

Final Report

A RAPID GEOHYDROLOGICAL STUDY OF MICROWATERSHEDS FROM BOLANGIR DISTRICT, ORISSA STATE

A scientific input to the consortium of organisations implementing watershed development programmes in Bolangir district, Orissa



Prepared by
Advanced Center for Water Resources Development and Management, Pune



October 2005

**A RAPID GEOHYDROLOGICAL INVESTIGATION
TO PROVIDE INPUTS TO WATERSHED PROGRAMME
PLANNING AND IMPLEMENTATION**

**A RAPID GEOHYDROLOGICAL STUDY OF
SOME MICROWATERSHEDS FROM PARTS OF
BOLANGIR DISTRICT, ORISSA**

Himanshu Kulkarni, Vinit Phadnis and Uma Badarayani

Advanced Center for Water Resources Development and Management

Plot 4, Lenyadri society, Sus road, Pashan, Pune-411021, India

Email: acwadam@vsnl.net

Website: www.acwadam.org



Technical Report: ACWA/2005/H-3

Bibliographic reference

Kulkarni, H., Phadnis, V. and Badarayani, U. 2005. A rapid geohydrological study of some microwatersheds from parts of Bolangir district, Orissa. ACWADAM Technical Report ACWA/2005/H-3.

October 2005

Chapter 1: INTRODUCTION

BACKGROUND

Land and water form the two fundamental entities of the natural environment. Together, they also represent the platform for launching any rural development programme. Moreover, land and water are linked in innumerable ways within natural and socio-economic frameworks. Land-use intensification in India has been very rapid especially over the last two decades or so. A significant fall-out of this land-use intensification has been the increasing use of water for agriculture and related activities. At the same time, extreme events like floods and droughts continue to wreck havoc in many parts of the country. In many areas, vulnerable livelihoods continue to be rendered increasingly fragile because of a combination of extreme events and poor management of resources.

Increasing demands on water supplies have affected both surface and ground water supplies to a large extent and many areas of the country are clearly showing tell-tale signs of acute water crises. Some apparent effects include small streams becoming seasonal, unconfined aquifers showing signs of water table decline and deeper aquifers showing reduced and uncertain yields. All these effects, in turn, have resulted in the users resorting to extreme measures like sinking deeper wells and drilling deeper bore wells and tube wells to catch falling water levels and augment uncertain water supplies thereby. The problem gains an altogether different dimension in areas of low and/or erratic rainfall, a common feature in many regions of India.

Bolangir district in Orissa forms a part of one of the hottest regions of India. This semi-arid tract, ironically has a fairly thick vegetative cover, mostly in the form of dry deciduous forests. It is also one of the more backward regions of India where land-productivity is quite low and opportunities and technologies for agriculture as a livelihood option remain relatively unexplored. Vagaries of rainfall and the underlying hard-rock geology further compound the problem and limit agricultural productivity to a great extent.



The landscape in the project areas of Bolangir district

Given such natural uncertainties, systematic implementation of a watershed management programme is the most viable avenue to overcome the problems of this region. Groundwater resources management forms an important component of any watershed management programme. However, the approach to groundwater management through programmes like watershed development / management ought to be systematic enough to take into account various aspects of a largely unseen resource. These aspects primarily depend upon the geohydrological setting of the programme areas and the status of the groundwater resource in each project setting.

The America India Foundation (AIF) was in the process of considering funding a novel initiative on the back of a watershed management programme in parts of Bolangir district. ACWADAM, Pune was invited, along with Samaj Pragati Sahayog, Bagli to conduct a pre-feasibility exercise leading to the planning of water resources management for pilot areas in Bolangir district. The water resources management included the following components:

1. *Soil and water conservation measures*
2. *Restoration of water harvesting structures*
3. *Groundwater resources management*

Advanced Centre for Water Resources Development and Management (ACWADAM) is a registered, non-profit organisation providing earth sciences inputs in general and hydrogeological

inputs in particular to projects like watershed development and environmental monitoring through activities like training, action research and technical interventions. ACWADAM has already provided fruitful inputs to watershed programmes through training and to specific projects (like the initiative in Orissa) in the form short-term, research-based inputs. These inputs have resulted in a set of object oriented outputs ranging from watershed prioritisation, contour mapping, geological mapping and baseline hydrogeological characterisation. ACWADAM has conducted rapid geohydrological feasibility studies in watershed development and drought proofing programmes in areas from Maharashtra, Madhya Pradesh and Karnataka.

The land and water resources management initiative in Bolangir will be implemented through a consortium of five organisations, three of which are NGOs (Non Government Organisations), while two are CBOs (Community Based Organisations). Table 1 provides a summary of these organisations and brief information on the locations where this initiative will be conducted.

Table 1: Summary of organisations and project areas

Organisation	Type	Block	Watersheds
Udyama	NGO	Muribahal block	1. <i>Chiknibaheli</i> 2. <i>Dongabanji</i>
Shramik Shakti Sangha (SSS)	CBO	Tureikela block	1. <i>Muribahal</i> 2. <i>Kadobera</i> 3. <i>Jubamal</i>
Agency for Social Action (ASA)	NGO	Muribahal block	1. <i>Kurlubahal</i> 2. <i>Katarlaga</i>
Bolangir Gram Seva (BGS)	NGO	Tureikela block	1. <i>Semla</i> 2. <i>Samarsing</i>
Anchalik Janaseva Anushthan (AJSA)	CBO	Bongamunda block	1. <i>Barkani</i> 2. <i>Barthala</i> 3. <i>Ganjiapada</i>

SCOPE OF WORK

In light of the background above, the present assignment was conducted as a very basic investigation that would help describe the physical makeup of the region in general and the watersheds in particular, focusing specifically on groundwater resources. Additionally, it was also thought important to study allied aspects like land and water use and go on to establish a preliminary framework for the future monitoring of the watersheds in order to study long-term sustainability criteria, particularly with respect to the water resources.

ACWADAM's scope of work in the above watersheds included:

- (a) *Geohydrological mapping to understand the overall conditions of groundwater resources in the area.*
- (b) *Describing the framework in which groundwater occurs within each of the watersheds.*
- (c) *Suggesting a strategy for planning the water management programme in the watersheds, with a focus on groundwater resources management.*

PROJECT AREA

The project area is a part of Bolangir district in Orissa and forms a portion of what is called 'KBK' districts, an abbreviation for Kalahandi, Bolangir and Koraput districts that constitute one of the most underdeveloped regions in the country. This region is characterised by extreme conditions, especially during the summer and is believed to be one of the hottest regions in the country. Temperatures are stated to reach the upper forties during this period.

The investigations were conducted in 12 microwatersheds in different parts of Bolangir district (Table 1, above), together constituting an area of 6000 to 7000 ha. Most areas were approachable by metalled roads, except in the interiors where roads were unmetalled. Nevertheless, access to all the 12 microwatersheds was never a problem.

METHODOLOGY

Due to certain constraints in finances and time, inputs to this study were primarily on the basis of field visits to the project areas. Remote Sensing tools thought to streamline the investigation could not be acquired due to financial constraints. Access to background data (other than that available with the concerned organisations) was difficult and therefore, field mapping and observations formed the main tool for this investigations. The study was undertaken as three steps:

- Study of general literature pertaining to the area/region.
- Field studies (undertaken by ACWADAM with the help of each organisation and co-ordinated through Udyama's office in Tetlagarh.
- Compilation and data analyses (carried out by ACWADAM on the basis of a, b and c above) at its office in Pune.

Field studies were conducted in the month of May 2005, over a period of one week. Traverses were undertaken in each of the nine watersheds, with an initial reconnaissance through all the project areas. Traverses were usually conducted in two sessions every day, first, during the early morning hours and later during the evenings. Daytime temperatures touched 48° centigrade at the time of the field programme. Afternoon sessions were utilised to conduct discussions with the staff of the above organisations and understand their perspectives of problems in the areas. Most traverses through the microwatersheds were conducted on foot and as far as possible, the entire microwatershed was covered during the traverses. Dr. Himanshu Kulkarni and Mr. Vinit Phadnis conducted the fieldwork.

The absence of good toposheets made the investigation somewhat challenging. Original toposheets were available for a few of the watershed sites. For the remaining sites, toposheets had to be borrowed and/or other base maps used as reference. The maps presented here have been created using a combination of what was available and sketch maps where original toposheets were either not available or were in truly poor condition.

The field investigations covered the following:

1. GEOLOGICAL AND HYDROGEOLOGICAL MAPPING

- **Mapping of each watershed based purely on field observations.**
- **Hydrogeological mapping – included weathering profiles, aquifer delineation, and well inventories on representative dug wells.**

2. TERRAIN AND LAND INFORMATION

- **Qualitative information on land-use and land-cover, wherever relevant.**
- **Topography and drainage were studied in detail.**

3. INTEGRATION OF INFORMATION INTO A TECHNICAL REPORT.

Chapter 2: REGIONAL CHARACTERISTICS AND EXISTING INTERVENTIONS

Regional geology

The geology of Orissa, like many other states in India is diverse. The project areas are located within a geological setting comprising the following lithological formations:

- Gondwana sediments, mostly in the form of sandstones (very small area in the Semla watershed).
- Proterozoic rocks belonging to the Chattisgarh group (only in small patches in some areas).
- Peninsular gneisses with younger phases and migmatites
- Archaean Khondalites and some Charnockites

Hence, igneous and metamorphic rocks constitute the lithological components of the geological setting over large part of the project area. As mentioned above, only a small portion of the Semla watershed shows exposures of fine grained, horizontally bedded sandstones and siltstones (?Gondwana sediments). Additionally, in some watersheds, there are small, thin exposures of quaternary alluvium, mostly along the higher order drainage. On the whole, the geology is dominated by granite gneiss with variations arising out of the following factors:

- Degree of metamorphism
- Banding and *foliation*
- Fractures and fracture patterns (vertical, horizontal, close-spaced, inclined etc.)

The features of hydrogeological significance, on the whole, therefore are the *degree of weathering and jointing of these rocks, the characteristics of foliation openings and the presence of linear features, mostly in the form of regional fractures, often filled up with pegmatite veins, which themselves have undergone later episodes of fracturing.*



A



B

Fracturing (A) and foliation in the rock (B) in exposures along the Lanth river

Slopes and landuse

The overall landscape of the region in which the concerned microwatersheds are located is constituted of two major divisions. Steep ridges constitute the divides in some of the microwatersheds. Otherwise, large portions of the microwatersheds are made up of undulating landscape dotted with isolated exposures of variable elevations formed from the weathering of the rocks. In some parts, where the bedrock is in the form of granites or gneisses, *inselbergs*, or relics of weathering are commonplace. Drainage, except in the upper ridge areas is relatively coarse with low drainage densities, although this varies to some extent, across the watersheds.

Forest areas are generally coherent with ridges, some of which show a fairly dense forest cover. In other parts though, there is virtually no soil cover and ridges are completely devoid of any vegetation making it easy to imagine that runoff over such rock surfaces must clearly be in the form of 'sheet flow'.

The lower reaches of most microwatersheds are flat or gently undulating lands, covered by agricultural fields.

Soils

Considering the overall landscape of the region, especially within the project microwatersheds, three broad soil divisions are apparent. These three types of soils are related to the slopes and the location of land with respect to the overall drainage in the watersheds. The uppermost reaches of the microwatersheds, that include soil cover (wherever present) on the ridges, are covered by red, sandy soils; lateritic soils were also noticed at one or two locations. Gently undulating or flat portions of land separating drainage channels that make up most of the agricultural land are covered by black (sometimes, typically 'black cotton' type) soils. Very fine, silty/clayey soils are found at the tail end of most microwatersheds; these include puddled grayish-yellow clayey soils along some stream channels (for paddy cropping). However, these puddled soils, along stream channels are relatively thin in comparison to the black soils that, at places, were observed to attain thicknesses of more than 1 m.



(A)



(B)

Soil cover varies considerably even within a single watershed. There are thick soils underlying vegetated slopes (A) while even on the lower plains, there are exposures of underlying rock without any soils (B)

Rainfall and Groundwater

Rainfall for the region is reported to vary between 1000 to 1500 mm, with a large proportion of the rains occurring during the monsoon season. Some rains are reported to occur prior to the monsoon while some rains occur during the winter season, However, the proportion of non-monsoon showers to the monsoon showers is negligibly small.

Groundwater in the region occurs mainly in the shallow weathered layer of the "hard rocks" exposed within virtually all the project microwatersheds. The occurrence and movement of groundwater depends upon the depth of the weathered zone and to a lesser extent on the nature of fractures that underlie the weathered zone or are directly exposed at the surface.

The occurrence and use of groundwater in the area is obvious as one travels through the region. The ubiquity of 'tendlas', a manually operated device for extracting water from shallow dug wells, makes it easy to guess the manner in which groundwater in the area is accessed. In addition, there are a few diesel operated pumps and fewer motorised (electric) pumps for extracting groundwater.

Most wells are shallow and 'partially penetrating' *i.e. they do not penetrate the full thickness of the shallow aquifer* (Figure 1a). In that sense, *groundwater development* can be said to be quite limited. Another testimony to this fact is that the annual water table fluctuation in most of the observed areas, is quite small (2-5 m). This, of course, may also indicate a low specific yield of the aquifer because the discharge from these shallow aquifers, except for a few cases, remains quite limited. Most streams, although dry during the peak summer, are reported to flow until the months of February and March, clearly indicating that base flows, *i.e. groundwater discharges to streams*, are active in the region. Considering that the region has a high rainfall and quick runoff characteristic, base flow contribution also indicates a fair share of infiltration to aquifers or groundwater systems (Figures 1b and c), taking place in locations where the surface and sub-surface conditions are conducive to recharge.

Most aquifers seem to have boundaries coherent with microwatersheds, although it was not possible to investigate this factor in detail, considering the constraints under which the study was conducted. Further, water quality in the shallow aquifers in the project areas could not be discussed in

the absence of any data on water quality. However, it was felt, considering the geological framework that it would be a good idea to keep testing the quality of water in representative samples. Potential for problems such as high TDS, hardness and fluoride concentrations exists and should not be discounted at the expense of simply developing groundwater.



Dug wells are seldom pumped with diesel engines like in the photograph

Existing interventions

One of the most significant features at virtually all the sites in the project area was the omnipresent structures constructed on slopes, in streams or simply in the form of *dugouts*. This clearly brought out the fact that most of the organisations working in the project areas had some background about water harvesting and conservation in general and the practice of watershed development as a means of achieving harvesting and conservation objectives.

At a conceptual level, it was evident that most of the organisations, and especially the CBOs, were attempting to combine people's participation in the efficient use and productive management of natural resources. During our discussions with many of the field level workers, it was evident that one of the objectives of their larger natural resources programme was to empower communities to help collectively utilize and sustain natural resources. It seemed an open-ended programme in its sense of co-operative effort, wherein peer communities and higher level agencies would also be involved from time to time. Therefore, we felt that the overall approach of these organisations included provisions for continuous improvement.

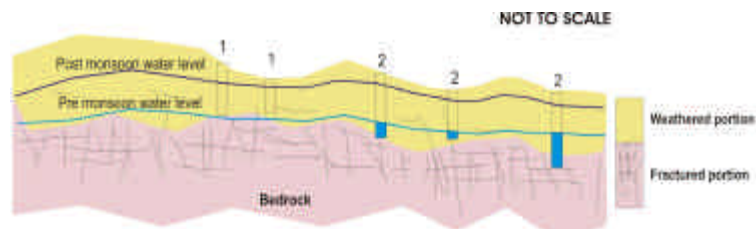
The overall programme, therefore, looks at a very broad spectrum of issues that are linked to natural resources. However, current interventions, where water is concerned still revolved around *physical* structures in the form of check dams, smaller (boulder) checks and percolation tanks. Two obvious questions were therefore raised:

- a. Whether watershed development itself could be strengthened either through a more intensive extension of constructing more structures in the field or repairs to existing structures (to make them more effective); and perhaps even a combination of these two alternatives.
- b. What is the process after construction of structures? Again with two possibilities in mind:
 - i. *systematic development of groundwater resources or strengthening the groundwater base in these areas and*
 - ii. *a management oriented approach towards groundwater, especially following the development phase.*

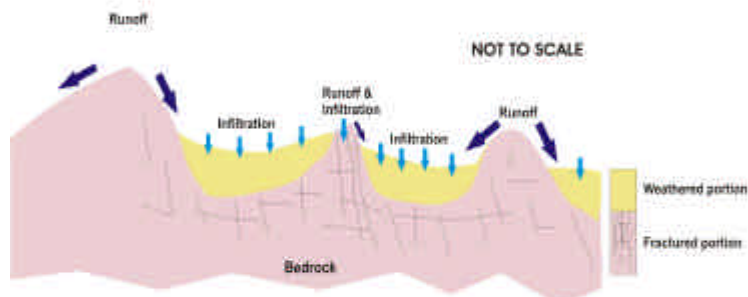
In the above light, it was thought relevant to describe under the heading of each organisation, the microwatersheds where they intend to work. This description follows and also includes specific recommendations. The last section lists more generic recommendations that are relevant to all the sites and organisations.



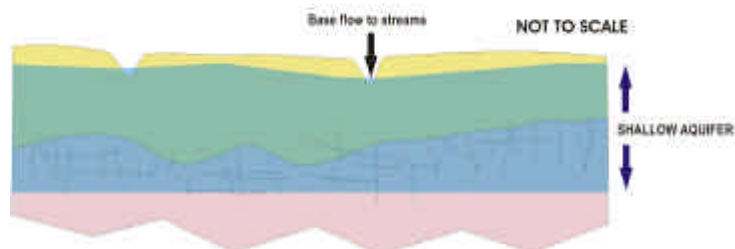
Some water harvesting structures such as this one are perennial despite being so close to catchment boundaries, clearly indicating base flow discharges even in lower order drainage



(a) Both 1 and 2 types of wells are partially penetrating, Type 1 wells dry up during the summer while type 2 wells last throughout the year, but generally show reduced yields in summer.



(b) Rainwater runs off the steep slopes; many of which are completely barren. Infiltration generally occurs on the gently undulating lands or plains, where the rocks are weathered. Infiltration may also occur on smaller ridges that are fractured.



(c) The shallow aquifer in the project area is constituted by the weathered and fractured portions of the bedrock. Foliation openings also attribute storage and transmission characteristics at some places. The water table fluctuation in most parts of the project areas is quite small, inducing base flow to streams almost throughout the year.

Figure 1: Setting the scene for Bolangir - some conceptual diagrams.

Chapter 3: ORGANISATION-WISE DESCRIPTION AND STRATEGY FOR THE PROJECT MICROWATERSHEDS (*limited data from original report presented here*)

UDYAMA: Dongabanji and Chiknibaheli

The project area where Udyama has been working are located close to Tetalagarh, where Udyama has its operations' office. Udyama is proposing to implement the water resources management of two microwatersheds:

1. Dongabanji
2. Chiknibaheli

The characteristics of the two sites and the specific recommendations are described below.

1. Dongabanji

Geology, soils and drainage

The Dongabanji site is underlain by a granitic gneiss, which shows banding and is variably foliated. The weathering of this gneiss also shows remarkable variation over an area that is barely 500 ha. At places, the gneiss is exposed on the surface as a massive sheet of rock, clearly exhibiting the main features in the rock.

Soils are also variable in thickness, ranging from being completely absent above outcrops of rock to as thick as 3 m in portions close to stream channels. Soils in the upstream portions of the area are red to brownish red in colour, whereas soils downstream (downstream of the main village) are yellowish, clayey soils.

The drainage in the area is southwesterly, with the mainstream bearing 3rd order (Figure 2). The anomaly in the drainage is evident in the northwestern portion where a prominent ridge is clearly evident. There is no drainage originating on the western flank of the project area watershed and runoff is reported to occur mainly as sheet flow, draining along the slopes in a southwesterly direction. The water harvesting structure in the southwestern portion of the area probably collects a large portion of this flow. The structure is not in connection with the main drainage channel which skirts it on the east.

Hydrogeological conditions

Groundwater conditions in the area can be studied through about 30 odd large-diameter dug wells. Virtually all these dug wells are partially penetrating with depths that are typically less than or equal to 5 m and diameters of less than 2 m. Most wells, are unlined (except in the top portion) and show a very clear-cut cross section of soil, the weathered profile and the fractured portion of the rock. The base of the fractured portion is seldom observed because of the partial penetration of wells.

Hydrogeologically, the most important features of the rock are its weathered profile, which is quite deep at places, sometimes overlain by red (?almost lateritic looking) soils. Foliation in the rock trends 283° (WNW-ESE), with foliation dips of 30-45° towards NNE. Some regional fractures traverse these gneisses and are parallel-subparallel to the foliation trend. These regional fractures run across the general drainage direction, which is NE-SW. Nevertheless, the weathering profiles in the microwatershed are variable and it is the weathering, as in most other microwatersheds in the project area, which controls the accumulation of groundwater in the shallow aquifers.

Groundwater occurrence in the area is in the form of shallow, unconfined aquifers. The top of the aquifer is marked by the water table and its base by a zone of discrete fractures and/or unjointed bedrock. Consequently, the depth of the aquifer varies from place to place, the deepest portions being close to the valley bottoms, where it may be about 10-12 m deep. Although, this study did not go into details of aquifer geometry in any of the study microwatersheds, observations during the well-inventory revealed that the high grounds are constituted of barren rock, with thin weathering profiles while lower, flatter portions show deeply weathered bedrock, the intensity of weathering also being pronounced in portions adjoining stream channels. The weathering, in most places, is manifested as

opening up of the rock openings along foliation planes. It is very likely that aquifers even within the microwatershed may be discrete from each other and groundwater occurrence could be very-very local in nature (Figure 3).

Water levels in these local aquifers are reported to fluctuate depending upon the location of the well. Generally, water levels to the north or west of the village fluctuate within a range of 3-5 m annually, whereas the water levels in wells downstream of the village, especially adjacent to the stream channels fluctuate within a range of 2-3 m annually.

Recharge and discharge

Recharge, to the local, shallow unconfined aquifer(s) occurs at the junction of exposed bedrock and the soil/weathered portion (refer Figure 3). Groundwater discharges to the surface in the form of seeps along stream channels that continue to hold base flow well into the summer. Base flow discharges are not very large but clearly indicate a continuous seep to the surface drainage. In this light, it is very likely that the recharge to the aquifers in Dongabanji is not only local but may also be quite limited in quantity.

Existing structures

Existing soil and water conservation works are evident in the region. In Dongabanji also, there are a couple of structures on or off the main drainage courses that hold water after the monsoon. Some of these structures are designed in such a manner that the low-discharge but near-perennial base flows feed them. Hence, some structures hold water even in the summer season. Some of these structures, especially the ones near the village could be repaired so as to increase their effectiveness with regard to augmenting recharge to the underlying aquifer(s).

Specific recommendations

- A broad plan of activities that can be taken up is illustrated on the watershed map (Figure 4).
- The best sites for recharge, where numerous, small dug-out structures (even in individual fields) can be located, are the portions of land adjoining rock outcrops, i.e. in areas where outcrops are bounded by soils/weathered profiles (mostly fields, where rainfed crops are grown). Two clear-cut indicators of such areas are *red soils* and *a soil profile which remains virtually dry throughout the year*.
- The best sites for recharge (where relatively little has been done) are in the portions along the base of the ridge, to the west of the main Dongabanji village.
- Most wells can be deepened to about 8-10 m below ground level (bgl) or to the bedrock, whichever is shallower.
- Some new community wells can also be considered, especially for small and marginal farmers without access to irrigation water. The locations for such wells should be in portions adjacent to the second and third order streams.

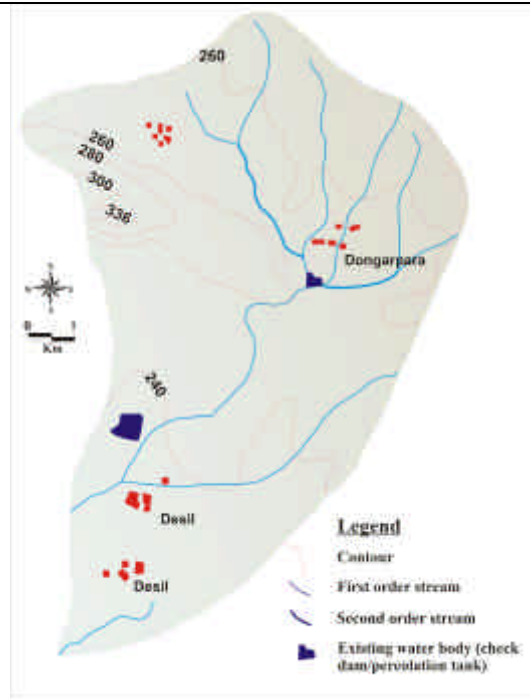
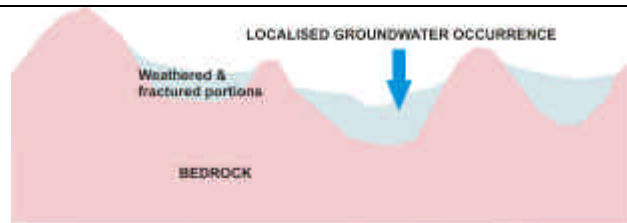
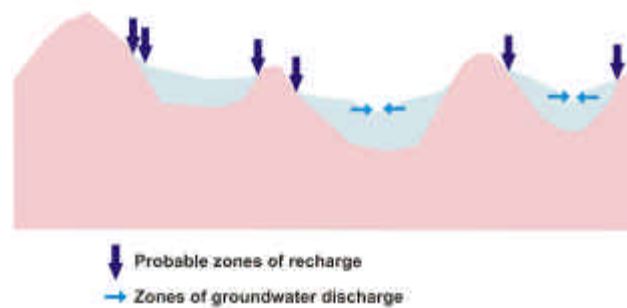


Figure 2: Dongabanji watershed



Groundwater occurrence in Dongabanji is in local pockets of highly weathered-fractured material separated (and often bounded) by impermeable bedrock exposures. Watershed development in such areas ought to consider mechanisms of recharge that are 'decentralised' and assume the 'local' nature of groundwater occurrence.



Natural recharge and discharge zones can be identified on the basis of water level water level fluctuation. However, a more direct indicator is also the type of soils; in recharge areas, soils are generally reddish and coarse grained while in discharge zones, soils are silty or clayey and are yellowish to grayish in colour.

Figure 3: Conceptual diagrams for Dongabanji watershed

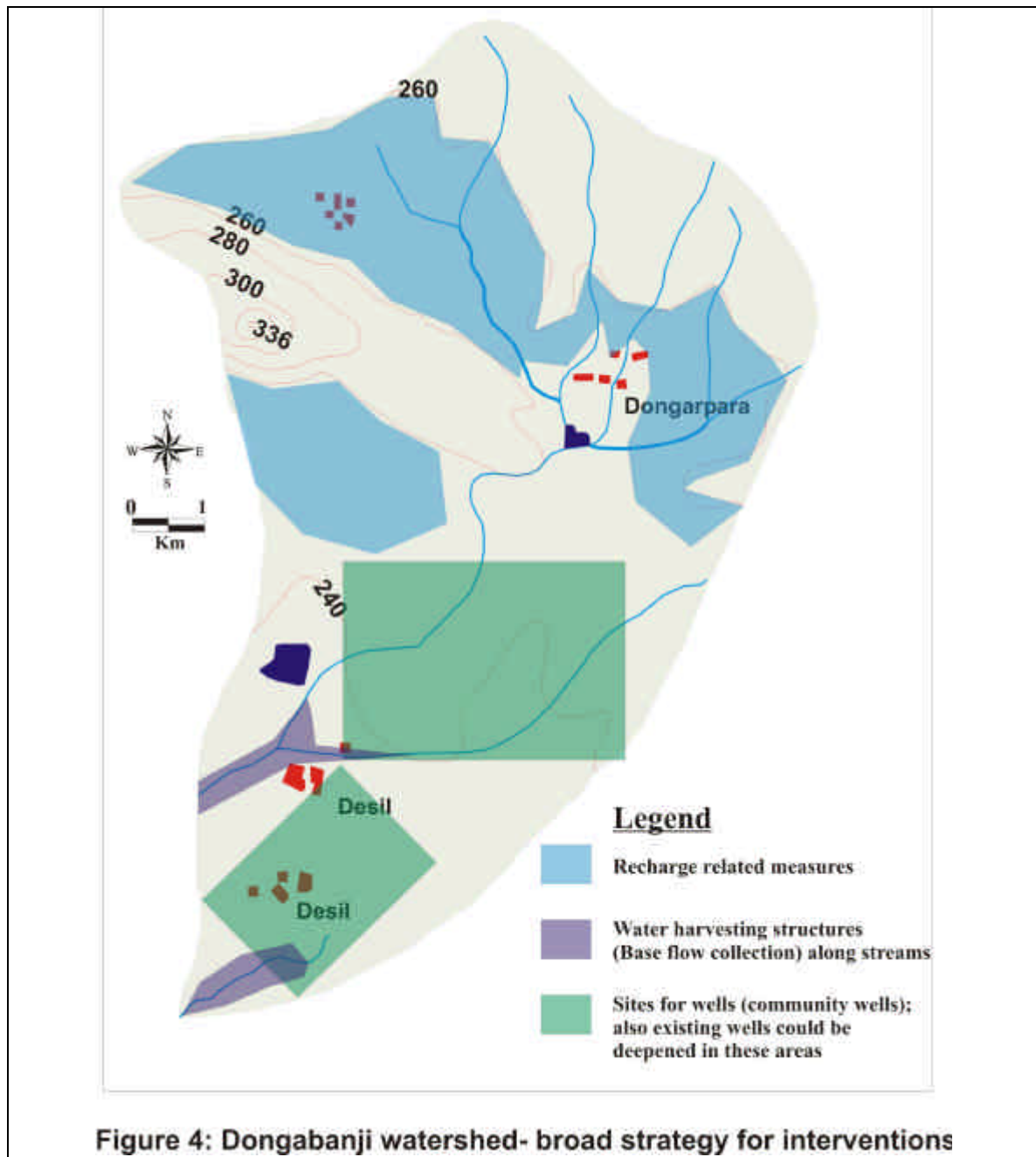


Figure 4: Dongabanji watershed- broad strategy for interventions

2. Chiknibaheli

Geology, soils and drainage

The Chiknibaheli site resembles the Dongabanji site in its geology. It is underlain by a garnet-bearing, mica gneiss, which shows banding and is variably foliated. It is traversed by pegmatite veins and is foliated just like the rocks in Dongabanji.

The soil distribution is also similar to that in Dongabanji, with soils in the upper portions being red coloured (ferralsols), appearing lateritic at some places while soils in the lower reaches are yellowish to gray. The Chiknibaheli watershed shows a relatively flatter landscape as compared to Dongabanji and also a more consistent soil cover that varies between 0.5 to almost 1.5 m.

The drainage in the area is towards the south or south-south-west, with the mainstream bearing 2nd order (Figure 5). The original drainage, in the lower reaches, has been obliterated by agricultural lands and the mainstream seems to simply disappear amidst the agricultural fields in the eastern part of the area.

Hydrogeological conditions

Groundwater conditions in the area can be studied through about 15-20 odd large-diameter dug wells. Virtually all these dug wells are partially penetrating with depths that are typically less than or equal to 5 m and diameters of less than 2 m. Most wells, are unlined (except one well, which is also relatively deeper at about 7.5 m) and show a very clear-cut cross section of soil, the weathered profile and the fractured portion of the rock. The base of the fractured portion is seldom observed because of the partial penetration of wells.

Hydrogeologically, the most important features of the rock, like in Dongabanji, are its weathered profile, which is quite deep at places. Foliation in the rock trends 283° (WNW-ESE), with foliation dips of 30-45° towards NNE. However, the foliation openings are not as open as they are in some portions of Dongabanji, clearly indicating a limited permeability for the rock. Some regional fractures traverse these gneisses and are parallel-subparallel to the foliation trend. These regional fractures run across the general drainage direction, which is NE-SW. Weathering is more consistent than in the Dongabanji watershed

Groundwater occurrence in the area is in the form of a shallow, unconfined aquifer. The top of the aquifer is marked by the water table and its base by a zone of discrete fractures and/or unjointed bedrock. Consequently, the depth of the aquifer varies from place to place, the deepest portions being close to the valley bottoms, where it may be about 10-12 m deep. The weathering, in most places, is manifested as opening up of the rock openings along foliation planes. The connectivity in the weathered layer is greater in Chiknibaheli than in Dongabanji and the aquifer continuity is greater as against the localised groundwater occurrence in Dongabanji (Figure 6).

Water levels fluctuations in Chiknibaheli are not all that pronounced and the average annual fluctuation of the water table is reported to be 2-4 m. Groundwater abstraction is limited and is generally through *tendlas* or manually driven mechanisms.

Recharge and discharge

Recharge, to the local, shallow unconfined aquifer(s) occurs at the junction of exposed bedrock and the soil/weathered portion as in Dongabanji. Groundwater discharges to the surface in the form of seeps along stream channels that continue to hold base flow well into the summer. Base flow discharges are not very large but clearly indicate a continuous seep to the surface drainage. The overall recharge to the aquifers in Chiknibaheli may exceed that in Dongabanji (with lesser rates of runoff) but due to a limited aquifer storage, much of the recharge is progressively lost as discharges in the form of base flows through streams.

Existing structures

Existing soil and water conservation works are evident in the region. In Dongabanji also, there are a couple of structures on or off the main drainage courses that hold water after the monsoon. Some of these structures are designed in such a manner that the low-discharge but near-perennial base flows feed them. Hence, some structures hold water even in the summer season. Some of these

structures, especially the ones near the village could be repaired so as to increase their effectiveness with regard to augmenting recharge to the underlying aquifer(s).

Specific recommendations

- A broad plan of activities that can be taken up is illustrated on the watershed map (Figure 7).
- The best sites for recharge, whether along stream channels (as check dams) or in the fields as *dug outs*, can be to the north of the village (upstream of the village).
- Most wells can be deepened to about 8-10 m below ground level (bgl) or to the bedrock, whichever is shallower.
- Some new community wells can also be considered, especially for small and marginal farmers without access to irrigation water. The locations for such wells should be in portions around the village or to its downstream.



(A)



(B)



(C)



(D)

Banded gneiss exposure near Dongabanji village (A). Soils are quite thick in some portions of both watersheds (B). The upper, weathered portion of the shallow gneissic aquifer, exposed in a well section (C). The overflows/spillways/exits for existing structures leave a lot to be desired and are in need of urgent attention (D).

Chapter 4: BROADER RECOMMENDATIONS FOR ALL SITES

WATERSHED DEVELOPMENT

There are a significant number of structures such as percolation tanks, check dams and small ponds in all the project areas. Specific suggestions, wherever applicable have been mentioned in the preceding chapter. However, the following list of suggestions will help all the organisations to consider (on a priority) that reviving older structures (or at least some of them) will have a significant impact than planning and executing new structures. This will also save time and costs on new structures.

- Repairs to old structures, especially earthen structures.
- Desilting of structures, especially in which finer clays (in some, even black cotton soils) have been washed in. Most of such structures are located in the downstream portions of 3rd order catchments.
- And last but not least, virtually all the existing structures have exits/spillways that need repair more than the main structure itself. Levelling of these exits, in some cases, is improper, allowing both unnecessary loss of water or silted up exits imply that the designed 'free board' is greater than the real world one, with unwanted stresses acting on some structures. *Considering the high rainfall and large runoff characteristics of many of these small basins, this aspect is of great importance.*

Likely Impact of watershed development measures and need to monitor...

The project area falls within a *high-rainfall, rapid and large runoff area*. However, its physical setting and rugged relief constrain the *lag time* for water to remain within the catchment in order that recharge to the relatively productive groundwater systems is optimized under the present set of conditions. At the same time, the hydrogeological variability has resulted in a naturally inequitable distribution of the groundwater resource; the fractured portions within each microcatchment possess a set of hydrogeological characters that induce higher yields, while the other reaches have more limited yields.

In the absence of a scientific hydrogeological analysis, benefits to the groundwater regime in many completed and ongoing watershed development programmes can only be termed "qualitative". In order to evaluate such benefits, it is necessary to evolve a continuous monitoring system that can gauge impacts of interventions (both positive and negative) on the water resources base within any project watershed.

The following factors could be monitored during the course of and following the implementation in the project areas:

1. *Quarterly water-level data from the observation well network of about 10 odd wells selected from the existing irrigation wells within the project microwatersheds. For this, the following period may be considered - end-September (corresponding to the end of the rainy season), mid-January (in the midst of the Rabi, i.e. major irrigation season), mid-March (corresponding to the end of the Rabi season - i.e. during harvest) and end-May (peak summer when water levels are at the deepest).*
2. *Groundwater abstraction could be estimated using well-inventory data from the monitoring wells; here some measurements regarding extraction of water using Tendlas (such as that done in one of the sites described in the previous chapter) may be used.*
3. *Baseflow monitoring could be undertaken at a select few localities near the structures created for surface water augmentation.*

GROUNDWATER RESOURCES MANAGEMENT – COMMON FEATURES

Having suggested a strategy for groundwater resources development in the project sites, it becomes necessary to summarize a set of common recommendations, some of which may not have been covered specifically for any particular village but remain implicit to the programme at large. These should prove useful during both, the well deepening and well sinking programme as well as in attempting to mobilize the community into after-care of wells and during groundwater resources management planning.

Groundwater resources development

- Wells will penetrate a larger section the shallow aquifer, in each area, after the programme. Well design has not been specified because we believe that the present design of about 2-3 m diameter should be sufficient for wells in almost all the areas. The structural part of the design could be decided between the villagers and the engineers from each organisation.
- In many villages, the increase in yields of different wells, even after deepening, will be somewhat variable because of the inherent inhomogeneity of the groundwater system from hard-rock regions. However, deepening will obviously reduce the inequity caused by water table fluctuations (especially the anomalous drop in water level during droughts).
- Community wells should be deeper than private wells.

Groundwater management

Although some equity will be achieved on completion of the well deepening programme, community management of the entire system (including well, and watershed development infrastructure) is a must if sustainability and drought preparedness are to be insured. The management of groundwater, across all villages will be successful if the following can be achieved :

- Regulation and control, the latter during drought years, on groundwater abstraction. **NO MOTORS/DIESEL ENGINES BEYOND 3 H.P./5 H.P. respectively.** *This does not seem an immediate risk in the absence or uncertainty of electricity. However, once wells are deepened, diesel engines may find their way into the area, more out of necessity than anything else.*
- Discourage bore wells and tube wells for irrigation.
- Proper care and maintenance of all structures, including wells (desilting and cleaning of wells, say every three to four years).
- Attempts at developing well-use networks for contiguous areas so that well interference is kept at a minimum and sustainable management of the shallow groundwater system is attained.

SELECTED BIBLIOGRAPHY

- ACWADAM. 1999 Geological and hydrogeological mapping of Shivare–Varve watersheds : Geofeasibility Assessment for Implementation of Watershed Development and Management using Remote Sensing Data. Report submitted to GOMUKH, Pune. *ACWADAM Tech. Report 99/H-3*.
- ACWADAM. 2000. Development of a sustainable groundwater management system : hydrogeological mapping of Neemkheda watershed, Bagli tehsil, Dewas district, M.P. Annual Progress Report submitted to *Samaj Pragati Sahayog for Dept. of Science and Technology project “Food security in the tribal drylands of India through appropriate technology, development and empowerment. 16p.*
- ACWADAM. 2000. Strategy for watershed development and management - Optimizing recharge and water management in the Kavalratti–Salparahalli microwatershed, Arsikere taluk, Hassan district, Karnataka : Based on rapid geohydrogeological mapping using remote sensing data. *Report submitted to BAIF Development Research Foundation, Pune. ACWADAM Tech. Report Y2K/H-3.*
- ACWADAM. 2001. Hydrogeological studies leading to groundwater resources development and management with main emphasis on deepening and sinking of large diameter open dug wells : As part of the CAPART (Govt. of India) funded “Drought Proofing” programme in several villages in the Narmada Valley, Udainagar tehsil, Dewas district, Madhya Pradesh. *Report submitted to Samaj Pragati Sahayog, Bagli. ACWADAM Tech. Report 2001/H-4*
- ACWADAM. 2001. Groundwater management initiatives through the Community Based Natural Resources (CBNRM) approach : based on a hydrogeological study with AKF partners. Report submitted to Aga Khan Foundation (India), New Delhi. *ACWADAM Tech. Report ACWA/2001/H-5.*
- Calow, R. C., Robins, N. S., Macdonald, A. M., Macdonald, D. M. J., Gibbs, B. R., Orpen, R. P. G., Mtembezeka, P., Andrews, A. J. and Appiah, S. O. 1997. Groundwater management in drought prone areas of Africa.
- Dougherty, T. C. and Walmsley, N. (1995) A framework for water resources planning procedure. *ODA Report OD/TN 70 (HR, Wallingford, UK in collaboration with Institute for Water Studies, Madras, India); 25p.*
- Fetter (Jr.), C. W. (1990) Applied hydrogeology. *Charles E. Merrill Publ. Co., USA; 488p.*
- Kulkarni H. (1998) Watershed Development and Management - a movement seeking inputs in earth sciences. *Jour. Geol. Soc. India, v. 52(2), pp. 239-241.*
- Legrand, H. 1979. Evaluation techniques of fracture rock hydrology, in : W. Back and D. A. Stephenson (eds.), Contemporary Hydrogeology - The George Burke Memorial Volume. *Elsevier Scientific Publishing Company, Amsterdam.*
- Lloyd, J. W. 1981. Initial investigation and drilling, in : J. W. Lloyd (ed.), Case Studies in Groundwater Resources Evaluation. *Clarendon Press, Oxford.*
- Macdonald, D. M. J., Kulkarni, H. C. , Lawrence, A.R., Deolankar, S. B. , Barker, J. A. and Lalwani, A. B. (1995) Sustainable Groundwater Development of hard-rock aquifers : the possible conflict between irrigation and drinking water supplies from the Deccan Basalts of India. *British Geological Survey (NERC) Technical Report WC/95/52 (BGS, UK in collaboration with University of Pune), 54p.*
- Samaj Pragati Sahayog. 1996. The struggle for survival ; Collective regeneration of endangered resource base of tribal communities in the Narmada valley. *Final Report submitted to Department of Science and Technology, Govt. of India.*