The WASH Basins Toolkit

Thank you for downloading the WASH Basins Toolkit! You are now part of a collaborative approach for bringing better water resources management to those who need it the most.

WASH BASINS

FOREWORD

Water is essential for life, and is the basis of livelihoods around the world. Using water safely and sustainably goes hand-in-hand with climate resilience, education, the empowerment of women, economic security and health. Addressing these and other inequalities are just some of the ways more and more communities are transforming their livelihoods, and this is underpinned by harnessing and managing safe water sources.

FRANK Water has helped communities to access safe water and sanitation in India and Nepal since 2005, benefitting nearly 400,000 people. Arup, a global engineering and environmental consultancy and thought-leader in the world of water management through a 'Design with Water' approach, has touched the lives of millions through its work. We have developed a unique partnership, bringing together our skills and expertise to tackle a complex issue head-on: how can the world's most marginalised communities manage their water resources sustainably, effectively and equitably?

To achieve this, we have worked with some of India's most innovative non-governmental organisations to bring the concept of 'integrated water resources management' into community water development and management, reaching those who most need it. The key to achieving this is through two main principles: entrusting power, and collaboration. The first principle entails giving communities the confidence and know-how to understand and take ownership of their water resources. The second enables people and organisations at different levels to access information and make better decisions about how water is managed collaboratively. Both our WASH Basins Toolkit and WASH Connect mobile application allow users to do this in a practical and meaningful way.

Bringing safe water and sanitation to all in the face of climate change, urbanisation and water scarcity is one of the challenges of the decade. However, by working together, and with the help of valued partners we are making real steps towards doing so.

The United Nations 2030 Sustainable Development Goals make it clear: safe water and sanitation is for all! It is, admittedly, an ambitious commitment, and none of us can achieve it on our own: we all need to do our bit. So please use, test and stretch the limits of the tools we have developed, and which are provided open source and free for all. Let us know how the tools could be changed and improved to better support your work and the work of others. We are at the beginning of a journey and, with your help, we hope to make WASH Basins more and more relevant for marginalised communities all around the world.

This has been supported by funding from the Arup Community Engagement Global Challenge and demonstrates how, together, we can all try to Shape a Better World!

Figure 1 : Girls carrying water in a Sarodadhar village, Chhattisgarh

Cover page: Woman drinking water from a pumped well

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ARUP

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FRANKWATER safe water saves lives

THE 'WASH BASINS' PROJECT

WASH Basins is a collaborative project between Arup, FRANK Water and two India-based WASH NGOs: People's Science Institute (PSI) and Samerth Charitable Trust (Samerth).

Together, the organisations have developed an India-specific practical approach to utilising Integrated Water Resources Management (IWRM) principles to support sustainable and inclusive water, sanitation and hygiene (WASH) services.

The need for a new approach

Arup, FRANK Water, and our partners identified a theoretical and practical disconnect amongst governmental and non-governmental organisations with regards to the application of IWRM and the provision of WASH services. IWRM frameworks are often seen to be at odds with, or disconnected from, the pressing need for expanded access to safe water, sanitation and hygiene amongst the world's most vulnerable communities. We also experienced a general lack of awareness of the significance of IWRM in relation to sustainable, long-term water and sanitation service provision. By working together, we have contributed towards bridging this gap at multiple levels of governance.

INTENDED KEY PROJECT OUTCOME

The sustainable development and management of water, land, and related resources using IWRM to maximise the availability of WASH in marginalised communities in India.

Figure 2 : Well in project village

ABOUT THE TOOLKIT

PURPOSE OF THE TOOLKIT

This toolkit empowers communities and local governments to understand and manage water resources in a way that addresses the water needs of their areas, whilst responding to the needs of the national and international context. Examples of national needs may include commitment to meeting UN Sustainable Development Goal 6 (SDG 6) in regard to water and sanitation provision, mitigating pressures on river basins and aquifers, as well as responding to climate change. The desired outcome is to optimise the availability of water for domestic and agricultural purposes, and maximise sanitation and hygiene in marginalised communities by actively improving the understanding and monitoring of the resource and its use. In turn, this will improve the livelihoods of the community, particularly for women and girls.

WHO IS THE TOOLKIT FOR?

The WASH Basins Toolkit can be utilised and applied, in whole or part, across a variety of contexts. Fundamentally, the toolkit has been designed to fit into the common activities typically carried out by water, sanitation and health (WASH) service delivery organisations, enhancing these with processes that support integrated water resources management (IWRM). We recognise that in many contexts, WASH delivery organisations exist where many other water-related management functions do not. The toolkit is also designed to guide practitioners in WASH delivery organisations, as well as government and local leaders. While the focus is on providing practical steps, tools and processes, it also provides sufficient background information to educate and inform users that may be new to IWRM and its intersection with WASH.

We envisage the toolkit being most beneficial for the following profiles of users within WASH delivery and local governance contexts :

- Users seeking a manual providing basic understanding and background on IWRM and how it relates to delivery of water and sanitation services;
- Users seeking to implement a structured process for deploying integrated water management planning processes and IWRM-supporting interventions in their working areas;
- Users seeking access to forms and templates relating to data collection, simple analysis and supporting IWRM interventions in WASH; and
- Users seeking to train staff, implement changes in their organisations and share information amongst the WASH community.

This is achieved by focusing on:

- Communities and all their water-related needs, including livelihoods;
- Local non-governmental organisations (NGOs) and how they communicate with, identify and respond to community water and sanitation needs;
- Local governance institutions, their structures, needs and ways of working, as well as how these can be harnessed to deliver for local communities;
- Digital technology approaches that support the collection, processing and understanding of water resources, water needs and water utilisation; and
- Supporting bottom-up and top-down approaches to sharing water data.

It is intended for the toolkit to enable a structured approach to data collection, analysis and sharing on key indicators of water availability and use. Regular monitoring information on the water resource will be gathered to support decision-making on how water is allocated and used. Used correctly, the toolkit will enable communities, WASH delivery organisations and governments to obtain information on SDG 6, and its underlying targets and indicators; particularly Target 6.1 on universal and equitable access to safe and affordable drinking water and Target 6.5 on implementing IWRM at all levels.

WASH BASINS

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HOW THE TOOLKIT WAS DEVELOPED

Arup and FRANK Water developed this toolkit, with a primary focus at the community level, to address the practical implementation of activities that support IWRM. The toolkit has been developed within and for India, but has been structured to apply in a wide range of developing world contexts, regardless of the institutional and organisational setup.

The toolkit is one of the outcomes of the joint Arup and FRANK Water 'WASH Basins' project which ran from 2018 to 2020, supported by funding from Arup through the Global Challenge Initiative 2017 - 2022. Despite the short duration, the project has achieved a limited, indirect influence on the barriers to IWRM applications in India, including government capacity, top-down incentives for service delivery and data sharing and management programmes.

However, the project directly supported two Indian NGOs - People's Science Institute (PSI) working in Madhya Pradesh State and Samerth Charitable Trust working in Chhattisgarh State - in developing, incorporating and applying technical competence in IWRM practices in their work. The direct output of the support is the set of transferable guiding principles and tools presented in this toolkit, for harnessing and embedding IWRM principles to promote sustainable water and sanitation services for vulnerable communities.

WATERAID AND WRM

"...different approaches and options are being promoted including [the] CWRM [Community Water Resource Management] approach as one of them. A better understanding of [a] WRM [Water Resources Management] approach is necessary. WaterAid will therefore place an increased emphasis on the concept, tools and techniques of WRM while designing water, sanitation and hygiene projects to ensure that the minimum requirements of WaterAid's Global Strategy are achieved."

These are:

- That all project proposals include an assessment of the sustainability of the water sources and either a description of the actions to be taken to safeguard or enhance that sustainability or reasons why no actions are required;
- That water quality policies are enacted in country programme and that all sanitation project proposals include an assessment of the risk of pollution of drinking water sources and actions to prevent the same, if necessary; and
- WaterAid and its partners will maintain relevant data on water quality and hydrogeology of the water resources that they have utilised and access to available to others.

WaterAid in Nepal, 2011a

Figure 3 : The WASH Basins team conducting site visits in project villages

FRANKWATER safe water saves lives

ARUP

WHY THE TOOLKIT WAS DEVELOPED

The toolkit was developed to address the need to truly embed IWRM and its principles in the routine delivery of WASH services globally at the community level. The toolkit builds on the specific experience of collaborating with WASH delivery organisations working in a relatively complex water resource management context in India.

Until the middle of 2019, there were at least five ministries responsible for aspects of water use or management, and five levels of operation from the national (centre) to the Gram Panchayat (a collection of several villages) level.

The toolkit recognises the community level and immediate watersheds as the essential building blocks that feed information on water resource use and monitoring upwards to the State, or national level, and catchment level respectively.

The SDG 6 'Ensure availability and sustainable management of water and sanitation for all' includes a target on implementation of IWRM at all levels by 2030:

> *"By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate"*
>
> UN SDG 6, Target 6.5[1]

However, IWRM is typically viewed as being applied at major basin or central administrative levels. But the Global Water Partnership (GWP) notes that "water-related decisions made at local and basin levels... do not conflict with the achievement of broader national objectives"[2] . The concept of a 'lighter-touch' approach to IWRM, more closely linked to the local service delivery level, is not new and has been explored in the past[3]. Some organisations engaged in WASH delivery have identified this need and developed their own internal guidance for embedding IWRM into their own services - WaterAid for instance[4]. At a national level as well, umbrella organisations representing the WASH sector - such as the Kenya Water and Sanitation Network (KEWASNET) - are also taking up the challenge.

The Institution of Civil Engineers (ICE) in the UK, jointly with Oxfam and WaterAid have also addressed the issue, stating: "the potential for monitoring and managing water resources at local or community level should be better acknowledged", and "monitoring and management of water resources at community level can contribute to greater water security"[5]. At the other end of the scale, IRC has developed a 'WASH Toolkit'. However, it has a much broader remit across the overall WASH sector, including service delivery ('establishing and strengthening key components of service delivery from financing to asset management') and delivering change ('knowledge, strategies and tools supporting changes needed in the sector to provide sustainable water and sanitation services).

KEWASNET VIEW ON LINKAGES BETWEEN WASH AND WRM

"WASH has a direct and indirect link to WRM. All entities are linked in terms of water quality and protection of water sources, so as to put to good use available water. With regard to water catchments, WASH is concerned with sanitation clean-up activities, water catchment protection and water quality management; while the WRM focuses on the formation of water management committees that become WRUAs [Water Resource User Associations] and contribute towards water catchment protection and management, reducing catchment degradation and ensuring quality water."

KEWASNET, 2017

1 www.un.org/sustainabledevelopment/water-and-sanitation/

2 www.gwp.org/en/About/why/the-need-for-an-integrated-approach/
3 Butterworth et al., 2010; Moriarty et al., 2010
4 WaterAid in Nepal, 2011b
5 The Institution of Civil Engineers, Oxfam GB and WaterAid, 2011

INTEGRATING IWRM INTO WASH DELIVERY

Users with a satisfactory knowledge of WASH, IWRM and approaches to integrating the two are advised to proceed to the Six-Stage Process.

WHAT IS WASH?

'WASH' is the collective term for water, sanitation and hygiene. Due to their interdependent nature, these three core human livelihood issues are often grouped together in funding and service delivery. While each is a separate field of work, each is dependent on the presence of the other. For example, without toilets, water sources become contaminated; without safe water, basic hygiene practices are not possible[1].

The benefits of having access to an improved drinking water source can only be fully realised when there is also access to improved sanitation and adherence to good hygiene practices. Beyond the immediate, obvious advantages of people being hydrated and healthier, access to water, sanitation and hygiene has profound wider socio-economic impacts, particularly for women and girls.

The fact that WASH is the subject of dedicated targets within Sustainable Development Goal (SDG 6) is testament to its fundamental role in public health and therefore in the future of sustainable development. Indeed, access to safe water and sanitation are human rights, as recognised in 2010 by the United Nations General Assembly.

1 www.unicef.org/wash/3942_3952.html

For universal fulfilment of these rights to become reality, the right systems are needed: well-resourced, capable institutions delivering services and changing behaviour in resilient and appropriate ways[2].

WHAT IS IWRM?

At its heart, IWRM aims for sustainable and holistic management of naturally occurring water resources, underpinning equitable access, to and sharing of, water for human and economic needs.

The Global Water Partnership (GWP) defines IWRM as:

"...a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"[3]

The GWP provides knowledge and builds capacity to improve water management at all levels, and is recognised globally as a leader in the theoretical and practical application of IWRM principles. The GWP defines 'three pillars' of IWRM:

- The creation of an **'Enabling Environment'** through policies, legislation and investment structures;
- The utilisation of **'Management Instruments'** such as economic incentives for controlling demand and supply, measures for encouraging efficiency, and decision-making processes backed up by data; and
- **'Institutional Arrangements'** such as regulatory bodies and responsible parties at different levels, capacity building programmes and water supply and sanitation utility providers.

2 www.unwater.org/water-facts/water-sanitation-and-hygiene/
3 www.gwp.org/en/GWP-CEE/about/why/what-is-iwrm/

KEY MESSAGES FROM UN WATER'S 'SDG 6 SYNTHESIS REPORT 2018 ON WATER AND SANITATION'

- Implementing IWRM is the most comprehensive step towards achieving SDG 6
- Integration across the water and water-using sectors is essential for ensuring that water resources are shared effectively among many competing demands, particularly in transboundary contexts
- There is a need for more and better data for effective management: the percentage of countries reporting on Indicator 6.5.1 (Degree of implementation of IWRM) and Indicator 6.5.2 (Proportion of transboundary basin area with an operational arrangement for water cooperation) are among the best
- Most countries will not meet the Indicator 6.5.1 target by 2030 at current rates of implementation
- These is no universal approach to implementing IWRM, and each country must find its own pathway based on political, social, environmental and economic circumstances

UN Water, 2018

The GWP further argues that these pillars can contribute to the three dimensions of sustainable development, namely: economic efficiency, equity and environmental sustainability.

The Millennium Development Goals (MDGs) between 2000 and 2015 focussed broadly on poverty reduction, promoting better livelihoods and environmental sustainability from a largely segmented perspective. With the introduction of the SDGs in 2015, including a specific goal on water and sanitation, IWRM now forms a critical part of the global development agenda.

The SDGs take a more holistic view of the sustainable and equitable use of the planet's resources and thus are better aligned to IWRM. They consider water in terms of the human, environmental and economic pressures, and specifically highlight how management through IWRM can be critical for water, sanitation and hygiene education provision (IRC, n.d.). The United Nations Environment Programme (UNEP) highlights how IWRM is key for alignment with the three dimensions of sustainable development:

- Economic efficiency to use water resources in the best way possible;
- Social equity in the allocation of water across social and economic groups; and
- Environmental sustainability to protect the water resource base, as well as associated ecosystems.

SDG Target 6.5 – Water resources management (Indicator 6.5.1 - Degree of integrated water resources management implementation) sets out how the implementation of IWRM will be monitored around the world. Indicator 6.5.1 is monitored at a national level using a global questionnaire which assesses responses in four sections, which are closely aligned with the three pillars of IWRM identified by the GWP, with an extra section on financing. The questionnaire assesses against the following categories:

- Enabling environment: Creating the conditions that help to support the implementation of IWRM, which includes policy, legal and strategic planning tools;
- Institutions and participation: The range and roles of political, social, economic and administrative institutions and other stakeholder groups that help to support the implementation of IWRM;
- Management instruments: The tools and activities that enable decision-makers and users to make rational and informed choices between alternative actions; and
- Financing: Budgeting and financing made available and used for water resources development and management.

Each country should assign an IWRM 'focal point', with the responsibility for completing the questionnaire and submitting the outcomes to UNEP. The most recent submissions evidence can be found on the IWRM Data Portal[1]. The 'SDG India Index Baseline Report, 2018' published by Niti Aayog[2] identified UN SDG target 6.5 is one of those for which there is a lack of data at national level for comparability and therefore was not included in the 2018 baseline national assessment.

1 iwrmdataportal.unepdhi.org/iwrmmonitoring.html
2 NITI Aayog, 2018

INVOLVING COMMUNITIES IN IWRM

The Dublin Statement of 1992 included the principle that "water development and management should be based on a participatory approach, involving users, planners and policy-makers at **all** levels... it means that decisions are taken at the **lowest appropriate level**"[1]. The apparent relevance of IWRM principles to the daily needs of communities has been limited in recent years, and guidance has focussed around top-down policy making and high level water governance. The applicability of IWRM has largely been obscured by the lack of "serious alternative options for water resource management" beyond state control mechanisms[2].

1 http://www.wmo.int/pages/prog/hwrp/documents/english/icwedece.html
2 The Institution of Civil Engineers, Oxfam GB and WaterAid, 2011

> "...the role of communities has been misrepresented because they are frequently excluded from important aspects of environmental management. For many people, community-based institutions can fulfil a fundamental role in the management of common pool resources, such as water resources or forestry. This is particularly true when state capacity is weak or communities remain on the periphery of support from any government."

The Institution of Civil Engineers, Oxfam GB and WaterAid, 2011

The voices of communities are frequently missing when considering the management of natural resources on which they are dependent. Furthermore, it has been argued that WASH organisations frequently advocate for the adoption of "generic IWRM frameworks", and that "...consideration of the water resources that sustain water supply systems has often been a neglected component of community management systems". The complexity of commonly-applied IWRM frameworks is preventing WASH organisations from incorporating water resources management into their ways of working, even though they understand the need for it and the impact it will have on sustainability.

This challenge can be addressed by considering how communities can be enabled and empowered to make water resources management decisions at a local level. To ensure that water resources management issues are considered at an appropriate scale, locally-appropriate actions should be linked into the appropriate governance levels above (vertical integration) and at the same time support the broader spatial (catchment, basin) scales at which IWRM typically operates (horizontal integration). These are explained further below and shown in Figure 4 overleaf.

This toolkit builds on the obligation to include communities and those who serve them in water resources management, and on the need for vertical and horizontal integration. The toolkit responds to the challenge by setting out a six-stage process that complements common approaches to WASH project delivery with steps - and suggested tools and approaches - that align with GWPs three pillars of IWRM at a more local (community) level.

INTEGRATING LEVELS OF GOVERNANCE

VERTICAL INTEGRATION

Working with governance and administration at levels above communities: the role of community-based institutions in monitoring rainfall, groundwater fluctuations, and abstraction as well as bargaining over water allocation and establishing operating principles for water usage can all complement higher-level water resource management frameworks, where they exist. For example, community-level data on water resource availability can help higher-level administrative bodies make better decisions on resource allocation. Therefore, focussing on up-skilling, awareness, cultural change, and data sharing from the top to the bottom and vice-versa can offer better outcomes for WASH organisations than simply advocating top-down frameworks[1].

HORIZONTAL INTEGRATION

Working with governance and administration at catchment scale: IWRM tends to operate over a larger spatial scale than typical WASH implementation projects, and can focus on high-level governance and interactions between national sectors and departments. IWRM frameworks, where well applied, could help integrate these higher-level institutions for better outcomes. They can also facilitate knowledge sharing, data sharing and collaboration amongst lower level institutions. This can be effective for the revival of traditional water management and groundwater recharge techniques, as evidenced by the work of Rajendra Singh in India.

1 WaterAid, ICE, Oxfam, 2011

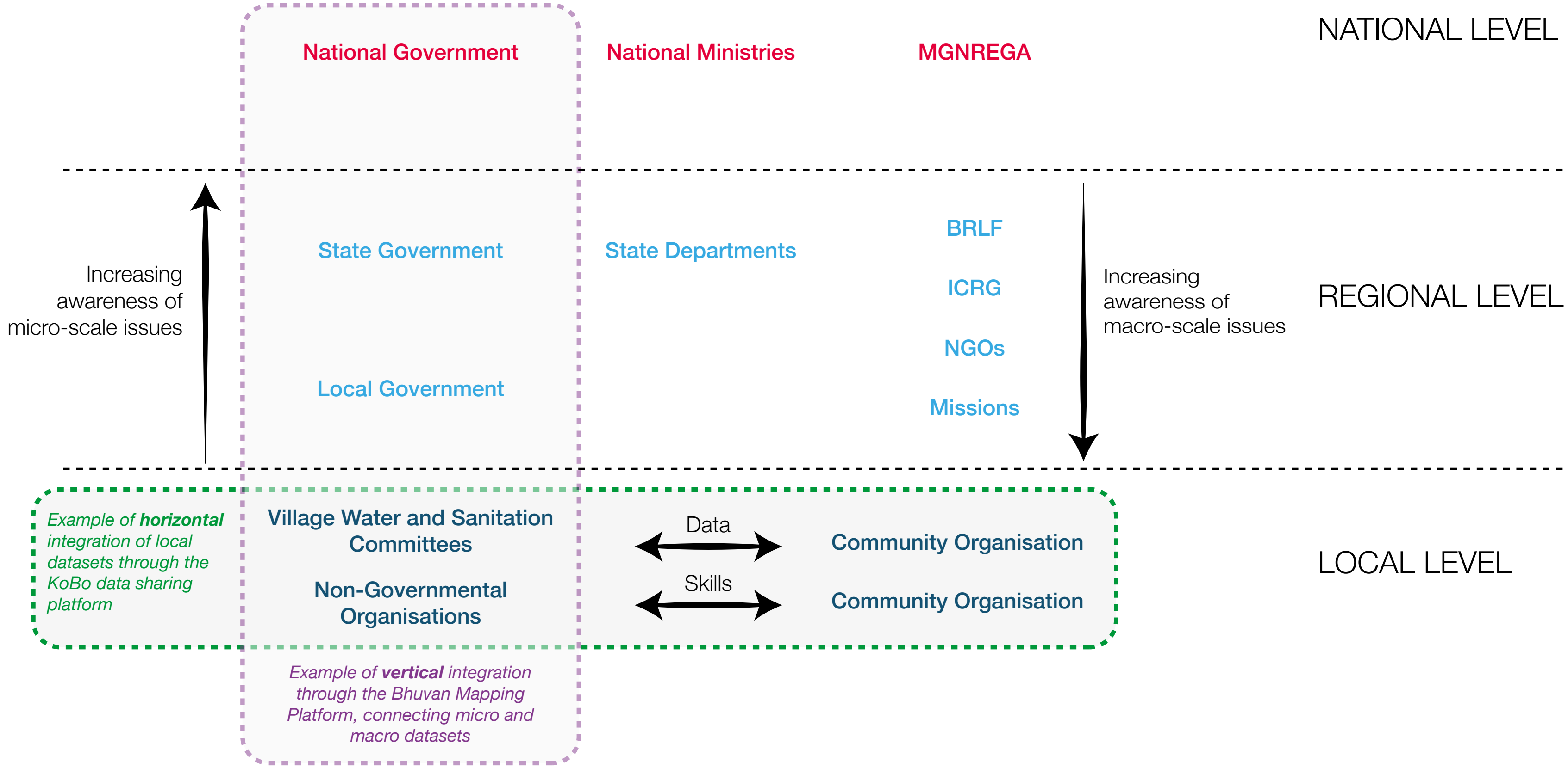


Figure 4 : Horizontal and vertical integration across the water resources management landscape

THE SIX-STAGE PROCESS FOR WATER SECURITY PLANNING

This section describes the toolkit, which consists of Six-Stages, working through from data collection to technical assessments and finally reporting and costing.

The kick-off stage, 'Stage 0 - Needs Assessment', is often one that most WASH delivery organisations have already carried out when developing work plans for funding or approval by governments prior to the start of the WASH project. In other cases, a needs assessment may have already been carried out by others, for example governments, as part of routine water service delivery planning.

We consider Stage 0 in much less detail in this toolkit, especially as it may take various forms. The key stages from the perspective of this toolkit are Stages 1 to 6. Each stage is divided into nine sub-sections, which are summarised below. Please also refer to the Table of Acronyms and the Glossary where appropriate.

Figure 5 : Inspecting a well in a project village

PURPOSE
Why is this stage important, what should it achieve?

OUTPUTS
What data and information should the stage provide?

TYPE OF INFORMATION
The types of information required, following the STEEP Framework - Social, Technical, Environmental, Economic or Political information.

TOOLS AND WAYS OF WORKING
What are the necessary tools for each stage and how should collaboration with the community be achieved?

DATA
Inputs, sources, digital forms of collection and analysis, users and sharing.

TASKS
Activities to be carried out.

SKILLS
An outline of the skills sets required to deliver the tasks.

RESOURCES
Links to digital forms and templates developed by the project team that can be applied in various contexts, as well as links to carefully-selected further guidance and external resources.

CASE STUDY
A case study from India demonstrating the outcomes for each stage.

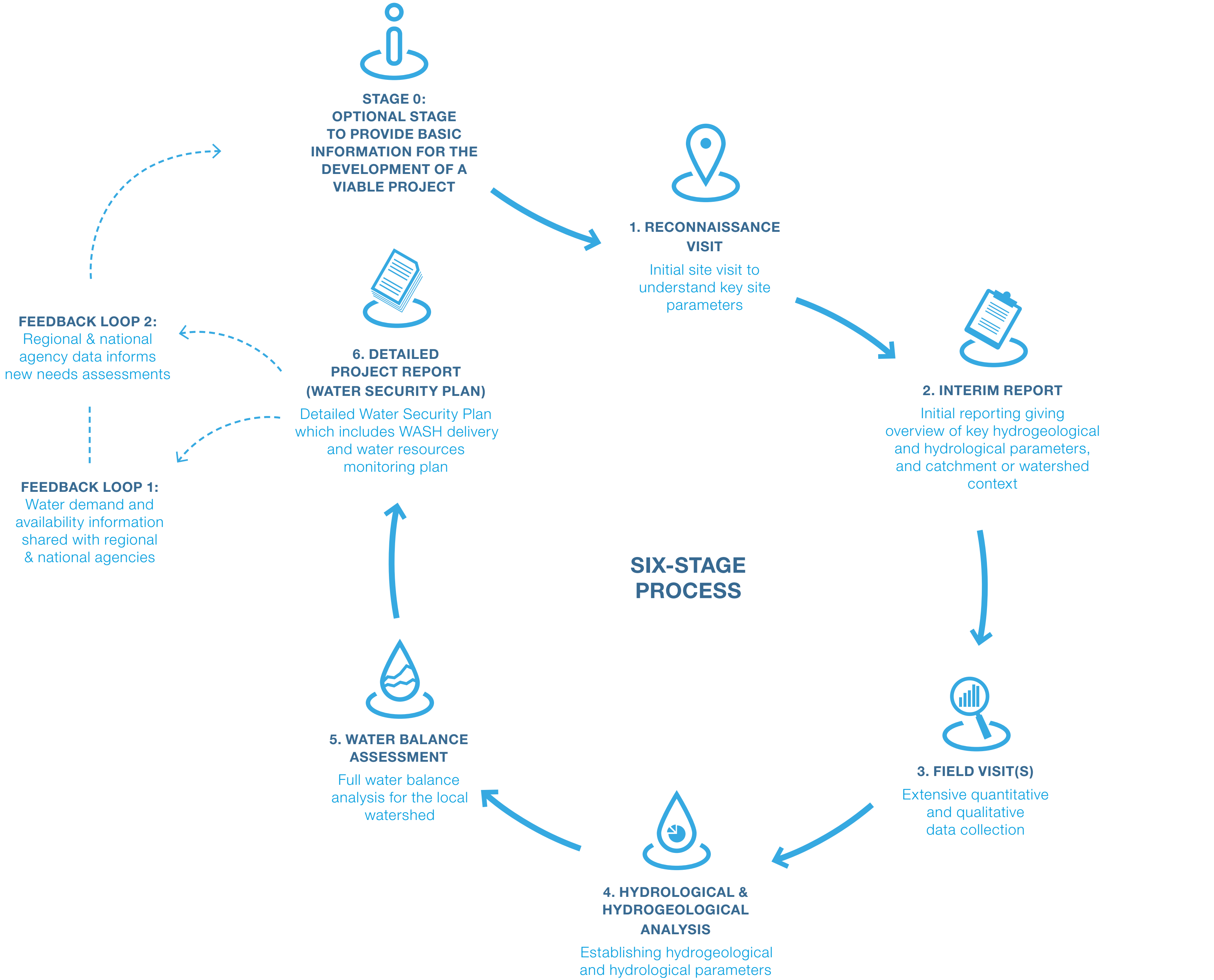


Figure 6 : An overview of the stages of the six-stage process for water resources management

STAGE 1
RECONNAISSANCE VISIT

PURPOSE

An initial field visit to understand the main site parameters relating to water availability and use in the community. This includes identification of water sources, water features, water uses and community views on the water situation.

OUTPUTS

- Field notes
- Meeting notes
- Georeferenced photos of key features and landscape
- GPS locations of key features

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social

T - Technical

E - Environmental

E - Economic

P - Political

TOOLS & WAYS OF WORKING

- GPS device or GPS-enabled device
- Camera
- Notebook
- Digital survey forms
- Pre-arranged meetings with community members
- Pre-arranged meetings with community leaders

DATA INPUTS

- Village name and location
- Catchment in which village is located
- Main aquifers

DATA SOURCES

- Needs assessment report
- Local (or central) government reports
- NGO reports
- Funders reports

Figure 7 : Samerth performing a site visit

STAGE 1
RECONNAISSANCE VISIT

TASKS

- Village reconnaissance
- Rapid assessment of predominant geographical features
- Rapid assessment of visible geological features
- Establish location and condition of existing water features and infrastructure
- Rapid assessment of village livelihoods and economic activity
- Confirm existing community leaders and leadership structures
- Community discussions - confirm rainfall, surface water and groundwater patterns

SKILLS REQUIRED

An initial field visit may not necessarily require specialist skills. However, it is recommended that staff on the field visit are trained to use recommended tools and techniques.

Ideally the field team should include the following skills:

- Community mobilisation skills
- Hydrology skills
- Hydrogeology skills
- Civil or mechanical engineering skills

SURVEY TEMPLATES

Groundwater Source Survey v1

Kobo account link[1]

Printable copy

Surface Water Source Survey v1

Kobo account link[1]

Printable copy

Water Source Flow Survey v1

Kobo account link[1]

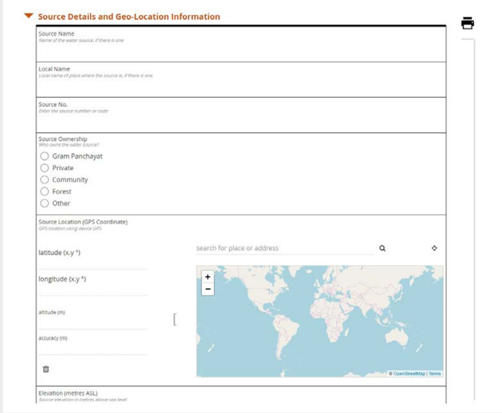
Printable copy

MyWell app

RESOURCES AND FURTHER INFORMATION

About KoBo Toolbox

KoBo Toolbox Help Centre



CASE STUDY
SAMERTH CHARITABLE TRUST, INDIA

Samerth works in some of the most remote and vulnerable tribal communities in Chhattisgarh State. These communities are typically underserved when it comes to water and sanitation services, with existing sources often no longer functional. Samerth needs to conduct reasonably detailed fact-finding visits to these communities, relying on paper-based forms to gather the data. This often took weeks to transcribe, analyse and report.

Working with Arup and FRANK Water, Samerth was able to digitise their key survey forms using KoBo Toolbox, and translate them into Hindi. Using a mobile app that works offline, water source surveys were carried out for 318 families in Shambupiper Gram Panchayat (GP) and 64 households in Bhira GP.

Samerth staff now work much faster using KoBo, and are adequately trained and comfortable using the tool. The approach is now being applied to all Samerth village surveys in Chhattissgarh.

Figure 8 : KoBo Toolbox Form

1 User must be logged into a KoBo account **before** clicking this link. The user can then '**clone**' the form to edit and deploy it within their own organisation.

ARUP

STAGE 2
INTERIM REPORT

PURPOSE

An initial report summarising information on the community and their water and sanitation situation. It should provide an overview of the watershed or catchment hydrogeological and hydrological features, as well as land cover, land use and other geographical characteristics.

OUTPUTS

- Geography, hydrology & hydrogeology of study area
- Existing infrastructure: water, sanitation, recharge, etc
- Water needs and pressures
- Basic water quality and health issues

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social

T - Technical

E - Environmental

E - Economic

P - Political

TOOLS & WAYS OF WORKING

- Suggested Table of Contents for interim report
- KoBo outputs - forms and analysis of survey data
- GIS software and mapping tools such as Google Earth (or Bhuvan in India)
- Excel-based analysis
- Hydrological and hydrogeological maps
- Groundwater conceptual models

DATA INPUTS

- National or state hydrological and hydrogeological datasets
- Field visit and meeting notes
- Field survey forms e.g in KoBo
- GPS data
- Field photographs

DATA SOURCES

- Geological maps 1:50,000
- Topographical maps 1:50,000
- Local (or central) government reports
- Field and meeting notes
- Field photographs
- KoBo or other field survey forms
- Web-based datasets, e.g Water Resources Information system
- Aqueduct or India Water Tool

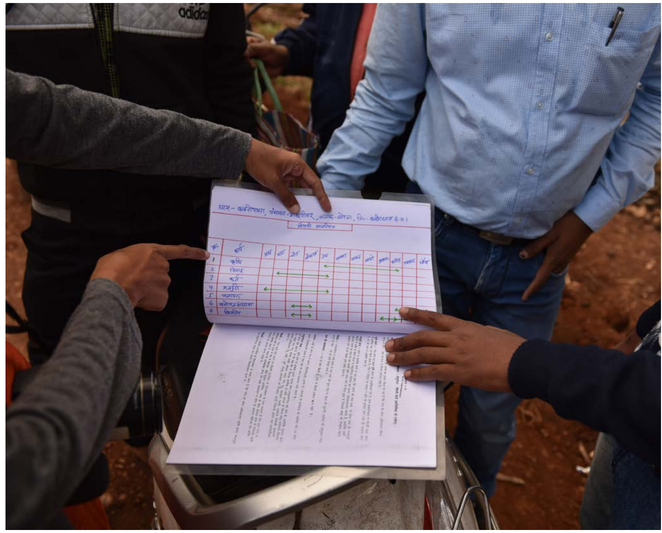


Figure 9 : Manual data collection

STAGE 2
INTERIM REPORT

TASKS

- Carry out data analysis and reporting: charts, graphs, GIS data and more
- Report on geography, hydrology and hydrogeology of watershed, including rainfall, surface water and groundwater patterns
- Report on location and condition of existing water features and infrastructure. Report on community water needs and pressures.
- Report on community leadership structure and water user committee
- Report on land availability for water infrastructure and recharge structures
- Report on potential solutions such as water sources, water delivery and source recharge at a high level

SKILLS REQUIRED

Reporting requires the involvement of field staff, to compile field notes, meeting notes and field photographs. Collation and analysis of datasets may involve office-based staff with specialist skills e.g in GIS or technical analysis. Ideally the report should be compiled by:

- Field team members
- Hydrologist and or hydrogeologist
- Social scientist
- Civil or mechanical engineer
- GIS specialist

USEFUL LINKS

India

India Meteorological Department

National Institute of Hydrology

Central Groundwater Board

Water Resources Information System

India Water Tool

International

WRI Aqueduct Water Risk Atlas

RESOURCES AND FURTHER INFORMATION

- Refer to relevant literature for the local area and watershed
- Refer to previous project reports on WASH and water resources
- Refer to relevant river basin (surface water) management plans
- Refer to aquifer (groundwater) management plans
- Refer to existing IWRM plans for the catchment or watershed

CASE STUDY
PEOPLES' SCIENCE INSTITUTE, INDIA

During the project, PSI provided samples of technical reports produced following an initial visit to the field. Typically, reports consisted of the following sections: geography of the area, regional geology, location, hydrogeology description and cross-sections, field photographs and recommendations for recharge structures.

The reports were structured by village, but the presentation of information was not always consistent. While some of the information suggested in this stage was collected, the adequacy varied from one report to another and from one village to another. In addition, recommendations for recharge structures were made early in the process and did not benefit from a full set of technical information.

Arup reviewed PSI's reports and made suggestions for improvement. This enabled PSI to restructure the report, in line with the approach in Stage 2, and use it for the remainder of the project. The comments were used to develop a proposed Table of Contents template.

Figure 10 : Reviewing technical reports

STAGE 3
FIELD VISIT(S)

PURPOSE

One or more field visits to each village or community to carry out more detailed or extensive collection of quantitative (numbers and quantities) and qualitative (views and opinions) data. This social and technical data is necessary for the design of solutions.

OUTPUTS

- Water source inventories e.g wells, springs
- Pumping test field data
- Completed household and institutional water use surveys
- Completed water quality tests
- Completed social and water resource mapping

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social

T - Technical

E - Environmental

E - Economic

P - Political

TOOLS & WAYS OF WORKING

- GPS device or GPS-enabled device
- Camera
- Notebook
- Digital survey forms
- Pre-arranged meetings with community and leaders
- (Digital) Well, borehole or spring inventory forms
- (Digital) Pump test forms and equipment

DATA INPUTS

- Locations of existing water sources and proposed sources
- Locations of proposed recharge areas
- Borehole or borewell logs
- Water uses and demands

DATA SOURCES

- Community members
- Field observation and measurement
- Previous assessment reports
- Local (or central) government reports
- Interim report

Figure 11 : Assessing a groundwater recharge location

STAGE 3 FIELD VISIT(S)

TASKS

- Field visits in village or community and immediate environs
- Household and institutional surveys to assess livelihoods and economic activity
- Household and institutional surveys to assess all water demands - community and external to community
- Water quality tests
- Pump tests
- Assess predominant geographical and geological features
- Confirm locations & condition of existing water features or infrastructure, including recharge structures
- Confirm rainfall, surface water and groundwater patterns

SKILLS REQUIRED

Detailed field visits often require specialist skills or people that have been trained in key aspects of the skills identified below. Staff on the field visit should at least be trained to use recommended tools and techniques necessary for field activities. Ideally the field team should include the following skills:

- Community mobilisation skills
- Hydrology skills
- Hydrogeology skills
- Civil or mechanical engineering skills

SURVEY AND WORKSHEET TEMPLATES

Water Security Household Survey v1

Kobo account link[1]

Printable copy

Basic Institutional Water Security Survey v1

Kobo account link[1]

Printable copy

Drinking Water Source Quality Test v1

Kobo account link[1]

Printable copy

Annual Water Level Monitoring Form V1

Kobo account link

Printable copy

RESOURCES AND FURTHER INFORMATION

About KoBo Toolbox

KoBo Toolbox Help Centre

Good Practice Guidelines for Water Data Management Policy

Link 1

Link 2

CASE STUDY
PSI AND SAMERTH, INDIA

Pump Testing: PSI is a reasonably large science and research-based organisation, with access to a broad range of technical skills and resources. As a result, PSI staff include trained hydrogeologists who often carry out step tests on deep wells and boreholes to determine transmissivity, hydraulic conductivity and storativity of the aquifer. Arup reviewed PSI's calculation spreadsheets and use of the Slichter Formula which is commonly used for comparing large diameter wells. A standardised calculation spreadsheet was developed to enable users with limited hydrogeological skills to analyse test information with relative ease.

Water Use and Water Quality Surveys: Samerth conducts detailed water use surveys to support the development of water security plans with communities. Working with Arup and FRANK Water, Samerth digitised household, institutional and water quality forms using KoBo Toolbox, with Hindi translations for ease of use. Using a mobile app that works offline, the surveys were carried out in two Gram Panchayats in Chhattisgarh State, resulting in much faster completion rates.

Figure 12 : Undertaking a well pump test

1 User must be logged into a KoBo account **before** clicking this link. The user can then '**clone**' the form to edit and deploy it within their own organisation.

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STAGE 4
GROUNDWATER & SURFACE WATER ANALYSIS

PURPOSE

Establish hydrogeological (groundwater) and hydrological (surface water) parameters for the watershed or catchment, applying appropriate analysis skills and using simple tools and established methodologies.

OUTPUTS

- Hydrogeological parameters: transmissivity, hydraulic conductivity and storativity
- Watershed delineation and flow characteristics: average, low and high flows; and seasonality
- Water quality parameters

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social

T - Technical

E - Environmental

E - Economic

P - Political

TOOLS & WAYS OF WORKING

- Water quality testing kit
- Analysis software
- KoBo survey data analysis
- GIS software and mapping tools such as Google Earth (or Bhuvan in India)
- Excel-based analysis
- Hydrological and hydrogeological maps

DATA INPUTS

- National or state groundwater datasets: aquifer types, boundaries, characteristics
- National or state surface water datasets: Catchments and watershed boundaries, surface water flow and storage data
- Field data

DATA SOURCES

- Geological maps 1:50,000
- Topographical maps 1:50,000
- Local (or central) government reports and data
- Field information
- KoBo or other field survey forms
- National or state groundwater and surface water databases

Figure 13 : A Water Testing Kit

STAGE 4
GROUNDWATER & SURFACE WATER ANALYSIS

TASKS

Groundwater

- Pump test data analysis
- Borehole or deep well lithology analysis
- Determine which geology (rock types) are water bearing
- Determine best drilling locations
- Determine potential recharge locations

Surface water

- Collate river or stream flow time series data (10+ years, ideally)
- Low flow analysis to establish Q95
- Flow frequency analysis using flow duration curves
- Determine sustainable abstraction and storage amounts

SKILLS REQUIRED

This is a technical stage that requires the following specialist skills, or staff with training in some or all of the required skills.

- Hydrology skills
- Hydrogeology skills
- Civil or mechanical engineering skills
- Water resources assessment skills

SURVEY AND WORKSHEET TEMPLATES

Annual Water Level Monitoring Form V1

Kobo account link[1]

Printable copy

MyWell app

Water Level Monitoring Worksheet - Excel

Pump Test Analysis Worksheet - Excel

LINKS TO ANALYSIS SOFTWARE

Bhuvan GIS (India)

QGIS (free)

GRASS GIS (free)

Manifold GIS (cost)

SAGA GIS (free)

Groundwater analysis software help document

RESOURCES AND FURTHER INFORMATION

About KoBo Toolbox

KoBo Toolbox Help Centre

India Meteorological Department

National Institute of Hydrology

Central Groundwater Board

Water Resources Information System

India Water Tool

1 User must be logged into a KoBo account **before** clicking this link. The user can then '**clone**' the form to edit and deploy it within their own organisation.

CASE STUDY
SAMERTH CHARITABLE TRUST, INDIA

As a primarily socially-based organisation, Samerth relied on limited technical skills when working in communities in Chhattisgarh State. Typical workflow involved development of paper-based maps to delineate watersheds and identify key water features. The maps were developed in discussion with communities and typically took up to two weeks to complete. Basic hydrogeological analysis was carried out based on paper geological maps in order to determine the most appropriate locations for boreholes and wells. This was achieved by training Samerth staff in basic hydrogeology skills.

During the WASH Basins project, a needs assessment was carried out which identified the requirements for a greater breadth in skills including: GIS, hydrogeology and engineering. Following a technical support visit by Arup staff in 2018, Samerth began to develop a digital-based workflow, which included the use of Bhuvan web-based GIS for mapping and hydrological and geological analysis, with training from the State Government-run 'Mega Watershed Project' in Chhattisgarh. This reduced the amount of time and effort required to bring together key technical information to support the development of water security plans.

Figure 14 : Paper-based mapping

STAGE 5
WATER BALANCE (BUDGET) ASSESSMENT

PURPOSE

To bring together quantitative information on available water resources, available water sources, total community and external water demands, constraints and confirm the baseline balance between all these components.

OUTPUTS

- Total existing and future domestic, industrial and agricultural water demand
- Total existing water abstractions and seasonal variations
- Total potential resource availability (groundwater, rainwater, other) and future changes
- Supporting data: rainfall, recharge, crops

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social
T - Technical
E - Environmental
E - Economic
P - Political

TOOLS & WAYS OF WORKING

- Water balance analysis spreadsheet and other templates on following page
- GIS software and mapping tools such as Google Earth (or Bhuvan in India)
- GIS-based watershed water balance models - see following page

DATA INPUTS

- KoBo survey field data
- KoBo survey field data analysis
- MyWell app field data
- Stage 4 hydrological and hydrogeological analysis

DATA SOURCES

- Local (or central) government reports and data
- KoBo or other field survey forms e.g MyWell app
- National or state groundwater and surface water databases
- Water Level Monitoring worksheet
- Pump Test Analysis worksheet

Figure 15 : An agricultural pond

STAGE 5
WATER BALANCE (BUDGET) ASSESSMENT

TASKS

- Estimate average annual rainfall in watershed
- Estimate annual average runoff in watershed
- Estimate annual average groundwater recharge in watershed
- If data is available, estimate annual average evaporation
- Estimate annual average surface and groundwater resource availability
- Determine irrigation water demand i.e land irrigated, crops irrigated, crop water requirements by type
- Determine domestic, industrial and livestock water demand
- Estimate total water demand
- Estimate baseline annual water balance (comparison of water available against water demand)
- If climate change data or future population data are available, estimate future water balance

SKILLS REQUIRED

This is a technical stage that requires the following specialist skills, or staff with training in some or all of the required skills.

- Hydrology skills
- Hydrogeology skills
- Civil or mechanical engineering skills
- Water resources assessment skills
- Analytical skills

SURVEY AND WORKSHEET TEMPLATES

Annual Water Level Monitoring Form V1

Kobo account link[1]

Printable copy

MyWell app

Water Level Monitoring Worksheet - Excel

Water Budgeting Assessment Workbook - Excel

LINKS TO ANALYSIS SOFTWARE

Bhuvan GIS (India)

QGIS (free)

GRASS GIS (free)

Manifold GIS (cost)

SAGA GIS (free)

SWAT Water Balance model (free)

RESOURCES AND FURTHER INFORMATION

India Meteorological Department

National Institute of Hydrology

Central Groundwater Board

Water Resources Information System

India Water Tool

Water Balance Assessment Using Q-SWAT (journal paper)

1 User must be logged into a KoBo account **before** clicking this link. The user can then '**clone**' the form to edit and deploy it within their own organisation.

CASE STUDY

PEOPLES' SCIENCE INSTITUTE, INDIA

During the WASH Basins project, PSI provided an example of a crop water budgeting Microsoft Excel workbook. This recorded detailed farmer and village level irrigation requirements, daily rainfall records and water demands. The information was used to produce 'water available' estimates for comparison with the water demands, and ultimately a water budget.

Arup reviewed the workbook and recommended standardisation of the form and data aggregation; for example, structuring of individual worksheets to reduce data needs and accommodate varying data availability; explanatory notes to improve clarity; and use of average rainfall statistics to simplify estimation of recharge and water resource availability. Arup, PSI and FRANK Water developed a template of the water balance spreadsheet which includes clear charts and infographics for better communication. The template is included in this toolkit, and enables a baseline water budget for a community and its watershed to be developed. Annual water level monitoring information should be incorporated into subsequent years' water budgets. In this way, a dynamic picture of water use and availability will be built up and inform decision-making.

Figure 16 : A rural well

STAGE 6
DETAILED PROJECT REPORT OR 'WATER SECURITY PLAN'

PURPOSE

To produce a Detailed Project Report or 'Water Security Plan' for a community, which uses all the data and information gathered to establish water needs, sets out how they will be met and how the available water resources will be monitored and managed within the local watershed.

OUTPUTS

- Geography, hydrology and hydrogeology of local area
- Description of social, environmental, economic and political context
- Baseline water balance and water quality assessment
- Future trends for water resource availability and quality, with monitoring plan
- Designs and locations of water sources, water pipes, storage and community access facilities
- Designs and locations of recharge structures
- Designs and locations of sanitation facilities
- Costs of delivery of water and sanitation facilities

TYPE OF INFORMATION COLLECTED (STEEP FRAMEWORK)

S - Social

T - Technical

E - Environmental

E - Economic

P - Political

TOOLS & WAYS OF WORKING

- GIS software and mapping tools such as Google Earth (or Bhuvan in India)
- Excel-based analysis
- Hydrological and hydrogeological maps
- Local engineering design standards and templates
- Report templates and suggested Table of Contents

DATA INPUTS

- KoBo survey field data analysis
- MyWell app field data analysis
- Stage 2 interim report findings
- Stage 4 hydrological and hydrogeological analysis
- Stage 5 Water Balance Assessment information
- Engineering designs and costing

DATA SOURCES

- Stage 2 interim report
- Stage 3 field information
- Stage 4 analysis worksheets
- Stage 5 water balance assessment worksheet
- Water and sanitation infrastructure designs
- Local government engineering designs, templates and standards

Figure 17 : A water testing kit

STAGE 6
DETAILED PROJECT REPORT OR 'WATER SECURITY PLAN'

TASKS

- Introductory section describing the project and its context: for example, location of community, needs assessment, local water and sanitation statistics and government intentions
- Background section on geography, geology, hydrology and hydrogeology
- Report on the community and their water needs: population, livelihoods, growth and associated demands
- Report on the balance between water supply and demand
- Report on proposed solutions and how they will be delivered
- Report on the costs of solutions
- Report on long-term actions for sustainability: stakeholder roles and engagement, monitoring and data gathering and reporting/sharing

SKILLS REQUIRED

A good project report or water security plan will require the involvement of technical skill sets and good report-writing and communication skills. Overall responsibility should lie with a sufficiently senior person with broad knowledge of the project, but contributed to by staff involved in field work and information analysis:

- Social science and community mobilisation skills
- Hydrology and hydrogeology skills
- Civil or mechanical engineering design skills
- Water resources assessment skills
- Analytical skills
- Infrastructure costing skills e.g quantity surveyor, civil engineer or civil engineering technician

REPORTING, SURVEY AND WORKSHEET TEMPLATES

Annual Water Level Monitoring Form v1

Kobo account link[1]

Printable copy

Water Level Monitoring Worksheet - Excel

Toolkit for Preparation of a Drinking Water Security Plan (2015)

CASE STUDY
PEOPLES' SCIENCE INSTITUTE, INDIA

In 2019, PSI helped to revise wells in Jamnia Mota village, Dhar district in Madhya Pradesh State. Jamnia Mota suffered from drinking water shortages, especially during summers when the wells dried up. The two hand pumps in the village were not safe for drinking purposes as they had high fluoride content due to the local geology. There are very few perennial wells, which are over a kilometre from the main village.

PSI set up a water supply tank at a central location in the village and advised the community to use the well water for drinking and cooking to avoid fluorosis. One resident says: "Initially, people were reluctant to accept change but gradually, with village meetings and door-to-door campaigns, the message that consumption of fluoride-free water is the key to preventing fluorosis spread across the community. One villager allowed his private well to be used for the water supply system". A Water User Committee was formed to manage access to water from the new tank. The community also participated in the laying of a 1.5 km long pipeline joining the source well with the supply tank. Finally, PSI rehabilitated a weir to recharge the source well and excavated new trenches and revegetated the area for increased recharge.

Figure 18 : A community meeting

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SUMMARY OF SIX-STAGE WATER SECURITY PLAN PROCESS

Table 1 : A summary of the Six-Stage Process

STAGE & ACTIVITY	NOTES ON ACTIVITY & WAYS OF WORKING	EXPECTED OUTCOMES	MAIN TYPES OF INFORMATION COLLATED
STAGE 0 NEEDS ASSESSMENT (OPTIONAL)	A pre-visit to a community earmarked for a WASH project, whose main purpose is to scope the potential project. This would involve understanding what the community view as their water-related problems, water-related priorities and historical background. The needs assessment may involve site walkovers, village meetings and informal interviews to gather local knowledge and anecdotal information. Ideally, this should be limited to information obtained solely from the community. Note that this stage may also have been carried out previously by other projects or as part of government routine planning and hence may be skipped when applying this toolkit.	– Develop a basic understanding of communities' water, sanitation and hygiene needs, and how these relate to peoples' livelihoods. – Provide basic information for the development of a viable project.	S - Social T - Technical E - Environmental E - Economic P - Political
STAGE 1 RECONNAISSANCE	Once the project has begun, a reconnaissance visit is normally carried out to collect basic community data, understand important site parameters and document water-related features. This may include: water source surveys, photographing water sources or potential sites, gathering GPS data and making field notes on water use, health and sanitation needs, existing infrastructure and catchment or watershed features. Where land is required, land ownership and potential availability of land for the water system should be discussed and identified. It is advisable to gather information in a structured manner, using bespoke forms or templates, such as those provided with this toolkit.	– Develop an initial understanding of communities' water, sanitation, hygiene and livelihood needs within the natural resource context. – Identify competing needs. – Establish baseline information for development of solutions. – Identify the community and leadership dynamics which will influence the development of the project	S - Social T - Technical E - Environmental E - Economic P - Political

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FRANKWATER safe water saves lives

ARUP

STAGE & ACTIVITY	NOTES ON ACTIVITY & WAYS OF WORKING	EXPECTED OUTCOMES	MAIN TYPES OF INFORMATION COLLATED
STAGE 2 **INTERIM REPORT**	Produce an initial report which summarises information on the community and their water and sanitation situation, and provides an overview of the main watershed or catchment hydrogeological and hydrological features, as well as land cover, land use and other geographical characteristics. The report should be compiled from the information gathered in Stage 1 (and any previous visits). This should include: – Survey forms and high level analysis – Field notes – Review of national hydrogeological and hydrological datasets for the relevant aquifer(s) and catchment(s) – Review of public geographical and geological data The report should include details of existing water infrastructure, existing sanitation infrastructure, existing water recharge infrastructure, basic water quality information (if available) and an assessment of the water-related pressures in the community and the catchment or immediate watershed. Relevant information should also be drawn from the literature, previous projects or previous project reports, where applicable.	– Document the basis of the project, including field data and contextual information. – Present the scale of the problem, outline potential solutions (high level only) and identify risks, including data gaps and assumptions. – Identify the information gathering required in Stage 3. – The Interim Report will not propose firm solutions in most circumstances, although potential solutions may be identified at a high level. – Refer to a suggested Table of Contents.	S - Social T - Technical E - Environmental E - Economic P - Political

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FRANKWATER safe water saves lives

ARUP

STAGE & ACTIVITY	NOTES ON ACTIVITY & WAYS OF WORKING	EXPECTED OUTCOMES	MAIN TYPES OF INFORMATION COLLATED
STAGE 3 FIELD VISIT(S)	One or more field visits to each village or community are recommended in order to carry out more detailed or extensive collection of social and technical data necessary for the design of solutions. The data collected should be both quantitative (i.e numbers of households, or measurements of infrastructure) and qualitative (e.g community views on water quality). Detailed household water use and sanitation surveys should be carried using bespoke survey forms or the templates provided with this toolkit. Information on livelihoods and economic activities and their water use should be obtained e.g animals, crops and irrigation. In addition to household data, technical information should include: borehole pump tests; river or stream flow gauging; groundwater well inventories; surface and groundwater level measurements; GPS locations of proposed and existing water sources; water quality measurements; geological features; existing groundwater recharge structures and identification of areas with potential for groundwater recharge structures and which water sources would benefit.	– Collate detailed social, technical, environmental, economic and political information necessary for baseline solution design. – Collate a technical dataset for the village or watershed for use in designing the solutions. – Develop a technical dataset (e.g groundwater levels, stream flows) and plan for long term monitoring and reporting. Ideally monitoring should be carried out at least once a month, but may be more frequent. – Share the technical datasets, monitoring plan and regular monitoring data with external stakeholders, including state and national level water management organisations.	S - Social T - Technical E - Environmental E - Economic P - Political
STAGE 4 HYDROGEOLOGICAL (GROUNDWATER) & HYDROLOGICAL (SURFACE WATER) ANALYSIS	We recommend that hydrogeological (groundwater) and hydrological (surface water) analysis is carried out using established methodologies, using software, standard pre-formatted spreadsheets or other established methodologies relevant to the state or national context. In some cases (for example where hydrogeological or hydrological analysis skills are limited) it may be appropriate to use simplified methodologies, such as the calculation templates provided with this toolkit. The aim is to establish hydrogeological and hydrological parameters for the immediate watershed or catchment. For groundwater, ideally this should include a conceptual model which describes the groundwater system. Examples of analysis software include bespoke, pre-formatted analysis spreadsheets, free or open-source GIS packages, smartphone, cloud or desktop-based apps and laboratory analysis (full laboratory or external laboratory kits).	– Establish hydrogeological conceptual model and parameters such as transmissivity, hydraulic conductivity and storativity. – Establish hydrological parameters such as maximum and average flow rates, low flows (Q95) and flow patterns (seasonality). – Establish water quality parameters such as total dissolved solids, chemical composition (Nitrates, Iron, Fluoride, etc), seasonality, sources of pollution, etc – Establish design parameters for water sources (e.g pumping requirements) and recharge structures (location, size and which wells will be recharged).	S - Social T - Technical E - Environmental E - Economic P - Political

STAGE & ACTIVITY	NOTES ON ACTIVITY & WAYS OF WORKING	EXPECTED OUTCOMES	MAIN TYPES OF INFORMATION COLLATED

STAGE 5
WATER BALANCE (BUDGET) ASSESSMENT
	A water balance assessment should bring together the quantitative information on available water resources in the watershed (or catchment), available water supply (all sources), total water demand for the community (human, animal, agriculture and other needs). It should also estimate available rainfall and runoff, as well as potential recharge amounts. Competing water demands from outside of the community should be identified, if they exist or are planned. Other constraints on available water resources should also be identified. The assessment should consider:
	– Total available water resources on a catchment or watershed basis (groundwater aquifers and recharge, rainfall, rivers and streams, ponds, reservoirs and other storage)
	– Total existing water abstractions and seasonal variations
	– Total existing and projected future water demand based on accepted growth projections (domestic demand, commercial and industrial demand, irrigation demand, animal-watering demand, cultural water needs, power-generation demands, other)
	– Climate change impacts at the catchment or most appropriate available unit such as region or aquifer. Supporting data should include:
	  – Farmer-level irrigation and crop water requirements
	  – Climate data - rainfall and evaporation data as a minimum
	  – Surface water storage - ponds, reservoirs, recharge structures
	  – Land use and management approaches and techniques
	  – Seasonal cropping patterns
	  – Livestock numbers and water requirements
	  – Population growth projections
	A template for such an assessment is provided with this toolkit.
		– A structured water balance spreadsheet which includes repeatable analysis and datasets identified.
		– Graphs and infographics presenting the baseline and projected water balance for the community, watershed and catchment where feasible.
		– Establish a single source of truth on baseline and future water use which is based on best-available data.
		– Use annual monitoring information plan and documents from Stage 3 to update the water balance assessment and evaluate the impact of interventions. Use this as a means of monitoring improvements in water resources management through annual or semiannual updates.
			S - Social
			T - Technical
			E - Environmental
			E - Economic
			P - Political

STAGE & ACTIVITY	NOTES ON ACTIVITY & WAYS OF WORKING	EXPECTED OUTCOMES	MAIN TYPES OF INFORMATION COLLATED

STAGE 6
DETAILED PROJECT REPORT OR 'WATER SECURITY PLAN'
	This stage should produce a Detailed Project Report which may be called a 'Water Security Plan' or 'Water Resources Plan' for a community or village or watershed. The report should include the following information: water resource availability and recharge solutions; water supply needs and how they will be met; sanitation and hygiene needs and how they will be addressed; livelihood and economic activities and how the water needs will be met; land use; stakeholder responsibilities; water management procedures; water quality testing and pollution prevention.
	The report should outline the sustainable and holistic solutions proposed, and how they were determined, as well as the associated costs. The report should summarise the information gathered in the preceding stages, and incorporate:
	– Appropriate field-based information and analysis
	– Hydrological and hydrogeological analysis outputs
	– Water balance assessment outputs, with the analysis spreadsheet appended
	– Water quality information for different sources
	– Proposed water and sanitation infrastructure solutions and their designs and costs
	– Proposed water recharge structures and their locations, designs, expected impacts and costs
	– Proposed catchment management solutions, implementation plans, costs and responsibilities
	– Proposed community contributions and responsibilities, including fees, maintenance or individuals with identified responsibilities
	– Proposed community engagement with external stakeholders, including frequency, timing and nature of engagement, as well as responsibilities as appropriate.
		Document 'Water Security Plan' or 'Water Resources Plan' agreed with communities.
		– The Plan should enable:
		  – A Project Implementation Agency (PIA) such as an NGO or Civil Society Organisation (CSO) to deliver the project as outlined.
		  – A funding body such as Public Health Engineering Department (PHED) or local government to fund for delivery.
		– Document the delivery process of the project for future reference, including monitoring, evaluation and learning (MEL) and reporting against SDG 6 Targets and Indicators, including Target 6.5 Indicator 6.5.1 'Degree of integrated water resources management implementation'.=
		– Confirm the WASH service delivery solutions and costs.
		– Refer to suggested Table of Contents.
			S - Social
			T - Technical
			E - Environmental
			E - Economic
			P - Political

DEVELOPING A WORKFLOW

This section of the toolkit aims to provide guidance on the importance of developing a standardised, repeatable and efficient workflow for delivery of WASH projects which implement IWRM principles.

The section expands on tools and processes described in the stages in the Six-Stage Process, including those developed or demonstrated during the WASH Basins Project. Finally, the benefits of the proposed tools and techniques over traditional approaches are identified, and 'Watch-Its' highlighted for when they can fail.

The approaches described in this section are intended to fill a gap for organisations which may not already have well-established processes. They should also provide suitable information for organisations which have gaps in some areas, as well as guidance in addressing problems faced by those with well-established procedures. Each section is summarised below:

Figure 19 : A Samerth project meeting

DATA COLLECTION AND MANAGEMENT
Collecting and managing vital data for further analysis and decision making

GIS ANALYSIS
Using desktop, mobile and web-based platforms for data management, analysis and presentation

HYDROLOGICAL ANALYSIS
Understanding the role of the hydrological cycle at project-level

HYDROGEOLOGICAL ANALYSIS
Establishing the groundwater parameters for aquifers, applying appropriate analysis skills and using simple tools and established methodologies

WATER BALANCE ASSESSMENT
Estimating water availability

AQUIFER RECHARGE AND AUGMENTATION
Protecting the long-term resilience of aquifers through practical techniques

COSTING AND DELIVERING WATER SECURITY PLANS
Building the full cost of water security planning into programme and project budgets

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DATA COLLECTION AND MANAGEMENT

The main purpose of data collection is to provide information for decision-making. At the start of the project, data collection is necessary to inform the development of the project. Examples of data collection and what the data is used for are given in Stage 0 (Needs Assessment), Stage 1 (Reconnaissance Visit) and Stage 3 (Field Visit(s)). Given the importance of the data collected in understanding the communities' needs and problems, and therefore possible solutions, it is vital that this data is collected as accurately and efficiently as possible. The second step is the aggregation and analysis of the data, which also needs to be efficient and accurate.

USING DIGITAL TOOLS FOR DATA COLLECTION

WASH delivery organisations often have well-established data gathering protocols, including village and household surveys, utilising organisational or hired enumerators to complete surveys. Often this is a paper-based exercise which relies on the filling of paper forms by hand. The forms are then returned to the office for transcription and data cleansing before analysis can take place, typically using spreadsheets. This can take up to several weeks, depending on staff availability and workload.

One of the main ways of reducing the amount of time that this takes is to apply digital tools that enable data to be collected in the same way, but instead entered into digital forms. This eliminates the requirement for office transcription and makes the data ready for cleaning and analysis.

A number of field survey software tools are increasingly available for use in the WASH and humanitarian sectors, which are tailor-made for sector requirements. They enable users to use standardised forms, create their own forms or pick from a library of publically-available forms made by other users. For example, offline field data collection, the data being uploaded when the surveyor is back in network range.

Three of the best available and most widely used tools include:

- KoBo Toolbox and KoBo Collect app
- mWater
- Akvo Flow

For the WASH Basins project, Arup, FRANK Water and partners used KoBo Toolbox to re-create and refine the partner's existing survey forms and make them available through KoBo Collect app. KoBo was selected based on existing awareness within the project team. However, other tools may be selected based on need.

Figure 20 : Collecting on-site data

FRANKWATER safe water saves lives

ARUP

HIGH LEVEL COMPARISON OF TOOLS

TOOL	COST	MOBILE APP	DATA / WEB PORTAL	MAPPING CAPABILITY	ANALYSIS CAPABILITY	SDG INDICATORS EMBEDDED?	WATER QUALITY TESTING?
Akvo Flow	Starter Partnership from 10,000 EUR	Yes	Yes	Yes	Yes - dashboards and interactive maps	No	Yes - basic test kit and Akvo Caddisfly app
KoBo	Free	Yes	Yes	Yes	Yes - basic graphical and statistical summaries	No	No
mWater	Free	Yes	Yes	Yes	Yes - customised, detailed dashboards and consoles	Yes	Yes - basic mWater test kit and mWater data portal

Table 2 : A comparison of data collection and management tools

WASH BASINS

HOME

BACKGROUND

THE WASH BASINS PROJECT

ABOUT THE TOOLKIT

INTEGRATING IWRM INTO WASH

THE PROCESS

SIX STAGE PROCESS

TOOLS AND WORKFLOW

DEVELOPING A WORKFLOW

REPORTING

WORKING WITH STAKEHOLDERS

MONITORING, EVALUATION AND LEARNING

ANNEXES

ABOUT WASH BASINS

CASE STUDIES

ACKNOWLEDGEMENTS

ACRONYMS

GLOSSARY

BIBLIOGRAPHY

CONTACTS

BENEFITS OF USING DIGITAL DATA COLLECTION TOOLS

- Reduces time between data collection and analysis
- Reduces risk of errors which occur during transcription.
- Uses portable devices which are affordable and available, and often only require an app to be downloaded.
- Data collection can be done offline with no mobile or wifi network required.
- Ease of data comparison and error cleansing as errors in recorded data can be easily seen.
- Quick analysis options provided, including mapping and graphs and charts - ease of reporting.
- Ability to export data in common file formats (e.g Excel files or CSV files) for external analysis.
- Data collection forms can be highly customised to a detailed level.
- Digitally collected data is easier to share with other stakeholders via the platform selected or in common file formats.

BENEFITS OF USING DIGITAL DATA COLLECTION TOOLS

The benefits of working with digital tools for data collection are outlined in the Samerth Case Study in Stage 1 of the Six-Stage Process. Further advice on data collection and management considerations can be found in the World Meteorological Organisation's Good Practice Guidelines for Water Data Management Policy[1].

1 World Meterological Organization, 2018

The benefits of digitally-collected data can be extended to stakeholders and external parties by making the data available to online databases. Examples are the India Water Tool or, if appropriate, the Water Point Data Exchange[2] as the data is in readily transferable formats.

2 www.waterpointdata.org

RISKS OR 'WATCH ITS' OF USING DIGITAL DATA COLLECTION TOOLS

- There is a learning curve and training in the use of the tools and software is required.
- Requires changes to established workflows which may lead to disruption (in the short term).
- Analysis software standard export formats and analysis options may not match organisations standardised reporting requirements.
- There is a residual risk that software access requirements and technical support may change or reduce without warning.
- Free-to-use software may be at risk of withdrawn due to lack of financial support.
- Adopters need to ensure that processes avoid duplication e.g mapping using the tools above versus mapping with Google maps or standard GIS products.

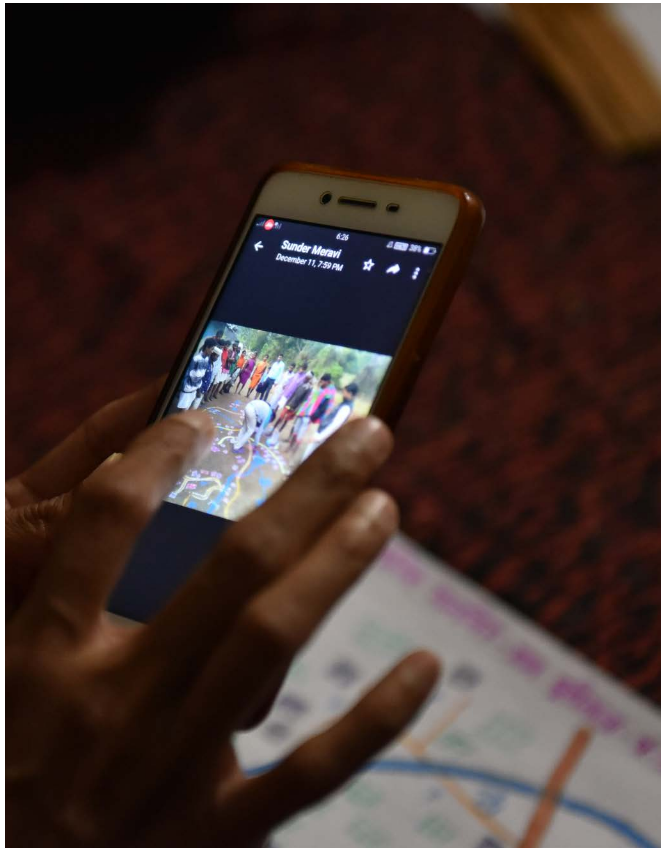


Figure 21 : Recording a community event

FRANKWATER safe water saves lives

ARUP

GIS ANALYSIS

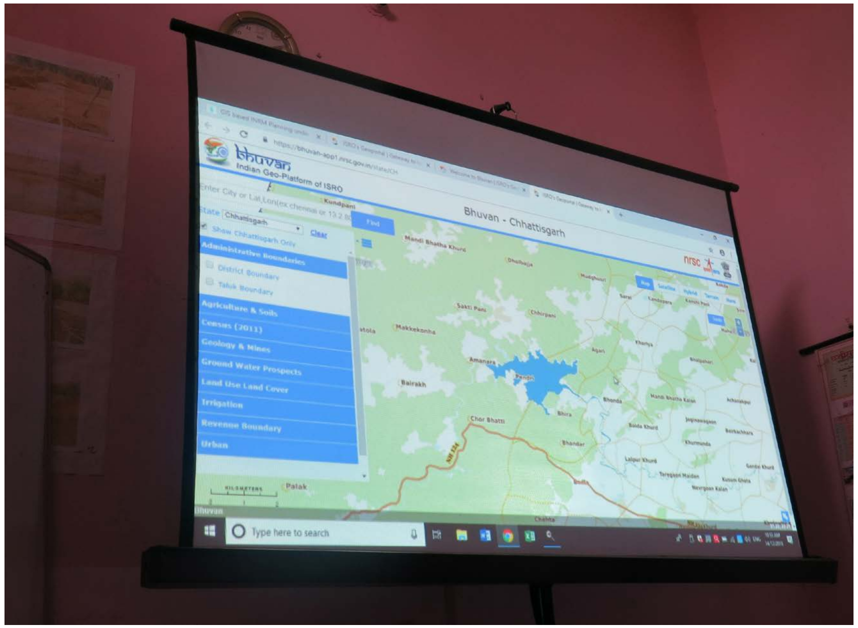
A Geographical Information System or GIS is a software system used to capture, store, manipulate, analyse, manage and present spatial or geographic data. Commonly used professional GIS software includes ESRI's ArcGIS, which is the best known. However, high licence fees and dedicated skills mean that it is often impractical for small to medium organisations, a common size for WASH delivery organisations. Similar, more affordable or free professional and open source options exist and are practical alternatives. These include QGIS (free) and GeoMedia (used by PSI).

In addition, advances in mapping and satellite global positioning system (GPS) availability have resulted in the ability to quickly collect, display and analyse location data within the context of common mapping systems from Google (Google Maps or Google Earth), Microsoft (Bing Maps) or the Open Street Maps. In KoBo, for example, location data for a water source can be collected using a smart device's GPS, uploaded with the rest of the survey information, and used to display the location of the source using Open Street Map, Open Topo Map or ESRI World Imagery (satellite).

The information on the map legend can then be displayed depending on responses to survey questions such as by type of water source.

Finally, there is a hybrid approach which utilises the strength of both professional, desktop GIS software and internet-based and satellite mapping. In the Indian context Bhuvan - a free, web-based visualisation system - is the best-known example. Bhuvan is described as "a geoportal of the Indian Space Research Organisation (ISRO), a versatile, interactive browser in which multi-sensor, multi-platform and multi-temporal images can be overlaid with thematic information, along with near real-time information on a GIS software". Bhuvan is in common use by organisations such as Pradan, and more recently Samerth Charitable Trust.

Figure 22 : The Bhuvan GIS Portal



HIGH LEVEL COMPARISON OF FREE OR AFFORDABLE GIS SOFTWARE

SOFTWARE	DESCRIPTION	OPERATING SYSTEMS	ADVANTAGES	DISADVANTAGES
Bhuvan GIS	Interactive versatile earth-browser which showcases multi-sensor, multi-platform and multi-temporal images. Capabilities to overlay thematic information, interpreted from such imagery as a vector layers, along with near real-time information from Automatic Weather Stations (AWS) and disaster support related information like forest fire alerts and periodic agricultural drought assessment.	Web browser based	– Users can add and share points of interest. – Users can delineate vector features as shape files. – Can be connected to GPS devices in real-time or playback mode. – Users can chart routes, plot areas, view terrain profile and overlay images. – Useful for administrators to monitor development schemes at the grassroots level.	– Requires an internet connection to function. – Slow compared to desktop based software. – Links and data sources not always working. – Mixed data sets; projects and programmes don't always cover relevant areas. – Datasets cover different timeframes and not always comparable. – Efficient workflow can be difficult to set up.
QGIS	User-friendly, professional GIS application licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo).	Linux, Unix, Mac OSX, Windows, Android	– Extendability with plugins. – Large user base, online support and thorough documentation. – Interoperability. – Open source and group effort	– Organisation of plugins and tools.

SOFTWARE	DESCRIPTION	OPERATING SYSTEMS	ADVANTAGES	DISADVANTAGES
GRASS GIS	Geographic Resources Analysis Support System, commonly referred to as GRASS GIS, is GIS used for data management, image processing, graphics production, spatial modelling, and visualisation of many types of data. It is free, open source software released under GNU General Public License (GPL), and is an official project of the Open Source Geospatial Foundation.	Linux, Mac OSX, Windows	– Top-notch geoprocessing and batch processing. – LiDAR and network analysis. – Extensive help documentation.	– Steep learning curve. – 'Clunky' user-interface and defining projects on start-up.
MANIFOLD GIS	Manifold nine blends spatial and non-spatial data to enable data discovery, analysis and management by experts and non-experts, together with advanced GIS editing and presentation capabilities.	Windows	– Stable and intuitive graphical user interface (GUI). – Wide range of functions with programmability. – Relatively low price (Current release is Release 9, costing \$595 - \$940. Release 8 costs \$395). – Free Manifold Viewer available separately.	– Minimal cartographical tools available.
SAGA GIS	SAGA is the System for Automated Geoscientific Analyses, a GIS software designed for an easy and effective implementation of spatial algorithms. SAGA is free, open source software which offers a comprehensive, growing set of geoscientific methods. It provides an easily approachable user interface with many visualisation options.	Windows, Linux	– Unique toolsets for geoscience not found in most GIS software. – Powerful for terrain data and raster processing. – Command line interpreter.	– Poor cartography and line and point symbology. – Missing documentation for some geoscience tools. – May be over-complicated.

Table 3 : Comparison of GIS software (based on primary research and https://gisgeography.com/mapping-out-gis-software-landscape/)

BENEFITS OF GIS PLATFORMS

- Presentation of information visually makes it more accessible to stakeholders.
- Production of village information maps using GIS saves time.
- GIS maps can be easily used in reports.
- Supports the use of affordable and available portable devices for field data collection.
- Depending on GIS solution selected, specialist GIS skills may not always be required.
- Ease of data comparison and comparison of context.
- Ability to export data in common file formats (e.g Excel files or CSV files) for external analysis.

RISKS OF GIS PLATFORMS

- There is a learning curve, and training in the use of the tools and software is required.
- Requires changes to established workflows which may lead to disruption (in the short term).
- Production of village information maps using GIS may reduce community involvement, leading to them feeling less involved.
- Software access requirements and technical support may change or reduce without warning.
- Free-to-use software may be at risk of withdrawn due to lack of financial support.
- Specialist GIS skills may be required, leading to increased overheads which may be an issue for smaller organisations.

PSI's use of GeoMedia GIS software has enabled the organisation's reports to regularly include maps showing village household and water features, geological features and land use and cropping patterns. This is dependent, however, on the right data being available in the formats required for use in GeoMedia. During the WASH Basins project, PSI also transitioned to providing management information system (MIS) style information using location data, survey data and Google Earth for ease of sharing with other stakeholders.

HYDROLOGICAL ANALYSIS

The hydrological cycle (also called the water cycle) refers to the circulation of water between the atmosphere and the earth. There are many processes involved in the cycle, the most important being: evaporation (from land), transpiration (from plants), condensation (which forms clouds), precipitation (rainfall, snow, hail) and runoff (surface water on land).

In the application of IWRM, the river 'basin' or 'catchment' or 'watershed' describes the unit within which all surface water flows linked to that river flow. This may include lakes and other surface water bodies such as wetlands. For groundwater, the equivalent unit is an aquifer.

Note that the boundaries of the surface water and groundwater units do not match, and that the analysis approaches differ.

Hydrological analysis typically requires the following:

- Precipitation data - rainfall, or ice and snow fall, depending on the area
- Stream and river flow data - usually long term time series of 10 years or more
- Land use data - land cover, vegetation types,
- Soil data - soil type, soil moisture, erosion factors
- Surface storage bodies - lakes, wetlands or artificial reservoirs
- Evaporation and evapo-transpiration data - from land and vegetation respectively
- Topography data - variation in land elevation above sea level; this could be contour maps or a GIS-based digital elevation model (DEM)

This is the approach adopted by Bhuvan, which provides a 'base hydrology' layer for the whole of India (Figure 23), in addition to high resolution satellite images, terrain and soil and vegetation types. Bhuvan also offers catchment analysis, consisting of catchment delineation using a DEM (up to 5,000 km^2) as well as hydrological parameters (such as discharge and lag-time) which are computed using "lumped and empirical approach to give an overall idea of the catchment". The delineation can then be downloaded for analysis in a desktop GIS programme. It should be noted that these may be approximate, but offer a potential solution where more accurate data is not available.

Most of the GIS software highlighted in Table 3 will also be capable of varying degrees of spatial analysis. Precipitation, river flow, storage and evaporation data should be obtained from national or state databases and sources, such as those identified in Table 4 overleaf.

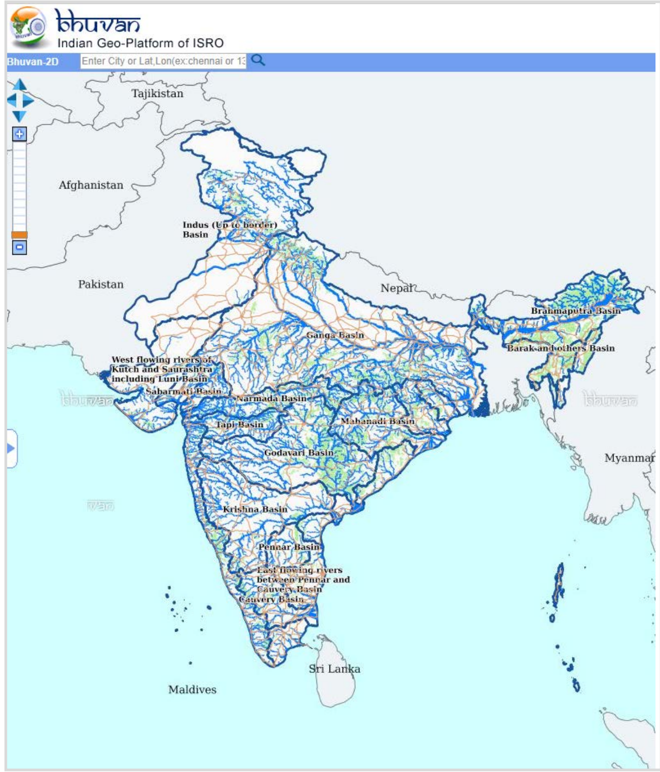


Figure 23 : India Base Hydrology Layer in Bhuvan[1]

1 https://bhuvan-app1.nrsc.gov.in/bhuvan2d/bhuvan/bhuvan2d.php

SOURCES OF HYDROLOGICAL DATA FOR INDIA

It is recommended that appropriate hydrology skills are developed through training or recruitment, in order to develop reliable and beneficial information.

ORGANISATION	DATA LINKS	DESCRIPTION OF AVAILABLE DATA
National Institute of Hydrology	Hydrology and Water Resources Information System for India	High level overviews, summaries, maps and statistics, but no actual downloadable data
India Meteorological Department	Observational network and hydrometeorology	National meteorological data
Bhuvan GIS	In-built hydrological layers and analysis Bhuvan NOEDA data products	In-built hydrological layers, such as 'base hydrology' layer and analysis options, such as 'catchment delineation. Additional data including satellite data, land use cover, forest types etc can be downloaded from the datastore

Table 4 : Hydrological data in India

The purpose of hydrogeological analysis is to establish the groundwater parameters for aquifers, applying appropriate analysis skills and using simple tools and established methodologies. The outputs - in the context of WASH projects - should include the main hydrogeological parameters that describe an aquifer, such as transmissivity, hydraulic conductivity or storativity and groundwater chemistry (chemical water quality parameters).

In order to understand the behaviour of the aquifer, determine sustainable abstraction levels, estimate the long term water balance and to inform demand and water allocation or demand strategies, it is necessary to develop an initial theoretical framework of the water resources in the project area. A 'conceptual model' (Figure 24) can be used to do this for groundwater. Conceptual models form the foundation of all hydrogeological investigations, and involve gathering sufficient information to develop an understanding of how a particular groundwater system works. Depending upon the requirements of the project the conceptual ground model usually starts as a qualitative description and evolves into a more quantitative account as more data becomes available.

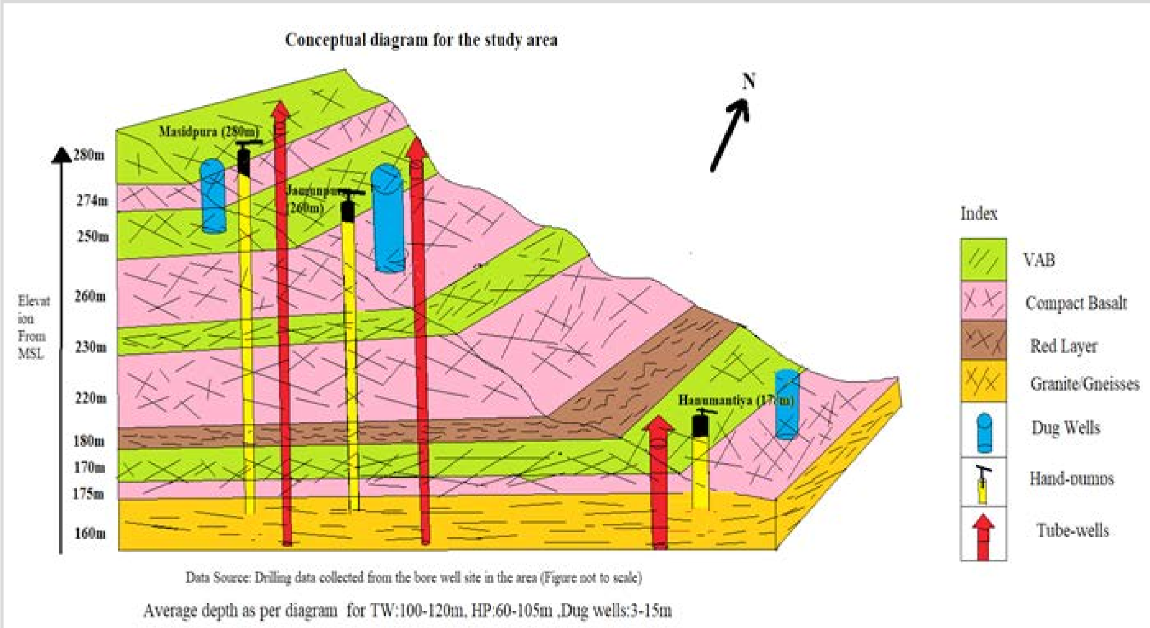


Figure 24 : A hydrogeological conceptual model

WHAT IS A CONCEPTUAL MODEL?

A conceptual model of a hydrologic system is a clear, qualitative, physical description of the various natural and anthropogenic factors that govern and contribute to the movement of groundwater in the subsurface. It usually involves the use of maps and drawings to show the subsurface geology, location of potential sources of recharge, flow paths and discharge. It is therefore the principal output of a hydrological reconnaissance study.

Kresic N., 2013

DESK STUDY

It is essential to have accurate intelligence and supporting scientific data to plan IWRM on a catchment basis. The first step in a project is the collection of data and a thorough search of the available literature and other sources of information. This is called a 'desk study', and its main value is to avoid the unnecessary duplication of existing data and information. Table 5 illustrates how the water resources aspects of an IWRM water security assessment and the development of a hydrogeological conceptual model would fit within the Six-Stage Process from the outset.

HYDROGEOLOGICAL ASSESSMENT STEP	ACTIVITY	RELEVANT STAGE IN SIX-STAGE PROCESS
Define objectives, understanding of needs and data requirements	Consider elements of study needed to provide the required information	Stage 0: Needs Assessment
Define catchment or watershed areas, topography landscape and land-use	Review available data and identify gaps in information	Stage 1: Reconnaissance visit Stage 2: Interim Report
Obtain initial understanding of 3D (three dimensional), geology and hydrology	Populate GIS systems	
Identify surface water features and water points	Begin with published topographic maps then supplement with a local water features survey	
Identify aquifers and non-aquifers assess hydraulic properties	Determine the need for field tests and laboratory measurements	
Establish groundwater levels and flow direction, aquifer behaviour and association with surface water	Identify the need for more data	Stage 2: Interim Report
Preliminary conceptual model	Initial reporting to give overview of catchment resource	
Monitoring programme, measurement of water levels and flows	Assess seasonal variations and impact of abstraction on groundwater levels and relationships with other aquifers and surface water bodies	Stage 3: Field Visits
Aquifer behaviour and relationships	Further interpretation of pumping tests, monitoring data water quality and stream flow data	

HYDROGEOLOGICAL ASSESSMENT STEP	ACTIVITY	RELEVANT STAGE IN SIX-STAGE PROCESS
Produce a description of the groundwater system ('Conceptual Model')	Establish and describe hydrogeological and hydrological parameters	Stage 4: Groundwater and Surface Water Analysis
Assess available groundwater resources using water balance	Full water balance analysis for the local watershed	Stage 5: Water Balance Assessment
Use the conceptual groundwater model, together with knowledge of surface hydrology to inform a water security plan for the catchment	Apply conceptual model to assess environmental impacts, inform a water security plan or feasibility of developing new abstractions	Stage 6: Detailed Project Report or Water Security Plan

Table 5 : Initial Hydrogeological Desk Study and Reconnaissance Activities (Brassington, 2006)

Examples of the type of initial outputs that would be expected to be produced as part of the hydrogeological analysis are shown in Figure 25 and Figure 26.

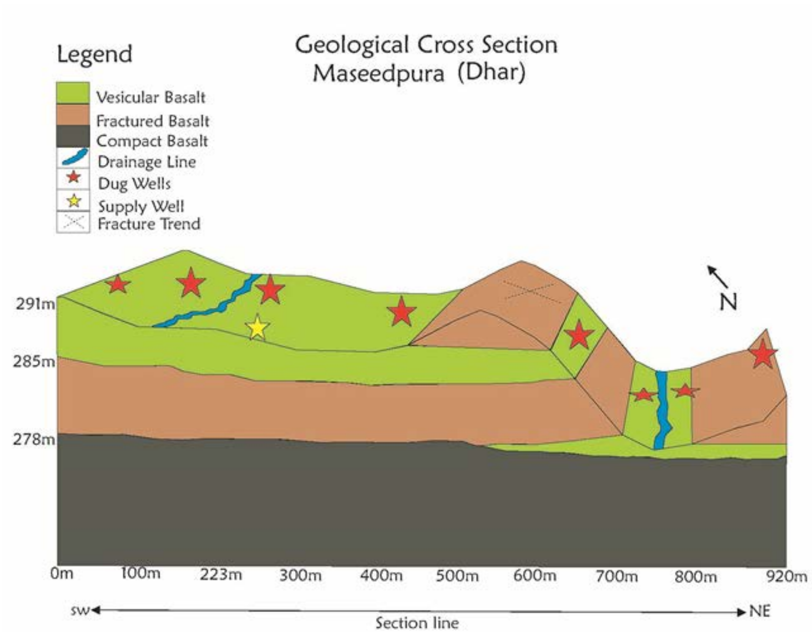


Figure 25 : Geological cross-section

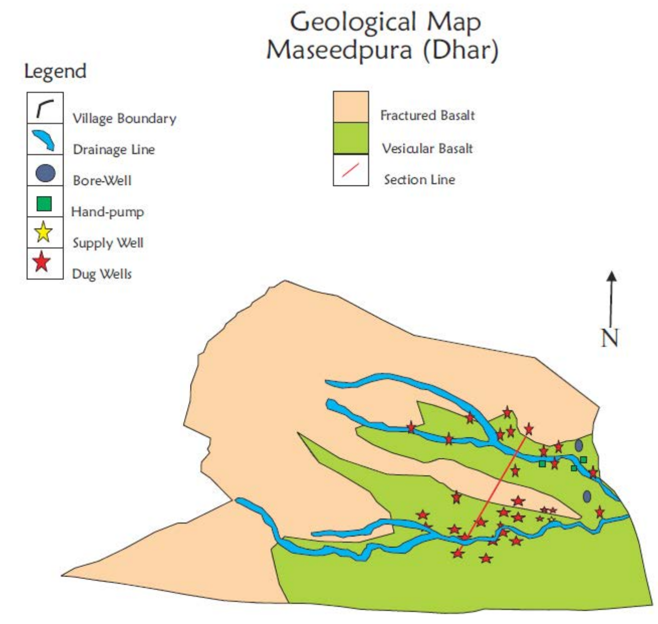


Figure 26 : Geological map

GROUNDWATER OCCURENCE

Estimates of the available sustainable resource, as required by the IRWM process, needs a good understanding of the flow and storage of water. Groundwater, by nature, is hidden below ground and can be difficult to fully understand and manage. Some understanding of the nature and occurrence of groundwater, and concepts of recharge, discharge, together with some of the physical flow processes of groundwater flow is an essential component of defining a complete water balance and may require the support of specialist hydrogeologists. This section provides a brief introduction to the occurrence of groundwater and principles of groundwater flow.

Groundwater forms an important part of the hydrological cycle, and characterising a groundwater system is a critical first step in solving aquifer and resource problems.

Groundwater systems

Groundwater is the water that seeps through rocks and soil and is stored below the ground. The rocks in which groundwater is stored are called aquifers. Aquifers are typically made up of gravel, sand, sandstone or limestone. Water moves through these rocks because they have large connected spaces that make them permeable. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which groundwater is found is called the water table. The water table can be as shallow as a few centimetres below the ground or it can be a few hundred meters deep.

Heavy rains can cause the water table to rise and conversely, continuous extraction of groundwater can cause the level to fall.

The principle input to groundwater is known as recharge and can be from infiltration from natural sources such as rainfall, surface runoff and standing water bodies such as lakes and reservoirs; it can also be from human activities such as surplus irrigation, leakage or even as deliberate aquifer recharge schemes. In the upper layers of soil and rock there may be pores and voids or 'holes' which are not filled with water – an area known as the unsaturated zone - where water will infiltrate vertically downwards under the force of gravity. In the saturated zone beneath all pores and voids are filled with water. The boundary between the unsaturated and saturated zones is known as the water table. Any water that percolates through the soil to reach the water table becomes groundwater, which tends to flow laterally (sideways), typically following the local topographic gradient. Unless groundwater is removed by pumping boreholes or wells it will flow through the rock to eventually discharge at the ground surface (as springs or seeps) or enter stream or river beds (as baseflow), or directly into the sea.

Aquifers, aquicludes and aquitards

A geological formation that contains groundwater and allows water to flow through it in useful quantities is called an aquifer. An aquifer is porous (it has space represented by pores or fractures which can be occupied by water) and permeable (water can move through this space). Aquifers are sometimes described according to their water level or pressure head conditions. An aquifer is said to be 'unconfined' where its upper boundary consists of a free groundwater surface at which the pressure equals atmospheric. The free surface is known as the water table and unconfined aquifers are sometimes known as water-table aquifers. An aquifer is said to be 'confined' when it is fully saturated, and its hydraulic head lies in an overlying low permeability confining layer. In some aquifers, the free surface could be above the ground surface. Water from such a well would overflow naturally; this is called an artesian well and the aquifer in this area is called an artesian aquifer.

Very low permeability layers bounding aquifers are known as aquicludes. However, some low permeability formations can transmit quantities of groundwater that may be significant on a regional scale and are called aquitards. Where an aquitard allows some leakage of water from or to an aquifer the aquifer is said to be semi-confined or leaky.

Porosity and aquifer storage

The ability of an aquifer to transmit groundwater is usually described by its hydraulic properties. Hydraulic properties include:

- Hydraulic conductivity,
- Thickness, porosity,
- Transmissivity, and
- Storage coefficient.

Pumping tests are the most common method of measuring hydraulic properties and give estimates of the storage coefficient and transmissivity. Definitions of the parameters are given below.

- **Porosity:** This is the total void space within a rock and defines the total amount of groundwater stored in an aquifer.
- **Hydraulic conductivity (also called permeability):** This describes the velocity that groundwater would flow through the rock if there was a pressure gradient of 1m per metre. Its is measured in metres/second (m/s).
- **Transmissivity:** This describes the ability of an aquifer to transmit volumes of groundwater and is calculated by multiplying the hydraulic conductivity by the aquifer thickness; it is usually measured in m^2/day.
- **Storage coefficient:** This is the amount of water released from storage within the aquifer when the water table falls by 1 metre, and is a more accurate measure of the amount of groundwater stored in an aquifer than porosity.

Accessing groundwater

There are many ways of accessing groundwater. Some of the more common methods are described below (MacDonald et al., 2007):

- **Springs:** A spring is a natural discharge point of groundwater water at the surface of the ground or directly into the bed of a stream, lake, or sea. Water that emerges at the surface without a perceptible current is called a seep. Because springs are usually shallow, they can be vulnerable to contamination and/or drought.
- **Hand-dug wells:** Dug by hand in soft materials, these are generally less than 20m deep and 1-2m in diameter, although larger diameters (up to 8m) are common in India. Generally, they need to be lined to protect them from collapse. The main advantage of a large diameter well is its large storage, which allows water to accumulate at times of low demand (e.g. overnight) to be emptied at times of high demand (e.g. in the morning). Because they usually tap into shallow aquifer units and usually exploit less permeable aquifers, dug wells can be quite vulnerable to drought. Thousands of open large diameter dug wells have been recorded in the rural areas of the Deccan of India where they are a significant source of water for agriculture. (Kulkarni et al., 1998). These wells are generally 4 to 8m in diameter and 8 to 15 m deep. Only the weathered rock in the upper 2 to 5m is sealed off, and the rest of the well is unlined.
- **Boreholes or tube wells:** A borehole is a narrow hole drilled into the ground to access water contained in an aquifer, and is the most common type of water source used on rural water supply projects. A pipe and a pump are used to pull water out of the ground, and a screen filters out unwanted particles that could clog the pipe. Wells come in different shapes and sizes, depending on the type of material the well is drilled into and how much water is being pumped out. There are three basic types of borehole:
  - *Bored or shallow wells are usually bored into an unconfined water source, generally found at depths of 30m or less.*
  - *Consolidated or rock wells are drilled into a formation consisting entirely of a natural rock formation that contains no soil and does not collapse. Their average depth can range from 25m to 200m.*
  - *Unconsolidated or sand wells are drilled into a formation consisting of soil, sand, gravel or clay material that collapses upon itself. These wells will always need to be screened and cased.*

Advantages of a borehole includes its speed of construction, the greater depth at which it can be developed and the fact that it can be drilled in very hard rock. But drilling can be expensive and requires specialist equipment and staff to construct and maintain the asset.

- **Collector wells or infiltration galleries**: There are a large variety of alternative collection systems, with some like the qanats of Arabia, having been in use for millennia. Generally, they are large, complex and expensive engineering structures and although can be highly effective, are usually beyond the scope of most WASH programmes.

FIELD ASSESSMENT OF GROUNDWATER RESOURCES

An understanding of the aquifer properties is vital for estimating the direction of groundwater flow and to give an understanding of the storage and sustainable yield of an aquifer. Aquifer properties can be measured in the laboratory or the field, but can also be assessed in general terms by consideration of the overall aquifer geology. Detailed hydrogeological investigations are expensive and require the input from experienced scientists and are therefore usually beyond the scope of community scale WASH delivery projects.

However, some assessment of the geological situation, identification of any significant aquifers and aquitards can be undertaken at the reconnaissance stage by non-specialist staff who have undergone some training. In addition, direct field measurements of hydraulic properties can be made by pumping tests.

Aquifer pumping tests

A pumping test is a means of investigating how much water is stored in the aquifer easily flows through the ground into a well. Pumping tests are conducted to evaluate an aquifer by stressing the aquifer, usually through constant pumping and observing the aquifers "response" or water level drawdown in observation wells. It is a common tool that hydrogeologists use to characterise an aquifer system, confining beds and flow boundaries. Test pumping a borehole provides the best indication of the performance characteristics of the borehole and the hydraulic properties of the aquifer because the test integrates a large volume of the aquifer. Pumping tests are therefore highly recommended component of a groundwater resource investigation if sufficient time and budget is available.

Design of pumping tests

Pumping tests enable hydrogeologists to: evaluate the performance of a well, observe the drawdown and estimate its sustainable yield, and estimate aquifer properties. Pumping tests are usually made in existing wells or in wells drilled for that purpose. The test is a controlled, field experiment made to determine the hydraulic properties of aquifers (hydraulic conductivity and storage) and is achieved by measuring the rate of groundwater flow that is produced by pumping a well and observing changes in the pumping wells and/or observation wells.

When a well is pumped, groundwater stored in the aquifer moves towards the well, forming a cone of depression in the water table around the borehole. The cone gradually moves further out as pumping continues. The size and shape of this cone of depression depends on the pumping rate and the properties of the aquifer. A pumping test also provides a good opportunity to take water samples to determine the quality of groundwater.

There are many different types of tests that vary significantly in the sophistication of equipment, cost and complexity of analysis. They typically include the following:

- **Discharge capacity test:** Often done by airlifting at the time of drilling. The test will give an approximate indication of the yield of a borehole but little information about the aquifer.
- **Variable discharge or step drawdown test:** Involves short duration pumping done at different rates. It is used to define the relationship between pumping rates and drawdown in a well. It is not particularly useful for determining aquifer properties.
- **Slug or bailer test:** A simple and quick method for testing the yield of a borehole. It is not particularly useful for determining aquifer properties.
- **Constant rate test:** Involves pumping a well at a constant rate for a determined period, usually several hours. The test will give more information than a simpler, shorter test - such as the bailer or step test - including information on the aquifer properties. More information can be gathered during a longer test or if there is an observation well drilled for testing purposes close by.
- **Recovery test:** Follows a constant rate test and can provide useful information and verification of aquifer properties such as transmissivity.

There are numerous standard references that describe the different tests and the theory behind them. Of these, the International Committee of the Red Cross (ICRC) provides a very accessible and in-depth overview. The comprehensive guide also explains how to select pumping tests in different situations.

The guide can be downloaded here: Technical Review: Practical Guidelines for Test Pumping in Water Wells, Ref. 403.

Alternatives to conventional pumping tests

Undertaking “conventional” pumping tests can be expensive and time consuming and difficult without the right equipment and skilled personnel. Ideally, to allow a complete analysis of aquifer properties, drilling and monitoring of dedicated observation wells is required. However, this is often beyond the scope and funding available for WASH delivery projects and programmes. Nevertheless, there are some simpler tests that can be used to assess groundwater resources. Some of the alternatives to “conventional” pumping tests that might be more applicable to a WASH programme in a rural area include the following (MacDonald, 2002):

- Initial yield estimates during airlifting
- Borehole specific capacity test
- Bail/slug test in low permeability aquifers or tube wells

Pumping tests can also be undertaken on the large diameter shallow dug wells that are common in India, but they require different analytical methods to interpret.

Analysis of pumping tests

Basic data collected during test pumping may include information such as: borehole yield, water level drawdown and water level recovery. The data is used to estimate the specific capacity of the borehole (specific capacity is the borehole yield divided by the drawdown in rest water level, measured in metres^3/metre/day), aquifer transmissivity, storage coefficient and water inflow rates.

The WASH Basins project produced a simplified template for analysing pumping test field data and producing estimates for specific capacity, transmissivity and storativity (storage coefficient). The template can be accessed here.

Assessing hydraulic properties from pumping tests

In addition to the template provided above, the WASH Basins project also compiled a list of free and affordable software that could be used for assessing hydraulic properties from pumping tests. The document can be accessed here.

Using hydraulic property information

The most simple, but often most useful data is time series information on the water table levels, or how water levels are changing over time. This can show full seasonal fluctuations, and indicate whether the resource is in good health or being stressed. The most useful outputs include:

- Water table contour maps
- Saturated thickness cross sections
- Bedrock contour maps
- Water level change cross sections or maps
- Time series hydrographs

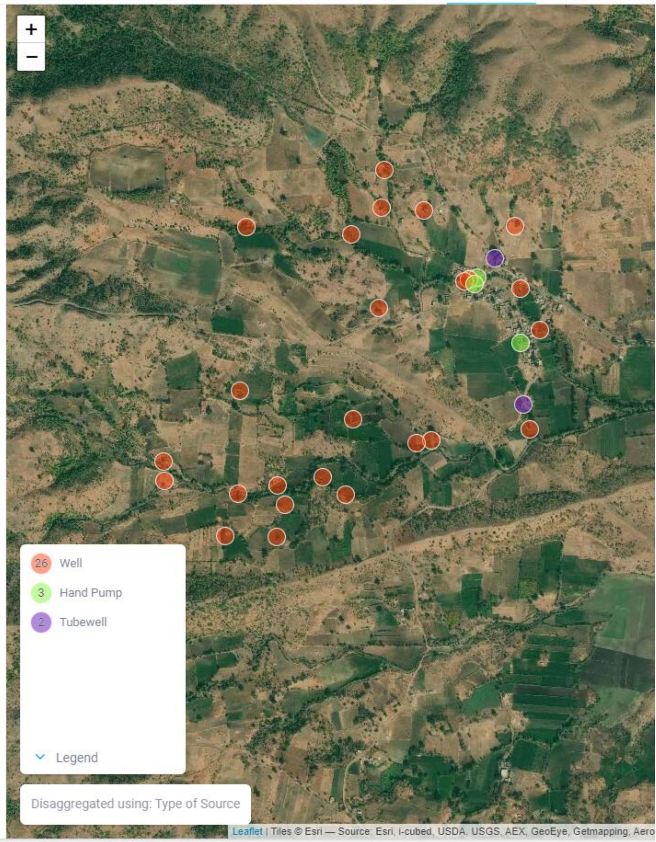


Figure 27 : Mapping rural water infrastructure

WATER BALANCE ASSESSMENT

A water balance assessment - sometimes known as supply-demand balance assessment - is a vital step in sustainable water management. It involves bringing together two main sets of information: how much water is available for use in a catchment, watershed or aquifer and how much water is required for human and livelihood needs (livestock, irrigation, other economic activities, including industry). The water balance assessment builds on the information developed through hydrological and hydrogeological analysis, enabling a reasonable estimate of water availability through rainfall, runoff and groundwater recharge to be assessed within a naturally-occuring watershed, catchment or aquifer.

Key concepts in a water balance assessment include the following, which can be linked to the hydrological cycle:

- **Inputs:** Rainfall, other precipitation
- **Influencing factors:** Vegetation type, soil type and underlying geology, topography (catchments and sub-catchments)
- **Available resources:** Stream flow, surface runoff, groundwater recharge, surface water storage
- **Outputs:** Domestic, irrigation, livestock, industrial and other water demands (abstractions), as well as evapo-transpiration

However, a fully accurate water balance assessment can be complex and difficult to develop, because of the amount of raw data required, all of which must be available at the same scale over the same time frame. This presents a difficulty: to invest time and effort in obtaining the amount and quality of data required to develop an accurate water balance, or to attempt a water balance assessment that achieves a reasonable level of accuracy, and whose biggest benefit lies in informing communities about the baseline balance between water needs and availability, while providing a means and motivation to continue to monitor how this changes over time. The logic is that this provides a basis for action if sustainability of resources is threatened, using data from ongoing monitoring instituted as part of a Water Security Plan.

As discussed above, there is uncertainty when the ideal data set is not available. The logic of this toolkit therefore assumes that two levels of resolution or accuracy are required, depending on the available data and the skills and time (resources) available to the WASH delivery organisation:

- A fully-quantitative assessment which is data-rich and characterises the whole hydrological cycle. This can usually can only be done on large scale across a watershed or full river basin.
- A qualitative, data-poor assessment which may not capture all inputs or outputs. This may be more suitable - or more likely to occur - for smaller micro-catchments, used in local community studies. The main long-term monitoring approach is often to look at long term changes in water table levels as an indicator of groundwater storage and sustainability. Because of the importance of groundwater in India, the change in storage over time is probably the single most important parameter.

Figure 28 : A hand pump in a project village

Based on experience with PSI and Samerth on the WASH Basins project, differing levels of hydrological and hydrogeological skills and experience present challenges for water balance assessment. Nevertheless, this toolkit proposes an approach - based on work by PSI - that provides a standardised Microsoft Excel workbook in which key information in each community can be captured in order to provide a high-level baseline water balance assessment. Through the WASH Basins project, the PSI spreadsheet was structured and standardised as shown below:

CHAPTER NUMBER	CHAPTER	DESCRIPTION
00	COVER PAGE	Project location, partner organisation, quality assurance, version and completion details
01	INTRODUCTION AND NOTES	General notes and assumptions
02	FARMER-LEVEL INFORMATION	Farmer land and water source holdings; farmer irrigation requirements
03	VILLAGE-LEVEL INFORMATION	Village population and irrigation requirements
04	CROP WATER REQUIREMENT	Crop water requirements
05	GROUNDWATER RECHARGE	Estimation of groundwater recharge
06	WATER AVAILABLE ESTIMATE	Estimation of surface and groundwater availability
07	WATER DEMAND ESTIMATE	Estimation of water demand
08	WATER BALANCE ESTIMATE	Estimation of baseline or annual water balance

Table 6 : Suggested layout for a water balance assessment report

In addition, pie charts and bar graphs provide a useful visual representation of the water balance. A summary sheet showing the key output information that is taken forward for decision has been added. When structuring the workbook, some thought to how the information could be collated for a) Villages b) Gram Panchayats c) Blocks e) Districts and f) Watersheds could be aggregated. By structuring it this way, the information gathered in different villages can help to build the bigger picture which can be used for IWRM baseline assessment and reporting. The workbook includes a standardised list of common crops and crop water requirements, from literature. When combined with area per crop type, a quick estimation of irrigation requirements per growing season can be obtained. The Farmer-Level information worksheet provides a detailed breakdown of individual family hectarage and irrigated hectarage broken down by Rabi (spring), Summer and Kharif (monsoon) season. The Groundwater Recharge worksheet aims to give an estimate of available recharge by bringing together information on the estimated aquifer area (from literature), water level data (from monitoring), seasonal variation and the aquifer specific yield, determined from pump tests or literature.

Finally the Water Available Estimate and Water Demand Estimate worksheets bring together input and output information respectively. The resulting balance is presented on the Water Balance Estimate worksheet using charts (Figure 29 and Figure 30).

The Water Balance Assessment workbook can be accessed here.

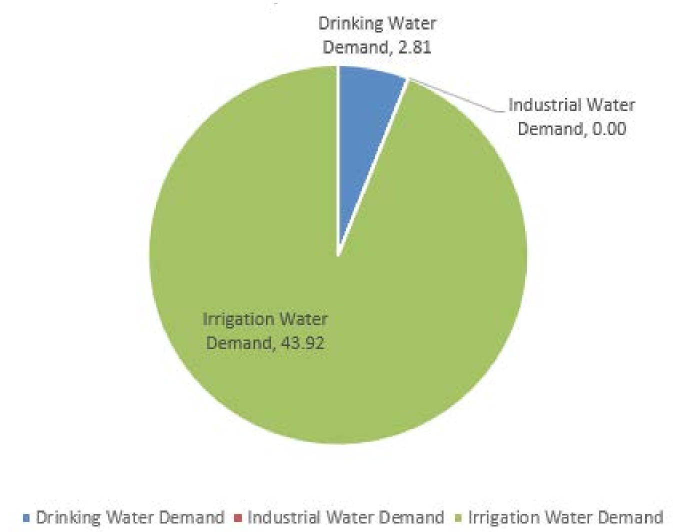


Figure 29 : Summary of water demand

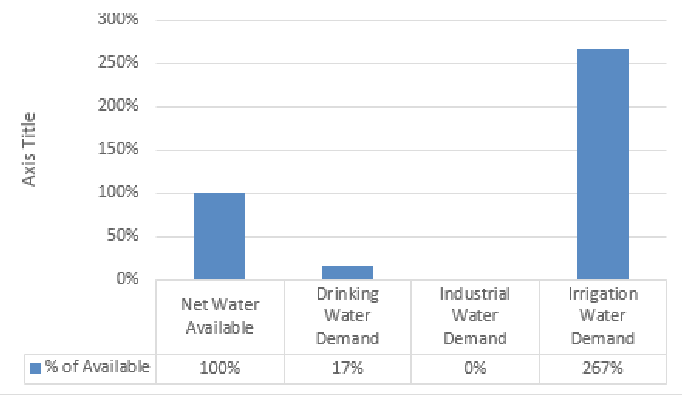


Figure 30 : Summary of water balance

AQUIFER RECHARGE AND AUGMENTATION

This section describes approaches to aquifer recharge: the theory behind it, the benefits, methodologies and issues to be aware of.

ENHANCING THE AVAILABLE WATER RESOURCE

In tropical monsoon areas absolute shortage of water is often not the root cause of water access issues, which are more likely to be driven by variability, timing and duration of water resource availability. Opportunities for increasing the available supply of water usually consist of "slowing" or storing excess water during wet seasons, for example by:

- Surface water storage – construction of dams and reservoirs, however these are usually large, high-cost schemes planned at the state or national level.
- Harvesting rainwater from roofs or hardstanding areas for storage – is highly beneficial but most useful in urban areas.
- Harvesting rainwater to enhance groundwater recharge – this is called artificial recharge, a process which can augment groundwater at rates much higher than normal. Artificial Recharge is practised widely across India and is very appropriate for development in rural areas.
- Soil improvement/catchment management – to slow down and capture surface water and enhance natural infiltration into soils and aquifers. Soil improvement strategies are also practised widely across India, have multiple benefits and are very appropriate for adoption in rural areas.

Because of the suitability for community schemes in rural areas, only the artificial recharge and soil improvement techniques are considered in some detail within this toolkit.

ARTIFICIAL RECHARGE OF AQUIFERS

Rain water harvesting is the technique of collection and storage of rain water at surface or in subsurface aquifers, before it is lost as surface run-off. The augmented resource can be harvested later at a time of need. Artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that under natural conditions of replenishment. The main purpose of artificial recharge of groundwater is to store "excess" surface water or stormwater runoff for future use and to reduce, stop or reverse declines of groundwater levels, in order to prevent eventual exhaustion of the groundwater resource in the long term.

Aquifer Recharge (AR) has great potential to increase the security and quality of water supplies in water-scarce areas and has many advantages, such as:

- The aquifer can serve as a distribution system.
- Little land is wasted for storage reducing need for population displacement.
- Groundwater is generally of good quality – and is not directly exposed to pollution.
- Evaporation losses from underground storage are much less than from surface storage reservoirs and the environmental impact is likely to be lower.
- AR often provides the cheapest form of new safe water supply for communities (UNESCO-IHP 2005).
- The increase in groundwater storage can help mitigate the effects of drought, reduce flood hazards and reduce soil erosion.

Figure 31 : A check dam

DESIGN CONSIDERATIONS

There are a wide range of technologies and methods that can be used to recharge water into the ground. Important aspects that need to be looked at when selecting and designing a rainwater harvesting scheme to artificially recharge groundwater include:

- The hydrogeology of the area including the nature and extent of the aquifer, soil cover, topography, depth to water level and the chemical quality of groundwater.
- The availability of source water – essentially assessed in terms of non-committed surplus monsoon runoff.
- Understanding of the area contributing to runoff - such as area available and land-use patterns.
- Hydrological factors such as rainfall duration, patterns and intensity.
- The topography of the area will control the retention period of surface and groundwater and will determine the choice of AR technique.

Artificial recharge schemes are most effective in the following situations:

- Where groundwater levels are declining on a regular basis.
- Where the aquifer is significantly de-saturated.
- Where availability of groundwater is inadequate in dry months.
- Where the cover soils and unsaturated zone are of good permeability, or highly permeable zones such as faults, fissured, or weathered zones can be identified.

Figure 32 : Assessing a groundwater recharge site

ARTIFICIAL RECHARGE TECHNIQUES

Subsurface AR techniques usually include recharge of wells and boreholes with good quality silt-free surface water from farm ponds, streams or from rainwater collected from roofs. The basic rule in AR is that the water being introduced should be of equal or better quality than the native groundwater.

Surface based AR techniques usually include a range of infiltration basins, check dams or percolation structures. Because these involve an element of natural filtration the quality of the recharge water is less of an issue. A percolation tank is constructed by putting an earth bund with a side waste weir across a stream. Surface runoff stored behind during the rainy season gradually percolates during the dry season to recharge the groundwater body. Ideally the water stored in the tank should percolate within the first three or four months of the dry season so that the shallow water body is not exposed to excessive evaporation later in the summer.

In areas where the native water quality is poor, such as with high salinity or arsenic or fluorides, percolation tanks can be used to dilute and improve the native water quality in downstream abstractions. Wells and boreholes that have been abandoned, perhaps because of poor quality or falling level, make good targets for recharge augmentation. Surface water flowing in effluent streams during the early post-rainy season can be pumped and delivered to such wells, thus saving water that would otherwise have flowed out of the area.

Techniques used for Artificial Recharge of groundwater broadly fall under the categories shown in Table 7 below.

ARTIFICIAL RECHARGE TECHNIQUES		
Direct Methods		**Indirect Methods**
Surface Spreading Techniques	**Sub-surface Techniques**	**Indirect Techniques**
– Flooding – Ditch & furrows – Recharge basins – Runoff conservation structures – Bench terracing – Contour bunds or trenches – Gully plugs, nalah bunds and check dams – Percolation ponds – Stream modification or augmentation	– Injection wells (recharge wells) – Gravity head recharge wells – Recharge pits, dug wells and shafts	– Induced recharge from surface water sources – Aquifer modification – Borehole blasting – Hydrofracturing – Subsurface dykes, groundwater dams, underground “Bandharas”

Table 7 : A summary of artificial recharge techniques (Central Ground Water Board, 2007)

A broad range of technologies and methods can be used to recharge water into the ground, but they are not applicable in all situations. If such projects are to be effective, they need to be well planned, designed, and maintained as part of the catchment and river basin water management strategy. Table 8 below gives an idea of how recharge techniques can be selected based on circumstances, such as topography and elevation.

TYPICAL POSITION AND GRADIENT WITHIN WATERSHED	RECHARGE TECHNIQUE	DESCRIPTION	ADVANTAGES/DISADVANTAGES	INDICATIVE COST / COMPLEXITY
Steep to intermediate slopes (5-20% gradient), piedmont & runoff zones	Gully plugs, nalah bunds, check dams	All are structures constructed across gullies, nalahs or streams to check and retain surface water flows. Gully plugs are used on 1st order streams in steeper terrain, whilst nalah bunds & check dams are used on bigger streams in areas of more gentle topography.	– Will need civil engineering design support – Need to consider how to prevent erosion or scouring of downgradient side – Wide variety of designs and materials can be used – Will need periodic maintenance	Moderate / High
Steep to gentle slopes (2-20% gradient) runoff, piedmont & transition zones	Contour bunds or trenches	Construction of small embankments or bunds across the slope of the land. A water-shed management practice to build up soil moisture content Trenches are rainwater harvesting structures which can be used in low & high rainfall areas to reduce velocity of surface runoff	– Bunds are best used in low rainfall areas – Require permeable soils not recommended for clay rich soils – Some surveying & levelling maybe required	Low / Moderate
Intermediate slopes, (5-10% gradient, piedmont zone)	Bench terracing	Involves levelling slopes with gradients of up to 8% and which have sufficient soil thickness to bring area under irrigation. Aim is to retain runoff to increase soil/ groundwater infiltration rate	– Helps conserve soils – Will require surveying & levelling	Moderate / High
Intermediate slopes, (5-10% gradient, piedmont zone)	Ditch & furrows	Excavation of shallow closely spaced ditches or furrows to provide maximum water contact area for recharge. Recharge from stream or canal, and also needs a collection channel to convey excess water back to the source stream.	– Ditches need adequate gradient to maintain flow velocity to prevent siltation – Easier to construct than recharge basins – Water contact area seldom exceeds 10% – Limited by topographic requirements & need for shallow permeable zone	Low / Low

TYPICAL POSITION AND GRADIENT WITHIN WATERSHED	RECHARGE TECHNIQUE	DESCRIPTION	ADVANTAGES/DISADVANTAGES	INDICATIVE COST / COMPLEXITY
Intermediate to gentle slopes, (2-10% gradient), transition zone	Injection wells (recharge wells)	Boreholes of wells drilled into deeper aquifers to recharge aquifers by gravity or pumping	– Need good understanding of aquifer properties – Expensive, complex installations – Will require specialist civil engineering and hydrological support – High risk of clogging unless backflush pumping can be arranged	High / High
River/stream corridor, intermediate to gentle slopes, (2-10% gradient), transition zone	Stream modification/ augmentation	Modification of the natural drainage channel to slow flows & increase streambed contact area. Can include widening, levelling, scarifying or construction of levees & low head check dams	– Most effective in areas with influent streams and deep groundwater levels – Must be considered to be temporary structures, liable to be destroyed by floods and which will need repair and maintenance	Moderate / Moderate
Intermediate slopes (2-10% gradient), base of piedmont or transition zone	Percolation ponds	Like nalah bunds, but generally larger earthen structures with masonry spillways. Are used to capture runoff to percolate and recharge to groundwater. Size of tank is determined by the infiltration capacity of the underlying soils/rock not the yield of the catchment.	– Most common runoff harvesting structure in India – Good for reducing evaporation losses – But need to be located in permeable areas – Will require periodic maintenance	Moderate / Moderate
River/stream corridor, gentle gradient (>2%) storage zone	Recharge basins	Basins commonly constructed parallel to ephemeral or intermittent stream channels to capture flow. Multiple basins can be used to increase contact time and reduce suspended sediment	– Can be highly effective recharge structures in the right location – Must be located close to surface water source – Will need periodic maintenance and desilting	Moderate / Moderate

TYPICAL POSITION AND GRADIENT WITHIN WATERSHED	RECHARGE TECHNIQUE	DESCRIPTION	ADVANTAGES/DISADVANTAGES	INDICATIVE COST / COMPLEXITY
River/stream corridor, gentle slopes, (<2% gradient), storage zone	Recharge pits, and shafts	Artificial recharge structures that are used to recharge shallow unsaturated aquifers which are not in hydraulic connection with surface water due to the presence of impermeable layers	– Susceptible to clogging & will need periodic maintenance	Moderate / Low
River/stream corridor, gentle slopes, (<2% gradient), storage zone	Gravity head recharge wells	In addition to specially designed injection wells, existing unused dug wells and tube wells or boreholes can be used as cost effective recharge structures when source water becomes available	– Can be very beneficial when wells/boreholes have been abandoned as a result of over-abstraction and lowering of water table levels – Attention should be paid to water quality and possible impact on nearby abstractions	Low / Low
River/stream corridor, gentle gradient (>2%) storage zone	Flooding	Ideal for land adjoining streams or canals. Embankments provided on two sides direct surface water over land, a collection channel to conveys excess water back to the source stream.	– Very cheap to construct – Low maintenance costs – But limited by topographic requirements and need for shallow permeable zone – Risk of flooding of low permeability application area	Low / Low
N/A	Indirect methods	Indirect methods for artificial recharge to groundwater do not involve direct supply of water for recharging aquifers but aim to recharge aquifers by indirect means. The most common methods are induced recharge from surface water sources and aquifer modification techniques. Alternative groundwater conservation techniques designed to slow subsurface flow include groundwater dams, subsurface dykes, underground "Bandharas" or grouting of fractures. All these techniques require a good understanding to the aquifer properties, favourable hydrogeological conditions and can be complex and expensive solutions. They are generally not suitable for WASH or rural water supply type projects and are therefore not considered further.		

Table 8 : Selecting groundwater recharge techniques

RAINWATER HARVESTING

From roofs

Rainwater harvesting is one of the simplest and oldest methods of water supply and involves the collection and storage of rainwater for reuse on-site, rather than allowing it to run off. Rainwater can be collected from roofs, and in many places, the water collected is redirected to a deep pit or a storage tank. The stored water can be used as water for gardens, livestock, irrigation, or domestic use with proper treatment. The harvested water can also be used as drinking water, longer-term storage, and for other purposes such as groundwater recharge.

Several states in India, such as Tamil Nadu, Karnataka and Maharashtra, have already made rainwater harvesting compulsory for every building to avoid groundwater depletion.

For surface water storage

In the arid western state of Rajasthan, India's 'Water Man' Rajendra Singh has helped villages restore their groundwater by promoting the building of small earthen dams called "johads" that collect rainwater and allow it to soak into the ground. Singh was awarded the 2015 Stockholm Water Prize for his successes in "improving water security in rural India."

Figure 33 : A rice paddy

LANDSCAPE INTERVENTIONS

The aim of land and soil management is to increase soil water storage and infiltration rates through re-vegetation and soil improvement measures. Landscape conversion from forest to agricultural land generally increases direct runoff and decreases base and inter flow (together, called groundwater flow) in tropical monsoon climates. Increasing baseflow by land management practices is an effective way to increase agricultural and biomass production during the dry phase.

Moreover, maintaining adequate groundwater flows is important for the health of rivers' habitat ecosystem. Soil and land management such as gully rehabilitation, land enclosures, infiltration furrows with bunds, stone bunds, waterways, planting of trees and fodder plantation, and treatment of degraded soils can be used to change the relationship between precipitation, discharge, and groundwater flow to increase baseflow and reduce surface runoff.

Catchment interventions are site specific and depend on the vegetation species used. Shallow rooted grasses and bushes should be used in low rainfall areas due to their low rates of transpiration. Long term quantitative studies are required, by taking data from the degraded watershed before conversion to a well managed and revegetated one.

During the WASH Basins project, following rehabilitation of existing but non-functional recharge dams and construction of new ones by PSI, the first rains after the summer washed significant amounts of loose soil and debris into channels. The soil at this time is still hard and largely impermeable. This prevents the first rain storms from percolating into the soil resulting in mostly surface runoff and silting behind recharge dams, especially where the land is sloping. This usually reduces after the first few events. WASH service delivery organisations need to be aware of this risk and include it in the operation and maintenance plans developed with Village Water and Sanitaiton Committees (VWSCs). VWSCs need to be made aware that this is not a failure of the system, but an expected risk and occurrence, and it helps to have a plan for desilting recharge dams in such instances as a general approach. Through time and observation it becomes apparent if any sites are more problematic than others, and for which targeted measures may need to be devised, including planting particular types of grasses that may regenerate quicker after drought, for example Vetiver grass. In the long term, preventing erosion through catchment management approaches is the most desirable outcome.

Figure 34 : Landscaping in a project village

COSTING AND DELIVERING WATER SECURITY PLANS

The costs of delivering Water Security Plans may vary between organisations, depending on the balance between a number of things including: scope of work, technical capacity or advocacy role. For example, the WASH Basins project involved PSI, a substantial research and development organisation with a broad range of technical skills available in-house, including hydrogeology, GIS and civil engineering. PSI often works as both an advocacy organisation and Project Implementation Agency (PIA). This means that following the joint development of Water Security Plans with communities, PSI staff would then be involved in the construction of wells and recharge structures, or refurbishment of structures, in addition to working with communities to address water issues or training VWSCs.

On the other hand, Samerth Charitable Trust is less-experienced in terms of the application of technical skills, but focuses and excels at advocacy and working with communities to produce plans for local government funding. Samerth works with a community to deliver a plan to the local government, fully costed and ready for funding and implementation by the District government in line with annual budget commitments for water projects, as allocated by the District Collector.

Nevertheless, in order for successful implementation of the WSP to occur, both organisations provide comprehensive engineering designs and accompanying detailed costs for each plan. Typically, these consist of:

- Capital costs;
- Engineering design drawings;
- Details of materials required for construction;
- Bills of Quantities for engineering structures, including water sources (e.g wells, boreholes, etc) and recharge structures e.g check dams;
- Costs for equipment e.g solar panels, pumps, pipes, tanks, taps, water quality testing equipment, etc;
- Costs for training of VWSCs and jaldoots;
- Costs for other works related to recharge e.g trench digging, boundary planting, pond deepening, bunding, etc; and
- Land costs, where applicable.

In addition to the above points, it is recommended that labour requirements are included, for example in person-hours or number of people working for a given number of days. This may have cost implications where costs are to be shared between programmes such as MGNREGA, BRLF, local government or NGO funds, or where the community is required to provide a minimum proportion of labour for free. It is also recommended that, in the interests of sustainability, the costs of ongoing management costs of the system are budgeted and included as operational costs. These typically should include:

- Costs of water quality testing;
- Costs of pollution prevention activities;
- Costs of proposed catchment management activities;
- Costs of maintaining and repairing recharge structures, water sources and equipment such as pumps; and
- Proposed community contributions (fees and labour), or other revenue streams.

Finally, a sustainable WSP should record how the community plans to operate and maintain the system, including:

- Proposed community responsibilities, or individuals with identified responsibilities e.g jaldoots, owners of private wells, etc;
- Signed agreements with landowners where community water infrastructure is located on private land; these should explain the terms of land use and any benefits or restrictions the landowners may enjoy or place on the community; and
- Proposed community engagement with external stakeholders, including the frequency, timing and nature of engagement, as well as responsibilities as appropriate.

HOME

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REPORTING

Reporting needs will vary from one organisation to the other, or depending on the project, its context and stage at which it is. Reporting requirements are also often determined by WASH funders' requirements.

Furthermore, a variety of tools and metrics for project reporting are in common use in the WASH service delivery sector. It's is difficult, therefore, to review the breadth of tools and metrics required for reporting across the political and social spectrum.

In the context of this toolkit, we have restricted the recommendations for reporting to outline structures for the two reporting stages within the Six-Stage Process i.e 'Stage 2 - Interim Report' and 'Stage 6 - Detailed Project Report or Water Security Plan'. The goal is to ensure that the information captured prior to each stage is presented in the most appropriate way, and at the right level of detail to support decision making with regard to ultimate delivery of WASH services in a sustainable and holistic manner that takes account of project needs and the need for IWRM-supporting processes to be built into the project throughout its life span. The following reports are described:

INTERIM REPORTING

Early-stage reporting following a reconnaissance visit for Stage 2 of the Six-Stage Process

DETAILED REPORTING

The final output of the feasibility stage of a WASH services delivery project following Stage 6 of the Six-Stage Process

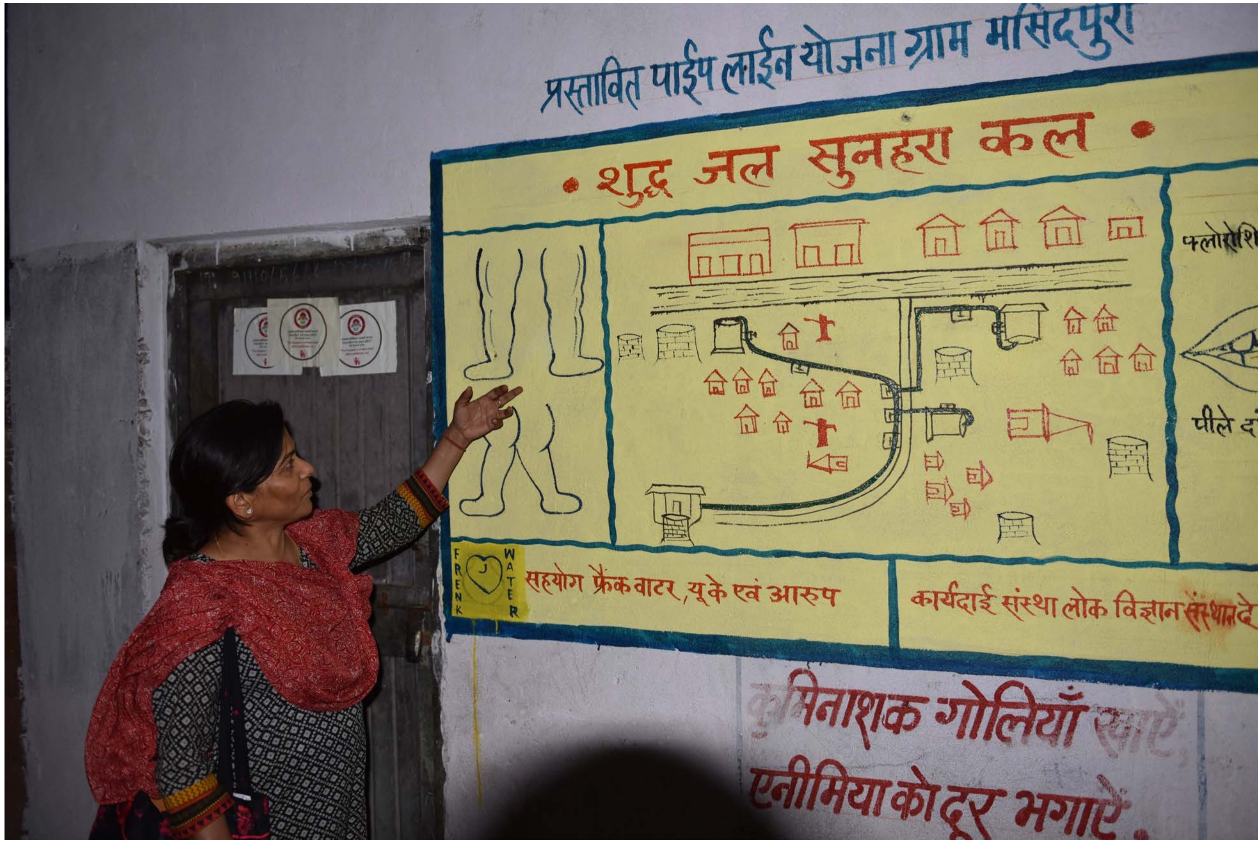

Figure 35 : A PSI member explains the long-term consequences of flouride exposure at a meeting

INTERIM REPORTING

The interim report follows soon after the start of the project, following the reconnaissance visit and initial gathering of information. The expected outcome is a document that:

- Describes the basis of the project, including field data and contextual information. This is useful for continued engagement with the community and other stakeholders, such as local government institutions.
- Presents the scale of the problem, outlines potential solutions at a high level and identifies risks to the project; it should include data gaps and assumptions.
- Identifies the information gathering required in the next stage (Stage 3).

The Interim Report should, ideally, not propose final solutions because more information will be obtained in Stages 3, 4 and 5 of the Six-Stage Process. Potential solutions may be identified at a high level - for example, surface water is not likely to be a suitable or sustainable source of supply all year round because the rivers, streams or reservoirs in the watershed dry up soon after the rainy season ends. In some contexts, the potential solution may be obvious, but would still benefit from further clarification and confirmation through the information and analysis obtained in Stages 3, 4 and 5.

A literature review of WASH resources did not identify clear advice and recommendations for structuring reports at this stage of a project. The suggested content structure provided in this toolkit is based on working formats provided by PSI, amended in line with best practice by Arup. The Interim Report should summarise information on the community and their water and sanitation situation. It should provide an overview of the main watershed or catchment hydrogeological and hydrological features, as well as land cover, land use and other geographical characteristics. The report should mostly consist of social, technological, environmental and political information, in line with the STEEP Framework.

Figure 36 : Simplified mapping of community assets

Below is a suggested outline for the Interim Report:

TITLE PAGE	– Include date, author, project name, village name, village location (District, State, etc) and organisation responsible for the report – Include evidence of quality assurance i.e review by an appropriate senior staff member
CHAPTER 1: INTRODUCTION OR BACKGROUND	– State the project aims and objectives – Identify the project beneficiaries and funders – Identify project stakeholders and roles or interests – Identify related projects
CHAPTER 2: COMMUNITY CONTEXT	– Describe village population and make up - use the results of initial surveys, information from the government or other reports. – Other water users in the watershed - identified from field visits, literature or government information – Discuss community leadership, including the existing leadership structures, including whether or not a Village Water and Sanitation Committee (or Water User Committee) exists – Discuss any land ownership issues, and the community's willingness to provide access to private land for the public good – Include analysis of field data - graphs, photographs and numerical analysis as appropriate
CHAPTER 3: STUDY AREA	– Describe location and details of local geography - topography, land cover, land use, soil types – Describe hydrology and details of watershed and external influences - rainfall, evaporation, etc – Describe geology and hydrogeology and external influences - rock types, water chemistry (presence of iron, manganese, fluoride, etc), preliminary conceptual models – Include analysis of field data - graphs, photographs and numerical analysis as appropriate
CHAPTER 4: WATER RESOURCES SITUATION	– Describe the key water resources - rainfall, groundwater recharge, surface water resources, groundwater resources and manmade structures – Describe how the local water resources fit into the wider context i.e political context (State) or natural context (catchment or aquifer) – Describe the main water demands and water uses - record external demands as well, such as tankers drawing water for urban areas – Describe any water related problems that have been experienced in the community e.g droughts, crop failure, flooding, pollution or illness due to poor water quality – Describe potential ways of addressing the problems (at a very high level) including community proposals or preferences – Include analysis of field data - graphs, photographs and numerical analysis as appropriate

CHAPTER 5: NEXT STEPS	– Describe themes arising from the information gathering – Describe gaps in data and information and how these will be addressed in Stages 3, 4, 5 and 6 – Describe any potential solutions at a very high level, which are subject to new information and data gathering – Describe further community engagement and other stakeholder engagement plans – Describe a programme for Stage 3 field visit or visits for data collection – Identify any gaps in skills required to carry out tasks in Stages 3, 4 and 5 – Include analysis of field data - graphs, photographs and numerical analysis as appropriate

Table 9 : Suggested structure for an Interim Report

In addition to the suggested report outline provided above, the following points should be taken into consideration:

- Try to obtain information on other water users in the catchment, especially if there are large users such as industries or power plants which can have a significant influence on water availability throughout the catchment.
- Is there a regulatory or registration system within the state or district which records details of abstraction licences? If not, could a simple format be used which combines local knowledge and reconnaissance information?
- Try as much as possible to display information using GIS maps or enhanced Google Maps, Google Earth, Bing Maps or Open Street Maps to which field information has been added. This improves the clarity of information and can be the basis for Management Information Systems (MIS), building on the digital collection of data.

DETAILED REPORTING

The detailed project report should be the final output of the feasibility stage of a WASH services delivery project. The next step is expected to be the construction phase of the project, following which handover to the community and operation commences, in accordance with local government and the project implementing agency's processes.

To ensure sustainability of the project, the detailed project report should not mark the end of the project, rather the beginning of a new baseline. It is critical for IWRM purposes that the operation of the project includes not just the expected aspects of a WASH project (maintenance, VWSC management, water quality testing, fee collection, sanitation training and measures), but information on the wider water resources context within which the project sits. Monitoring of water sources, water use (demands) over time and the impacts of recharge should be included, in line with the baseline information and templates outlined in the project report and throughout the Six-Stage Process.

Where appropriate information on threats and risks including climate change are available (refer to information links in Stages 1 to 6), they should be monitored and incorporated into updates on the sustainability of the community's water resources. On a regular basis (monthly, quarterly, six monthly or annually) the monitoring information should be actively shared with local government as appropriate (District and State) and with other relevant stakeholders, for example other water-sector projects.

It is through adhering to this holistic approach that the report begins to fulfil its function as a Water Security Plan.

The expected outcomes of a Detailed Project Report or Water Security Plan are to:

- Document the 'Water Security Plan' or 'Water Resources Plan' agreed with communities;
- Confirm the WASH service delivery solutions and costs;
- Enable a Project Implementation Agency (PIA) such as an NGO or CSO to deliver the project as outlined;
- Enable a funding body such as PHED or local government to fund for delivery; and
- Document the delivery process of the project for future reference, including monitoring, evaluation and learning (MEL) requirements and reporting against SDG 6 Targets and Indicators, including Target 6.5 Indicator 6.5.1 'Degree of integrated water resources management implementation'.

A literature review of WASH resources did not identify clear advice and recommendations for structuring project reports, or a standard structure. The suggested Table of Contents in Table 10 structure provided in this Toolkit is based on working formats provided by PSI and Samerth amended in line with best practice by Arup.

The Detailed Project Report should bring together all the project information in a coherent manner, enabling non-participants to understand the problems faced, solutions developed and how they have been arrived at, as well as the proposed execution, operation, maintenance and monitoring of the project objectives and outcomes. The report should consist of all Social, Technological, Environmental, Economic and Political information, in line with the STEEP Framework.

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Below is a suggested outline for the Detailed Report:

TITLE PAGES	– Include date, author, project name, village name, village location (District, State, etc) and organisation responsible for the report. – Include evidence of quality assurance (QA) i.e review by an appropriate senior staff member
CHAPTER 1: INTRODUCTION OR BACKGROUND	– 1.1 Background to project and location/area – 1.2 Objectives of project – 1.3 Expected outcomes of project – 1.4 Project methodology in brief, including application of Six-Stage Process
CHAPTER 2 : STUDY AREA	– 2.1 Description of community - village or Gram Panchayat – 2.2 General demographic and social information - families, census data, types of households, land ownership, etc – 2.3 Livelihoods - land use, cropping patterns, village level livestock Information, social implications, water use implications, etc – 2.4 Local government and local social institutions - e.g. schools primary health centres, anganwadis (early child care centres), village-level self-help groups, etc
CHAPTER 3: LOCAL GEOGRAPHY, HYDROLOGY AND HYDROGEOLOGY	– 3.1 Geography - topography, land cover, land use, soil types, etc – 3.2 Climate - the most relevant elements are rainfall (amount and patterns), temperature and evaporation or evapotranspiration – 3.3 Hydrology (surface water) - rivers, streams, surface water bodies, watersheds, catchments – 3.4 Geological formations and hydrogeology (groundwater) - soil and rock formations, occurrence of water-bearing aquifers, water chemistry
CHAPTER 4: BASELINE (CURRENT) WATER AVAILABILITY (SOURCES) AND WATER USE (DEMAND)	– 4.1 Village water sources - wells, handpump boreholes, bore wells, ponds, canals, storage reservoirs, rainwater tanks, etc, and how they are used – 4.2 Identification of existing water issues in the village - water quality, water-related illness, water availability, seasonality, drought, competing demands, non-functional infrastructure, maintenance and management problems, soil erosion, flooding, etc. Record external demands as well, such as tankers drawing water for urban areas – 4.3 Problem identification - discussion of water problems within community context i.e water needs and important issues relating to water use – 4.4 Assessment of potential solutions, including availability of land and access to private land or water sources for community good – 4.5 Assessment of the status, capabilities, roles and responsibilities of the Village/ Panchayat Water and Sanitation Committee

CHAPTER 5: WATER RESOURCE PLANNING	– 5.1 Project methodology, including the Six-Stage process – 5.2 Household water demand and availability – 5.3 Institutional water demand and availability - schools, anganwadis, etc – 5.4 Livestock water demand and availability – 5.5 Irrigation water demand and availability – 5.6 External water demands, if they exist - for example tankers drawing water from local wells for urban areas; industrial demand, etc – 5.7 Baseline water supply-demand balance - report outputs of calculations from the water balance assessment in Stage 5.

CHAPTER 6: WATER SECURITY PLAN	– 6.1 Explain the water supply-demand balance - whether it is in deficit (i.e demand is greater than supply) or surplus (i.e supply is greater than demand). Determine what solution is required: for deficit - reduce demand or increase supply, and by how much. For surplus, how big is the surplus, is it likely to change and how best can the surplus be maintained? Livelihood and economic activities should be discussed, and how the water needs will be met.
	– 6.2 Solution identification - map potential solutions to the problems identified. This will include creation of new sources; improvement, refurbishment or replacement of existing sources; identification of recharge potential and development of recharge solutions and refurbishment of existing recharge structures in order to improve supply availability and utilise monsoon rains.
	– 6.3 Water supply plans for each village - sources of water for each demand type, water quality, management, VWSC, fees, frequency of use, source protection measures, other proposed interventions, etc
	– 6.4 Water recharge proposals for each source, where feasible and appropriate or for each village
	– 6.5 Sanitation and hygiene needs, and how they will be addressed. Include proposed water and sanitation infrastructure solutions and their designs and costs
	– 6.5 Budget costs, funding requirements, engineering designs and hydrological or hydrogeological requirements, as appropriate
	– 6.6 Sustainability activities
	  – Land use, stakeholder responsibilities, water management procedures, water quality testing and pollution prevention activities
	  – Proposed catchment management solutions, implementation plans, costs and responsibilities
	  – Proposed community contributions and responsibilities, including fees, maintenance or individuals with identified responsibilities
	  – Proposed community engagement with external stakeholders, including frequency, timing and nature of engagement, as well as responsibilities as appropriate

Annex 1: Photographs; **Annex 2:** Data Tables and Analysis Graphs or Templates e.g Water Balance Assessment, Pump test results, etc; **Annex 3:** Design Details and Drawings; **Annex 4:** Costing Details	

Table 10 : Suggested outline for the Detailed Report

WORKING WITH STAKEHOLDERS

Working with stakeholders representing different scales and interests is core to successful IWRM implementation.

Vertical and horizontal integration across these groups, for example by sharing skills, data and responsibilities, can help all stakeholders make better decisions around water management. India has a unique and continuously evolving system for water governance. It is hierarchical (descending from the National Government to Village Panchayats), but also complex - with different Government Ministries and State Departments having influence and ownership over aspects of the water cycle.

Figure 37 : An impromptu discussion with community members

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STAKEHOLDER ENGAGEMENT

Awareness of the key stakeholders, both inside and outside government, is important when implementing a water resources management project - especially where policies, programmes, missions or procedures already exist in relation to IWRM. It is also important to understand the different levels at which the stakeholders are involved, in order to encourage efficiency by engaging with those most relevant to WASH service delivery and able to build on community-based data relevant for IWRM.

Some of the key hierarchical actors within the system of government in India are summarised below.

THE NATIONAL GOVERNMENT

The National Government sets the high-level policy and strategic goals for how water is managed in India at all levels, including the National Water Policy, groundwater policies, sanitation policies and many others. It guides investments in the water sector and supports State governments with funding, training, research, quality monitoring and human resource development, and sanctions funds to States. The sanctioning process is monitored to ensure that the States deliver on the set targets and show progress against them.

Furthermore, the National Government is responsible for monitoring and reporting their progress against the Sustainable Development Goals, including Goal 6.5 - Integrated Water Resources Management, although India has not yet reported against this at the time of writing.

A minimum level of awareness of the broad strategic goals of the National Government can aid working with stakeholders at other levels.

STATE GOVERNMENTS

States are responsible for the planning, design and execution of water resources management programmes. State governments are supported by various State departments, including:

- The Public Health and Engineering Department (PHED);
- Rural Development Department and Water Boards; and
- The State Water and Sanitation Mission (SWSM).

Each individual State has a high degree of freedom over the application of water resources management, and may engage in projects which reflect their own understanding of how IWRM principles can be applied. An example is Chhattisgarh State's High Impact Mega Watershed Project, in collaboration with Pradan, the Bharat Rural Livelihoods Foundation and Axis Bank Foundation. The aim is to work at a watershed scale to sustainably improve the productivity and income of small and marginal farmers.

DISTRICT GOVERNMENT

The District Collector is one of the primary distributors of funds for water resources management projects, and therefore building a relationship with this individual can be a critical part of ensuring project sustainability. Each District is likely to have a format and timetable for the submission of proposals for funding, which the WASH delivery services project implementer should be aware of. For example, 'Gram Panchayat Development Plans' (GPDPs) may be submitted for approval on a regular basis, and can be used to fund water resources, water supply and sanitation infrastructure. Evidence suggests that building local capacity within local communities for developing GPDPs can increase the chances of funding being awarded to water resources management schemes.

The 'District Water and Sanitation Mission' is tasked with helping communities plan, implement, operate and manage schemes in their areas. The 'Public Health and Engineering Department' (PHED) at District level is the body responsible for constructing and managing water and sanitation infrastructure on behalf of the government. It may be possible to partner with this organisation to up-scale an approach to IWRM using District funds, where it can be clearly demonstrated that there is alignment between each organisation.

GRAM PANCHAYAT

Gram Panchayats (or Village Panchayats) play a crucial role in the water management process. They are required to take over planning of programmes at a village cluster level, and submit regular development plans to the District Government. They may be considered the main partner, or client, in any water and sanitation scheme.

VILLAGE-LEVEL INSTITUTIONS

Village Water and Sanitation Committees (VWSCs), or other organisations with similar names and remits such as Water User Committees (WUCs), are commonly found at village-level across India. They are responsible for managing small scale water and sanitation infrastructure, both for domestic and agricultural use. They may be responsible for allocations between competing users, and in some cases for monitoring. This makes them a crucial partner for the successful implementation of a local IWRM framework.

Also at village level, community leaders (in formal or informal positions) may hold great influence over other members of a community, have a deep appreciation of historical contexts and can support the long-term sustainability of schemes.

Village land can be owned collectively or privately, and it is common for wells or other water supply infrastructure to be sited on common land. This could be provided by the private owner free of charge (pro bono), or for a regular fee. It is important to engage significant landowners from an early stage if there is a chance infrastructure could be constructed on private land. There is a significant and real risk that the status of land provided for free could change over time, or that access could be limited, which would have implications for the sustainability of schemes. It may therefore be necessary to formalise the status of land designated for water infrastructure as far as possible.

GOVERNMENT-SUPPORTED SCHEMES AND NON-GOVERNMENTAL ORGANISATIONS (NGOS)

A range of institutions and missions, and non-governmental organisations exist outside the hierarchical structure of government. Some examples are given below:

MGNREGA

The Mahatma Gandhi National Rural Employment Guarantee Act is a guaranteed 'right to work' for rural communities. It guarantees 100 hours of paid employment per year for all rural households who engage in unskilled labour. The scheme has successfully been used for the construction and maintenance of water infrastructure, such as wells, across India.

Bharat Rural Livelihoods Foundation

The Foundation was set up by the Government of India to upscale civil society action in tribal areas of central India. They offer grant support, research and knowledge management and capacity building. In recent years they have supported watershed-scale management and sustainable agricultural development.

Infrastructure for Climate Resilient Growth

This programme aims to improve the design and implementation of Natural Resource Management activities carried out under MGNREGA. They are supporting the deployment of GIS mapping using a shared India-wide platform, Bhuvan. The mapping platform includes projected climate impacts on temperature, rainfall and forest cover. Working with the programme can help communities to develop climate-resilient water infrastructure.

MONITORING, EVALUATION AND LEARNING

The benefits of water resources management projects are rarely realised immediately.

The ouputs of water resources management projects are typically complex, collaborative, multi-sectoral, and intangible in the short term. Therefore, it is important that monitoring, evaluation and learning (MEL) is considered from the very start of project planning to provide assurance, or otherwise, as to the value of physical interventions.

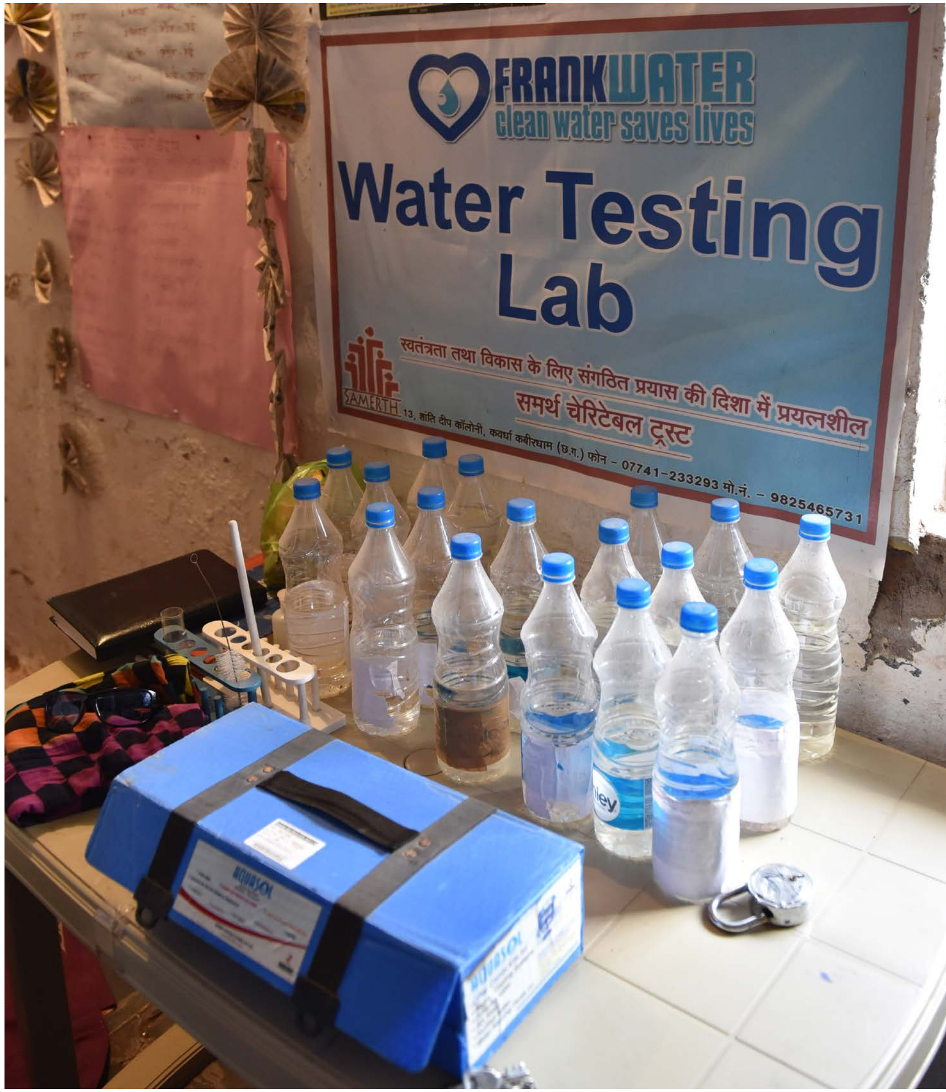

Figure 38 : A water testing lab

MEL is a widely studied topic within the WASH and development sectors. Selected guidance for project-level MEL is provided below:

SOURCE	DESCRIPTION
BOND Monitoring, Evaluation and Learning Resources	Bond is a respected UK network for organisations working in international development, and they host a wide range of resources for MEL and impact planning
Theory of Change	The Theory of Change is used by a multitude of high profile organisations, including the UK's Department for International Development, for project impact planning.

Table 11 : Selected guidance for Monitoring, Evaluation and Learning

The purpose of any MEL framework is to understand the extent to which a project is progressing to a defined goal, and learns from the success or otherwise of this process to improve the process of future project iterations and to inform others. Some key definitions relevant to this area are:

MONITORING	The process of measuring the progress being made towards achieving goals and objectives. It focuses on tracking projects and the use of funds, but also on tracking strategies and actions being taken, and establishing what new strategies and actions need to be taken.
INDICATOR	A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, recognise the changes connected to an intervention or to help assess the performance of a development actor. There are two basic criteria for indicators: validity and efficiency. Validity refers to the quality of the indicator in measuring the current conditions and in measuring progress; efficiency refers to the effects of the indicator in relation to the cost and effort required to collect information.
EVALUATION	The process of determining the relevance, efficiency, effectiveness and impact of activities in the light of their objectives in a systematic and objective manner. It encompasses the gathering of information, including but not only that obtained through monitoring, and the use of such information to make judgements and take informed decisions about a given process. While monitoring is a continuous process, evaluation is a task that takes place at critical times in a given process.

Table 12 : Defining monitoring, evaluation and learning

THE INTERNATIONAL CONTEXT

The Sustainable Development Goals (SDGs) are 17 globally-agreed goals that aim to contribute to development for everyone, everywhere. The goals explicitly reference the sustainable management of water across the water cycle. SDG Target 6.5, Water Resources Management, aims to "implement integrated water resources management at all levels, including through transboundary cooperation as appropriate".

Progress towards implementing sustainable water resources management at a National level (excluding transboundary considerations) is monitored using Indicator 6.5.1 - "Degree of integrated water resources management implementation".

Indicator 6.5.1 is monitored by the United Nations Environment Programme (UNEP) at a national level using a primarily qualitative global questionnaire. It assesses four key components of IWRM:

- **Enabling environment** - Creating the conditions that help to support the implementation of IWRM, which includes policy, legal and strategic planning tools;
- **Institutions and participation** - The range and roles of political, social, economic and administrative institutions and other stakeholder groups that help to support the implementation of IWRM;
- **Management instruments** - The tools and activities that enable decision-makers and users to make rational and informed choices between alternative actions; and
- **Financing** - Budgeting and financing made available and used for water resources development and management.

Each country is assigned an IWRM 'focal point', with the responsibility for completing the questionnaire and submitting the outcomes UNEP. At the time of writing, India is one of 16 nations which have not yet submitted evidence for Indicator 6.5.1.

The indicator is high-level, largely qualitative, and disconnected from the experience of individuals on the ground. However, practitioners may wish to consider whether it would be fruitful to align their framework for monitoring with Indicator 6.5.1, and therefore demonstrate compliance and contribution to the global Sustainable Development Goals.

Useful links to support alignment with SDG Goal 6.5, Target 6.5.1 are given in Table 13.

THE NATIONAL CONTEXT - WATER RESOURCES MANAGEMENT MONITORING

As previously noted, at the time of writing India has not yet submitted evidence for SDG Indicator 6.5.1. However, NITI Aayog (a policy think tank of the Government of India) produces the Composite Water Management Index which compares State-by-State performance for water management using a consistent framework. Indicators include the rate of groundwater exploitation, groundwater recharge, water harvesting, demand management and others. Project practitioners may wish to consider close alignment with the NITI Aayong methodology to order to gain State-level support for an IWRM scheme.

SOURCE	DESCRIPTION
Local and District monitoring for SDG Indicator 6.5.1	Qualitative guidance for the alignment of District-level monitoring of IWRM with the higher-level requirements of SDG 6.5
Step by step monitoring methodology for Indicator 6.5.1	A step-by-step guide for national-level monitoring of SDG Indicator 6.5.1
IWRM Data Portal	Up-to-date information on national submissions for Indicator 6.5.1

Table 13 : Guidance for monitoring SDG Indicator 6.5.1

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PROJECT-LEVEL MONITORING

As part of the development of the WASH Basins toolkit, a common framework was developed with both quantitative and qualitative indicators aligned against the SDGs. A summary of the indicators used is given below:

SDG INDICATOR	PROJECT-LEVEL INDICATOR
Target 6.1 - By 2030, achieve universal and equitable access to safe and affordable drinking water for all	A-1 Number of constructed water supply systems
	A-2 Percentage of population in target villages or Gram Panchayats using safely managed water services
Target 6.2 - By 2030, achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	B-1 Number of applications submitted for toilet construction
	B-2 Proportion of population in target villages or Gram Panchayats using a hand-washing facility with soap and water
Target 6.5 - By 2030 implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	C-1 Proportion of total renewable water resources used at village level
	C-2 Outcome of qualitative assessment of Knowledge, Attitute and Practice of village-level institutions
	C-2 Outcome of qualitative assessment of Knowledge, Attitute and Practice of District-level institutions

Table 14 : SDG and project-level indicators for the WASH Basins project[1]

1 https://sustainabledevelopment.un.org/sdg6

REFERENCES & ANNEXES

ANNEX I: ABOUT THE WASH BASINS PROJECT

WASH Basins is a collaborative project between Arup, FRANK Water and two India-based WASH NGOs; People's Science Institute (PSI) and Samerth Charitable Trust (Samerth). Together, the organisations set out to to develop an India-specific approach to utilising Integrated Water Resources Management (IWRM) principles to support sustainable and inclusive water, sanitation and hygiene (WASH) services.

THE KEY INTENDED OUTCOME OF THE PROJECT

"The sustainable development and management of water, land, and related resources using IWRM to maximise the availability of WASH in marginalised communities in Madhya Pradesh and Chhattisgarh States in India."

FRANK Water, Arup and their partners identified a theoretical and practical disconnect amongst governmental and non-governmental organisations with regards to the application of IWRM and the provision of WASH services. IWRM frameworks are often seen to be at odds with, or disconnected from, the pressing need for expanded access to safe water, sanitation and hygiene amongst the world's most vulnerable communities. By working together, we have contributed towards bridging this gap at multiple levels of governance.

Through research and site visits at the outset of the project in 2018, Arup and FRANK Water found a mixed level of understanding in India of the relevance of IWRM at District and Gram Panchayat levels, and a misalignment between national and state level IWRM policies and frameworks. They have also experienced a general lack of awareness of the significance of IWRM in relation to sustainable, long-term water and sanitation service provision.

ABOUT ARUP

Arup is a multi-disciplinary global consultancy, with knowledge and expertise in services across the water cycle. As a strategic partner of FRANK Water since 2016, through technical and financial support, they are helping to upscale and improve the effectiveness of their work in India and Nepal.

ABOUT FRANK WATER

FRANK Water is an international development organisation working in India and Nepal. They tackle the global water crisis by helping marginalised communities to improve their own lives by creating the capacity and enabling environment for community development to occur. FRANK Water's partners in India and Nepal have a wealth of experience empowering communities to manage their own water, sanitation and hygiene programmes.

THE ARUP GLOBAL CHALLENGE

The WASH Basins project is part of Arup's five-year internal Global Challenge programme. Launched in 2017, Arup's Global Challenge allows Arup staff to use their skills and expertise to benefit vulnerable and marginalised communities by designing and delivering transformative projects collaboratively with charitable organisations, NGOs, public bodies and other partners. The programme forms part of our firm's broader Community Engagement work and commitment to supporting the UN Sustainable Development Goals (UN SDGs). We have focused on the SDGs where we can deliver the greatest positive impact, based on our skills and experience.

Arup has committed £5 million over the period 2017 – 2022 to Global Challenge. Of the 17 UN SDGs, Arup Global Challenge focussed on projects aligned to SDG 6 'Water and Sanitation' and SDG 7 'Affordable and Clean Energy' between 2017 & 2018.

REFERENCES & ANNEXES

ANNEX II: INTERNATIONAL CASE STUDIES

Arup and FRANK Water worked with PSI and Samerth over a two-year period to navigate the complexities associated with the governance of water resources in India whilst developing the processes and approaches described in this toolkit. Case studies for each partner are described in the Six-Stage Process. The project also identified selected case studies which explore approaches to community-based IWRM which influenced the development of the toolkit.

CASE STUDY I: WATERAID IN INDIA AND WEST AFRICA

WaterAid have played an internationally significant role in helping to realise the benefits of IWRM for communities through the development of theoretical approaches, practical guidance and 'on the ground' applications. Through their experiences in India and West Africa, they have applied techniques in participatory identification of risks to water security, water budgeting and the use of mobile applications for data collection and analysis.

Through their recently published Water Security Framework they present a broad overview of threats to water security, explain its multifaceted nature, and present a five stage approach to improving it:

1. **Assessment** of the water balance, risks and current coping strategies;
2. Fair and equitable **bargaining** over water rights;
3. **Codifying** water rights;
4. **Delegating** responsibility for water management; and
5. **Engineering** water infrastructure.

Their structured and holistic approach has influenced the development of the WASH Basins Toolkit to give it additional focus where guidance is presently lacking.

Source: https://washmatters.wateraid.org/water-security

CASE STUDY II: MARVI PROJECT, INDIA

The "Managing Aquifer Recharge and Sustaining Groundwater Use through Village-level Intervention" (MARVI) project has developed a village-level participatory approach for measuring groundwater levels and improving water-use efficiency in groundwater-stressed regions of India. As part of the project, local volunteers are up-skilled to measure and monitor groundwater levels to support the planning of groundwater use at a local level. The project focussed on two areas in India with depleting groundwater, and helped to build participatory processes for improving cooperative decisions around sustainable groundwater use through, for example, Village Groundwater Cooperatives. The project used the "My Well" app to share and visualise groundwater data in a way that farmers could understand. As a result, farmers have rehabilitated groundwater recharge structures, improved water use efficiency, diversified crop types based on water consumption and avoided drilling boreholes too deep. The project has demonstrated how a trans-disciplinary, participatory approach has enabled communities to make better decisions about groundwater management. It has helped to influence our work with our partners, especially the need to empower and up-skill community members in groundwater management.

Source: http://www.marvi.org.in/

CASE STUDY III: WATER UP, RAJASTHAN AND COLOMBIA

How can we achieve rural resilience in arid environments? Globally, around 2.4 billion people in hyper-arid, arid and semi-arid climates live with water shortages. With the more extreme weather events predicted with climate change, this number is only expected to increase.

Through the observation of both traditional and newly-constructed rainwater harvesting structures in Rajasthan, India, the WaterUp team quantified the benefits for groundwater hydrology and community livelihoods, in addition to fully documenting the construction process. Using this information, WaterUp will produce language-neutral, digitally-enabled educational materials on the use of traditionally engineered, community-driven water management techniques to catalyse landscape restoration. These are being tested in different communities in India and Colombia to test the transferability of both the learning materials and groundwater recharge techniques.

WASH Basin is working closely with WaterUp to share project outcomes and lessons learnt, with the possibility of integrating the two approaches at a later stage.

Source: https://www.arup.com/projects/waterup

REFERENCES & ANNEXES

ANNEX III: ACKNOWLEDGEMENTS

Arup and FRANK Water would like to say a huge thank you to our India-based partners on the project - **PSI** and **Samerth**! Through their deep and wide-ranging knowledge of the water and sanitation sector in India, their expertise in integrated water resources management and their work empowering the poorest and most marginalised communities in India, they are the ones who have driven the creation of this toolkit.

Thank you especially to **Gazala Paul**, Director of Samerth and **Anita Sharma**, Director of PSI for their work applying and demonstrating the value ot IWRM in maginalised communities. Particular thanks go to **Vargish Bamola**, lead hydrogeologist at PSI, **Palash Agrawal**, hydrogeologist at Samerth and to **Dr. Manjeet Kaur Bal** of Samerth for her dedication to the project and for harnessing her amazing networks within India. And of course, to the rest of the team at PSI and Samerth!

Within FRANK Water, Programme Manager **Jon Shepherd** took on the task of managing this complex and multi-faced project, supported by experienced India-based Deputy Project Managers **Praveena Sridhar** and **Sachin Tawari**. Back in the UK, **Claire Allen** helped to bring the toolkit to the world with her marketing and web support.

Within Arup, **Philip Songa** and **Gerd Cachandt** brought their technical expertise and extensive international experience to the project, supported by **Hamish Hay** as technical reviewer and former leader of Arup's partnership with FRANK Water. **Vera Ngosi** and **Lia Silva** expertly steered the project as successive Project Managers whilst **Steven Johnson** initiated and saw the potential in the project.

Catherine Wenger provided calm and collected guidance as Project Director throughout whilst **Mark Fletcher**, as project sponsor, donated his endless enthusiasm and experience in the world of water and sanitation. A big thank you is also extended to **Irene Gleeson** and **Tim White** from the Arup Community Engagement Global Challenge Team for their support throughout the project, and for commiting to providing initial funding and the bulk of the project budget.

Finally, we would like to thank **Iñigo Ruiz-Apilánez** from Arup's International Development Team, **Arjen Naafs** from IRC WASH and **Harm Bouta** from ZOA for reviewing and providing valuable feedback on the draft toolkit.

Figure 39 : The WASH Basins Team on a site visit in Kawardah District in April 2018

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ACRONYMS

AR	Artificial (Groundwater) Recharge
AWS	Automatic Weather Stations
BRLF	Bharat Rural Livelihoods Foundation
CSO	Civil Society Organisation
CWRM	Community Water Resources Management
DEM	Digital Elevation Model
GIS	Geographical Information System
GP	Gram Panchayat
GPDP	Gram Panchayat Development Plan
GPS	Geographical Positioning System
GWP	Global Water Partnerhsip
ISRO	Indian Space Research Organisation
IWRM	Integrated Water Resources Management
KEWASNET	Kenya Water and Sanitation Network
MDG	Millenium Development Goals
MEL	Monitoring, Evaluation and Learning
MGNREGA	Mahatma Gandhi National Rural Empoyment Guarantee Act 2005
MIS	Management Informatino System
NGO	Non-Governmental Organisation
PFZ	Potential Fishing Zone
PHED	Public Health and Engineering Department (India)
PIA	Project Implementation Agency
SDGs	Sustainable Development Goals
STEEP	Social, Technical, Environmental, Economic and Political
SWSM	State Water and Sanitation Mission (India)
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VWSC	Village Water and Sanitation Committee (India)
WASH	Water, Sanitation and Hygiene
WRM	Water Resources Management
WRUA	Water Resource User Associations

GLOSSARY

Important hydrological and hydrogeological terms.

Hydrology	
Term	**Description**
Artificial reservoirs	Man-made reservoirs. May be lined with a low permeability liner, or dammed.
Catchment	An area of land that is drained by a river and its tributaries.
Condensation	The conversion of water vapour in the air into liquid water.
Discharge	The volumetric flow rate of water. Some examples include through the ground, into a river, or out of a spring.
Evaporation	The conversion of liquid water into water vapour in the air. Occurs on free water surfaces such as lakes, reservoirs and rivers. Rate is dependent on temperature, wind and the humidity of the air above the water.
Evaporation data	Measure of the total evaporation from a surface water source.
Evapotranspiration	Conversion of water from soil and plants into water vapour in the air.
Evapotranspiration data	The measured value of evapotranspiration across an area. This may be measured using an atmometer or using a soil moisture depletion equation.
Hydrological Cycle	The water cycle.
Lag-time	The time delay between a period of rainfall and the rise in surface water and groundwater levels. Usually shown on a time-series hydrograph.
Land use data	Usually overlaid on a map which shows the different uses of land. May include farming, residential and industrial uses as an example.
Precipitation	Condensation of water vapour from the atmosphere falling form the air as rain, snow, sleet, or hail.
Precipitation data	A measure of the amount of precipitation over a period of time. Usually measured using a rain gauge.
River basin	The drainage area of a region. Usually bounded by topographic highs.
Runoff	Water that flows overland. Can occur when ground conditions do not allow water to sink into the ground, for example due to high saturation or low permeability.
Stream and river flow data	Specific measurements can include the river stage (height of water), and the flow rate.
Surface water features	Any main water feature that is on the surface of the ground. These include, lakes, streams, rivers, canals and springs.
Topography data	A measurement of the height of a land surface. Topographic data can be converted into ground level contours and digital elevation models.
Transpiration	Evaporation of water from plant leaves.
Water balance	An equation to show the flow of water into and out of a system.
Water points	A point where water is sourced from, for example a well, river or lake.
Watershed	The divide between water catchments.
Wetlands	Saturated land consisting of marshes or swamps.

GIS	
Term	**Description**
Delineation	Drawing lines onto a map to identify a watershed's boundaries.
DEM	Digital elevation model - topographic data of a region which can be used to simulate the ground surface.

Hydrogeology	
Term	**Description**
3D geology	Changes in geology both vertically and horizontally, which can greatly influence the way groundwater behaves. Groundwater can either move vertically or horizontally dependant on the 3D geology.
Abstraction	Removal of groundwater from an aquifer.
Aquiclude	A geological unit of such low permeability that is incapable of transmitting significant quantities of water and can act as a barrier to regional groundwater flow. Aquiclude rocks include: clays, shales and unfractured crystalline rocks.
Aquifer	A layer or layered sequence of rock/sediment with sufficient permeability to transmit and store groundwater. These can be exploited economically from wells or springs. Aquifer rocks include: Sands, gravels, sandstones, fractured crystalline rock (highly fractured).
Aquitard	A lower permeability geological formation that may transmit quantities of water that are significant over a regional scale, but from which negligible supplies can be obtained. Aquitard rocks include: fluvial and glacio-fluvial silts and sandy clays, sedimentary rocks with few fractures and fractured crystalline rock (less fractured).
Aquifer behaviour	The way an aquifer responds to pumping and levels of stress. The behaviour of an aquifer can provide an indication of the aquifer parameters.
Aquifer pumping test	A pumping test involves abstraction of water from a well and observing the resulting drawdown. This drawdown over a set period of time can then provide information on how the aquifer behaves under stressed conditions. Aquifer parameters (characteristics) can then be established using this information.
Aquifer recharge	The volume of water within an aquifer will refill (recharge) overtime as a result of infiltration from surface water sources above the ground. The recharge rate depends on the pathway from the surface to the aquifer itself, and the volume of water available from rainfall, surface water sources and man-made water sources.
Aquifer recharge schemes	Man-made schemes to maximise the amount of recharge an aquifer receives. These schemes can also be referred to as "artificial recharge" or "managed aquifer recharge". These can include check dams, infiltration ponds, boreholes or shaft recharge, and riverbed scarification.
Aquifer response	The way in which an aquifer responds under stress during a pumping test. This will determine the potential yields available.

Aquifer stress	Removing more water than is recharging the aquifer by over pumping, causing in a decrease (drawdown) in water levels.
Aquifer thickness	The thickness (usually vertical and measured in metres or feet) of the permeable geological unit. Many aquifers may be constrained below by an aquitard or aquiclude if unconfined, and may also be constrained above if confined.
Artesian Aquifer	An aquifer under high pressure head conditions which may cause flow upwards. A well drilled into an artesian aquifer may cause groundwater to flow to the surface under natural conditions.
Baseflow	The groundwater flow into a river. The flow can either be towards the river, or away from the river depending on the groundwater level relative to the water within the river.
Bedrock contour maps	The mapped surface of a geological unit beneath the ground. Just as a topographic map shows the elevation at the surface, a bedrock contour map will show the shape of the surface of the geological unit, allowing an estimation of the distance from the surface to the geological unit.
Borehole / tube well	A narrow hole drilled into the ground to access water within an aquifer. These can be either groundwater monitoring boreholes (for monitoring groundwater levels), or abstraction boreholes (for the removal of groundwater for use).
Borehole construction	The design of a borehole and the construction method will depend on the geology of the drilled unit and the depth.
Borehole drilling	A borehole is usually drilled using a drilling rig and a drilling crew. There are a variety of different types of drilling rig suitable for different geologies.
Borehole pump	There are a wide range of different pumps that can be used for a borehole. These can either be submersible (within the borehole), or on the surface.
Confined aquifer	A confined aquifer has a low permeability layer above and below it, and the water within the aquifer is contained under pressure. If the water is lowered below the top of the aquifer, it becomes unconfined. A hole drilled into an aquifer may be artesian if the position of the borehole is lower than the hydraulic head within the aquifer.
Confining layer	A low permeability layer overlaying an aquifer causing the water within the aquifer to act under pressure.
Constant rate test	Pumping at a constant rate to test the aquifer's response.
Contamination	Degraded quality of water which can come from range of sources. May include hydrocarbon, biological or inorganic contaminants. Common sources can be both naturally occurring and man-made.
Desk Study	A preliminary study conducted prior to any site works using available data and scientific literature for the area. This data can then be used to create a preliminary conceptual model of the expected hydrogeological conditions, which can later be added to when additional data is gained through testing.
Discharge	The point at which groundwater leaves the ground surface. These can be springs, seepage, or into a river through baseflow.
Discharge capacity test	A basic test performed during drilling which can give an indication of the approximate yield of a borehole by airlifting whilst drilling. However this will not give any hydraulic parameters for the aquifer and should not be used as a replacement for performing an actual pumping test.
Drawdown	The measure of the change in height of the water table during groundwater abstraction through dewatering or pumping through a borehole.

Drilling equipment	A drilling rig is normally required to drill boreholes. There are a variety of types suitable for drilling in different types of geology. Common types include: Rotary, Cable Percussive (Shell & Auger), Sonic and Window Sample Rigs).
Field experiment	A test performed in natural in-situ conditions. Gives a more accurate representation of the expected conditions, however each type of experiment is still subject to limitations.
Flow boundaries	An aquifer may be constrained by flow boundaries in both a vertical and horizontal direction. These may include low permeability faults, or low permeability geological layers.
Free surface	The point where the saturated zone meets the unsaturated zone. In an unconfined aquifer this is the water table.
Groundwater flow direction	Groundwater can flow in 3D, usually flowing downgradient relative to geological surfaces. However if under pressure, groundwater can also flow up gradient.
Groundwater chemistry	The chemical makeup of groundwater. This is a major part of groundwater quality, and can change due to man-made and natural influences.
Groundwater drought	A depletion of groundwater through the lack of sufficient recharge from the surface, or due to over abstraction from wells and boreholes.
Groundwater flow	The way in which groundwater moves through an aquifer. Characteristics include: flow speed (dictated by the geology, gradient and pressure) and flow direction (see flow direction).
Groundwater parameters	Measurable characteristics of the way groundwater behaves in an aquifer. Can include: hydraulic conductivity, transmissivity, storage coeffecients and aquifer thickness.
Groundwater quality	The chemical and suspended sediment makeup of groundwater. Poor groundwater quality can occur naturally and through man made pollution. Some examples include high levels of hydrocarbons produced from industrial processes, bacterial pollution from waste water, inorganic natural chemistry such as arsenic, or high sediment levels.
Groundwater system	The overall interaction between aquifers, aquicludes and aquitards within a regional setting.
Hand dug well	A large diameter well constructed through excavation of the ground. Most commonly lined with concrete rings or masonry, which are made permeable below the water table. Alternatively in competent rock wells can be left without any lining at depth.
High demand	Periods where high volumes of water are needed for use in the society it feeds. This is typically during the day or during the summer months. These periods can cause aquifers to become stressed.
Hydraulic conductivity (permeability)	A measure of the ease with which a fluid can be moved through a rock. Hydraulic conductivity is affected by structure and makeup of the rock material.
Hydraulic head	A measure of the pressure the water is under within the ground. In an unconfined aquifer, this head will be the same as the water table. In a confined aquifer, the hydraulic head may be at a higher elevation than the water surface within the ground.
Hydraulic gradient	The difference in hydraulic head at two different points within the ground. This difference will control the speed and direction of groundwater flow.
Hydrogeological analysis	Understanding groundwater flow conditions by analysing data from pumping tests, monitoring data and from conceptual models.
Infiltration	The process by which water enters into the ground from the surface through soils, eventually recharging the aquifer.

Lateral flow	Flow sideways within a rock unit, rather than down. Groundwater flow occurs in three dimensions, and normally flows down topography within geological units.
Low demand	Periods where water may not be needed for use in the society it feeds. This is typically over night or during the winter months. These periods can give aquifers additional time to recharge.
Monitoring data	Groundwater level and quality data that has been collected over a period of time. This informs how groundwater changes over time for that geological unit.
Monitoring program	The collection of monitoring data over a period of time. Ideally 12 months of monitoring should be completed for a full understanding of groundwater conditions in both wet/dry seasons.
Observation well	A groundwater monitoring well positioned away from the pumped well during a pumping test which can be used to assess the drawdown caused in the pumped well.
Porosity	A measure of the free space between aquifer grains. Porosity is not always a good indication of the ability of water to flow through a rock, for this use hydraulic conductivity (permeability).
Pressure head conditions	The pressure that the water within an aquifer is under. Within confined aquifers, the hydraulic head lies in an overlying low permeability confining layer and can sometimes cause artesian overflowing wells at the surface.
Pumped well	The well where water is abstracted from during a pumping test.
Pumping test	A test to determine the hydraulic parameters of an aquifer by abstracted water at a predefined rate. There are multiple types of pumping test including: Step tests, constant rate tests, dimension pumping and recovery test.
Qanat	An ancient middle eastern method of constructing a series of tunnels used to direct groundwater from beneath a mountain to the surface.
Quantitative	Using measured data and values to construct an understanding of the groundwater beneath the surface. This may include groundwater computer modelling, geological modelling, pumping tests, and detailed qualitative risk assessments.
Qualitative	Less specific information which can be used to produce a conceptual model in the absence of specific data. This may include descriptive information such as generalised geological cross sections/maps, historical maps, anecdotal evidence. Generally this type of data is more subjective than quantitative data.
Recovery test	Analysis of the recovery of groundwater following removal of water through pumping or bailing. Can be used to calculate the hydraulic parameters of an aquifer.
Saturated thickness cross sections	A geological cross section which also shows the expected water table of an aquifer. Usually the saturated thickness is represented as a line on the cross section.
Saturated zone	The area below the water table where pore spaces are completely full of water.
Screen	A (usually slotted) metal or plastic casing inside a well will allows groundwater to enter the well. The area within the aquifer the well is installed is called the response zone.
Seep	The point at the ground surface where groundwater will emerge. Seeps are wet patches and do not have water flowing from them, unlike springs.
Semi-confined / Leaky aquitard	A aquitard which allows some flow through it, allowing limited recharge and flow to the aquifers below and above.

Slug test (or bailer test)	Involves the sudden drop or raise of water through adding a known volume of water.
Specific capacity (SC)	The flow per distance unit measure of a well. Is defined by the equation SC = flow / drawdown.
Spring	A point at the ground surface where groundwater will emerge. Springs have water flowing from them unlike seeps.
Step Test	A pumping test performed on a borehole which involves gradually increasing the pumping rate at "stepped" intervals. This test can be used to determine the hydraulic parameters of the aquifer.
Storativity (Storage Coeffecient)	The amount of water available from an aquifer. Measured as per unit change in hydraulic head (i.e. how much water will be released as the water table decreases).
Sustainable abstraction	Managing abstraction so as not to offset the water balance of water into and water removed from the aquifer.
Time series hydrographs	Shows the change in water levels over time. Groundwater data can sometimes be combined with rainfall data and surface water levels to produce a full understanding of the responses to changes in the water cycle.
Topographic gradient	The change in ground surface height across a land surface.
Transmissivity	The hydraulic conductivity multiplied by the thickness of the aquifer. Should only be applied to confined aquifers.
Unconfined aquifer	An aquifer with no overlying impermeable rock layers. Unconfined aquifers are subject to different pressure conditions compared to a confined aquifer. The upper surface of an unconfined aquifer is called the water table.
Unsaturated zone	The area between the water table (where the ground is fully saturated), and the earth's surface. Sometimes called the vadose zone.
Water level change cross sections or maps	The change in water level over time can be marked on a geological section showing the relative position of the water table to the geology of the area.
Water level recovery	The amount of time it takes for groundwater conditions to return to resting level following drawdown from groundwater abstraction.
Water quality	The chemical and sediment makeup of groundwater. All natural groundwater will have a differing chemical makeup which can be influenced by man-made and natural pollutants. Sediment content can also degrade groundwater quality.
Water table	The depth beneath the ground at which groundwater is encountered.
Water table contour maps	As with topographic contours, the surface of the water table can be mapped with contours. This gives the expected position of groundwater beneath the ground. Groundwater contour maps can be created with a minimum of three boreholes.
Weathered rock	The upper surface of a rock is commonly weathered due to exposure to the surface. Highly weathered rock often contains more fractures and pore spaces, thus is more likely to hold water. The weathered surface of crystalline rock is key for holding groundwater.
Well diameter	The drilled diameter of a well. This may not be the diameter of the installed well, as some wells need to be cased and packed with materials to prevent them from collapsing.
Well performance	The ability of a well to provide water. A well's performance can decrease over time without proper maintenance. A poor installation can also lead to poor performance.

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