Watershed Management Planning

Watershed is a natural unit of drainage system. It has its importance for development planning within the existing natural boundaries (Guleria, 1987). A watershed or hydrological unit is a super local region considered to be appropriate for planning and management (Subramaniam et al., 1987). Working on these lines is important, especially in the hilly and mountainous terrain which have fragile and vulnerable ecological systems. A watershed is a homogenous unit in terms of lithology, structure, geographic terrain, socio-economic conditions and eco-cultural settings. Land, soil, water, forest and living organism have optimum interaction in a watershed. The watershed problems and its management issues are likely to undergo rapid changes in the years to come. Further, there is a need to establish balance between diverse demands from diverse human groups, and scarcely available resources within the watershed. The watershed is considered to be an ideal management land segment for identifying prevalent problems, recharging capacities, managing the water resources and overall sustainability after fulfilling the requirement and managing the resources.

In the Himalayan region, the problem of soil erosion and water scarcity is increasing day by day and a lot of attention is required for their conservation measures. The participatory approach in managing soil and water conservation on the basis of unit area and application of conservation measures such as rainwater harvesting; recharging water sources through pitting and contouring in the selected areas may be the useful techniques. Educating communities for land restoration, water harvesting, and water conservation may be some of the important steps in this regard. Exploitation of watershed in an unskilled manner has cumulative effects that lead to degradation of overall micro and macro components of the environment. This all cause low productivity of natural ecosystems resulting in loss of income and environmental degradations. It is, therefore, well accepted phenomenon that watershed is a natural criterion for scientific management and development. This is a valuable geographic unit considered one of the most important units for planning, land productivity, water resource development and biomass production keeping in mind sustainable development.

Though ecological consequences may not be visible at the instant, yet these
become visible in the decades after. Long term analysis indicates that the day to day activities have strong and ever lasting effects. Anthropogenic activities in spatio-temporal perspectives have a great role to play in determining the biotic pressure and management issues for a sustainable development of the watershed. The land use phenomena within a watershed are increasingly influenced by social, economic, and biological factors. Other emerging issues in watershed management mainly include the hydrological characteristics (mainly drying of the springs, floods, erosion, and siltation), global climate change, dwindling forest and wildlife resources which collectively influence not only the immediate watershed but also its adjacent areas.

There is always a requirement for improved social and technical tools for a planning and management of multi-purpose resources in a part of the world having an increasingly high human pressure (Swanson et al. 1992). The concept of river basin planning or watershed management is not a new. It is rather an exercise and effort of several decades. The importance of river basin planning was considered as a part of regionalization technique through which planning could be made possible based on per unit area of land. It is either partial planning, or multi-level planning or the integrated area development planning for metropolitan region, or sector which nowadays is becoming very effective concept. Whatever might be a unit of area in planning, it is now being mainly concentrated in contents to protecting environment, understanding and improving social behaviour and valuing cultural values which at least fulfil the basic objectives set for planning. Identification of the watersheds is therefore an important method for regionalization under planning.

In the mountainous region, watershed is taken as a primary unit of eco-development. A village ecosystem within the watershed consists of mainly biotic components (human beings, plants, animals, microbes, by-products of living organism) and a biotic components (land, soil, water bodies, etc.). Based on a balanced flow of energy input/output within these sub-systems, a watershed ecosystem is possible to be stabilized, productive and efficiently functional.

In the present watershed- the Dhundsir Gad watershed, has been taken for environmental monitoring, impact assessment and management. There have been three emerging issues pinpointed in watershed management planning. First, it concerns about the effects of integrated geo-ecological planning concentrated mainly on the hydrological and
ecological aspects. Second, it incorporates the effects of geo-ecological planning on watershed management. Third, it concentrates the issue of rainwater harvesting as the prime issue in the mountain environment.

### Integrated Eco-development Planning

According to United Nations Environment Programme (UNEP), “the eco-development concept has been originally designed to support the efforts of people living in the villages and such other rural settlements, and subsequently to understand and utilize that system in their development, the basic national resources and human skill available in their own environment”. Accordingly, eco-development means development of ecosystem inferring to maintain growth and increasing productivity.

Individual programmes designed to solve regional problems within a catchment cannot be undertaken at par in accordance with optimum benefits for the people affected otherwise. For this reason, there are broad plans for managing different land uses, hydrological, and environmental issues in the catchments. The integrated river basin development schemes have recommended optimizing various needs within a catchment for fulfilling different needs. These could be issues based on drainage and irrigation, navigation, flood control, soil erosion, agricultural production, industrial and domestic water supply, recreation and environmental conservation measures, etc. Thus integrated eco-development means optimum utilization of natural and cultural resources for a balanced and sustainable development of a region.

### Environmental Management

The deterioration in environmental components requires always some treatment to make system fit to natural setting so as to run this system for long without causing any of the harms either to biotic or abiotic components. The environmental management therefore means to conserve and regulate utilization of natural resources within acceptable limits. Environmental components with the human interferences are going to be modified and thus changing in the nature that requires regular monitoring. It is therefore having three important aspects in environmental planning, one prioritization of problems or issues, second environmental monitoring and third environmental management (Rawat, 2002).

The important components considered to be taken care of from ecological and sustainable planning at the watershed level are: (i) population stabilization, (ii) integrated
land use planning, (iii) watershed management including biotic and abiotic components, (iv) wasteland management, (v) vegetation regeneration and afforestation, (vi) biodiversity conservation with ecosystem basis for biosphere reserves, and (v) environmental education and awareness.

**Planning Strategies for the Watershed Management**

Before initiating the watershed management planning, among the determinants mainly a geographic unit of planning is always taken into account on top. A drainage unit can be hierarchically classified as catchment, sub-catchment, watershed, sub-watershed, mini-watershed, and micro-watershed (Rawat, 2002). The catchment which is taken for the present study is a mini-watershed.

**Aims of watershed management**

The basic concept of watershed management is to incorporate every independent component or resource together as a result these are termed as interdependent. Managing land, water and vegetation in an integrated manner as natural resources on sustainable basis is the need of current management practices. Watershed management implies the proper use of all land and water resource of a watershed for optimum production with minimum hazard and degradation to natural resource and environment. The important objectives of a watershed management programme therefore are as under:

1. To control surface runoff so as to cause minimum damage through soil erosion to the catchment area.
2. To control soil erosion and to apply effective measures to reduce the sediment yield.
3. To reduce flood incidents in the downstream areas and to apply preventive measures in safeguarding human habitation, farms, forests, ponds, reservoirs, etc.
4. To enhance a storage of groundwater by a way of recharging through rainwater, and snow harvesting.
5. To suggest a rational use of land resources in the watershed with a purpose of developing forest and fodder resources.
6. To protect, conserve and improve the land for efficient and sustained productivity, and
7. To develop and manage the water sources, springs and streams; thus regulating
and making available supply to irrigation, drinking water, hydropower, pisciculture, etc.

**Geo-ecological Zoning**

While considering different elements for geo-ecological zoning and studying hydrological cycle, it is generally observed that topography, geological setting, running water, infiltration on one hand and anthropogenic activities on the other determine most soil erosion in the hilly slopes. Considering the aforesaid factors in mind, the study area is divided mainly into three geo-ecological-zones (Table 7.1, Fig.26&69). These are as follow.

1. Geo-ecological zone of high erosion areas (1000 - 1600 m)
2. Geo-ecological zone of moderate erosion areas (> 1600 m)
3. Geo-ecological zone of low erosion areas (< 1000 m)

The detailed description of these three zones is shown in Table 7.1.

**Table 7.1 Geo-ecological zoning for Dhundsr Gad Watershed**

<table>
<thead>
<tr>
<th>Ecological zone</th>
<th>Sub-tropical Zone</th>
<th>Sub-temperate Zone</th>
<th>Temperate Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (m)</td>
<td>&lt; 1000</td>
<td>1000 - 1600</td>
<td>&gt; 1600</td>
</tr>
<tr>
<td>Landforms</td>
<td>&quot;V&quot; shaped valley, gorge, interlocking spurs</td>
<td>Scars, dip slope, convex slope, water divide and colluvial fans</td>
<td>Hill range, Khul, water divides, scars and planer surfaces</td>
</tr>
<tr>
<td>Average slope</td>
<td>Moderate to high</td>
<td>Moderate</td>
<td>Steep</td>
</tr>
<tr>
<td>Slope shape</td>
<td>Concave</td>
<td>Convex</td>
<td>Linear</td>
</tr>
<tr>
<td>Slope aspect</td>
<td>NS/SE</td>
<td>NE/SE/SW</td>
<td>SSW/SE/E</td>
</tr>
<tr>
<td>Drainage</td>
<td>Defined</td>
<td>Well defined</td>
<td>Undefined</td>
</tr>
<tr>
<td>Discharge</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Lithology</td>
<td>Phyllite</td>
<td>Quartzite, metasics</td>
<td>Gneissic and quartzite</td>
</tr>
<tr>
<td>Soil</td>
<td>Fine</td>
<td>Coarse</td>
<td>Skeletal</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Zone of reduced recharge and seepage</td>
<td>Zone of recharge and over flow</td>
<td>Zone of infiltration and surface runoff</td>
</tr>
<tr>
<td>Climate</td>
<td>Warm with low rainfall</td>
<td>Moderate by warm and medium rainfall</td>
<td>Cold with moderate precipitation</td>
</tr>
<tr>
<td>Natural vegetation</td>
<td>Mixed tropical vegetation</td>
<td>Degraded pine</td>
<td>Degraded oak, dense pine</td>
</tr>
<tr>
<td>Land use</td>
<td>Wasteland</td>
<td>Cultivated and forested</td>
<td>Pastureland and degraded forest</td>
</tr>
<tr>
<td>Hazards</td>
<td>Slope failure, landslides and floods</td>
<td>Mass wasting and stream bank erosion</td>
<td>Sheet wash and gully erosion</td>
</tr>
<tr>
<td>Impacts</td>
<td>Zone of less inhabitation with scattered form of cultivation</td>
<td>Extensive cultivation with compact settlements, road construction and congestion of other developmental activities</td>
<td>Zone of scattered settlements and intensive intensive grazing</td>
</tr>
</tbody>
</table>
1. Temperate zone (1000-1600 m)

These areas are marked by active landslides, high biotic pressure, moderately steep slopes with thin vegetation cover and high concentration of gullies caused due to streams. Soil creep, gully erosion and riverine erosion are very common. It is interesting to note that all the potential landslide zones could easily be recognized in this area. Some of the old landslide zones which could not yet fully be stabilized and where the slumping or sinking activities are still occurring are also characterized under this category. Due to excess seepage, clay is associated with the gneissic boulders as a weathered product which later slips down on moderate slopes, as a result soil creep occurs. In some places, soil or debris creep occurs below the surface, resulting in sinking or subsidence of the upper part of the land.

The process of erosion is observed in the form of slithered rocks with or without debris, debris slides and rock falls. The causative agents of rock slides and debris slides is due to fast running rainwater, infiltration through cracks, gravity movement due to lubricating action of surface water and frost action. Examples of debris slides could be seen around Koti and Dharkot village (Plate-10) where old landslide debris, deposited on steep slopes of the hills, gets assembled after becoming saturated with water. Frost action and chemical weathering from winter to the rainy season are important agents in disintegrating rocks in the study area. The products of weathering are removed by running rainwater and gravity action. This is evident from the marks available in Semgarh (Shivalaya) valley and adjoining areas. Here, the rock formations are mainly limestone and ferruginous quartzite. The effect of frost action is observed to be dominant in higher reaches around Semgarh where moisture and the lubricating effect of water provide a very strong mechanism for movement along the slopes.

Underlying impermeable slates get slide along weaker planes like joint and bedding which are lubricated by moisture. Most of the major slide zones mapped in the area are confined to the quartzite units (Fig.26&69). Some potential slide zones adjacent to springs are also noticed around Kafana village.

2. Sub-temperate zone (> 1600 m)

This unit is generally characterized by old landslide zones with gentle to moderate slopes and sparse vegetation cover. Cultivated lands are located along south facing slopes. Sheet flows, concentrated and diffused runoff with and without loss of soil, creep, rill and
gully erosion are seen in varying degrees. The process of gully and rill erosion occurs with variable intensity and erosion rate. Such zones are seen in adjacent areas of Khal and ridges. Most of the slopes are stable, excluding the areas having heavy gully and rill erosion. On gentler slopes, thick material consisting of mixture of water and sediments moves down as a mudflow. Such flow results in not only in the removal of detritus, but also plough up its track breaking up hard rocks. In Panduwakhal and Gaddikhal areas, degraded forest areas are covered with mudflows. Soil creep, rill and gully erosion are the common geomorphic processes. The longer and steeper the slopes, the more would be soil erosion due to surface runoff (Fig.26&69).

3. Sub-tropical zone ( < 1000 m)

These are the areas starting from low altitude to slopes with dense mixed forest type and less cultivated lands. Old landslides were also observed in these areas which have been stabilized and forest growth has occurred. It is also observed that on steep scarps, where little or sparse vegetation cover was developed, no development of gullies was found. As a result, the erosion rate is also less in this zone.

On slopes where rills are not developed, unconcentrated overland flow causes the surface erosion (Plate-20). In the pastures (thatches), the impact of falling raindrops is reduced by vegetation and grass cover and the infiltration capacity of a grass surface is high. The erosion rate due to surface runoff is considered to be moderately low. This area is lying in Sema and Rankandiyal villages. It is characterized by open or dense mixed forests. The slopes are reasonably stable at present but any imbalance due to human activity like deforestation may cause unstable slopes. Some old landslide zones falling in this type of area can also be recognized around the mouth of Dhundsir Gad which as a result of slumping have given rise to the formation of landslides.

Geologically, the slope zone of low erosion is characterized by dense mixed forest cover, and shrubs (Fig.26&69). The rock types are exposed to phyllite and minor bands of schist. The effects of weathering and erosion on phyllite are not so pronounced. It is evident from these results that the landslides are caused due to a variety of reasons in varying regions. But some of the contributing factors in causing landslides play a significant role as follows.

(a) The zone is covered by dense mixed forests, hence part of the rainfall is intercepted and splash erosion occurs.
The area receives minimum rainfall for short term, whereas high rainfall occurs sometimes. Erosion in this region is generally in the form of sheet wash or mudflow.

Due to terrace farming and the harder gneissic rocks, the erosion rate is not so high. Most of the moderately high erosion zones are with undulating terrace cultivation and moderate slopes.

Geo-ecological Planning

The Himalaya includes all aspects of hydrological cycle influenced mainly due to prevailing geological setting, landforms and ecology. In context to Dhundsir Gad watershed, inhabitants living within the boundaries of the watershed mainly depend on land and water, so that the need of irrigation is experienced at a greater extent. Being a hilly terrain and scarcity in seasonal availability of moisture, the problem of irrigation is realized in many areas. At higher altitudes above 1000 m, the main sources of water are either perennial springs or streams. The villagers showed their right on these water sources which are used for irrigation. Paddy, the staple food, is generally grown on the fertile lands adjoining the River Dhundsir Gad. However, other varieties growing in upland or higher reaches do not get water for irrigation and depend mainly on summer and winter rains.

The summer season or Kharif crops are consisting of maize, pulses (moong, mash), etc. The winter season or Rabi crops include wheat, peas, beans and mustard. On either of the side of the Dhundsir Gad, the valley begins to rise in terraces, and water passes through gravitational force through canals which are found in the lower parts of the study area. In the Dhundsir Gad, the low lying valleys have a gentle flow of streams. It is because of these reasons; ponds and tanks are needed to be constructed for water storage.

The embankments are also constructed in the study area which is aimed at protecting cultivable land from floods and surplus water during rains. The overflow of water into mud water channels need to be regulated to irrigate other crop fields where most of the agriculture is dependent on monsoon rains. An important attempt is made by the local people in this regard for the development of controlled drainage system and irrigation facilities which helped make this valley a little bit productive in terms of agricultural farming. Near Shivalaya, the large rocks that had rolled down from the hill tops, are lying either of the banks and obstructed at frequent places within the Dhundsir Gad. This top is dragged out the rocks and the level of river was lowered down. Thus, this topography
from the valley to mountains regulates the water within the Dhundsir Gad.

There is a prime need to construct such protective rainwater harvesting structures so as to arrange the supply of water regularly to each village. Due to lack of these farm inputs mainly irrigation, agricultural productivity steadily declines. One of the important measures to fulfill water requirement is possible through the construction of concrete canals in the valley. The Rampur canal was constructed through the right bank of River Dhundsir Gad that runs along the phyllite cliffs above Dang. Here, it splits into four channels, and finally falls over the ridge of the top at Rampur village. Some of these canals are still important sources of irrigation, but in most of the cases they have been narrowed down. The surplus water of the Dhundsir Gad, for example, is used to regulate and harness for irrigation purpose before Mathana.

Looking at the present growth of population, the output of these irrigation projects lies in the fact that these drain into marshes which after reclamation are converted into crop cultivation. Besides, no ecosystem is either self-sustained that can be further linked to other systems to establish inter-linkages in terms of export-import of food energy flow.

The high altitude range of the present watershed supports one of the densest and richest parts of the sub-tropical and temperate forests in the region which covers more than 60 per cent of the total land area. In a recent development, the forests in the Dhundsir Gad watershed are destroyed in search of fuelwood and fodder which is highly required by the livestock population of the local people. The smuggling of wood for building construction and other similar purposes has been high for the last some years. The deforestation in the valley has unfortunately been disturbed by the ever increasing ecological imbalances that has increased the local temperature. Because of these reasons, there is a scarcity of irrigation and drinking water mainly in the summer season. There are instances that at many places, local people supply drinking water from a distance of 3-4 km and irrigation is mostly dependent on rainwater. If these determining factors are not regulated within a time, the economy at local level will be shattered down. Thus, it will not be wrong to state that economic progress of a region depends much on availability of irrigation water and its proper management.

Similarly, the problems of ever increasing pollution in water and soil loss has caused due to construction of motorable road and frequent use of chemicals in agriculture and pesiculture. This has become very serious day by day. The inhabitants living in the villages dispose of their refuse in the open places. In the rainy season, it is transported by
these polluting agents of water. This polluted water poses a serious threat, not only to human life but also to wildlife. The road construction adds landslide and soil loss. It has disturbed the entire ecosystem and the law of the forest prevails these days which is considered most responsible for sedimentation in the river and land slide zones.

In fact, the Dhundsir Gad is the lifeline of all the inhabitants. The river is getting polluted with siltation at an alarming rate. The liquid and solid wastes of the entire valley also drain into it.

Geo-ecological plan for forest

Geo-ecological plan has shown above 2000 m where top ridges of the watershed occupies first ecological zone. At present, this zone is under degraded oak forests. But for the sound ecosystem, this zone is proposed for afforestation under deodar and oak forests. In a rotation, these tree species should be replanted by forest department. The pine forests need to be replaced on compartment wise. Just under first zone between 1200-1600m altitude, mixed forests of oak and associated species Burans (Rhododendron arboreum), Kafal (Myrica esculenta), Anyar (Lyonia ovalifolia) etc. should be replanted in the area which is present under wasteland or with pine forests in scattered forms. There are 16 villages located in this zone. Climatically, this zone comes under humid temperate. Occasional snowfall is very common feature during winter. The proposed oak forests can be used for fodder by the villagers on a rotational basis mainly in an early spring season. Deodar and oak forest species will retain the moisture in the soil, as a result the infiltration capacity of water increases. Recharging ground water in the aquifer zone is becoming short and are being dried up day by day.

Wasteland is the key component of watershed management plan. In this context, village community land requires proper planning. Above 2000 m, village land is under pastureland and very rare pine forest in scattered form constitutes the wasteland. It has moderately gentle slopes with convex features of topography. Therefore, it is suggested that the area is suitable for fodder tree plantation. There will be a growing need of the inhabitants at village level plan. It helps earn money to the villagers in making them self-sufficient. Below 1200 m, geo-ecological zone is under pine forests which are under exploitation and the steep slopes are as if wasteland. The geo-ecological profile (Fig.-26&69) of the existing villages shows that this zone has high intensity of erosion by numerous streams. This zone should be brought under dense pine forests on rotational
basis. The local requirement should be kept in mind before any planning. Conservation measures such as requirement of drinking water, grazing land and daily requirement of the villagers would be of prime importance to be planned in a scientific manner.

**Geo-ecological plan for agricultural land**

Above 1600 m particularly in the upper valley, entire steep and moderately slope areas should be under horticulture. The apple, orange, lemon, peach, plum, etc. are the major citrus fruits considered to be suitable to grow widely. Citrus fruits can be more successful in the watershed because of: (i) less damage due to wild animals, (ii) durability for storage, (iii) simple but not hard packing during transportation, and (iii) easy transportation from one place to other.

Citrus fruits are useful to grow in the high altitude villages, *i.e.*, Sema, Kafana, Arari, Gonikhal, etc. Ogal (*Fygyopyrum esculentum*), kotu or madua (*Elucine coracana*) and Ramdana (*Amranthus paniculatus*) should also be grown in the moderately steep land all over the catchment.

Based on the farming practices, Madua, Jahangora (*Panicum miliacum*) and dry rice in the summer (*kharif*) and wheat, barley in the winter (*rabi*) season should also be grown on the gentle slope lands throughout the catchment. The straw of the crop residue is used for fodder. Rice and wheat are usually grown in the valley regions in summer (*kharif*) and winter (*rabi*) seasons respectively. Keeping in view the growing demand of vegetables such as potato, onion, beans, peas, cabbage, tomato, *etc.* should be grown in the valley land wherever irrigation is possible.

**Rainwater harvesting**

Rain water harvesting is a scientific way to capture the rainwater during rains. The rainwater can be stored above ground or regulated to recharge the underground aquifers which can become as reserves later to use. These alike practices are mostly in use in the rural localities through natural process. But scientific structures in harvesting rainwater in the mountain areas where topography is steep and rugged, creation of skillful methods in harvesting rain is a need of the hour.

**Why rainwater harvesting?**

Rainwater harvesting has therefore become a priority of the hour because of mainly following two reasons.
a. Surface water is inadequate to meet the day-to-day demand as a result most of the time the continuously growing populations have to depend on underground water resources.

b. Recharging of ground water has also been decreasing due to rapid deforestation and low infiltration of rainwater into the sub-soil.

**Traditional rainwater harvesting techniques**

Rainwater harvesting is practically reliable and accepted techniques for watershed management in the Himalayan region. There is a need to develop scientific structures under the hill area development planning so as to fulfil its demand from drinking to irrigation water. Traditionally, the rainwater harvesting was mainly concentrated on power generation, development of irrigation canals and developing small scale industrial units such as water mills (*Gharats*). The villagers harvest the raindrops directly from rooftops which they collect water and store it in the tanks in their courtyards. They collect rain from open community lands and store it in artificial wells. They harvest monsoon runoff by capturing water from swollen streams during the monsoon season and store it through various forms of water bodies. But now the situation is quite different. The existing indigenous practices are in use to fulfil the need of water in the past. With the diminishing discharge from natural resources, such practices presently have become inadequate and incapable to meet the ever increasing demand of water of the local communities.

Year round availability of water is a major problem. The rivers in the Himalayan region receive too much water during the monsoon but too little in rest of the months of the year. It is also clear from the previous chapter that there are a number of channels which use both perennial and seasonal sources to supply water in agriculture. These channels are constructed, operated, managed and repaired by the local communities. Similarly, these water sources not only provide access to springs and groundwater but also are helpful in harvesting the rainwater. The traditional techniques are generally suitable for the headwater zones of the study area.

Considering ever increasing demand of water resources in the study area and to ensure adequate supplies of this commodity to fulfil different purposes in coming future, identifying, developing, implementing appropriate policies and programmes for the management of mountain water resources, the following steps could be helpful as under:

1. Inventory of water harvesting techniques and their assessment in terms of potential, cost and benefit is always desirable.
2. Better understanding of water harvesting practices in the mountain areas including the impact of local culture, traditional practices, available policies and programmes on water harvesting techniques.

3. The farmers need to be trained by way of technical know how and field visits about to create greater extent of awareness about sustainable water harvesting techniques.

4. Development of databases on different aspects such as hydrology, meteorology, geomorphology, geology, and biological study of the environmental impacts of different water harvesting systems.

In the study area, high amount of water is received through torrential and high intensity of rainfall that goes waste as runoff and cause problems of soil erosion and floods. In addition, it has uneven and erratic distribution which results in low moisture to the crops and vegetables. On account of these reasons, the crop yields are low and instable which adversely affects the socio-economic status of the people in the region. Moreover, due to undulating topography, canal irrigation system is not easily feasible to provide and springs from groundwater are inadequate in water supply and are not economically accessible in this region. Minimizing water scarcity from the region, traditional techniques such as rainwater harvesting at farm level prevail where the natural rainwater is stored in providing storage structures and are usually being used for domestic and irrigation purposes.

Based on the salient features of topography, climatic conditions and occupation of the people within the study area, traditional and new techniques on farm level for rainwater harvesting is developed. These include construction of contour bunds, semi–circular hoops, trapezoidal bunds, “nala bandhan”, graded bunds and other different types of check dams. Developing new harvesting techniques at the farm level, rainwater harvesting in the foothills are selected which receive high amount of rainfall and were degraded due to unscientific land and water management practices. Due to climate, landform changes and increase in population, the following techniques may be helpful to harvest the maximum rainwater.

A- Traditional Techniques

1. Dammed Ponds: Ponds are constructed by constructing a dam of soil across a flowing stream of water. These ponds may be very suitable for those areas where topography is rugged and slope is steep. In these structures, the collection of water is raised up to an optimum height. “Talab” is constructed by digging out soil in a leveled land. These ponds
are fed by the surface runoff. The areas having heavy soils are suitable for these ponds because of low flowing rate of water into these ponds. Such types of dammed ponds are found in Margaon village.

2. **Cemented or Stoned:** In the hilly areas due to steep slopes, it is not easy to construct big ponds. As a result, in these areas rainwater is carried out through “khuls” (mud irrigation water channel) to the agricultural fields and is stored then in small ponds. These ponds are made up of by cement and stones.

3. **Construction of “Bauris” (springs):** The “Bauris” (springs) nowadays are cemented storage structures which are used to collect water from natural sources and hence are rainfed. In this case, cemented storage structures are constructed across natural source of water and automatically considerable quantity of water gets accumulated therein.

**B- Modern techniques**

1. **Run-off harvesting short-term storage:** Contour bunds constructed along the contour lines trap the water and retain water behind the bunds, whose height and slope determine the water storage capacity. Crops or trees are grown within the bunds. Contour bunds range in the height from 0.3 to 1 m. The length of the bunds may range from 10 m to 100 m. This technique has been used in various countries as well as in this part of the country.

2. **Semi-circular hoops:** semi circular hoops consist of earth embankments which are constructed in the shape of a half moon with the tips of the semi-circle on the contour. The water is collected within the hoop from the area just above it and impounded to a maximum depth defined by the height of the bund. The height of bunds ranges from 0.1 to 0.5 m and the radius may range from 5 m to 30 m.

4. **Trapezoidal bunds:** Trapezoidal bunds consist of earth embankments constructed in the shape of trapezoids. The tips of the bund are placed on the contour. Water is collected from the slopes above the bonded area and excess water overflows around the tips. The rows of bunds are intercepted to overflow from the above rows. The layout of trapezoidal bunds follows the same principles as those for semi–circular bunds, but they usually enclose a large bounded area. The height of the bunds ranged from 0.3 m to 0.6 m and their width across the tip ranges from 40 m to 160 m. These bunds are used extensively for irrigation.
of crops, grasses, shrubs or trees and enable inter-cropping within the large enclosed area.

4. **Nala Bandhan (mini earthen check dams):** The gullies and ravines originating from hills are transformed into the shape of “nala” (small stream) at the foothill and divide the agricultural and non-agricultural land into various segments. These “nalas” could conveniently be converted into series of mini water reservoirs with suitable structures such as earthen check dams. For constructing the check dams, trenches of size 1 m depth and 0.75 m width are excavated and filled with puddle clay. Above this foundation core, wall of the dam is prepared with puddle clay and the embankments over the core wall are prepared with locally available soil. Stone pitching on the upstream side is done to prevent damage of the dam. To drain out the excess rainwater side spillways at suitable height are provided with stone pitching. Between the earthen check dams for its strengthening, wall from loose boulders is constructed for minimizing the effect of run-off due to its velocity.

a. **Off-contour bunds or graded bunds:** Off-contour bunds consist of earthen or stone embankments which are built along 0.5-2.0% slopes. These contour bunds during high intensity of rain can be used for irrigation as well as safe drainage in case of access amount through the field. It provides opportunities of additional water for irrigation and safe disposal in case of excess water from the channels to the crop fields. The height of the bunds ranged from 0.3 m to 0.6 m. The bunds constructed below this range usually have a wing to help intercept water that over flows from the upper portion of the bunds.

b. **Rock catchment:** Exposed rock surfaces are used for the collection of water. The rainfall on the exposed rocks is drained through gravitational force to the lowest points, sometimes along low walls. Here, it is collected in a storage tank or reservoir of earth fill embankments; gravel stone fill embankments, stone masonry dams or concrete dams. The water from these reservoirs may be used for domestic, irrigation or sometimes for stock purposes.

c. **Ground Catchment:** The ground surface is used to collect water into storage tanks or reservoirs. The vegetation from ground is cleared, compacted and then reshaped to create a series of channels leading to the reservoir. So these grounds are compacted which sometimes are covered with gravel.

d. **Flood water harvesting–short term storage:** The wide valleys are re-shaped to form a series of broad terraces. The rainwater is collected within these terraces to form in these series of accumulating water flowing through stones, gabion or concrete weirs. The
terraces are used to grow trees or crops. This water harvesting system is also useful in growing trees along the main roads.

e. Diversion of run-off: Diversion of water through flood is directly made into the fields. Water is diverted by a diversion dam which is sidetracked through channels to basins where the crops are irrigated with the help of flooding.

f. Check dams for aquifer recharge: Small rocks or concrete dams are built across the depressions to slow down the velocity of flow to enable a large amount of water to infiltrate into the alluvium under the channel bed. This added infiltration helps replenish the aquifers. Water is stored in the aquifers and utilized through wells. This system permits less evaporation losses than a surface reservoir and also has less problem of siltation.

g. Sub-surface dams: Sub-surface vertical barriers are constructed across the alluvium and down to bed rock. The water intercepts within the alluvium. This water flows along the surface and is collected in sub-surface reservoir created by the barriers. Evaporation losses are minimal. Expensive construction is avoided so as to become these adoptable at user levels. Barriers are constructed from clay stone masonry, concrete or steel sheet and pipes. Water is utilized by gravity flow or shallow wells or bore-holes. It is a common practice to construct sub–surface dams together with sand dams.

h. Roof rain water harvesting: Now-a-days the techniques of roof rain water harvesting have been evolved with a view to encouraging rainwater harvesting and its use to supplement irrigation and domestic uses. Under this scheme all the buildings at household level have to bring within the provisions of roof water harvesting and its storage. With this practice rainwater is collected from the rooftops and is stored in the dug wells and ponds for washing, drinking of livestock population and irrigation.

At some places, there are big gullies and ephemeral streams in the watersheds originating from low hills and flows down through cultivated lands. Earthen check dams across these gullies or streams can be constructed at suitable sites to store runoff with multi-purpose benefits like recharging underground water, irrigate crops and other similar uses.

Works related to the development of land, crop, vegetation and drainage line treatment need to be designed and developed in the catchment first, and then the runoff and silt load is required to estimate for treating the catchments or micro-watersheds. It should be designed for 60 to 80 per cent probability level of lowest assured runoff.

The hilly part of the villages particularly in the north western part has been leveled
with moderate slopes. The area is sloppy and undulating. The soils are loamy sand to sandy in texture and at some places there are silt, loam, sub-angular to angular blocky structures having very deep and erodable features.

There is an urgent need for flood protection and irrigation water at farm level down slope the hills. The techniques to utilize surface run-off would remain a viable options. The rehabilitation of the upper watersheds after reducing run-off and erosion from the hills through soil conservation measures need to apply on priority. For the successful implementation of traditional rainwater harvesting techniques, the capacity building of the implementing agencies should be done for undertaking investigations and research in the areas mainly surface hydrology, groundwater and watershed behaviour.

**Model for Sustainable Watershed Development**

Attaining sustainable development, identification of watershed at micro, meso and macro levels is the primary need (Fig.70). It should then include identification of emerging watershed issues such as change in landforms, land use changes affecting the landscape pattern, effects of land use pattern, interaction between different components, and landscape pattern. Thereafter, a process of impact analysis of prioritized problems and their continuous monitoring for reasonable period would be needed. Thus, a long period approach to minimize the adverse impacts is required to resolve sustainably these issues. The participation of different agencies is also required to manage through coordination among these. This would ultimately bring together the natives, concerned agencies and ultimately enrich the stakeholders and the affecting policy at the watershed level. The better understanding of these complex phenomena suggests therefore a model that incorporates the need based issues of the stakeholders as well as the concerned government.

**Conclusion**

The technical feasibility of many watershed projects mainly focus on applying corrective measures in response to deforestation, declining soil fertility and productivity, erosion, landslides, sedimentation, flood in downstream water quality and non-dependable water supply, etc. Changing hydrologic behaviour triggers a chain of reactions in other processes such as soil erosion, nutrient leaching, water quality, spatial and temporal distribution of water. Therefore, the emphasis in watershed development is generally
focused on crop farming, forestry, land use, and other structural interventions. Such interventions mainly affect the hydrologic responses within a watershed through increased infiltration rate in the existing soil, decreased surface run-off, regulated flow and flash floods, water storage, and recharge of the aquifers. Implementing different aspects in accordance with ecosystem approach to different land use parameters enable one to understand better the hydrologic responses. Under these circumstances, the assessment of the hydrologic effects of land use transformation on both water yield and its flow regimes work with the basic processes which later trigger the environmental impacts in the watershed management.

The analysis of geomorphic background reveals that Dhundsir Gad watershed is a homogenous landscape with the differences in geological structure, relief and soil profile. This micro watershed gets the water circulation from the three tributaries Ulari Gad, Taula Gad, and Chauni Gad.

The area also suffers from cloudburst in and around the Sirsed village which is located on colluvial fans. In the geological past, the weathered material is deposited in the forms of fans at the bottom of steep slopes. Recently human settlements are coming up in these locations.

The surface hydrology in the Dhundsir Gad watershed is also influenced by human activities and natural hydro-climatic process. The variations in seasonal water availability need to be regulated and be matched in accordance with the ever increasing year round demand for water. Harvesting and sustaining local water resources need to be better understood and applied at household level in the watershed.

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