



CoDrIVE  
VISUAL  
Integrator

Community Driven  
Vulnerability Evaluation

Making the Invisible, Visible



Manual for  
preparing the CoDrIVE - Visual Integrator  
to overlay surface and sub-surface characteristics  
for sustainable groundwater management

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# FOREWORD

In our efforts to demystify technology and knowledge for the empowerment of the local community, Watershed Organisation Trust (WOTR) presents the tool “Making the Invisible, Visible: Manual for preparing the CoDrIVE - Visual Integrator to overlay surface and sub-surface characteristics for sustainable groundwater management.”

Frequent droughts, the growing water crisis, and the ease of accessing groundwater, particularly through bore wells, have triggered an over-dependence on groundwater to meet agriculture demands. This has led WOTR to motivate and capacitate rural communities for “Water Stewardship”, where the village as a whole comes together to learn of their resource/s to manage this better, i.e. to enhance the supply of water through water harvesting structures as appropriate, but more crucial, to manage the use of water. Demand-side management is the challenge as the general idea is that the water found below one’s particular farm belongs to the landowner. Besides, what is below the surface and is not visible, is not understood.

WOTR successfully implemented in various villages the CoDrIVE - Visual Integrator (CoDrIVE-VI), which is a “Participatory Three-Dimensional Modelling (P3DM)” derived through constructing and demarcating geo-referenced, scaled relief models (this concept was developed in the late 1980s in Thailand). We observed that the local community is able to relate to their village model in a meaningful manner such that they use it to communicate between themselves, as well as with the local officials and outside agencies. Encouragement from the local community and the urgency for good groundwater management motivated WOTR to further develop the CoDrIVE - Visual Integrator, i.e. to prepare the sub-surface characteristics of a village/cluster of villages that lie below the surface topography.

Having implemented the CoDrIVE - Visual Integrator together with the sub-surface characteristics, to understand the groundwater scenario in over 25 villages, the response from the local community is astounding. They now see the groundwater resource as a common pool. They now understand why some farmers sunk many bore wells but had not struck water. But more importantly, what they have come to realise is that this resource belongs to all; it is finite; they need to work together to enhance the supply, to use it judiciously, and to protect these resources for future generations.

We wish you far richer experiences as you use this how-to manual to “Make the Invisible, Visible” so that by a better understanding of the unseen, we are able to face the challenges and adapt to climate variability and change through the better management of our precious groundwater sources.

Please share with us your experiences so that we can improve on this tool and learn from you.

Marcella D’Souza  
Director  
WOTR Centre for Resilience Studies (W-CReS)

# WHY THIS TOOL...

Generally, rural communities are left out of development planning as they are considered unable to project their views and needs with a long-term vision. Development workers, however, are aware that without the active participation of the local community, sustainability cannot be achieved. Hence, it is best to engage the local inhabitants at the onset with planning. The gap lies in the ability of the rural inhabitants to communicate their views.

To be fruitful, effective communication between the three main players, i.e., the local communities, project facilitators, and relevant governmental bodies, is the most important requirement. Each player may seem correct in their respective sphere. However, when seen in the totality of the context, the chips may not add up. These discrepancies and differences may be due to various reasons.

The information supplied on the social, economic, physical/spatial, and ethnic structures in a cluster of villages may be interpreted differently by the various stakeholders. Given our legendary diversity and existing disparities, interest holders are likely to deduce and respond in ways most suited to current personal interests. At times this may run counter to the interests of other stakeholders, to natural justice, and even future generations.

Participatory Mapping or Participatory Rural Appraisal (as in PRA) is a commonly used tool in rural development for communicating indigenous spatial knowledge. Though these convey local human relationships with the surrounding landscape, they often lack a precise geo-location and/or consistent scaling that makes them useful only for temporary, localised purposes. Hence, PRA is not usually acknowledged by research scientists or governments as “credible” spatial information, due to which rural communities get excluded from decision-making processes. This, in turn, has a direct bearing on the development and management of the local landscapes and resources.

Enter “Participatory Three-Dimensional Modelling (P3DM)” – a methodology derived through constructing and demarcating geo-referenced, scaled relief models that displays indigenous knowledge in a way that is meaningful not only for policymakers and academics but to the communities themselves. P3DM, now adapted and presented as CoDrIVE - Visual Integrator (CoDrIVE-VI), was conceived in the late 1980s in Thailand.

Having applied this tool in various villages, the experiences have helped WOTR adapt the methodology to bring together, in a visual manner, a complex spatial local scenario. Historical information of 30–50 years earlier, where satellite data may not be available, can now be captured. Of particular importance is its modification for climate change and Disaster Risk Reduction. It has been adapted by WOTR and is now presented as a participatory project integrator, while it may also be used for adjustment, monitoring, and assessment. It is specifically useful for:

1. To improve the capacity of villagers to understand and address the conceptual complexity of climate change about their water resources (surface and subsurface)
2. To communicate indigenous spatial knowledge concerning land use, cultural identity, and environmental history to local villagers and pinpoint the vulnerabilities that help them refine the available water resources

It is important to mention, that this is a “work in progress”. We believe that CoDrIVE-VI is an inherently adaptive tool, and we encourage future practitioners to consider specific village needs while following these basic guidelines.

# ACKNOWLEDGEMENTS

This manual is the consequence of experiences gained while implementing “CoDrIVE – Visual Integrator.” on the ground in various villages in Maharashtra.

We are thankful to the communities of Ahmednagar and Jalna districts (Maharashtra) for their active participation in the process and for contributing valuable inputs for preparing the models on the ground and taking it forward. This helped generate insights to improve this manual.

We are thankful to all the field teams of WOTR for their valuable assistance in organising the various stakeholder engagement workshops and motivating the villagers for active participation. The CoDrIVE-VI team wishes to thank all who have contributed to the preparation of this manual.

Special thanks to local community teams that participated and willingly shared their local understanding of their village topography during the workshops.

We are grateful for the support from the ProSoil project in publishing and showcasing this useful guidance manual at the UNCCD COP14. We also extend our thanks to HSBC Software Development India, for providing generous support for printing this manual.

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# CoDriVE VISUAL Integrator

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# 1. INTRODUCTION

## 1.1 Groundwater development scenario in India

Groundwater is the most important component of the water resource and constitutes about two-third of the freshwater resources of the world (Chilton, 1992). It is also described as the world's 'hidden treasure' broadly as it is an invisible resource that provides safe drinking water and livelihood security to millions of people in dry regions (Chevalking, 2008). Major agriculture and economic activities in the arid and semi-arid regions depend on groundwater use. Compared to surface water, the development of groundwater has brought many advantages. Groundwater, for example, is less vulnerable to sudden changes in rainfall and offers better insurance against climate variations. Furthermore, irrigation with groundwater needs little transport from the source to the plot and is available throughout the year. Hence, the groundwater is the lifeline for drinking, domestic, industrial, livelihood, and irrigation purposes and its backbone in these regions (Shah, 2013).

Although a precious and life-saving resource, for decades groundwater faces multiple challenges at different levels, particularly in its management and regulation. Many approaches are being designed and tested for decades. However, reality shows that at a wider level, they do not sustain. The resource is challenging to manage because of its "invisible" nature, which leads to its overuse and the drastic decline in groundwater levels, threatening to push the vital resources out of reach for millions of farmers. Changing precipitation patterns, increased evapotranspiration rates linked to rising temperature, and changes in the runoff cycle can affect groundwater recharge rates (Kale & D'Souza, 2019). Apart from the scientific development of available resources, proper groundwater resources management requires focused attention on the judicious utilisation of the resources to ensure their long-term availability. Stewardship of groundwater, adequate literacy of surface water-groundwater linkages, i.e. at least rough estimations of aquifer boundaries, the involvement of stakeholders in various aspects of planning, execution, and monitoring of appropriate crop-water management and effective implementation of regulatory measures are the important considerations with regard to demand-side groundwater management (D'Souza et al, 2018).

## 1.2 Challenges in groundwater management

As stated earlier, groundwater is the backbone of India's agriculture and drinking water security, contributing to 84 % of the total net irrigated area in India (Shah, 2013) and 90 % of rural water needs being met by it (Prakash, 2013). In the 1950s and 1960s, the share of surface water in irrigation was around 60%, which reduced to less than 30% in 2007, while the groundwater share increased to around 60% in 2007 (Shankar et al. 2011). The CGWB report (2017) states that in the last ten years, groundwater levels have fallen in around 50 % of areas of Maharashtra (TOI 2018).

Another reason for the depletion of the groundwater crisis is its invisible nature which puts farmers into a competitive mode as they search it through the drilling of wells and bore-holes (Kale, 2017). While rainwater stored in surface structures such as lakes, ponds are easily seen, and the amount can be measured when it comes to groundwater, people have no idea of its quantity that exists in aquifers, as this is not visible to the naked eye. Thus the increasing demand for groundwater and its inefficient use has led to its unscientific exploitation, causing water stress in many states. Besides, due to decades-old customary laws in India, groundwater is seen attached as a chattel to the land property, a notion that results in the farmers' unrestricted exploitation of water below their land and even from the surrounding areas (Iyer, 2003; Ballabh, 2008).

Hence, the challenge is how to make the invisible groundwater resource visible. This necessarily involves understanding the aquifer systems, basic hydrogeology, groundwater flows, depth of groundwater, and sustainable aquifer yields. It is not only important to investigate groundwater systems but also to share the knowledge in a way that is widely understood by its users. Without such a shared understanding, it will be difficult, even impossible, to envisage collective management of the groundwater resource.

Therefore, to ensure that the access of water is adequate, equitable, and sustainable, WOTR's approach is to demystify the science of local hydrology and geology, to communicate this easily with villagers who are the prime stakeholders, and with this develop an understanding of the collective nature of this resource and motivate them for sustainable groundwater management.

### 1.3 Approaches to raise groundwater literacy

Groundwater management in India has a rich history. Along with numerous policy prescriptions by the government both at the centre as well as state levels, various agencies have initiated groundwater management under the broad framework of Community Based Natural Resource Management (CBNRM). Many civil society organisations have piloted Participatory Groundwater Management (PGM) activities and even the management of groundwater at the aquifer level. Considering the need for groundwater management at the aquifer level, the government of India has initiated the National Aquifer Management Project (NAQUIM) and formulated policies to promote groundwater management at the aquifer level. Although these initiatives are well intended and many of them based on delineation and mapping of aquifers, the challenge is how to make villagers literate and demystify the unseen aquifer and provide groundwater-related knowledge to villagers.

### 1.4 CoDriVE - Visual Integrator (CoDriVE-VI): A Possible Solution

In this context, there is a need to demystify the sub-surface / groundwater status for people so that they understand it, and can communicate the same to others while also making plans. WOTR's on-ground engagement in many villages and approach of 'demystifying knowledge' led WOTR to prepare the CoDriVE-VI for the surface topography. It's the need to understand that surface water flows and the groundwater flows and aquifers generally do not match, scientific investigation is inevitably required for the latter. Preparation of this tool (with both the surface topography and groundwater aquifers) gets enriched with people's traditional knowledge of surface typology and local hydrogeology. Through these models, the community can visualise their surface topography and get to know the sub-surface characteristics (potential zones) in the form of the 3D model and inter-linkages between both.

## 2. CoDriVE - Visual Integrator

### 2.1 Concept

CoDriVE - Visual Integrator is a community-mapping tool that combines indigenous spatial knowledge with hydrogeological information to produce a scaled relief model resulting in a 3D subsurface model that can be visualised and helps the community to plan and manage their water resources effectively.

### 2.2 Objectives

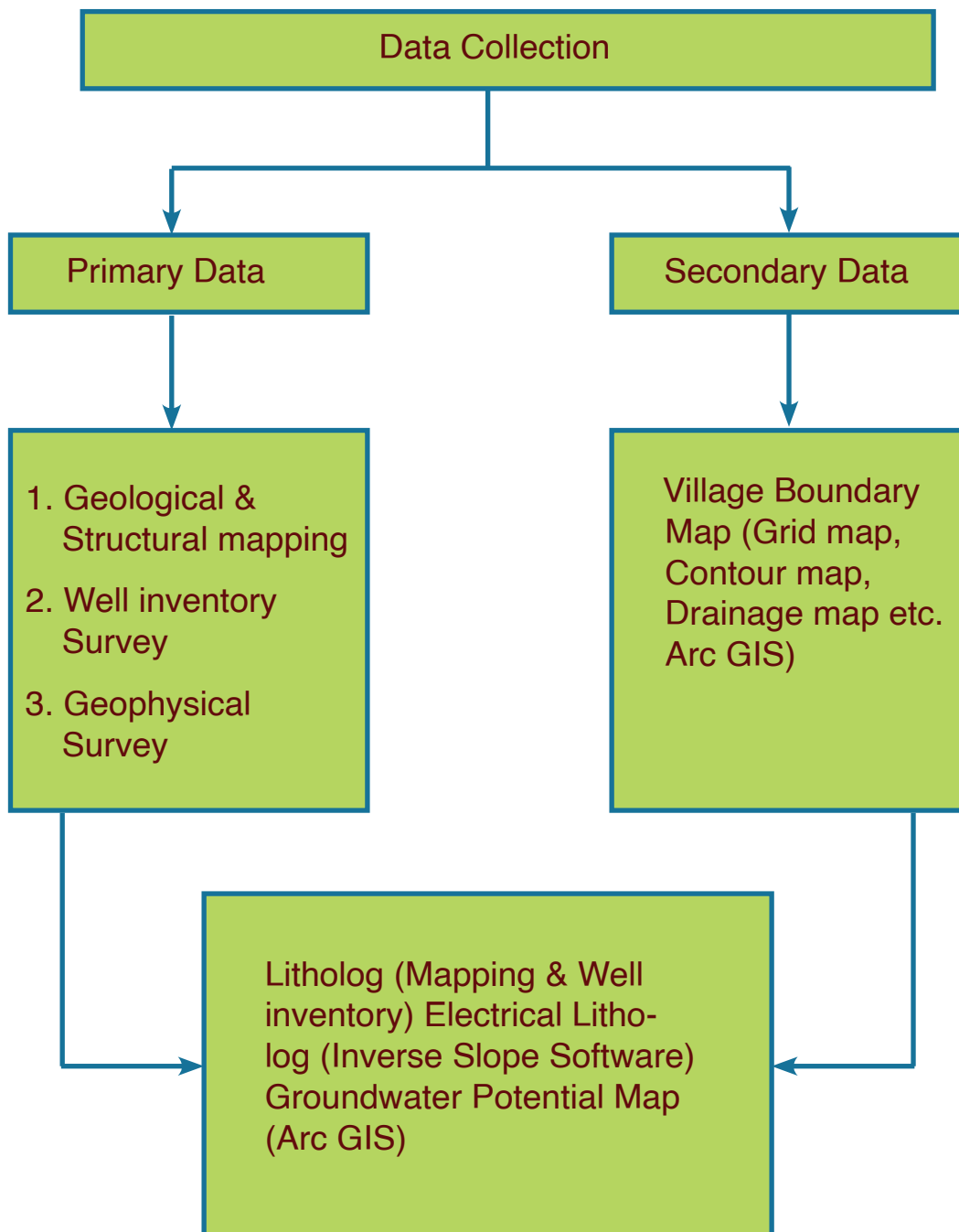
- To improve the capacity of villagers to understand and address the conceptual complexity of climate change about their water resources (surface and subsurface)
- To enhance participation of villagers in preparing disaster risk reduction plans and for building resilience to drought
- To communicate indigenous spatial knowledge concerning land use, cultural identity, and environmental history to local villagers and pinpoint the vulnerabilities that help them refine the available water resources
- To transfer indigenous spatial knowledge to relevant government officials and other development agencies

### 3. Methodology

CoDrIVE - Visual Integrator (CoDrIVE-VI) is a 3D combined product of advanced GIS technologies, geophysical data, and local information collected from local stakeholders. In the tool, the science of hydrogeology gets demystified using different scientific tools to directly help villagers visualise the water reserves underlying their known topography.

CoDrIVE-VI prepares two models, the surface and sub-surface. WOTR has already published a detailed manual to prepare the surface model and is available at <https://wotr.org/books/wotr-codrive-visual-integrator>. The present manual describes the step-by-step methodology to prepare the subsurface model.

The process diagram of preparing the sub-surface model is as below:

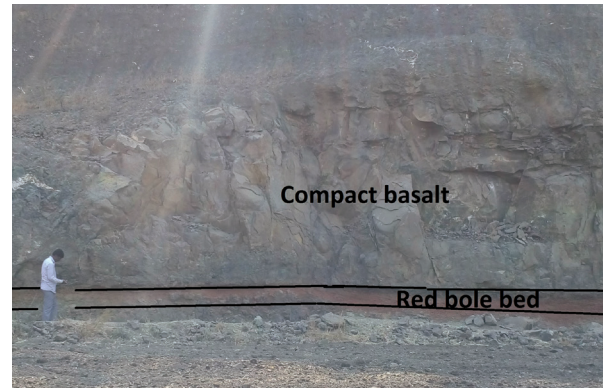


### 3.1 Subsurface map

To manage groundwater effectively requires a comprehensive and consistent database together with an adequate understanding of the aquifers, as well as other relevant aspects. This helps to derive effective groundwater management strategies. To develop the groundwater potential map, surveys using different scientific tools and observations are conducted, including geological mapping, well inventory survey, and geophysical survey.

#### 3.1.1 Geological mapping

Geological mapping is the process by which the lithological variations are mapped in detail with their characteristics and properties. Geological data collection and mapping is the primary component in delineating the aquifer. Different rock types and their thickness are mapped with their lateral and vertical limits (Balasubramanian, 2007). The mapping is mainly done in continuous traverse wherever large exposure is observed to get an idea of variations within the lithology. The mapping is also done in a systematic point-location-wise method where continuous exposures are absent but connecting these points generates continuous litho-section. The information derived from geological mapping marks the rocks forming potential subsurface storages, surficial features, and cross-cutting structures.



Geological Mapping

The interpretation of rock formation explains the hydrological properties of that area, such as water holding capacity and primary porosity of the aquifer. Features like fractures largely support water percolation and movement through rocks (transmissivity); the intensity of flow increases with intersecting, a deep, and long stretch of fractures. Locations of fractures often observed in sets are important to demarcate as these play a vital role in the selection of potential sites for water harvesting and recharge structures such as check dams, percolation ponds, recharge pits, etc.

#### 3.1.2 Well inventory survey



Well Inventory Survey

Well inventory survey is a shorthand questionnaire tool used to gain information about each selected well for the survey. The main components of the well inventory are well ownership details, GPS location, total depth of well, static water level (SWL), pump and pumping details, discharge of well, etc. (Babar, 2018). Subsurface lithology encountered during digging/drilling well is noted sequentially.

Scientific comments on aquifer types are made, and the general observations of the lithology are also noted.

### 3.1.3 Geophysical survey



Geophysical survey at the field



Readings taken during geophysical survey

The geophysical survey is the non-destructive testing technology in earth science (Rai, 2015). The geophysical surveys are based on the principle of variations in apparent resistivity values of media through which the electric current of known value is passed. Values of apparent resistivity representing the lithology, its texture, porosity, fluid saturation, subsurface structures like fractures, sinkholes, faults, etc. The depth of penetration of electric current and finer marking of subsurface thicknesses during the survey depends on the configuration of instrument installation.

For developing the subsurface map, the Schlumberger array of Vertical Electrical Sounding (VES) method is used for subsurface investigation. Later the data is interpreted using IGIS inverse slope software. A groundwater potential map for the survey area is generated by synthesising geological mapping, well survey data along with lithology derived by the geophysical survey.

## 3.2 Interpretation of data and Groundwater Potential Map

Inverse weightage slope technique gets applied for interpretation of the resistivity data. The software is provided by IGIS to plot the data collected along with the resistivity information. The graph generated from this gives the thickness and resistivity of different geo-electric layers within the subsurface. With the given resistivity relation, one can identify lithological units and conductive zones of the subsurface.

## 3.3 Preparing 3D surface and subsurface model

### 3.3.1 Material list

To prepare the 3D subsurface model following material is required:

1. Reference map
2. Corrugated cardboard for tracing contour lines
3. Carbon paper, for tracing the contours from the reference map to corrugated cardboard layers
4. Fevicol, for superimposing corrugated cardboard layers one above the other
5. Permanent markers, for marking elevation and orientation on the corrugated cardboard layers as well as the base map
6. Box cutters
7. Ballpoint pens, pencils
8. White acrylic medium, for priming and sealing the base model

### 3.3.2 Steps to prepare subsurface 3D model

#### STEP 1

- Corrugated cardboard sheets of the exact same size as the reference base map are prepared.
- A layer of carbon paper is taped to the bottom of the reference map (topographic), with the marking side facing out.



#### STEP 2

- On each sheet of cardboard, a single contour is traced, using the base map with carbon paper underneath as a reference.



#### STEP 3

- Contour is cut from cardboard sheets.
- Sheets are labeled with the contour elevation and a north-pointing arrow, for proper orientation.



#### STEP 4

- Community members place the unsorted cardboard one above the other according to the elevation.



#### STEP 5

- After the entire model is ready white color is applied as a base coat.



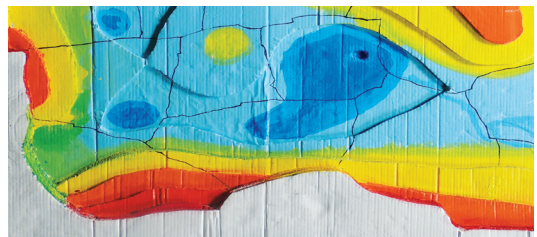
#### STEP 6

- Community members color the subsurface using different colors indicating the different groundwater potential zone as per the facilitator's instruction.



#### STEP 7

- After the model is completed it is placed on plywood and the index is demarcated on it.



## 4. Application of the CoDriVE - VI 3D model for groundwater management

### 4.1 Education and capacity building

The combined interpretation of both models during the model preparation phase and even while presenting it is an eye-opener for villagers. Although in practice, farm owners consider groundwater as private property, when the surface model is superimposed on the subsurface model, farmers can easily find that they are pulling the groundwater from a single pot/stock. This makes the villagers significantly aware of the common pool nature of groundwater and establishes a sense of collective ownership over the resource. Villagers' knowledge is enhanced regarding groundwater potential zones, which triggers greater responsibility of the local community with regards to better management of groundwater in a most efficient manner so that farmers in other areas can also receive water for a longer period. It thus ensures the judicious use of groundwater. In a way, these models make the invisible aquifer characteristic and the sub-surface groundwater visible to villagers so that they understand the dynamics of the resource. Thus, the awareness of local water resources with this scientific approach helps the community to manage the sustainable use of their aquifers. Preparing these models and making communities literate for better decision making is important in the context of aquifer based crop plans and aquifer management at the community level as it is proposed by existing policies, such as the Maharashtra Ground Water Act 2009, the National Project on Aquifer Management (NAQUIM), Atal Bhujal Yojana, and others.

### 4.2 Sustainable agriculture

CoDriVE-VI 3D model is useful for roughly estimating the stocks of groundwater; it thus enables the water budgeting process. This precise level of groundwater estimation can help out farmers to grow suitable crops and plan irrigation schedules to avoid the incidence of crop loss and failure due to water scarcity during the crop cycle.

## 5. Application of the model on ground

By engaging villagers, WOTR has prepared the CoDriVE-VI model in 25 villages of Ahmednagar and Jalna districts. During the exercise, participants were encouraged to participate in preparing the model actively; the process is enriched by observations, reflections, and experiences shared by people on the characteristics of the local topography at the surface and subsurface. The surface model gets developed by extensive inputs of the villagers about the surface characteristics (settlements, drains and streams, land distribution, etc.). The subsurface maps are the output of the data generated through scientific observations. These models help villagers to understand their groundwater scenario and help them scale up good practices in the sustainable use of groundwater management. As a result of effective stakeholder engagement, workshop participants have started to understand their local groundwater system and accept that groundwater is limited. The falling water table is a common concern that needs to be tackled as a community. CoDriVE-VI has strengthened the farmers' perceptions that individual efforts alone will not solve their groundwater problem. Based on this understanding, villagers are motivated to make decisions for using groundwater efficiently through collective efforts. It also brings social benefits such that they promote equity amongst users and avoid groundwater overexploitation. This enhanced understanding helps them for the sustainable and judicious use of groundwater through the application of tools like water budgeting, setting rules and regulations within the village, water land efficiency measures.

In our experience, in many villages people took these CoDriVE-VI models to larger groups and initiated discussions on the findings and the inter-linkages within the village and the cluster of villages.

## 6. Feedback from the stakeholders during workshops

The CoDrIVE-VI model preparation was an insightful journey for many participants. We present here some of the inputs of participants. After preparing the model by themselves, villagers could visualise their entire village, which they had never seen in a 3D format. All were amazed to see their entire village topography as well as subsurface in this format. One of the participants remarked: “I never thought that I could see our groundwater resource. Now, I can see every surface and sub-surface of our village, especially the number of bore wells and dug wells. This aquifer stakeholder engagement made us realise that we pull out groundwater from the same aquifer. It is a common pool resource and therefore, important to manage together.”

Sarpanch from the Palsunde village of Akole block said, “Attending this workshop enhanced our knowledge regarding the different rock types that are available in our village. It made us realise that if we do not manage water sustainably now, the coming generation will suffer. At the same time, women must be involved in these efforts as they face water problems in everyday life.”

When a single workshop for three villages was conducted, participants could understand the groundwater scenario not only of their respective villages but also of their neighboring villages. They could appreciate the recharge and discharge zone, which helped them come up with different ideas to collectively manage water at the local level.

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