climate-related events (long dry periods, heavy rainfall, coastal storms, flooding etc.) occur in this area?
    b. Are you aware of changing climate patterns in the region?
    c. Are you aware of future climate change scenarios for the region?
    d. How is the water supply impacted by the climate? Are there seasonal changes in water quality and yield?
2. Monitoring and record keeping
    a. Do WASH managers monitor and keep records of rainfall data andtemperature?
    b. Do they monitor and keep records of seasonal water quality and yield?
3. Capacity to resolve problems with water supply
    a. Have you built sanitary protection measures around the water supply (e.g. to prevent flood damage, to

divert contaminated water from coming into contact with water source)?

b. Do you repair the water supply when needed? If so, how long does it typically take to carry out repairs to the water supply (e.g. 1-2 days, one week, longer than a week)? If not, what prevents you from doing these repairs?

c. Do you test water quality or add any treatment chemicals to the water?

d. If there is decreased yield during the dry season, how have you responded to this in the past (e.g. reservoir construction, using alternative improved sources etc.)?

e. Are there limitations on the quantity of water allowed per household? Does thischange for different seasons?

4. Income and record keeping
    a. Where does your income/funding for come from?
    b. Does the management committee keep records of income and expenditure?
5. Trainings
    a. Have you received training in water quality testing, infrastructure maintenance, building protection measures around the source or conducting risk assessments (with or without the focus of climate change)?
6. Awareness of threats from unsafe sanitation (which may be exacerbated with heavier rainfall and more frequent flooding)
    a. Are you aware of the link between unsafe sanitation (open defecation, unlined pit latrines etc.) and water quality?
    b. Does the WASH committee coordinate and work with health workers to promote safe sanitation and hygiene?
7. Inclusivity of management and support from community
    a. How are members chosen to be on the WASH Committee?
    b. Are there female members on the committee? If so, what role do they play?

Step 2 Score each sub- indicator based on which set of conditions describe the level of water supply management most closely.

Step 3 After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

Indicator scoring on the 5-point scale

Table 8 The service management indicator scored on a 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Management	Strength of management	No effective management; no actions taken to solve water supply problems; untrained and unskilled operators	Weak management; severe delays in solving water supply problems; limited knowledge and skills of operators	Moderately effective management; minor delays in solving water supply problems; moderately good knowledge and skills of operators including source protection but no water treatment knowledge	Strong management; no delays in solving water supply problems; adequate knowledge of source protection and basic water treatment *(e.g., roughing filters)*	Very strong management; monitoring systems to prevent disruptions; no delays in repairs; well-trained operators with full set of engineering skills; support to households to cope with temporary disruptions *(e.g., provision of water treatment chemicals, boil notice, alternative water supplies in emergency)*
	Understanding of climate change and adaptive management	No understanding of climate change or potential risks to water supply; no steps taken to reduce risks (e.g., from drought or flooding)	Some understanding of climate change and some awareness of potential risks; no steps taken to reduce risks (e.g., from drought or flooding)	Clear understanding of climate change and awareness of specific risks water supply; no steps taken to reduce risks (e.g., from drought or flooding)	Clear understanding of climate change and specific risks to water supply; some actions taken to reduce risks but not based on risk assessments (e.g., from drought or flooding)	Clear understanding of climate change and specific risks to water supply, steps taken to reduce risks based on risk assessments (e.g., from drought or flooding)
	Gender and social representation	No participation of women or marginalized groups in planning or management	Minimal participation of women and marginalized groups in planning and management; none in leadership roles	Good participation of women and marginalized groups in management but none in leadership roles	Good participation of women and marginalized groups in management and some in leadership roles	Equal participation of women and marginalized groups in management; with active involvement in leadership roles and decision-making

Indicator scoring on the 3-point scale

Table 9 The service management indicator scored on a 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Service management	Strength of management	No effective management and no timely actions taken to solve water supply problems; untrained and unskilled operators	Moderately effective management with some actions taken to solve water supply problems, but with delays; operators have basic skills with some training in sanitary protection and water treatment	Very strong management with preventative measures and timely actions to solve water supply problem; well-trained operators with full set of engineering skills; support to households to cope with temporary disruptions *(e.g., provision of water treatment chemicals, boil notice, alternative water supplies in emergency)*
	Understanding of climate change and adaptive management	No understanding of climate change or its impacts on drinking water supply; no participation in risk assessments	Limited understanding of climate change and its impacts on drinking water supply; limited participation in risk assessments to evaluate and monitor some climate-related risks to water supply	Clear understanding of climate change and its impacts on drinking water supply; active participation in climate risk assessments to evaluate and monitor a comprehensive set of risks to water supply
	Gender and social representation	No participation of women or marginalized groups in planning or management	Minimal participation of women and marginalized groups; none in leadership roles	Women and marginalized groups take equal number of leadership and decision-making roles in both planning and management

INSTITUTIONAL SUPPORT

Objective To conduct key informant interviews and assess the institutional support available to water suppliers by the government to provide effective services and prepare for climate threats

Methods

Step 1 Develop a set of questions for key informant interviews (KIIs) with managers or operators of water supplies, for both community-managed and professionalized services; and government officials (at the local or district level) in charge of overseeing these systems. The KIIs with government officials should collect information on the support and training programmes offered to managers or operators, especially to prepare for climate threats (an example of this support is training in climate resilient water safety plans or climate vulnerability assessments). Support can exist in the form of help in procuring consumables and spare parts, installing resilient infrastructure and carrying out timely repairs after an extreme event as well as in the form of financial support for maintenance and system upgrades.

The existence of this support must be verified through KIIs with water suppliers. Interviews should capture their perception of the support available to them by the government to provide effective services and prepare for the effects of current climate variability and future change. Additionally, the KII should capture any trainings provided to the managers, as well as support given to them by the government in the form of access to spare parts and consumables, and financial or technical help.

Below is a topic guide with sample questions for the KIIs. Interviewers should modify/develop further questions to suit the local context and use specific terms to get appropriate, context-specific responses. The responder should be encouraged to give as much detail and personal experience as possible. Additional follow-up questions may be needed to gather more detailed information.

Responder: User committees, water supply managers and operators

Sample questions

1. Have you received training in risk assessment or management from the local/districtgovernment?
2. Do you feel the WASH committee receives adequate and timely support to carry out minorrepair and maintenance in terms of access to skilled labour and parts?
3. Do you feel the WASH committee received adequate and timely support for repairs neededafter a major climate-related event?
4. Does the local/district government discuss the threats of climate change and variability inthe region to your WASH system?

5. Have you received support from the local/district government to implement measures toaddress climate variability or prepare for climate change?
6. Do you receive financial support (or other) from local/district government?

Responder: Government officials

Sample questions

1. Have officials had any training with respect to climate change? If so, from what sources?
2. Does the local/ district government have a climate change strategy? If so, what does itentail? Are there plans to develop climate adaptive measures?
3. What forms of support does local government get from central/federal government forWASH-related issues (i.e., training, equipment, expertise etc)?
4. Is there a formal risk assessment or management program for officials overseeing WASHcommittees and committee members?
5. What kind of support does the local/district government offer to committees to procureparts and carry out minor repairs or preventive maintenance?
6. What kind of support does the local/district government offer to committees for major repairs?
7. Does the local/district government conduct water quality monitoring?
8. Does the local/district government train WASH committee members in water quality testing,repair and maintenance etc.?
9. Do the local/district government officials in charge of water supplies coordinate with officials in the sanitation, health, agriculture, water resource or other relevant sectors?

Step 2 Score each sub- indicator based on which set of conditions describe the institutional support provided to the water suppliers most closely.

Step 3 After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

Indicator scoring on the 5-point scale

Table 10 The institutional support indicator scored on the 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Institutional support	Risk management program and support for adaptation	No formal risk management program in local government; no technical or financial support to water suppliers to manage climate change risks; no risk management training	No formal risk management program but some technical support is available to manage climate risks; no financial support to manage climate risks; no risk management training	No formal risk management program but technical and limited financial support available to manage climate risks; some risk management training is provided but is not comprehensive	A formal risk management program exists, and water suppliers are provided some training and technical support; limited financial support is available to manage climate risks	A formal risk management program exists, and water suppliers are provided comprehensive training and technical support; financial support is available based on national cost estimates of adaptation
	Support after emergency	Substantial delays *(e.g., several weeks or more)* in providing support to water suppliers after emergencies; no plans for emergency water supply	Substantial delays *(e.g., several weeks or more)* in providing support to water suppliers after emergencies; informal plans for emergency water supply with unregulated service providers	Some delay *(e.g., up to 1 week)* in providing support to water suppliers after emergencies; informal plans for emergency water supply with unregulated service providers	Some delay in providing support to water suppliers after emergencies; formal plans for emergency water supply with regulated and licensed service providers	No delays in providing support to water suppliers after emergencies; formal plans for emergency water supply with regulated and licensed service providers

	Inter-sectoral coordination	No coordination between sectors on climate change	Informal coordination between water supply and some other sectors on climate change	Formal coordination between water supply sector and some other sectors affected by climate change is being set up	Formal coordination between sectors affected by climate change is established but coordination is irregular	Formal coordination between water supply sector and all other sectors affected by climate change is well-established and effective

Indicator scoring on the 3-point scale

Table 11 The institutional support indicator scored on the 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Institutional support	Risk management program and support for adaptation	No formal risk management program in local government; no technical or financial support for water suppliers to manage climate risks; no risk management training	No formal risk management program but technical and limited financial support available to manage climate risks; some risk management training is provided but is not comprehensive	A formal risk management program exists in local government and water suppliers are provided technical support and comprehensive risk management trainings that include climate risk assessments; financial support is available based on national cost estimates of adaptation
	Support after emergency	Substantial delay *(e.g., several weeks or more)* in providing support to water suppliers after emergencies; no formal plans for emergency water supply	Some delay *(e.g., up to 1 week)* in providing support to water suppliers; informal plans for emergency water supply with unregulated service providers	No delay in providing support to water suppliers after emergencies; formal plans for emergency water supply with regulated and licensed service providers
	Inter-sectoral coordination	No coordination between sectors on climate change	Formal coordination between water supply sector and some other sectors affected by climate change is being set up	Formal coordination between water supply sector and all other sectors affected by climate change is well-established and effective

SUPPLY CHAINS

Objective To conduct key informant interviews with managers or operators of water supplies to assess the robustness of the WASH supply chain and the critical infrastructure that supports it.

Methods

Step 1 Develop a set of questions for key informant interviews with managers or operators of water supplies to assess the robustness of the WASH supply chain and the critical infrastructure that supports it. The interviews should capture the experience of managers with procuring spare parts and consumables required to maintain the water supply service, and whether they experience delays in procuring parts during a particular season or after a climate-relatedevent. The interview should also capture whether any critical infrastructure (related to transport or communication networks) is damaged or disrupted during or after a climate-related event that disrupts the supply chain (e.g., if a major road is flooded or damaged after heavy rainfall, preventing access to a market to purchase parts needed for repair).

Below is a topic guide with sample questions for the KIIs. The interviewers should modify/develop further questions to suit the local context and use specific terms to get appropriate, context-specific responses. The responder should be encouraged to give as much detail and personal experience as possible. Additional follow-up questions may be needed to gather more detailed information.

Responder: User committees, managers or operators

Sample questions

1. Where do you buy spare parts, pumps, or consumables to maintain the water supply?
2. Do you have access to multiple markets or just one?
3. How do you travel to these locations (e.g., by car, by foot or other means of transport)?
4. Are there roads or bridges that are frequently damaged or flooded?
5. How long does it usually take to buy parts and carry out repairs?
6. Does this time change after a climate-related event?
7. Can you still access these locations after a heavy rainfall or a landslide in your area?
8. Do you store any surplus parts needed for minor repairs or maintenance?
9. Have you experienced a delay in buying parts or consumables because a road or bridge wasflooded or damaged or because communication networks were disrupted?
10. If yes, how long did it take for these to be repaired?
11. What do you do if you can't repair the problem (e.g., use alternative

improved sources, use unimproved sources, buy water from private vendors etc.)?

Step 2: Score each sub- indicator based on which set of conditions describe the supply chain for the water supply most closely.

Step 3: After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

Indicator scoring on the 5-point scale

Table 12 The supply chain indicator scored on the 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Supply chains	Access to spare parts and consumables	No markets for consumables and parts near the community, only one route exists between community and the market	One market for consumables and parts near the community, but not all parts are readily available; one route exists between community and the market	One markets for consumables and parts near the community, but not all parts are readily available; multiple routes exist between community and the market	Multiple markets for consumables and parts near the community but not all parts are readily available, multiple routes exist between community and the market	Multiple markets for consumables and parts near the community, parts are readily available; multiple routes exist between community and the market
	Robustness of supporting infrastructure	High risk of damage to roads, bridges and mobile communication networks around the community	Medium risk of damage to roads, bridges and mobile communication networks around the community	Medium risk of damage to some of the roads, bridges and mobile communication networks around the community	Low risk of damage to some of the roads, bridges and mobile communication networks around the community	No risk of damage to any of the roads, bridges and mobile communication networks around the community
	Availability of spare parts locally	No surplus parts stored locally by water supplier	Some parts needed for minor repairs are stored locally by water supplier	Most parts needed for minor repairs are stored locally by water supplier	Some parts needed for minor and major repairs are stored locally by water supplier	Most or all parts for both minor and major repairs are stored locally by water supplier

Indicator scoring on the 3-point scale

Table 13 The supply chain indicator scored on the 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Supply chains	Access to spare parts and consumables	One market for consumables and spare parts, but not easily accessible from community; one route for travel between market and community	One market for consumables and spare parts near the community and most spare parts readily available; with multiple routes between communities and market	Multiple markets for consumables and spare parts, parts are readily available; multiple routes between communities and markets
	Robustness of supporting infrastructure	Roads, bridges, and communication infrastructure at high risk of damage from climate-related events	Roads, bridges, and communication infrastructure at medium risk of damage from climate-related events	Roads, bridges, and communication infrastructure at low risk of damage from climate-related events
	Availability of spare parts locally	No spare parts are stored by water suppliers locally	Some spare parts are stored by water suppliers locally, but not for major repairs	Most spare parts are stored by water suppliers locally, for minor and major repairs

COMMUNITY GOVERNANCE AND ENGAGEMENT

Objective To conduct key informant interviews to assess the strength of community governance and engagement around issues related to the water supply.

Methods

Step 1 Develop a set of questions for key informant interviews (KIIs) with service providers, managers or operators of water supplies, and community residents (users). The KIIs with service providers should capture the extent to which they engage with users in the community to raise awareness around climate change, assess their needs (especially those of marginalized or underrepresented groups), and communicate information on changing exposure and availability of water supply services.

For community-managed systems, assessment teams should look for evidence of cooperation and conflict over the use, maintenance, and control of water resources. Look for evidence where groups have worked to put aside individual interests and have cooperated for mutual benefit, e.g., by sharing water during the dry season or helping neighbours build or repair their latrines. For professionalized services e.g., utilities, look for evidence of mechanisms where users can register complaints about their water supply and report disruptions.

KIIs with community residents, especially representatives of prominent local groups, can be helpful in identifying the perception of the residents regarding the water supply. It is especially important to capture the experience of women and marginalized groups in the community.

Below is a topic guide with sample questions for the KIIs. The interviewers should modify/develop further questions to suit the local context and use specific terms to get appropriate, context-specific responses. The responder should be encouraged to give as much detail and personal experience as possible. Additional follow-up questions may be needed to gather more detailed information.

Responder: User committees, managers or operators

Sample questions

1. How are members chosen to be on management committees?
2. How do community members engage with the management committee? e.g., are there community meetings to make decisions around the water supply? Do users contribute financially?
3. Are there rules around sharing water, especially during the dry season?
4. How does the management committee handle conflict over water supplies?
5. Are there community awareness programs on cleanliness around the water supply?

Responder: Women's groups' representatives

Sample questions

1. Do women play an active role in making decisions around shared water supplies in your community?
2. Does your group coordinate with managers or operators while making decisions on services such as location of new water sources, tariff, and other water access rules?
3. Are you satisfied with the performance of the water supply managers in the community? Are they sympathetic to the water-related needs of women in the community?
4. In your experience, is there conflict over the use of the water source especially during the dry season? If so, what is done to resolve this issue and by whom?
5. What would the Women's Group like to change about the management of the water supply in the community?

Responder: Community elders, leaders or members of prominent local groups

Sample questions

1. Do the community play an active role in making decisions around water supply in your community?
2. Does your group coordinate with managers or operators while making decisions on water supply services such as construction of new water points, water sharing rules, etc.?
3. In your experience, is there conflict over the use of the water source especially during the dry season? If so, what is done to resolve this issue and by whom?
4. Are managers sympathetic to the water- related needs of residents in the community, including marginalized groups?
5. What would you or your group like to change about the water supply services in the community?

Step 2 Score each sub- indicator based on which set of conditions describe the level of community governance and engagement around the water supply most closely.

Step 3 After scoring each sub-indicator, assign an indicator score corresponding to the resilience level of the majority of the sub-indicators.

Indicator scoring on the 5-point scale

Table 14 The community indicator scored on the 5-point scale

Indicator	Sub-indicators	Resilience scale				
		Very Low = 1	Low = 2	Medium = 3	High = 4	Very high = 5
Community governance & engagement	Civic engagement and participatory behaviour (for community-managed supplies)	Frequent conflict over the water source, leading to damage or disruptions of the water supply; no rationing or water sharing during scarcity	Occasional conflict over the water source, with minor damage or disruptions of the water supply; no rationing or water sharing during scarcity	Occasional conflict over the water source but no damage or disruptions; users share or ration water sharing during scarcity *(e.g., buying or collecting water from private well owners)*	No conflict over the water source; users share or ration water sharing during scarcity	No conflict over the water source; management committees have formal mechanisms for water rationing and users share water during scarcity
	Inclusivity (for community-managed supplies)	Management committees do not involve the wider community in decision-making	Management committees occasionally involve some prominent community members in decision-making, but not women or marginalized groups	Management committees regularly involve prominent community members in decision-making, but not women or marginalized groups	Management committees regularly involve most community members in decision-making including women and some marginalized groups	Management committees regularly involve all community members including women and marginalized groups in decision-making *(e.g., development of new water sources, setting tariffs and rationing water)*

	Reporting mechanisms and engagement (for utility-managed supplies)	No mechanisms for users to register complaints, report service disruptions or engage with water suppliers on climate risks	Some mechanisms for users to register complaints, report service disruptions exist with slow response times; no engagement with water suppliers on climate change	Some mechanisms for users to register complaints, report service disruptions with slow response times; some engagement with water suppliers on potential climate risks	Clear mechanisms for users to register complaints, report service disruptions with moderate response times; some engagement with water suppliers on potential climate risks	Clear mechanisms for users to register complaints, report service disruptions, with timely response by the water supplier; water suppliers inform users about projected climate risks and long-term behaviour change *(e.g., conservation measures, use of water-efficient appliances)*

Indicator scoring on the 3-point scale

Table 15 The community indicator scored on the 3-point scale

Indicator	Sub-indicators	Resilience scale		
		Low = 1	Medium = 2	High = 3
Community governance & engagement	Civic engagement and participatory behaviour (for community-managed supplies)	Frequent conflict over the water source, leading to damage or disruptions of the water supply; no rationing or water sharing during scarcity	Occasional conflict over the water source but no damage or disruptions to the water supply; users share or ration water sharing during scarcity	No conflict over the water source; management committees have formal mechanisms for water rationing and users share water during scarcity
	Inclusivity (for community-managed supplies)	Management committees do not involve the wider community in decision-making	Management committees regularly involve some prominent community members in decision-making but not women or marginalized groups	Active involvement of users including women and marginalized groups in decision-making including development of new water sources, setting tariffs and rationing water
	Reporting mechanisms and engagement (for utility-managed supplies)	No mechanisms for users to register complaints, report service disruptions or engage with water suppliers on climate risks	Some mechanisms for users to register complaints, report service disruptions, but slow response times; some engagement with water suppliers on potential climate risks	Clear mechanisms to register complaints, report service disruptions and engage with water suppliers on climate-related issues, with timely response by the water supplier; water suppliers inform users about projected climate risks and long-term behaviour change *(e.g., conservation measures, use of water-efficient appliances)*

SYSTEM RESILIENCE AND ACTIONS TO IMPROVE RESILIENCE

Assigning system resilience scores

A key element of the *How tough is WASH* framework is that it allows water supplies to be assigned a system-level resilience score, based on the scores of the six indicators. This system score is calculated simply by adding the scores of each indicator and using the resilience categories shown in Tables 16 and 17.

For systems with very low or low resilience, actions to improve resilience will likely be required across all indicators. For systems with higher resilience, focus will most likely be on maintenance or addressing specific failures in a few domains.

A worked example on scoring each indicator and calculating a system resilience score for a gravity-fed scheme managed through a community-management model is provided in Table 18.

The rationale for each score is provided to illustrate what information was collected for each sub-indicator and how an indicator score was developed. We also illustrate how an overall score was assigned to this water supply.

Table 16 System resilience based on indicator scores for the five-point scale

System score	Resilience	Priority	Qualifier	Action
25-30	Very high	Low	If score reduce because of failure on one indicator action required	Maintain performance
19-24	High	Low	Action focused on specific indicator failures	Limited improvements
13-18	Medium	Medium	Likely to be across multiple indicators	Substantial improvements
7-12	Low	High	Action required across all indicators	Large-scale improvements
6	Very low	Very high	Action required across all indicators	Systemic improvements

Table 17 Calculating system resilience based on indicator scores for the three-point scale

System score	Resilience	Priority	Qualifier	Action
13-18	High	Low	Action focused on specific indicator failures	Limited improvements
7-12	Medium	Medium	Likely to be across multiple indicators	Substantial improvements
6	Low	High	Action required across all indicators	Large-scale improvements

Table 18 An example of assigning resilience score to a gravity-fed community-managed water supply system using the five-point scale

Indicator score (based on sub-indicator score)	Sub-indicator	Sub-indicator score (from 1 to 5)	Rationale for the score
Environment: 4	Topography and land-use in the catchment	4	The source is located in agricultural land with no terracing or other conservation measures in the catchment. The maximum gradient of the slope in the catchment is 10 degrees (gentle slope)
	Exposure to flooding	3	Low to medium risk of flooding
	Population density in the catchment and risk of faecal contamination	4	There are clusters of houses uphill of the collection point between 120 and 2800 meters away. Low population density around the source. Latrines are located downhill of the source and are more than 1.5 m above the water table
	Competition for water source	4	Low competition for water source from agricultural activities
Infrastructure: 1	Sanitary protection	2	Median sanitary risk score: 3/11 (intermediate), worst sanitary risk score: 6/11 (high) [based on 4 rounds of seasonal sanitary inspections]
	Yield	1	No data on trends in yield
Service management: 2	Strength of management	2	Delays in repairing handpumps; some training on repairs and water treatment but no training in risk assessment or management
	Understanding of climate change and adaptive management	2	No perception of changing climate patterns in the region or awareness of future climate change scenarios; awareness of link between rainfall and threats to water quality

	Gender and social representation	2	Positive perception of the WASH committee among the village elders and representatives of the women's groups. However, the only female member of the management committee (in charge of finances) recently resigned and was replaced by a male member
Community governance and engagement: 3	Social cohesion	4	Some water sharing mechanisms and allocation rules are in place; no conflict over the water source reported by community
	Inclusivity	3	Less participation of women than men in WASH committees and community decision-making, men are in leadership roles within the community and in WASH-related issues; male members of the community choose people for leadership roles
Institutional support: 2	Risk management program and support	3	The district provides support to the management committee for buying materials for repairs; The district office has discussed the threats from climate change with the committee. They gave recommendations on conserving water during the dry season and how to develop alternative sources, but the committee has received no technical or financial support on how to address climate variability or prepare for climate change; The district has not provided any training in risks assessment or management to the management committee. There is limited supply of water treatment chemicals
	Support after emergency	1	No expert support received from the district during water scarcity
	Inter-sectoral coordination	2	Informal coordination between sectors on conservation and catchment protection

Supply chains: 3	Access to spare parts and consumables	3	Spare parts and consumables are available in the nearest town; committee members travel by car to go to the markets; one travel route available. Minor repairs are done in one day, but during the rainy season it can take up to one week
	Robustness of supporting infrastructure	3	A road connecting the community to the nearest town was damaged after heavy rains some years ago, but now a bridge has been built making it easier to access markets
	Availability of spare parts locally	3	Management committee stores some parts locally
Overall system score: 15/30 **Resilience: Medium** **Action required: Substantial improvements required across multiple aspects of service delivery**			

Using system resilience scores

By amalgamating the indicator scores into a single score, systems can be ranked in terms of their overall resilience. This can be used to identify systems that are at greatest need of support and to prioritise efforts to improve resilience. An example of ranking water supplies belonging to a district in east Ethiopia is provided in Table 19. The systems that are in the lowest blocks of total resilience should be prioritised for investments, while those showing high or very high resilience would not be a priority but would still require monitoring and routine support.

System scores also permit comparisons between different types of systems (determined by technology type, management model or environmental setting) to see if there are systemic weaknesses. For instance, the comparison may show that dug wells are less resilient than piped water supplies; or systems with formal water user committees are more resilient than those with more *ad hoc* management.

Table 19 Ranking water supplies in increasing order of resilience

Domain / Supply type	Environment	Infrastructure	Service management	Institutional support	Community governance and engagement	Supply chains	System resilience score
Borehole with handpump	4	1	1	1	1	2	**10**
Protected dug well	3	3	1	1	1	4	**13**
Protected dug well	2	2	2	2	3	3	**14**
Borehole with handpump	4	2	3	2	3	2	**16**
Gravity-fed scheme	4	2	2	2	3	3	**16**
Borehole with handpump	4	3	3	2	4	3	**19**
Median scores	**4**	**2**	**2**	**2**	**3**	**3**	

Decreasing order of priority for action

Resilience scores of multiple systems within a district or region can also be analysed to identify weaknesses in particular indicators. Median scores for the systems shown in Table 19 have been plotted for a visual representation of these trends. As Figure 2 shows, the infrastructure, service management and institutional support indicators are the weakest across the region, suggesting the need for concerted effort to tackle these systemic failures.

In this way, the framework builds on previous work that has looked at water safety risks and integrated multiple measures (in that case sanitary risks and water quality) into an easily understandable system for prioritisation. Such approaches have been useful at national levels to understand where and how to invest to improve access to safe water supply.

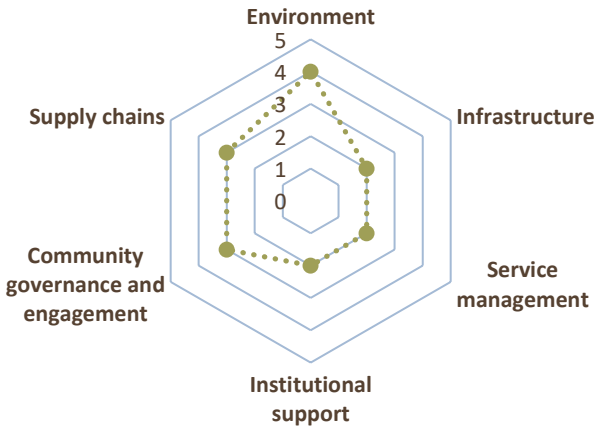

Figure 2 Trends in resilience scores across multiple water supply systems

ANNEX 1. EXAMPLE OF GEOSPATIAL ANALYSIS OF A WATER SOURCE USING GOOGLE EARTH™

1. Open Google Earth™ using Google Chrome browser (https://earth.google.com/web/).You may be required to sign into Google Earth Web using a Gmail account.
2. Click on the search button in the left-hand side menu and input the GPS coordinates of the point of interest. This will add coordinates of the water point/sanitation system as a placemark which can be renamed or edited as required, which looks like the blue placemark in Figure A1. The source of the satellite or aerial image is given on the bottom bar. In this case, it is by Maxar technologies, a US-based space technology company.

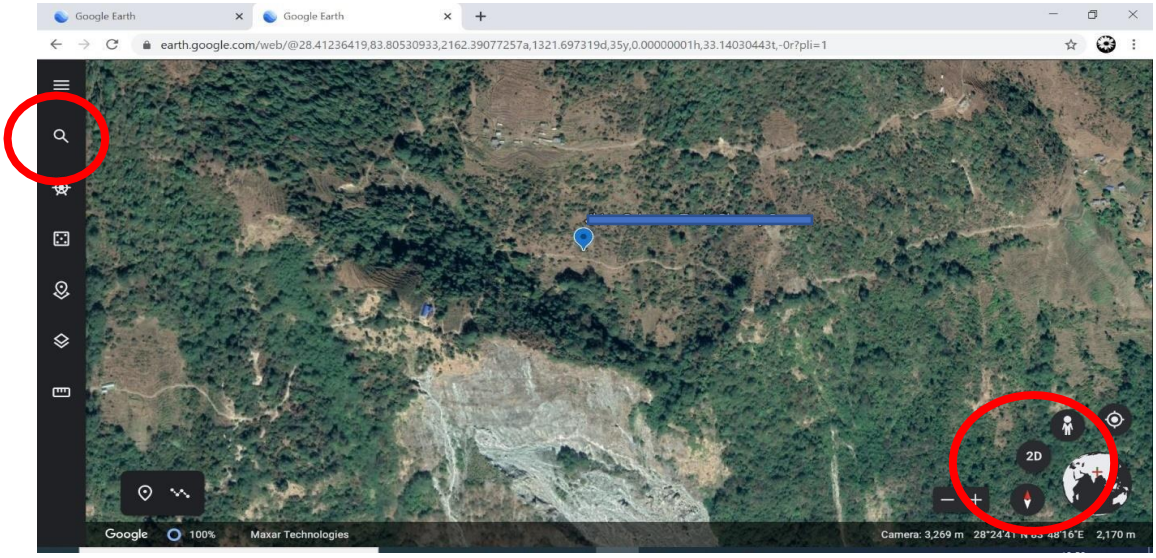

Figure A1 Tools within Google Earth™

3. On the bottom right corner, you can switch between 2D and 3D images. 3D imagescan help to better identify what is located uphill of the source, this can be hard to tell from the 2D top view. You can zoom in and out using the plus and minus signs,respectively. 3D view looks like Figure A2.

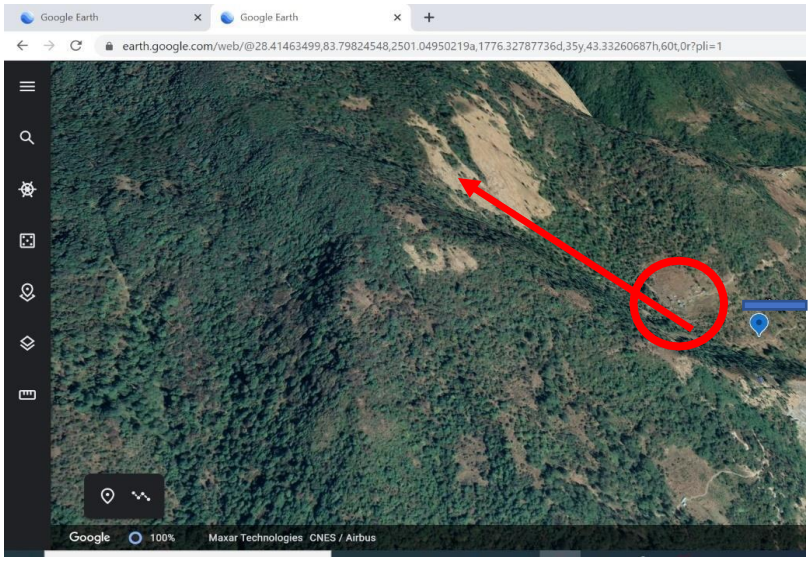

Figure A2 3-D view of the aerial image

4. When you switch to 3D view, the image starts to rotate to give a 360° view. You canstop this rotation at any time by clicking anywhere on the screen. 3D view can help to better locate features on slopes. In this case, the 3D view shows us that there aresome huts and landslip marks uphill of the source. You can zoom in to see the huts inside the red circle in Figure A2.
5. You can measure distances between points and their altitudes in Google Earth. As you move your mouse around the image, the altitude above sea level is displayed at the bottom right corner, as shown in Figure A3. To measure distances between points, click on the symbol that looks like a scale measure or ruler (Figure A4).
6. A white box will appear on the top right. Now you can click on your starting point and end point, to measure the distance between them (Figure A5). Figure 5 is a zoomed-in version of Figure A4, and you can see the huts and some farmland uphill of the source more clearly. The yellow line is a straight line between the huts and the source, and the measured distance between them is 205.62 m. This can be done for any two points on the map.

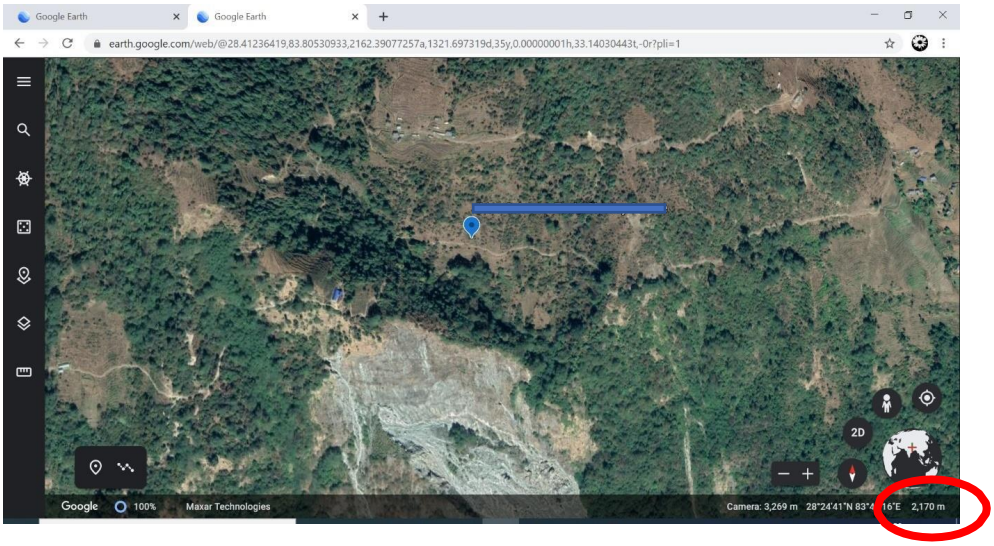

Figure A3 Altitude displayed on the bottom right corner of the screen

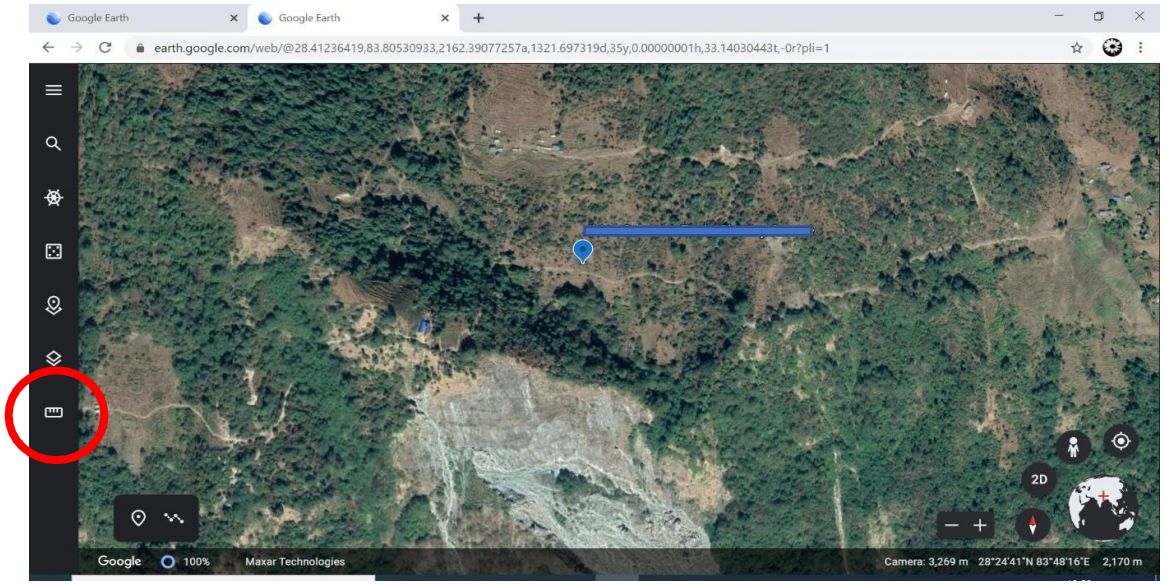

Figure A4 Scale measure on the left of the screen

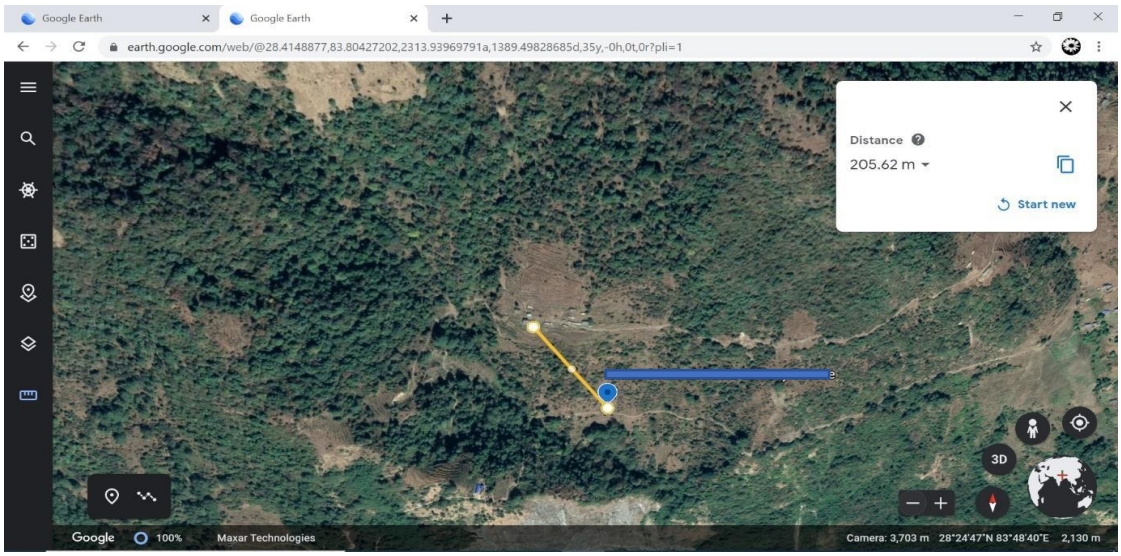

Figure A5 Zoomed-in version of Figure A4

Front cover: Abandoned public tap near Watar, Ethiopia. Photo credit: Anisha Nijhawan

Back cover: Water supply reservoir along the Annapurna Trekking Route, Nepal. Photo credit: Moti Poudel

University of BRISTOL