British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

DFID Department for International Development

Augmenting Groundwater Resources by Artificial Recharge (AGRAR): Progress of activities May-November 2003

Groundwater Systems and Water Quality Programme

Commercial Report CR/03/298N

BRITISH GEOLOGICAL SURVEY

COMMERCIAL REPORT CR/03/298N

Augmenting Groundwater Resources by Artificial Recharge (AGRAR): Progress of activities May-November 2003

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Key words

Groundwater; aquifer recharge, India.

Front cover

Cover picture shows the inauguration of the weather station at the Chikhalgaon research site, Kolwan Valley, Pune, India

Bibliographical reference

GALE, I N. 2003. Augmenting Groundwater Resources by Artificial Recharge (AGRAR): Progress of activities May-November 2003. *British Geological Survey Commercial Report*, CR/03/298N. 23pp.

Keyworth, Nottingham British Geological Survey 2003

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Acknowledgements

In addition to the BGS project staff who have commented on and contributed to the report, acknowledgement is also given to all project staff working for the partner organisations for their contribution in establishing the field sites and undertaking initial field surveys. The contribution made by Dr Marcus Moench to planning meetings and in reviewing the draft review reports is also appreciated.

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Overview

Progress of the DFID-funded KAR project entitled "Augmenting Groundwater Resources by Artificial Recharge" – AGRAR (R8169), was reviewed in early November 2003 at the three research sites and during a meeting of all partners in Ahmedabad, Gujarat.

Draft inception reports for the three research sites and review reports for the two ancillary studies were presented and discussed by all partners. It was agreed that final draft versions of these reports would be prepared by mid-December 2003 for publication on the project web page in January 2004.

The delay in initiating the instrumentation and surveys at the three research sites has resulted in significant loss of data during the 2003 monsoon season. However, the conceptual understanding of the sites has improved and aspects that need to be monitored have been more closely identified. For example, the understanding gained from monitoring water levels in wells around recharge structures has helped in the siting of observation boreholes that are currently being drilled in preparation for monitoring through the forthcoming monsoon season.

The work undertaken, at some of the research sites, by the related ComMan[1] project has provided a valuable basis on which to build in order to achieve the distinct objectives of AGRAR. This has been especially the case with the rural livelihoods surveys which, in ComMan, have addressed the issue of demand management in the context of community approaches to managing groundwater resources, and have set out to examine whether hydrogeological, institutional and socio-economic conditions exist to enable such user-based schemes to be set-up and sustained. The AGRAR project will complement these activities by focusing on the potential and effectiveness of augmenting groundwater resources, while ComMan will concentrate on the challenges associated with controlling the demand for groundwater. Surveys and methodologies have therefore been designed to build on the findings of ComMan in order to specifically address the impacts of artificial recharge structures on the livelihoods of the communities.

The AGRAR project was commissioned by DFID to address the specific issue of the effectiveness of artificial recharge structures, from both the technical and socio-economic perspectives. This is being done in the context of other projects being undertaken by a range of organisations; government, NGOs and researchers. Contact with these organisations has been maintained in order to learn from their experience and hence avoid duplication. A brief review of the relationship of the activities of AGRAR in relation to other projects is given.

[1] Community Management of Groundwater Resources in Rural India (R8058)

1 Summary of progress

Augmenting Groundwater Resources by Artificial Recharge – AGRAR (R8169), is a project funded by the United Kingdom Department for International Development under the Knowledge and Research Programme. Phase 1 of the project ran from April 2001 to March 2002 and Phase 2 of the project started in July 2002 and will be completed in July 2005, a total of 37 months. The contract between BGS-DFID was signed on 6 November 2002.

The initial activities were to select field sites for detailed case studies with partners and produce an Inception Report detailing instrumentation and monitoring of field sites as well as surveys of impacts on livelihoods by January 2003. This was achieved by holding a seminar in India in November 2002 and BGS staff visiting all field sites to discuss survey and monitoring activities. Project partners then submitted detailed proposals and budgets for each research site. These were incorporated into the Inception Report, which was submitted to DFID in the first week of February 2003.

The findings of the report are summarised in the following paragraphs, the main focus of activity being carried out at three research sites in India in order to assess the effectiveness of using artificial recharge to augment groundwater resources in differing hydrogeological environments and differing institutional and socio-economic settings. The research sites are located at:

- Coimbatore area, Tamil Nadu
- Kolwan Valley, Pune, Maharasthra
- Satlasana, Aravalli Hills, Gujarat

The results from these studies will be compared with studies in the Alwar district of Rajasthan, where some additional information may be collected depending on the results of a review. To complement and broaden the scope of the project, a study will also be undertaken in the Kathmandu valley in Nepal. Here the demand is for a sustainable supply to meet urban needs, in conjunction with surface water sources and in competition with demand for irrigation water.

Activities at each research site will vary depending on preceding levels of knowledge and infrastructure but will all be approached in the following generic manner:

- Produce a report of a conceptual model of the research site on which to base data collection during the life of the project
- Undertake hydrological assessment and monitoring of the research sites
- Study the operational and institutional issues at each site
- Assess the impacts of artificial recharge interventions on livelihoods, both positive and negative
- Report the results of the studies at each research site

The partners have led in the design, instrumentation, data collection and analysis, and manage the programmes of activities at the research sites. The role of BGS is to co-ordinate and to provide assistance and guidance on technical and survey methodologies. The knowledge gained will be disseminated to inform those involved in watershed development and drought relief programmes.

The strategy for dissemination and stimulation of feedback throughout the life of the project involves the production and distribution of information via the project website as well as information leaflets etc., through a network of researchers and organisations – e.g. IAH, UNESCO etc. – as well as through local communities, government, NGOs and universities at a local level, and through presentations at conferences and publication in journals as well as in the popular media.

The revised budget in the Inception Report and other concerns were discussed with DFID and addressed prior to approval for the project to proceed being given on 24 April 2003. This process resulted in a delay in the initiation of the instrumentation of field sites, which was planned for completion by May 2003, prior to the onset of the monsoon season. In order to minimise the impact of this delay an additional visit was made to India and Nepal by BGS in early March 2003 in order to give feedback on the Inception Report, clarify planned programmes, disseminate information on protocols and equipment specifications as well as resolve outstanding contractual issues.

On receipt of approval to proceed, seven sub-contracts were let for the period 1 May 2003 to 31 July 2005. Incorporated in these contracts were agreed schedules of activities. Partners immediately started field activities but the late start resulted in the predicted delay in installation of monitoring boreholes, weather stations etc., and the consequent loss of data.

Impetus on the project was maintained through correspondence and with a visit by BGS staff to the three research sites in May 2003 to further advise on instrumentation, monitoring and survey methodologies, both hydrogeological and livelihoods. Attention at this meeting focused on the application of modelling to understand the effectiveness of AR structures and methodologies for undertaking livelihoods surveys. Modelling tools were developed for the partners to use in assessing their research sites. Reference water samples were collected for analysis by BGS. One outcome of these meetings was the need to provide further guidance on all aspects of data collection and analysis in order to bring a uniformity of approach the research being undertaken at the three research sites. BGS staff compiled a guidance document (BGS report CR/03/167N), which was distributed in July 2003.

Progress was reviewed at the three research sites during a visit to all three sites by BGS staff in early November 2003. A meeting of all partners followed the individual site visits to enable presentation, comparison and discussion of progress and to plan and co-ordinate forthcoming activities. Draft Inception Reports for each of the three research sites were presented at the meeting. Comments on, and discussion of the activities undertaken will be addressed in a second draft of the reports, programmed for mid-December 2003. Publication of the reports on the web site is planned for January 2004. In addition, the review reports on water harvesting and recharge activities in Rajasthan as well as the aquifer recharge activities in the Kathmandu Valley were discussed. These review reports will follow the same timetable and will be published on the web site in January 2004.

The broader profile of the project, and aquifer recharge in general, has been maintained through contacts with UNESCO-IHP, by attending the International Symposium on Artificial Recharge, ISAR-4, producing and disseminating a 12-page brochure on managing aquifer recharge (MAR), and maintaining the IAH-MAR web site. Additionally, a briefing note was prepared for distribution at WWF-3, Kyoto, Japan.

A meeting of the International Association of Hydrogeologists, Commission on Managed Aquifer Recharge, IAH-MAR, was convened at the IAH congress in Prague in September 2003. Progress was made on the production of a booklet aimed to provide guidance on MAR in arid and semi-arid regions as part of the dissemination remit.

2 Progress at the research sites

2.1 SUMMARY OF PROGRESS AT KOLWAN VALLEY SITE, MULSHI TALUKA, PUNE DISTRICT, MAHARASHTRA

2.1.1 Background

The Kolwan valley in Pune district of Maharashtra state is a typical river basin located in the Deccan basalt setting covering large parts of western and central India. Kolwan valley is a name that connotes the catchment of the Walki river, a tributary of the more well-known Mula river. The area offers a unique opportunity to study groundwater in its various dynamics: physical, social, institutional and economic. Understanding these dynamics is the key to describing how the livelihood aspects in typical Deccan basalt settings are linked to groundwater resources and explore further how artificial recharge has or can affect livelihoods in this setting.

The Advanced Center for Water Resources Development and Management (ACWADAM) is conducting research in Kolwan valley under the AGRAR project to gain better insights into various aspects of artificial recharge in a typical rural setting within the Deccan basalt. GOMUKH Trust, which has implemented watershed programmes in the Kolwan valley is assisting ACWADAM in this research.

2.1.2 Project progress

Although research activity on the AGRAR project at the Kolwan valley site commenced formally in May 2003, ACWADAM has been visiting the site on a regular basis and looking at background data available with GOMUKH, since 1998. The geological mapping and preliminary hydrogeological surveys, including well inventories, were completed last summer in anticipation of the AGRAR project proceeding. Some base-maps were prepared, modified and developed into thematic maps as a result of these surveys.

It would have been logical to put in monitoring boreholes and most of the equipment before the monsoon, but the delayed start to the project meant that some of these activities had to be postponed to a post-monsoon slot. This postponement was basically due to lack of ‘lead-time’ for arranging finances, equipment and logistics for activities like installing bore holes, the meteorological station, water level recording equipment etc, especially with the prospect of early rains in the area. Moreover, it was well understood that in this ‘heavy rainfall area’, access to the sites for installation would often be risky.

Nevertheless, in order to optimise time during the monsoon, monitoring of existing check dams, wells and collection of rainfall data from existing stations was planned and executed. Weekly water levels from nearly 30 wells in the valley have been recorded and so has the flow over some of the check dams. Some of these data have been plotted and preliminary analyses attempted. Estimates of stream flow, especially around the recharge structure site have also been attempted.

A major activity during the summer and early monsoon period was ascertaining the elevations of all the measuring points (meteorology, hydrogeology and hydrology). In other words, all the structures and wells were ‘levelled in’, using three different methods (to cross check and get accurate measurements). Elevations were measured using GPS, theodolite levels and Paulin’s altimeter readings. All measuring points have been numbered and their elevations noted properly, on site as well as in a database in ACWADAM’s and GOMUKH’s offices.

Preliminary socio-economic surveys have been initiated in some of the villages being covered under AGRAR. Background information has also been collected from various sources, both primary and secondary. Participatory rural appraisal was conducted in Chikhalgaon recently but informal interviews with various groups of people divulged more in terms of peoples' perception of benefits from artificial recharge structures than the formal PRA.

An automatic weather station was installed in Chikhalgaon, after the rains ceased. The station was formally inaugurated and the benefits of climatological information explained to the villagers in the valley recently. Data from the weather station are immediately available to the villagers including school children, so will provide a useful educational resource. In addition, some non-recording, mechanical rain gauges and pan-evaporimeters are being installed to understand the variability in climatological factors within the Kolwan valley.

Inauguration of weather station at Chikhalgaon village

2.1.3 Review of impact of delayed start and proposed remedies

The delayed start to the project has meant a delayed commencement of some activities, which in turn, would mean a shortened 'time series' for some data. At the same time, it has meant better planning of sensitive activities like installation of the automatic weather station and drilling of boreholes around the recharge structure. A better understanding, in a conceptual sense, of the behaviour of rainfall, stream flows and groundwater, along with some preliminary quantitative and qualitative analysis of limited data, has actually resulted in the 'fine tuning' of locating measuring points and the methodology of measurement. It is envisaged that this fine-tuning will lead to more relevant data (albeit slightly shortened in time) and improved understanding of processes, especially in a spatial sense.

The delayed start, in Kolwan valley, has also meant better optimisation of resources. The plan for two automatic weather stations has been changed to incorporate several measuring points (rainfall and evaporation) into the meteorological measurement across the Kolwan valley (with only one automatic weather station). Delayed start to some activities like drilling has allowed better understanding of the situation around structures to be monitored, which in turn has implied focused planning (and therefore more focused implementation) of location and methodology around special measuring points like the observation bore holes.

2.1.4 Proposed work for forthcoming period

Collection of data will form the major aspect of work during the forthcoming period. Fine-tuning the conceptual model as new data on meteorological, hydrological and hydrogeological aspects is recorded will be one of the activities for the forthcoming period. Data from the weather station and also from the several other sites (primary and secondary) will be collected, plotted up and some preliminary analysis attempted on these data. Water levels in existing wells are being monitored and will continue to be taken on a weekly basis. Drilling of observation bore holes, installation of automatic water level sensors in one or two of these and the setting up of a 'stilling well' to monitor water levels in the check dam (the core site for monitoring) will be activities that will be taken up over the next couple of months. This will be followed by contour surveys in the check dam so as to calibrate recorded water level rises and falls in the check dam to changes in storage.

Pumping tests on selected wells will be conducted to estimate aquifer characteristics and well-yield factors. Transmissivity and storativity values will be generated from these tests. Specific capacities of wells will be estimated and information of water use from wells will be collected, although some headway has already been made in this direction.

Information on how the effects of artificial recharge in particular, and watershed programmes in general, are perceived by people will be collected in Chikhalgaon village, as well as in other villages that form a part of the AGRAR project. Livelihood-related information, in the context of groundwater and groundwater recharge from such programmes will be collected on the basis of discussions during the Ahmedabad meeting. These surveys will be based on some exchange of ideas, basically around check-lists that are already developed in the guidance document and experience gained during the course of the initial parts of this study in Kolwan valley.

2.2 SUMMARY OF PROGRESS AT THE SATLASANA RESEARCH SITE, ARAVALLI HILLS, GUJARAT

2.2.1 Background

VIKSAT case study is being carried out in five villages namely, Nedardi, Mumanvas, Bhanavas, Samrapur and Nana Kothasana in Satlasana taluka of Mahesana district in Gujarat. In the first phase of the project, VIKSAT identified the study area and collected socio-economic profile data of the households in these five villages.

The second phase of the project started in July 2003 and will be completed in July 2005. The study aims at increasing the knowledge by developing and disseminating guidelines on effective application and operation of recharge enhancement schemes.

2.2.2 Activities Carried Out

The following activities have been carried out since November 2002:

STUDY AREA SELECTION

The study villages in Satlasana taluka were identified based on the knowledge and research findings of VIKSAT in the last 10 years. The study area comprises Gneiss basement rock intruded by granite. The alluvium, carried by wind and water, is deposited along the streams. Groundwater occurs under both un-confined and semi-confined conditions. Groundwater is the main source of water for drinking and irrigation purposes. There has been a gradual increase in the number of groundwater extraction wells causing decline of groundwater levels. Also the ‘water market’, which was prominent in the 1980s and up to late 1990s aggravated groundwater depletion. Added to these factors is the recurrence of droughts, at least four years in a 10-year cycle.

In order to make people understand the implications of groundwater exploitation and involve them in proper water management, VIKSAT facilitated the formation of People’s Institutions at the village level. These village level institutions have federated at the taluka level as *Gadhwada Jal Jameen Sanrakshan Samiti*. A few check dams constructed during the drought of 2000-01 demonstrated to a certain extent the effectiveness of groundwater recharge. In addition to this, in 2003, six check dams were constructed in the area under a government programme *Sardar Patel Jal Sanchay Yojana* (SJSY). However, there has been lack of scientific data and analysis on the amount of recharge and its extent and impact on groundwater resources. The present study will help quantify recharge and assess aquifer characteristics. The project villages include three check dams, two sub-surface check dams and two ponds.

TOPOGRAPHIC SURVEY

A topographic survey of the study area has been conducted. A base map containing all the recharge structures and the existing dug wells and bore wells has been prepared. This will help prepare piezometric contours for monitoring the groundwater levels (on a monthly basis).

A capacity contour survey of all the recharge structures comprising three check dams and two ponds has been completed. Contours have been drawn for each of the structures to find the volume of water stored in the structures depending on the height of standing water.

The following table gives the capacity of each of the recharge structures:

Sr. No.	Name of the Structure	Capacity of the structure up to the FRL in cu.m.
1	Mumanvas Check Dam	6,404
2	Bhanavas Check Dam	21,774
3	Samrapur Check Dam	12,541
4	Nedardi Percolation Tank	27,650
5	Nana Kothasana Pond	31,194

INSTALLATION OF WEATHER STATION

The nearest weather station is at Dharoi (12 km away) while another is at Mahesana (100 km away). Due to local variations, weather data such as rainfall and evaporation vary significantly. In order to minimise the local variations and improve data accuracy, a weather station has been established in Mota Kothasana village about 1 km away from Mumanvas and Bhanavas check dams. The data from these stations would also help compare data from all the three weather stations and understand the degree of variation.

Weather Station at Mota Kothasana

The following meteorological instruments have been installed:

1. Automatic and Manual Rain gauges
2. Anemometer
3. Pan-evaporimeter

4. Thermo-hygrograph

5. Sunshine Recorder

Weather data are collected everyday at 8 o'clock in the morning in conjunction with a local school, thus ensuring community involvement and providing an educational resource.

DRAINAGE MAP

A drainage map beginning from the Aravalli hills covering the study site has been prepared using two topo-sheets 45 D/12 and 45 D/16 of the Survey of India (SOI) having a scale of 1:50,000. The extent of the catchment area is found to be 25.25 sq. kms.

WATER LEVEL MONITORING

Monitoring of groundwater levels in the open wells and bore wells in Samrapur, Bhanavas, Nedardi and Mumanvas is carried out on a monthly basis. In all, 60 well structures (dug wells, dug-cum-borewells and borewells) around the three check dams located in a radius of 1 km and ten wells down-stream of the Nedardi percolation pond are being monitored. These wells were identified by taking into consideration the distance from the recharge structures and the probable zones of influence. All the wells are marked with identification codes. Water levels are measured using an electronic water level indicator.

Well monitoring in the vicinity of the check dam

AQUIFER PERFORMANCE TESTS

Pumping tests have been conducted on two bore wells, one in Mumanvas and another in Samrapur villages, to determine the aquifer parameters. The existing submersible pumps in the bore wells have been used for the pumping. The pumping could only be carried out for three and four and a half hours in the bore wells respectively due to electricity supply problem.

In the Mumanvas bore well, there was interference due to pumping of the neighbouring bore well. Hence, there was fluctuation in the water level readings. Whereas, in the Bhanawas bore well there was constant drawdown for every 15 minutes of the reading. Recovery was measured until 80-85% water level was recovered.

The data have been analysed using Theis method. The analyses of both the tests have given transmissivity (T) value for the aquifers at Mumanvas as 7.8 m^2/day and at Samrapur 194 m^2/day. The Transmissivity for recovery tests again using the Theis method of analysis also showed the nearer values of 8.4 and 172 m^2/day respectively.

2.2.3 Impact of Delayed Start

The delayed start of the project has not made any adverse impact on the project. Notwithstanding the formal delay, VIKSAT has taken necessary steps to install the weather station well before the advent of the monsoon. Topographic studies were begun and also the well inventory. The only activity that got delayed was the installation of piezometers. However, in retrospect, it appears that the data available now such as the well inventory data,

data on aquifer characteristics and the sedimentation behaviour of the check dam sites, will be helpful in determining the location, depth etc. of the piezometers more precisely. Further, we now have a better understanding of the geo-hydrology of the study area to decide appropriate and strategic locations for installation of the piezometers.

2.2.4 Activities Planned

The following activities are planned to be conduced shortly:

LIVELIHOOD IMPACT ASSESSMENT STUDY

A sample survey of farmers will be conducted after the harvest of Kharif and Rabi crops, sometime in February 2004. The sample will include farmers belonging to various categories including the landless. The sample will also have a spatial spread to cover areas of recharge influence, such as those which are located nearer to the recharge structure (< 250 m), those in the medium range of 250 and 500 m and those located farther (> 500 m) from the structures.

INSTALLATION OF ADDITIONAL INSTRUMENTS

Piezometers with water level sensors connected to data loggers will be installed. In addition to this, a Pyronometer (to measure Solar Radiation) will be installed as part of the weather station.

Additional rain gauges will be installed near the recharge structures.

Staff gauges will be installed in the ponds and check dams for measurement of water levels.

Aquifer performance tests on dug wells and bore wells are planned to get data on shallow and deep aquifer characteristics, covering the entire study area.

The Mumanvas check dam, which is the first structure from the upstream side of the Dhamani River, got filled up with sediments twice during the recent monsoon. The first time, it got silted up in July when there was a heavy rainfall of 83 mm in two hours. This was removed. The structure filled up again gradually by the end of the monsoon (September 2003).

After removal of the sediment, a few staff gauges will be installed for future monitoring of the Mumanvas check dams and also on the two ponds-Nedardi and Nana Kothasana.

The other structures on the downstream side did not receive any significant sedimentation. However, the data are being collected for analysis from the Bhanavas and Samrapur check dams.

WATER QUALITY

Four samples have been collected, three from wells in Mumanvas and Bhanavas, and one sample from Nedardi pond. Some more samples are being collected from selected wells for analysing the physical and chemical parameters. This includes analysis for stable isotopes, which can indicate the history of water samples. The results will determine the suitability of the site for further use of isotopes for tracing the extent of recharge induced by the structures.

2.3 SUMMARY OF PROGRESS AT KODANGIPALAYAM VILLAGE, PALLADAM TALUK, COIMBATORE DISTRICT, TAMIL NADU

2.3.1 Background

Coimbatore District is located in the west of Tamil Nadu State and includes the city of Coimbatore. The District is bordered to the west by the mountains of the Western Ghats but is dominated by the plains to the east. Although still important, the role of agriculture in the rural economy is diminishing. Migration to the textile industry in the urban centres is a significant source of income as are the many weaving sheds that have been established in the villages. Annual rainfall in the District averages 650 mm and has a bimodal distribution related to the southwest monsoon and the northeast monsoon. Crystalline basement rocks, typical of much of peninsular India, underlie the District.

The Water Technology Centre (WTC) is conducting research as part of the project "*Augmenting Groundwater Resources by Artificial Recharge* (AGRAR)" in Kodangipalayam village to gain better insights into various aspects of artificial recharge in a typical rural setting within the project area.

The main recharge structure under investigation is located in Kodangipalayam village in Palladam block of Palladam taluk of the Coimbatore district. It has been selected for the AGRAR study because it is typical of the recharge structures found in this region of Tamil Nadu. The satellite sites to be monitored are located within the same micro-watershed, within a radius of 5 km. This village is located in Noyyil river basin. The area offers the opportunity to study groundwater in its various physical, social, institutional and economic aspects. Understanding these dynamics is the key to describing how livelihood are linked to groundwater resources and further, how artificial recharge has, or can, affect livelihoods in this setting.

The case study is being carried out in Kodangipalayam village. This village contained six hamlets namely, Sangothipalayam, Karanampettai, Perumagovandampalayam, Rasagovendampalayam, Chinnakodangipalayam, Periyakodangipalayam. In the first phase of the project, WTC identified the study area and collected socio-economic profile of the households in these six hamlets.

2.3.2 Project progress

The research activity on the AGRAR project at the Kodangipalayam village site commenced formally in March 2003. WTC staff have been visiting the site on a regular basis and looking at background data available with other institutions like PWD, TWAD Board etc. The geological mapping and preliminary hydrogeological surveys, including well inventories, were completed.

It was originally planned to install monitoring bore wells and most of the equipment before the monsoons, but a delayed start to the project meant that some of these activities had to be postponed.

In order to optimise time during the monsoon season, monitoring of existing percolation ponds and wells and collection of rainfall data from existing stations was undertaken. Daily water levels from 23 wells and three ponds in the project area have been recorded. Some of these data have been plotted and preliminary analyses made.

During the early monsoon period, approximate locations and elevations of all the measuring points were ascertained using GPS. These will all be surveyed in for the greater accuracy required. All measuring points have been numbered and their elevations noted, on site as well as in WTC office. Preliminary socio-economic surveys have been initiated in some of the villages. Background information has also been collected from various sources.

2.3.3 Activities Carried Out

The following activities have been carried out:

A. INSTALLATION OF WEATHER STATIONS

The nearest weather station is at Sulur (5 km away). Due to local variations, weather data such as rainfall and evaporation can vary significantly. In order to minimise the local variations and improve data accuracy, an Automatic Weather Station has been established in Karanampettai village. The Automatic Weather Station will also help have control on the accuracy of data and measurement on a regular basis.

The following meteorological instruments have been installed:

Automatic Rain gauges

Air Temperature

Pan-evaporimeter

Relative Humidity

Solar Radiation

In addition to the Automatic Weather Station, two automatic rain gauges are installed near to the Kodangipalayam East and West ponds to check for the spatial variations in rainfall.

B. WATER LEVEL MONITORING

Monitoring of groundwater levels in the open wells in Karanampettai and Kodangipalayam villages is carried out on a daily basis using a water level dipper to ensure accurate readings.. In all, 28 well structures including three percolation ponds (dug wells, dug-cum-borewells) are located within 1 km are being monitored. These wells are identified, taking into consideration the distance from the recharge structures and the probable zones of influence.

Installation of automatic water level recorder

All the wells are marked with bench-mark identification codes. Recently an automatic water level recorder and data logger has been installed in the Karanampettai pond (KP PP).

C. WATER QUALITY ANALYSIS

Water samples were collected from the observation wells and percolation pond before the monsoon period, samples were collected at an interval of 15 days, three times before the monsoon, showing the following characteristics from initial analysis.

In general pH of water increased with progressive stages of sampling in many wells excepting wells KPW 2 and KPW 5 in Kodangipalayam and KP 10, KP 11 and KP 12 in Karanampettai.

The Electrical Conductivity (Salinity hazard) of the water samples collected in many of the wells of Kodangipalayam and Karanampettai showed medium to high salinity (EC between 0.25 and 2.25 $dScm^{-1}$). Very high salinity was recorded (>2.25 $dScm^{-1}$) in four wells (Nos. KPE2, KPE3, KPW7, KPW8) of Kodangipalayam and in three wells (Nos. KP7, KP8 and KP9) of Karanampettai. Remarkably well No. KP 9 of Karanampettai had high salinity (>5 $dScm^{-1}$). There was slight variation in salinity with stage of sampling showing a steady increase at a few locations.

The concentration of chloride exceeding 10 $m.e.L^{-1}$ in irrigation water is injurious to plants. In many of the wells, the chloride ion concentration was at injurious level. Many of wells in Karanampettai had more injurious chloride levels than of Kodangipalayam with the second stage of sampling chloride level generally increased slightly, and later decreased in the third stage of sampling.

In all the samples the Sodium Adsorption Ratio (SAR) estimated was within safe limits (0-10 SAR). With respect to Residual Sodium Carbonate (RSC), the well Nos. KPE 3, KPEBW, KPW 5 of Kodangipalayam showed development of carbonate and bicarbonate hazard, which induces sodicity in soil upon irrigation, at moderate levels (1.25 – 2.50 RSC). Other well water samples were within safe limits.

2.3.4 Impacts of the delayed start

The delayed start to the project has meant a delayed commencement of some activities and loss of data through the first monsoon season. However the data that have been collected have provided an improved understanding of the hydrogeological regime around the structures to be monitored. This has led to better planning of, for example, the location of the automatic weather station and the location and drilling of observation boreholes around the recharge structure.

2.3.5 Proposed work for forthcoming period

New data on meteorological, hydrological and hydrogeological aspects are being recorded and will be one of the activities for the forthcoming period. Data from the weather station will be collected, plotted up and preliminary on-going analysis made. Water levels in existing wells are being monitored and will continue to be taken on daily basis. Groundwater contours will be drawn based on the water level data collected from the observation wells and test boreholes to identify the movement of groundwater.

LIVELIHOOD IMPACT ASSESSMENT STUDY

Livelihood related information, in the context of groundwater and groundwater recharge from such programmes will be collected. These surveys will be based on some exchange of ideas, and basically around check-lists that are already developed in the guidance document and experience gained during the course of the initial parts of this study. Sample surveys of farmers will be conducted after the harvest, sometime in February 2004. The sample will include farmers belonging to a range of categories, including the landless.

TOPOGRAPHIC SURVEY

Topographic surveys of the catchment area for the recharge structure and a contour survey of the water-spread area will be done to create a stage-volume relationship for the pond. The watershed boundary will be located after the topographic survey and the same will be drawn digitally locating the observation wells and test bore holes for better understanding of the hydrogeological conceptual model.

INSTALLATION OF ADDITIONAL INSTRUMENTS

Staff gauges will be installed in the Kodangipalayam West and East ponds for measurement of water levels.

GROUNDWATER QUALITY AND MOVEMENT

Water samples will be collected after the monsoon period to check for the variations in parameters. It is also planned to conduct isotope studies to understand the groundwater movement and the recharge and discharge zones. Information is being gathered on the methodology and the procurement of isotope analysis.

DRILLING OF TEST BORE HOLES

Karanampettai percolation pond is the core site for WTC's AGRAR research. Seven bore wells will be drilled as exclusive observation points for collecting water level data and water quality (including isotopic) samples. Considering that the shallow aquifer in the area is within an upper zone of 20 m, these bore wells may be drilled to the depth of 25 m maximum. One bore well (upstream of the structure) will be drilled deeper to log the lithological sequence (50 to 100 m). Based on the discussion made at the progress meeting held at VIKSAT, the location of the bores will be adjusted so that the recently constructed check dam, downstream of the main recharge structure, will not influence them.

AQUIFER PERFORMANCE TESTS

Pumping tests on selected wells will be conducted to estimate aquifer characteristics and well-yield factors. Transmissivity and storativity values will be generated from these tests.

3 Reviews of Aquifer Recharge activities in the Kathmandu Valley and Rajasthan

In order to complement the activities being undertaken at the three research sites, additional work was undertaken at two additional sites; one in the Kathmandu Valley, Nepal and the other focusing of the watershed development activities in the Alwar District of Rajasthan but also elsewhere in the state.

The analysis of the situations in these two areas at the Inception Report phase of the project identified that there was a great deal of work that had been, and continues to be done by a range of government and NGOs. It was therefore concluded that in order to identify areas where AGRAR could contribute to the debate and knowledge on the effectiveness of augmenting groundwater resources by artificial recharge, it would first be necessary to further investigate the nature and depth of related activities and plans. A review report was therefore commissioned to address the issues in each area. Work programmes were devised (see below) and progress presented at the meeting in Ahmedabad on 14 November. Comments raised in discussion will be addressed in revised drafts by the middle of December 2003 for completion and posting on the web pages by January 2004.

3.1 WORK PROGRAMME FOR NEPAL WATER CONSERVATION FOUNDATION (NWCF)

Compile a review report on the potential for recharge of the Plio-Pleiostocene and quaternary deposits in the Kathmandu Valley. The JICA report and the Manohara wellfield artificial recharge well study should be used together with other data and reports that will be sought out. The data behind the “engineering and environmental geological map of the Kathmandu Valley should be investigated as should the data provided by the Melamchi evaluation project together with the Mike-She model. The background to and data behind the recently commissioned (6 March 2003) induced recharge scheme – and the others planned - should be reviewed.

- The report should attempt to address questions such as:
- What is the horizontal and vertical permeability (and transmissivity) distribution?
- Is the drawdown in wellfields due to well losses or more general?
- Approximate natural (and irrigation leakage) recharge
- What are the predicted impacts of the induced recharge schemes?
- What are the water quality issues associated with the wellfields, deep injection recharge and induced recharge schemes?
- Are there any areas where spreading basins could be constructed or is land too much in demand?

Make recommendations for further work that could be undertaken to add to the technical understanding of the potential for artificial recharge in the wider context of conjunctive use scenarios. These could include:

- Construction of monitoring wells sealed at different depths and in a transect at right angles to the Manohara river to determine the chemistry and hydraulic discreteness of aquifers and there response to annual hydrological cycles, including irrigation.

- Undertake hydraulic tests to provide better data for model assessments
- Geochemical sampling and analysis of water and aquifer material in order to understand processes.
- Infiltration tests in irrigated and other areas
- Develop a simple model to test a variety of operational scenarios and to provide comparative results to the more complex Mike She model.

The draft report is to completed by the end of October 2003 and will form the basis for recommendations for further work. The final report will be posted on the project web page in January 2004.

3.2 WORK PROGRAMME FOR INSTITUTE FOR DEVELOPMENT STUDIES (IDS), JAIPUR

Compile a review report on the research activities in Rajasthan, but focussing on the Alwar District. This report will capture the relevant results from reports and discussions with groups such as IWMI that are relevant to the objectives of the AGRAR project. The report will aim to draw together all relevant information and data on aquifer recharge and identify areas where gaps in knowledge could be addressed. The scope and content of the report will be agreed on in discussions with BGS and other partners.

The draft report will be completed by the end of October 2003 and will be posted on the project web page in January 2004.

Depending on the findings and recommendations in the above report, promote their implementation and funding through DFID and other sources.

4 Review of related projects

The AGRAR Phase 2 Inception Report (CR/03/028C) briefly described the relationship of the project to other watershed and rural livelihood development projects currently being undertaken, some supported by DFID funding. On acceptance of the Inception Report, BGS undertook to review the relationships with a view to ensuring that knowledge gained was assimilated into the work of AGRAR and duplication of effort was avoided. AGRAR should focus on adding to and complementing the collective knowledge. The description of the relationships of AGRAR to other projects has therefore been revisited and updated in the light of developments and published results made available in the interim.

The project is therefore set in the context of the large amount of current activity in watershed development and management programmes and research projects, including:

- *Water, Households and Rural Livelihoods,* WhiRL' (DFID Project R7804)
- *Community Management of Groundwater Resources in Rural India,* Comman (R8058)
- *Improving Policy-Livelihood Relationships in South Asia* (R7604). Watershed development in Andhra Pradesh.
- *Karnataka Watershed Development Project*, KAWAD.
- *IWMI-Tata India Water Research Program.* Collaborative research to develop policy recommendations for sustainable use of groundwater and other water resources in India.
- *Smallholder water management systems in south Asia* (IWMI led, DFID funded project).

These projects have been monitored through their descriptions and output as well as contact with some of the lead researchers. The complementary nature of the relationship of AGRAR to ComMan and WhiRL is particularly important.

The AGRAR project was commissioned by DFID to assess the effectiveness of recharge structure interventions in watershed development. This stemmed from a concern that augmentation of groundwater recharge was being applied as a panacea to water resource problems, resulting from rapidly falling water tables through overexploitation of groundwater. Phase 1 of the project reviewed the issue but found little detailed information on the technical effectiveness of the structures, a lot of the evidence being anecdotal relating to increased groundwater levels and cropped areas.

Phase 2 of the project was therefore designed to collect a full suite of primary data on all aspects of the water balance of selected individual structures in differing geological and climatic settings in order to be able to provide guidance on their effectiveness. This has not been done by any of the other related projects, which focus on water management and livelihood issues at the watershed scale. WhiRL, for example, has collected primary data for water audits at a watershed scale and has identified that the construction of a large number of check dams along the drainage lines is a major cause for reduced runoff, and hence flow into irrigation tanks. Groundwater extraction in the vicinity of drainage lines is also a contributory factor but the relative importance of these two causes and the interactions could not be differentiated in the study (Andhra Pradesh Rural Livelihoods Programme Water Audit Report, 2003). This is where the results of the AGRAR project will be able to improve understanding and hence management.

To complement the physical assessment, the socio-economic impacts of the structures are also being investigated by AGRAR. Institutional control and management of recharge structures as part of wider watershed development can have a major impact on the success, or perceived success, of the investments made. AGRAR will aim to reach, and objectively defend, conclusions about the efficacy of different structures in different environments, in terms of their impact on groundwater conditions, including scale effects.

The research sites have been selected to illustrate and compare different environments from which useful conclusions and guidelines can be drawn. Preliminary conclusions indicate that, at the Satlasana site, the extreme variability and intense nature of the rainfall events combined with the coarse alluvial sediments, requires different management of recharge structures to those in the Coimbatore area where rainfall is more evenly distributed and structures remain full for several months. In contrast, the structures in the Deccan basalts in the Kolwan Valley may act as collection points for groundwater base flow for part of the year and not as recharge structures. This knowledge is important because choice and siting of structures needs to be based on efficacy, as well as social and economic decision criteria.

Augmentation of water resources through artificial recharge has largely been approached from the perspective of increasing water storage and hence increasing resources from the supply side. However it is becoming increasingly clear that this must be done in combination with management of demand. It is this management of demand that holds the key to sustaining communities, which, even in an environment of changing livelihoods, continue to rely on agriculture. The ComMan Project aims to examine the issue of demand management in the context of community approaches to self-regulation and sets out to examine whether hydrogeological, institutional and socio-economic conditions exist to enable such user-based schemes to be set-up and sustained. The AGRAR project will complement these activities by focusing on the potential and effectiveness of augmenting groundwater resources, while ComMan will concentrate on the challenges associated with controlling the demand for groundwater.

The IWMI-Tata India Water Research Program aims to undertake collaborative research to develop policy recommendations for sustainable use of groundwater and other water resources in India. An example of the type of project that is undertaken is the North Gujarat Sustainable Groundwater Initiative. Starting October 2001, it is proposed that the initiative be implemented on a pilot basis in three talukas of the region during the first two years and then extended to cover all the three districts over a 5-year period.

The table of activities for this IWMI project (below) illustrates the wide range of actions being undertaken by this programme. Although some of the major activities (shaded) involve tank rehabilitation, and construction of and recharge wells and structures there is no specific attempt to quantify the effectiveness of these structures. This clearly demonstrates the complementary nature of the AGRAR project, the output of which will guide the management of structures that have been designed for either recharge or as irrigation tanks.

Action Items	**Primary project input**
1 Tank rehabilitation program	Catalytic intervention; seed grants; 'honest brokering' with resource providers; co-ordination; resource mobilization; sub-basin perspective
2 Promotion of private well-recharge work	Promotion and extension; technical support
3 Support to community water conservation and recharge structures	Planning and design; mobilizing communities and govt. resources; technical support; sub-basin perspective

4 Promotion of the *use* of chaff cutters among dairy farmers	Collaboration with dairy co-op field staff; Intensive promotion and marketing; user feedback and product improvement; strengthening Appropriate Technology International presence and fire-power
5 Promotion of low-cost micro-irrigation & water saving technologies in alfalfa cultivation	Engaging International Development Enterprises to implement an intensive promotional program; getting other irrigation equipment majors to set up shop; Collaboration with dairy co-op field staff; Intensive promotion and marketing; user feedback and product improvement; field trials with leveling and plastic mulching;
6 Promotion of water saving farming methods in non-fodder crops	Collaboration with dairy co-op field staff; Field trials of technologies and best practices; farmer demonstration and promotion;
7 Promotion of water-saving, high value crops, especially orchards	Farmer participatory trials; package promotion
8 Roof water harvesting for drinking and cooking water security	Demonstration and promotion of roof water harvesting structures; linking up with GWSSB scheme of financial support
9 Communication campaign to support demand & supply side interventions	Design and implementation of messages, medium and communication strategy; bi-weekly water education posters at dairy co-ops; video-films about best practices and show-case villages like Khopala and Dudhara
10 Community Monitoring of Groundwater table fluctuations	Establish and run the participatory monitoring systems in a learning mode on a pilot basis to start with.

Enormous investment continues to be made in watershed development, including the use of recharge structures and wells. They are generally perceived to be beneficial although, amongst other issues, concerns have been raised about the down stream impacts. Little attention has been paid to detailed quantification of the effectiveness of structures, their cost benefits and their impacts on the livelihoods of the surrounding communities. AGRAR aims to address some of these issues and to provide guidelines on optimising use and management of structures, thus complementing other watershed development activities.