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Project: R8333

Sustainable Use of Groundwater in the Semi-arid Ribbon Valleys of Northeast Brazil

Final Technical Report

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Final Technical Report

Issue and Revision Record

Rev	Date	Originator	Checker	Approver	Description

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List of Acronyms

AMAS	Associação Menonita de Ação Social	Mennonite Social Action
ASA	Articulação do Semi-Árido	Semi-Arid Articulation
AS-PTA	Associação Projeto Tecnologia Alternativa	Alternative Technology Association
CAATINGA	ONG Ambientalista (Ouricuri- PE)	Environmental NGO located in Ouricuri - Pernambuco
CARITAS	ONG Católica internacional	International Catholic NGO
CEDAPP	Centro de Apoio ao Pequeno Produtor (ONG de Pesqueira)	Support Centre for the Small Farmer (Pesqueira NGO)
CIDA	Agência Canadense de Desenvolvimento Internacional	Canadian International Development Agency
COMPESA		State Water Supply Company
CPR		Common Pool Resources
CPRH	Companhia Pernambucana de Meio Ambiente	Pernambuco Environmental Company
CPRM	Servico Geologico do Brasil	Geological Services of Brazil
CPT	Comissão Pastoral da Terra	Pastoral Land Commission of the Catholic Church (Land Reform Movement)
DFID	Departamento de Desenvolvimento Internacional (do Reino Unido)	Department for International Development, UK
DIACONIA	ONG Evangélica	Evangelical NGO
EMBRAPA	Empresa Brasileira de Pesquisas Agropecuárias	Brazilian Agency for Agricultural Research (Federal)
FADURPE	Fundação Apolônio Salles (UFRPE)	Foundation within UFRPE (research services)
FETAPE	Federação dos Trabalhadores da Agricultura de Pernambuco	Federation of Agricultural Workers in Pernambuco
FIDA	Fundo Internacional para o Desenvolvimento Agrario (das N Unidas)	IFAD - International Fund for Agricultural Development
FUNAI	Fundação Nacional do Indio	National Indian Foundation
FUNASA	Fundação Nacional de Saúde	National Health Foundation
FUNDAJ	Fundação Joaquim Nabuco	Joaquim Nabuco Foundation
FUNTEPE	Fundo de Terras do Estado de Pernambuco	Land Fund of the State of Pernambuco (State Government Land Reform Agency)
IBAMA	Instituto Brasileiro do Meio Ambiente	Brazilian Environmental Intitute
IBGE	Instituto Brasileiro de Geografia e Estatística	Brazilian Institute of Geography and Statistics
INCRA	Instituto Nacional de Colonização e Reforma Agrária	National Institute of Colinisation and Agrarian Reform
INPE	Instituto Nacional de Pesquisas Espaciais	National Institute of Spatial Research
IPA	Instituto de Pesquisas Agropecuárias (Estadual)	Agricultural Research Institute (Pernambuco)
MMTR-NE	Movimento de Mulheres Trabalhadoras Rurais do Nordeste	Northeastern Rural Workers Movement

MST	Movimento dos Sem Terra	Landless Movement
OXFAM (UKI)	ONG Britânica (Escritôrio nacional em Recife)	UK NGO (National office in Recife)
P1 MC	Programa um milhão de cisternas	A Million Cisterns Programme
PFL	Partido da Frente Liberal (Governo Municipal de Pesqueira)	Liberal Front Party (Pesqueira Municipal Government)
PROASNE	Proyeto das Águas Subterráneas do Nordeste	Underground Water Project for NE Brazil
Projeto Dom Helder Câmera	Projeto de Reforma Agraria e Desenvolvimento Rural - financiado pelo FIDA	Land Reform and Rural Development Project funded by IFAD and The Ministry of the Environment
Projeto Renascer	Projeto de Reforma Agrária do governo do Estado e Banco Mundial	Land Reform Project (State Government and the World Bank)
PT	Partido dos Trabalhadores (Governo Federal)	Workers Party (Federal Government)
SECTMA	Secretaria de Ciência, Tecnologia e Meio Ambiente	Secretary of Science, Technology and Environment (State Government)
STR	Sindicato dos Trabalhadores Rurais	Rural Workers' Union
UFPE	Universidade Federal de Pernambuco	Federal University of Pernambuco
UFRPE	Universidade Federal Rural de Pernambuco	Rural Federal University of Pernambuco
WRMP		Water Resources Management Policy

Glossary of Portuguese terms

assentamento	Legally established rural settlement where each family is allocated an area of land.
assentado	A legally recognised settler in an assentamento.
parceleiro	A settler who, although not legally recognised, occupies land which he or she may have purchased.
morador	A resident – in this case of an *assentamento* with no land entitlement.

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Summary

DFID ENGINEERING KNOWLEDGE AND RESEARCH PROGRAMME

Project: R8333
Sustainable Use of Groundwater in the Semi-arid Ribbon Valleys of Northeast Brazil

"It is easier to observe the movement of the stars than to understand the movement of the waters"

Galileu Galilei

The Project

The Project had four main aims:

1. Develop and disseminate clearly understandable and culturally appropriate guidelines for sustainable groundwater resource management, primarily targeted at rural communities.

2. Facilitate and increase understanding amongst the rural population of the potential benefits that arise from sustainable and technically appropriate groundwater resource management, and to create awareness of the implications of overuse of the resource, in the context of seasonal and long-term variability in hydrological and climatic conditions.

3. Empower community representatives (farmers, farmer representatives and other local groundwater users) in the active monitoring and collective management of the groundwater resource.

4. To empower the younger members of the communities through active participation in environmental education and monitoring and in this way ensure long-term sustainability of Project principles.

The Local Communities

- Originally three communities were included in the Project. Two additional communities were included early in the Implementation Phase
- The social structures within the local communities that participated in the Project are diverse. Their livelihoods revolve around subsistence agriculture and livestock, with irrigation playing a role of varying importance. Uncertainties in climate, combined with inadequate understanding of groundwater resource availability and sustainable use, has led to both reluctance to invest and loss of income due to crop failure.
- Droughts severely impact on community relationships due to inadequate institutional arrangements for the exploitation of groundwater. Groundwater is being exploited by entrepreneurs for water supply to the more affluent in urban centres possibly at the expense of water users within the communities. Access to scarce groundwater resources also becomes constrained by well and land ownership.
- Lack of water for domestic use, sometimes attributed to deterioration in water quality (salinity) is evident during drought periods and creates significant inconvenience and suffering for the local communities. During drought periods, traditional water supply sources become unavailable due to either water shortage or poor water quality and communities become dependent on water supply by water truck.

Key Project Issues

Project outputs have been identified as follows:

(a) Inception: Livelihood, Water Use and Environmental Surveys

(b) Package 1: Guidelines for Sustainable Water Resources Management

(c) Package 2: Framework for Participation and Education

(d) Package 3: Operational Strategy for Integrated Communications

(e) Package 4: Guidance on Monitoring and Intervention Strategies

Commencing from the basic aim of the Project which is:

- Capacity building of local communities in semi-arid areas to achieve sustainable use of groundwater resources for domestic and agricultural needs.

And seeking to achieve this aim by:

- Developing community awareness of catchment hydrology and appropriate methods of water resources assessment and sustainable management.
- Developing community level awareness of short and long-term approaches to minimising the impact of drought that acknowledge the uncertainty in the climatic conditions in the region and include some assessment of risk (notably by the farming communities).
- Developing community understanding of water management and the role of community-based water management, recognised and supported within existing national and regional policy frameworks.
- Education in the areas of water harvesting, storage and water quality, health issues and environmental awareness.

Then a key issue for the Project was to decide the approach to creating the community framework that can be the recipient and repository for the anticipated developments in such a way as to ensure that the developments achieved during the two-year Project period have a lasting rather than a transient impact.

Key Activities

- Livelihood, water use and environmental surveys within the rural communities participating in the Project
- Engagement of local communities in the Project process through the establishment of an Advisory Group, comprising representatives from the participating communities, Project team members, health workers and teachers. Monthly meetings have been held and have contributed to cross-community awareness, conflict resolution and enhanced awareness of water and environmental issues.
- Themed workshops have been undertaken to engage the local community and to begin to demonstrate the relationship between community control of groundwater and drought mitigation. The workshops were largely run by the local communities with the Project team members acting as facilitators. The themes have included:
  - Water storage and use for domestic purposes
  - Water for farming, including irrigation
  - Land management for improved water harvesting and retention
  - Institutional and organisational aspects of groundwater management
- Collaboration with local education and health authorities on the introduction of Environmental Education at schools located within the participating community areas. School children are now involved in various types of monitoring, such as for example rainfall and groundwater levels, using monitoring equipment developed at very low cost at UFRPE (Rural University of Pernambuco).

- Extended involvement of rural communities, including the Xukurú indigenous community, a group with unique organisational structure and environmental awareness in the region, and the Mimoso Seco community, a group with long-established irrigation practices and recent involvement in organic agriculture.
- Technical studies, including monitoring and assessment of groundwater resource availability, with involvement of students from both UK (Birmingham) and Brazilian (UFPE & UFRPE) Universities.

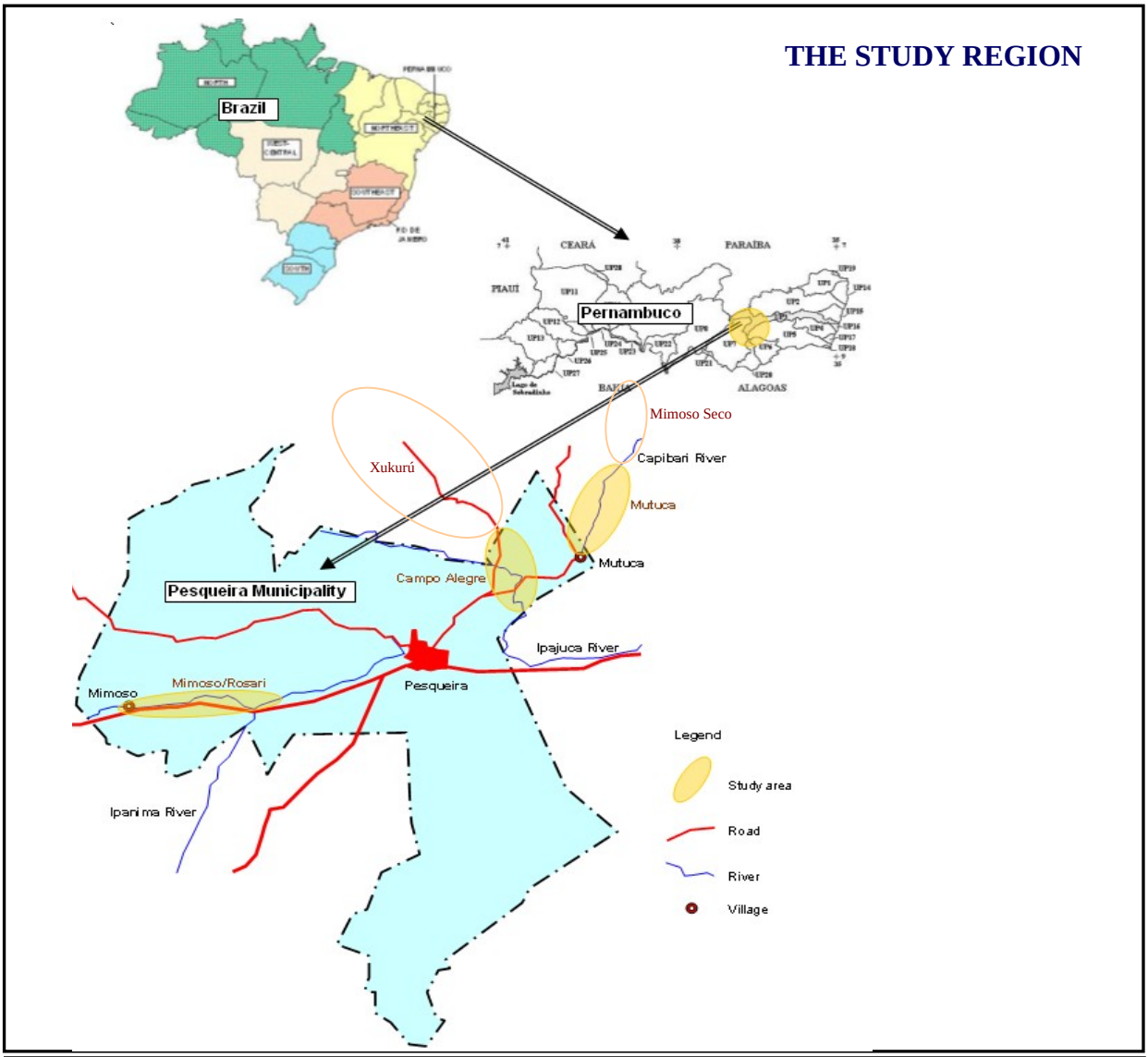
Achievements and Findings

- Successful integration of social and technical Project contributions.
- A strong participatory approach and full inclusion of the communities in all Project activities has been successful.
- Through active participation, community members, local teachers and health agents have been empowered and have developed the interest and skills to continue the Project activities.
- Improved understanding of water resource availability in the context of climate and land management and active participation of local communities in water resources monitoring.
- Water and land resources management concepts and participatory monitoring have been included as components of an Environmental Education Programme. The programme has been implemented at 10 rural schools with municipal government support and involvement of teachers, education specialists, health agents, as well as local farmers. Farmers are involved in teaching activities and in the preparation of the educational material, thus recognising their traditional knowledge.
- The inclusion of the two additional communities in the Project has enhanced community awareness of social organisation (already well established in those two communities) as well as organic agriculture. This has resulted in other communities embracing social organisation principles as well as practicing organic agriculture.
- Resolution of conflict between the indigenous Xukurú community (owners of the Pão de Açucar Reservoir) and local farmers in downstream Campo Alegre has resulted in water sharing and active participation of the Xukurú in the Project. This has resulted in the establishment of a Water User Group with representation from the two communities. This has been an important action towards sustainable water resources management in this catchment.
- The inclusion of the Xukurú in the Project. has given them the opportunity to express their beliefs and explain to the other communities their social organisation and their willingness to share available water resources. This has benefited neighbouring communities, particularly the Campo Alegre community. It has also, to a major extent removed the animosity between the Pesqueira municipality and the indigenous community.
- Guidelines for sustainable water resources management have been developed in relation to resource monitoring and usage, and in relation to water use and water saving in rainfed and irrigated agriculture. However, there is clearly a requirement to ‘translate’ the guidelines in a ‘language’ appropriate for use by the rural communities. Guidelines are being incorporated in the statutes of water user association in three of the five communities.
- The diversity of social structures within the five participating communities has had an impact on the degree of uptake of the Project messages. The communities with better established social organisation have benefited more from Project activities than the others.

- The diversity clearly highlights the need to approach communities in ways that consider their social structure. It is clear that more time and effort is required to bring the poorly organised communities to the level of the better organised ones. Steps towards achieving this have, however, been successfully taken.
- The land and water focussed Environmental Education Programme was conceived at the start of the final year of the Project. Its implementation at ten rural schools has been so successful that three municipalities in the region have embraced it and will introduce the programme at all rural schools in those municipalities. The provision of low cost monitoring equipment by the Rural University of Pernambuco has allowed students to participate in monitoring.
- The final Project seminar held on 17 November 2005 was attended by representatives from the rural communities, NGO's and representatives from Recife based organisations. During the seminar, the success of the project was voiced by many of the community representatives. The establishment of a Project Advisory Group, comprising representatives from all participating communities, as well as the organisation of teachers in the environmental education initiative have contributed to active cross-community collaboration and participation. The Project has valued opinion of the rural communities to the extent that Project activities have changed direction in response to community wishes. This has had a powerful impact on the way the Project has been perceived by the rural communities and on their commitment to continue with the activities started during the Project.

The Project actions have demonstrated that, once the population is listened to and is given voice, projects of this type can be successful and contribute to an improvement in the livelihoods of the beneficiary communities.

THE STUDY REGION



The study region for this Project is based in the state of Pernambuco, which has a climate ranging from tropical along the coast to semi-arid (Sertão) in the interior. Long periods of drought have limited the extent of agricultural activity, with rural productivity in the region in the past fifty years centring on logging of local forests for charcoal production. This activity has had severe detrimental effects on the local micro-climate resulting in desertification, ensuing increased rainwater run-off and decreased recharge of the local alluvial aquifers.

Extreme Contrasts in Climate (Campo Alegre)

1 Introduction

This Final Technical Report describes the activities, progress and findings of the Project. For the first seven months of the Project these have been described in detail in the Inception and Knowledge Review Reports, issued in July 2004. This report summarises activities, progress and findings from the inception and subsequent periods, but clearly identifies how Project activities undertaken since July 2004 have been influenced by the early findings.

This report summarises the activities, progress and findings of the Project activities in the log frame. Detailed descriptions and information are provided in the supporting documents. References to these are included in the activity summaries in this report. The supporting documents are contained on the CD, included with the report.

The Project goal, purpose and outputs are given in the log frame, which is presented in Document 1 of the supporting documents. The log frame has been changed in the course of the project and the version shown in Appendix 1 is the final version. The changes to the log frame relate to the change in focus from groundwater for agricultural use by rural farmers to the use of land and water by rural communities. Furthermore, the target areas for the Project have been expanded from three to five as explained in Chapter 2.

Chapter 3 describes the delivery of the messages embedded in the main themes identified during the Inception Phase.

Chapter 4 includes the summaries of the activities contained in the log frame. It describes progress and findings, measurable indicators, means of verification and risks and assumptions.

Chapter 5 focuses on the general findings of the Project in relation to the Project outputs. The chapter also provides information about approaches adopted in the Project that have contributed to its successful conclusion and to the empowerment of the rural communities that participated in the Project.

Chapter 6 includes conclusions and recommendations. The recommendations include follow-up activities that are believed to be necessary to guarantee full empowerment of the rural communities and ensure they possess the capacity to undertake sustainable management of land and water resources.

2 Background

2.1 The Inception Stage

For detailed information, reference should be made to the Inception Report and the Knowledge Review Report, both issued in July 2004 and included as supporting documents on the enclosed CD.

The Inception report concluded that sustainable exploitation of scarce groundwater resources can only be successful if the following key concepts are observed:

- *Decentralised Control* - Responsibility for resource management should be delegated to the rural communities directly affected by resource utilisation/exploitation.
- *Knowledge of the Resource System* – The basis for sustainable resource management stems from a thorough understanding of the behaviour of the resource system under a variety of environmental conditions and anthropogenic interventions. This understanding needs to reside with the local communities.
- *Monitoring* – The understanding of groundwater resource availability and behaviour can only be obtained through active monitoring of the influences exerted on the water environment. These include observations of climatic conditions, groundwater reserves and quality, water utilisation and land use.
- *Variations in Water Need* - Water is used for a variety of purposes and the priorities for different uses may vary between and within communities and with resource availability. The first priority for water is potable use: thereby enhancing the health of the community. However, the use of groundwater for irrigation also has considerable benefits: resulting in enhanced income from the sale of produce and so improving livelihoods.
- *Ownership Issues* - The ownership of and the responsibility for the groundwater resource needs to be clearly defined and be agreed upon by the members of the local communities.

These key concepts have had a direct influence on the Project activities.

The Inception Report indicated that one of the key challenges for the Project was to ensure that the process of learning and awareness-raising regarding the benefits of groundwater management would not stop when the Project came to an end. It was incumbent upon the Project team to make every effort to ensure that the processes that commence during the duration of the Project continue with the active support of other relevant agencies. The Project has introduced and implemented processes that contribute to the continuation of this awareness building, including a land and water focussed environmental education programme, introduced at rural schools within the participating communities.

The Project developed a strategy for staged, incremental dissemination of the messages from the Project. This was to allow the full engagement of the communities and to allow them the time necessary to develop their own organisational structure to take advantage of the information and ideas that were being made available. It was also to enable Project team members to acquire a good understanding of local knowledge of water resource management and to develop a dynamic dialogue with local people.

The findings that arose from the Inception Stage have influenced Project delivery. The detail is provided in the Inception report. Important findings were:

- The study areas are diverse, both in terms of the water resources and social settings.

- The exploitation of groundwater resources of the area could be termed haphazard.
- High levels of curiosity in the Project and interest to participate were expressed by both local authorities and the local population. It was realised that specific action would be required to maintain and stimulate this interest, and that this could be achieved through engagement of the communities in the Project activities.
- The challenge of full co-ordination and collaboration between the Project technical and social development teams was recognised and was a key factor for the successful outcome of the Project.
- There was a lack of a clear community basis for water management, other than the farmers associations (which are not fully functional) and a lack of government regulatory controls at the local level to support the empowerment of the local population.
- There was a need to engage both men and women in the water debate and to provide a greater focus on domestic level water supplies and the improvement of strategies for managing these. The broader issues of water consumption for all uses was highlighted as an important alteration to the emphasis of the Project, whilst recognising that the main thrust of the study is concerned with agricultural water use.
- There were complex differences between the participating rural communities in terms of physiographic, underground and demographic conditions. This called for a sensitive approach to knowledge transfer that avoids the 'one size fits all' concept, while permitting clear messages to be exchanged without creating apparent inconsistency in style and knowledge spanning the study areas.
- The establishment of the Xukurú reservation, within which one of the major surface water reservoirs is located was celebrated by the Xukurú but deeply resented by many of Pesqueira's city population. In relation to water resources, the Campo Alegre area was affected by the lack of water releases from the Pão de Açucar reservoir.

2.2 Inclusion of Additional Study Areas

Two additional study areas were included in the Project for reasons outlined below:

- The Xukurú indigenous community was included because of the livelihood dependence of the Campo Alegre community on water releases from the Pão de Açucar reservoir, which is located within indigenous area and owned by the Xukurú. The intention to include the Xukurú community was expressed in the Inception Report and a brief overview of the socio-economic setting of the community is included in the same report.
- The community of Mimoso Seco, located to the north of Mutuca, was included for two reasons. Firstly, the community is cohesive and well organised with a well-functioning farmer association. Secondly, the livelihood of the community depends to a large extent on irrigation from groundwater. The community had expressed interest in participating in the Project.

The livelihood, water use and environmental surveys undertaken during the Inception Phase in the original three study areas could not be undertaken in the two additional areas without additional funding. The inclusion of the two areas has placed an obvious burden on Project staff and financial resources, which was managed within the original Project budget. Despite these constraints it was believed that the inclusion of the two communities should help to guarantee the successful outcome of the Project. The subsequent Project outputs have shown that this belief was justified.

The location of all five study areas is shown in the Summary of this report.

3 Project Implementation – the Delivery of the Project Messages

3.1 Introduction

The Project Implementation Phase aimed at translating knowledge into practice. A dissemination of a number of themed messages was proposed, with the main themes being closely related to the Project outputs defined in the Log Frame. The themes were integrated into an overall approach to deliver the long-term aim of sustainable development of groundwater resources and where relevant, surface water resources. The main Project themes are:

1. Water storage and use for domestic purposes
2. Water for farming
3. Land management for improved water harvesting and retention
4. Institutional and organisational aspects of groundwater management

The messages were to be progressively introduced through workshops and the principles disseminated and discussed in all communication with the local communities. The establishment of an Advisory Group comprising representation from all participating communities was considered an appropriate way of encouraging knowledge dissemination and cross-community communication. The members of the group were carefully selected and a number of criteria were used in the selection in order to achieve optimum effectiveness of the group. These criteria included:

- Good local (including traditional) knowledge in relation to both water resources/use and community relationship/organisation issues
- Respect within their communities
- A positive attitude towards livelihood improvement
- Ability to communicate and disseminate knowledge and experience

The group included health agents and teachers, who are mainly women and who have not only an intimate relationship with community individuals, but also are able to exert positive influence on the communities.

The planning for the delivery of the messages embedded in the four main themes took place during the early stage of the Implementation Phase and is described for each theme in the following sections. It should be noted that the Project took a flexible approach to delivery of the messages and it was therefore recognised that changes to the original approach and emphasis would arise in the course of the Project implementation. The Project adopted a strong participatory approach in the delivery of all messages. This implied full inclusion of communities in decisions related to the nature of message delivery and to the emphasis/priority given to individual messages. This went as far as providing openness about Project expenditure in relation to message delivery and allowing community members, where appropriate, to have a say in how to most effectively spend available funds. This flexible and inclusive approach was seen as an important means of empowerment of local communities and in ensuring ‘buy in’ to the Project aims.

3.2 Planned Delivery of Project Messages

3.2.1 Theme 1: Water Storage and Use for Domestic Purposes

(i) Introduction

According to the survey results, this theme is of interest to all community members, particularly women who are the ones mostly responsible for the storage and treatment of water for domestic consumption. Data indicated that during drought periods, community members tend to share water for domestic consumption with others in need if they have a well or a cistern, Therefore, there is collaboration among community dwellers with regard to this source of water.

This theme is also closely related to health and health agents who are responsible for raising the consciousness of community residents about the importance of appropriate water treatment so that water related illnesses can be prevented.

Important sources utilised for the collection of drinking water such as rainwater harvesting were to be discussed under this theme. It was important to make clear that the Project does not provide the means for constructing rainwater harvesting cisterns so that community members do not have false expectations. The purpose of the workshop on this theme was the exchange of knowledge through a dialogue among the participants, Project team members and other stakeholders. The discussion of the messages related to this theme was conceived by considering specific issues given in the box below:

- Groundwater is a readily available resource of water in the ribbon valleys. What is it being/can it be used for in the domestic context?
- To what extent is groundwater used and from what sources (mainly wells)?
- Do people find it a reliable/acceptable source of water?
- Are there times of the year when the groundwater from wells is/can not be used and why not?
- If it is not a preferred source, then why not? Has it to do with salinity or contamination or quantity?
- If groundwater is saline, but not contaminated, it may not be used for drinking. Would it be acceptable for other domestic purposes?
- If groundwater is thought to pose a risk to health, is it due to salinity or contamination?
- If wells were protected from contamination would people use it for domestic purposes?
- How do they perceive this protection could be achieved (for example, purpose built domestic wells, covering of existing wells, keeping the area around the well clean by avoiding cattle approaching the well and rubbish to accumulate, avoiding return flow into the well, etc)?
- Note that wells used for domestic water supply can be low capacity and could thus be successful even in low permeable formations.
- Would they consider involvement (eg provision of free labour) in the construction of purpose built wells or improvement of existing wells?
- Are they (or we) aware of the existence of purpose built (low tech) water supply wells, within the project area or in similar environments elsewhere in NE Brazil? (project team to explore)
- If so, can we find out more (design, construction, use, cost, satisfaction of users, etc)?
- If groundwater is not considered a viable option, what is the valid reason for this?
- One could then consider the alternatives and address the issues related to those alternatives. Alternatives include rainwater harvesting and possibly desalination.

(ii) Target Audience

The issue of domestic and drinking water is of particular concern to women and these were therefore targeted. The Project also targeted landless people and other poorer households on this issue. Men were included as it was felt important that they too understand where finance or assistance might be found for the installation of cisterns etc.

(iii) Method of Delivery

The delivery of the messages through the workshop sessions was planned to be as participative as possible. Community members were encouraged to participate in the discussions by providing information about the situation they face in their own communities. Therefore the workshop sessions were expected to be initiated by a brainstorming session in which the participants were expected to identify indicators concerning the situation in their community, the problems and the solutions regarding drinking water.

Owing to the close relationship of the messages in this theme with health issues and the important role of health agents in the communities, the participation of health agents was encouraged. They were invited to speak about the health of community members and about what they do to raise the consciousness of the population in regards to water treatment and the prevention of illnesses.

Project team members were expected to share new knowledge regarding alternative water treatment, how groundwater sources as well as rainwater harvesting relate to this theme, and how the management of these sources could be properly done. Their presentations were to be delivered through the use of a simple language and they would also utilise example illustration material to attract the attention of participants and raise their interest.

The workshop would also include a session to entertain the participants. It could be a theatre performance. Discussions on that were to be made with health agents and they would be encouraged to elaborate the script of the play as well as the performance.

Since one of the aspects involved in the methodology was to encourage the participants to try to experience the information discussed and the new knowledge acquired, the Project team members were to think of activities related to that. For example the idea of distributing small trees used in the treatment of water was considered.

(iv) Risks and Issues

One of the risks was that community members may have expectations about the financing of infrastructure from the Project, such as the digging of wells and the construction of rainwater harvesting cistern. In order to minimise this risk, it was felt important that the participants understood the purpose and aims of the Project from the very beginning. This was to be done not only during workshop sessions, but during other activities such as, the training of the health agents and the meetings with community members.

3.2.2 Water for Farming

(i) Introduction

Two important aspects related to this theme had to be considered, namely:

- Assessing available groundwater using water level measurements *and*
- Understanding evaporative losses in irrigation scheduling.

One of the greatest challenges of the Project was to introduce changes in practice along the lines proposed above. The work around the second aspect, which relates to water saving and is closely associated with aspects of land management messages, was believed to pose less of a challenge (for example weed management, use of mulches and creation of wind breaks).

Uptake of this very important message on water saving would depend on a clear demonstration of longer term benefits to the farmers that could improve their livelihoods and reduce fluctuations in income. It would, however, equally depend on a clear understanding, by the farmers, of water saving options and the related net benefits.

Water saving options may be understood to include:

1. Reduction in evaporation from the soil surface, which is particularly relevant during the early stages of crop development.

2. To a lesser extent, reduction in evaporation from the crop canopy and from the air (eg during application of water using overhead sprinklers).

3. Reduction in transpiration from unproductive vegetation.

These water saving options are understood by many farmers (but not all). However, their implementation is constrained by the farmer's ability to change, by perception and by lack of communal responsibility/care for the resource ('my good' rather than a 'common good').

Why should there be water saving? The argument is often that when I don't take it now, someone else will. So why?

An improved resource available for crop production could benefit the farmers in two ways:

(a) A large area could be irrigated, yet equally rapid depletion would occur with subsequent shortages in supply and failure to grow crops once the resource runs out.

(b) Longer period over which the resource could be utilised for irrigation.

Option (b) appears desirable, but what are the net benefits for the farmers, given that there may be costs associated with water saving, and that uncertainty in the market forces and hence market prices makes cost benefit analysis difficult. Yet given knowledge of historical information, it may be possible to develop cost benefit analyses for alternative resource management scenarios (improved in terms of water saving versus current practice). These models could incorporate uncertainty related to market forces.

Options 1 and 2 could be achieved by:

- Change in irrigation application technique (for example drip irrigation to avoid to a large extent the wetting of bare soil and hence reduce evaporation, and also evaporation listed under 2 above).
- Covering bare soil with a mulch would result in a reduction in evaporation from the soil surface, although its effectiveness is also influenced by irrigation frequency (for example daily application with sprinklers would wet the mulch and most of the applied water would still evaporate).
- Less frequent irrigation application (in the case of sprinkler irrigation) would result in a reduction of the period of wetness of the soil surface. Evaporation from a bare soil surface reduces rapidly once the upper part of the soil dries out.

Option 3 (weed clearance) simply requires the removal of unwanted vegetation (even on plots not yet cultivated). However, there are considerations:

- Weed removal is labour intensive if done manually
- Weed control with herbicides provides a potential health risk through direct exposure or, indirectly, through contaminated groundwater
- Local perception (expressed by two farmers in Rosario) such as:
  - Weed removal requires access and this damages the crop
  - Removal (by pulling out) damages the roots of the productive crop
  - Weeds provide shade, thus protecting fruits from exposure to direct sunlight
- Weeds may be beneficial when practicing organic agriculture

It is interesting to note that clear differences were apparent in community attitudes to weed control (plots in Rosario with lots of weeds and in plots in Mimoso Seco being largely weed free). It would thus interesting to find out how and why perceptions/practices vary.

It was felt that the frequency of irrigation also required attention. Observations in the field indicated daily or two-daily irrigation cycles and limited quantities of irrigation application. Irrigation every other day appeared to be dictated by well operation (particularly the shared community wells) rather than by other considerations.

It was considered worth investigating soil properties (moisture holding properties in particular). Using this information with data on water salinity and crop water requirements (etc), and using standard irrigation application 'theory', could lead to a better understanding of appropriate irrigation scheduling. Soils data are already available for some areas, but would be useful also for the communities where farmers irrigate daily. Soil sampling and analysis could be covered by the monitoring component of the field investigation undertaken during the Project (including the participation of MSc students).

(ii) Target Audience

Work related to passing messages about how to assess available groundwater using water level measurements and understanding evaporative losses was believed relevant both to those working in irrigation and to those who practice rainfed agriculture.

The main audience would be farmers using groundwater from the different groundwater bodies for irrigated agriculture and users of surface water for irrigation.

(iii) Method of Delivery

The participative methodology was also the basis for the dissemination of this message. Given the fact that this message involves mostly technical aspects, it was very important that Project team members utilise a simple language and illustration material in the dialogue with community members so that they could get the new information across through an effective way.

Land and water focussed environmental education, if introduced at rural schools, was seen as a means of fulfilling the aim of establishing long-term involvement of community members (in this case school children) in various aspects of resource monitoring. It was believed that young people are likely to be more receptive to new ideas and keen to experiment and learn the practical applications. They could then be encouraged by the Project to carry their learning home to their parents.

(iv) Risks and Issues

Any work related to the introduction and use of new monitoring equipments would be a challenging area of Project activity and, ultimately, may be the area where the Project team would experience the greatest difficulty in achieving Project aims. It was believed that this risk could be minimised if the community members understood well the benefits of using monitoring facilities for their own lives. In order to achieve that, it was considered important for Project team members to raise the consciousness of the community members about monitoring facilities and equipment and involve them as much as possible in the activities.

3.2.3 Land Management for Improved Water Harvesting and Retention

(i) Introduction

The topic relates to capturing rainwater (rainwater harvesting) and land management practices to enhance water availability to rainfed crops. Land management includes the practice of organic agriculture and thus the avoidance of using harmful pesticides. The benefits and methods that were considered and used for discussion during workshops and field visits included the following:

Benefits:

- Enhanced water availability to rainfed crops (more water will be stored in the soil profile thus reducing the risk of crop failure and enhancing the crop yield).
- Reduction in land degradation through soil erosion (gullies) and soil washout (overland loss of soil suspended in overland water flow)
- Soil build up within the cultivated land (could be local) to the extent that crop diversification can be achieved.
- Rainwater runoff will be reduced through capturing it in the soil. This will result in reduced short-term water contributions to streams and thus in reduced risk of flood damage (if conservation is practised on a large scale).
- Enhanced infiltration of rainwater will not only result in enhancement of soil water availability. It may also result in recharge to the underlying rock and a more sustained groundwater flow towards the alluvial deposits in the river valleys.

Methods:

The methods that were considered and shown in the following are not exhaustive and some may be combined. The pros and cons of the methods are also briefly highlighted where of relevance.

- Terracing

This is widely practised in many parts of the world (for example France, Nepal, Indonesia, Africa and Rosário in the past). Examples could be shown on the display boards. The advantages would include reduced runoff, retention of soil, enhanced soil depth, enhanced infiltration of rainwater and thus enhanced moisture availability. The disadvantage could be the efforts required to establish terraces.

- The establishment of ridges

  The establishment of ridges, preferably built of solid material, or of soils held in place by vegetation (hedges, palma), would result in a reduction in overland flow and soil loss and reduces the risk of gully erosion. The reduction in overland flow would result in enhanced infiltration of rainwater and the build up of soil behind the ridges. Over time the ridges could be heightened so that terracing evolves.

- Contour ploughing

  This would result in a reduction in overland flow and should preferably be combined with the methods described under the previous two bullets. Ploughing would, however, generally only be possible after the soil has been wetted by rainfall (the soils become very hard when dry) and significant runoff losses could therefore still occur in the period before ploughing is possible. Breaking up the dry soil may be possible as an additional measure. The advantages would include a reduction in overland flow and enhanced infiltration of rainwater.

- Diversion of rainfall runoff from small streams onto cultivated land

  Rainfall runoff accumulates in small streams and is then flowing downhill towards the rivers that run along the alluvial valleys. Rainfall may be captured by the construction of small cross dams and diverted onto the cultivated land and thus enhance water availability. If combined with the establishment of ridges, water could be more easily distributed over the cultivated land. The cross dams could easily be built with local rock material and do not have to be large in size. In larger streams they need not block the full width of the stream to enable diversion.

The use of pesticides:

The two communities included in the Project at a later stage (Mimoso Seco and Xukurú) were interested in organic agriculture, partly because of their awareness of the dangers of chemical pesticides on human health and on the environment. The Project believed that organic agriculture would be a relevant issue and elaboration would involve communication of ideas amongst participating communities and involvement of local NGO's in the region who actively promote the practice. In the communication and knowledge dissemination process the following questions where believed relevant:

- Why use organic pesticides? (benefits to health?, the environment?)
- How did they learn?
- From whom did they learn (CEDAPP?)
- In what form was the advice?
- How does it work?
- How effective is it, if compared with chemical pesticides?
- Do you manufacture it yourself and how?
- How long have they been using it?
- Can it be used elsewhere and would you recommend it?

- How much does it cost?
- How does cost compare with the cost of chemical pesticides?
- Has there been follow up advice?

(ii) Target Audience

In the view of the Project team, those who most needed to be targeted for this message were farmers working in rainfed agriculture. Land management messages were, however, also considered relevant to all who farm or grow some crops, herbs and fruit trees on small plots of land for family use only.

(iii) Method of Delivery

The methodology to deal with this theme was again as participative as possible due to the technical nature of the issues involved. Farmers who had been identified as having significant knowledge and experience with the concepts of this theme had important participation in the activities, particularly in the workshop sessions. Visits to their plots were planned so that they could demonstrate their experiences. The Project team members discussed and planned the workshop sessions in a way to encourage community participation and make the workshop as dynamic as possible.

The Project manager's dialogue with Seu Djalma in Rosário is a good example of using appropriate ‘language’. This dialogue was also a reminder that the spoken words of Project Team members may not always convey the message they think they are conveying. This is what happened:

> After a lengthy conversation about rainfed farming on the hill slopes, the project manager was able to communicate with and learn from Seu Djalma, a farmer from Rosário, by creating a mound of earth on the ground and tracing contour lines on the mound with a stick. Seu Djalma then engaged actively in dialogue with the Project manager about his own experience in preventing water runoff on his land and terracing. He even corrected the contour lines with the same stick in the light of his experience!

This experience taught the team members that some of the community members are very experienced and knowledgeable and that they can teach others. The active involvement of community members (including farmers) in the workshops and other activities was therefore to be encouraged. This would show the acknowledgement of the importance of local traditional knowledge as well as an important means of empowerment of community members.

(iv) Risks and Issues

The main risk was that if the way through which the messages were disseminated were too technical, the theme would not be successful. It was therefore felt necessary for the farmers to become involved and feel part of the training activities.

3.2.4 Institutional and Organisational Aspects of Groundwater Management

(i) Introduction

This was considered a very important theme and the messages found within it overlap and crosscut all of the other themes. Community organisation was considered a key aspect for a successful dialogue concerning this theme. As the survey analysis had shown, the three communities originally included in the Project lacked a solid social organisation and therefore needed to be better organised so that they could benefit from the Project. It was hoped that by the time this theme was dealt with, community members would be more empowered and would have succeeded in better organising themselves. The inclusion of two additional communities in the Project, the Xukurú and Mimoso Seco, was already considered at the time of preparation of the message delivery. Both these communities have well established social organisation and were believed important examples to the three other communities.

The collective management of water can only be achieved by communities who are organised. Beyond community organisation, the messages within this theme would also deal with the institutional and legal aspects of water management. In this regards, involvement of the State Government Institutions such as SECTMA – The Secretariat for Science, Technology and the Environment, was considered and it was hoped that they would support the Project initiatives and become an important partner.

The organisation of community members in water users groups and/or associations was considered one of the most important aims of the Project. One of the ways through which community members could be encouraged to organise themselves was by promoting visits to established water users associations and/or inviting NGO activists and members of water users associations to visit the communities and share their experience with them. So, an effort was to be made to bring invited speakers to the community meetings as well as to workshops and seminars.

(ii) Target Audience

The target audience in this case were the women and men of the communities. Since the participative management of water concerns in the whole community, this theme was of interest to all community members.

Dialogue between the initial Project communities and the new Project communities (which are organised) was arranged so that lessons could be learned. The Project Advisory Group played an important role in encouraging dialogue among the Project communities as this could bring the communities together and provide them with the opportunity to share knowledge and experience.

(iii) Method of Delivery

As in the other themes, a participatory approach was utilised in all the actions involved. Although the Project team members were not responsible for organising the communities and form water users groups or associations on their behalf, this could be encouraged and the first step towards this was believed to be the empowerment of the community members. By making them feel important actors in the Project and by considering the importance of local traditional knowledge, it was hoped that they could improve their social organisation and benefit from that.

The delivery of the messages under this theme would therefore be centred on the promotion of a strong participation of community members:

(iv) Risks and Issues

In all aspects of the work, The Project would need to encourage and support local people to take their own initiatives to encourage autonomous activity. Creating a relationship of dependency would need to be avoided. Efforts were made so that by the end of the Project water users groups were formed or actions towards their establishment taken.

4 Project Activities

4.1 Overview of Activities

4.1.1 Introduction

In order to achieve the Project purpose and to effectively assess the progress of the Project, Project outputs are identified and outlined in the following sections. For each of the output packages the related activities are listed in this section from 4.1.2 to 4.1.6. The results of the activities undertaken are summarised in Section 4.2 with reference to supporting documents that provide further detail.

The land and water focussed environmental education programme started in the final year of Project implementation. Although considered as a useful initiative at the early stages of project Implementation, its impact on rural life has greatly surpassed expectation. A detailed discussion of the programme and its impact on the communities is given in Section 4.3.

4.1.2 Inception: Livelihood, Water Use and Environmental Surveys

This output relates to the development of a clear understanding of livelihood framework for small farmers in the study areas (men and women), and the role of water and irrigation water. The understanding is based on livelihood, water use and environmental surveys undertaken during the inception stage.

Only qualitative livelihood surveys were undertaken for the Xukurú and Mimoso Seco communities, while collection of information related to water and environmental aspects was in part integrated in the projects undertaken by MSc and PhD students from UK and Brazil universities. The contributions from the MSc students from the UK are summarised in Appendix B.

4.1.3 Package 1: Guidelines for Sustainable Water Resources Management

This package included the development of guidelines for sustainable resource management for irrigation schemes at farmer level. The following activities were undertaken:

- Review of current monitoring arrangements and the implementation of new monitoring systems and schedules.
- Assessment of groundwater resource availability in each study area and the determination of indicators of groundwater stress.
- Evaluation of the impacts of groundwater development and the sustainability of the resource under different operational conditions and the timing of intervention.
- Dissemination of the findings arising from activities 1 to 3 through the communication channels created to address Package 2 and the resources developed under activity 2.

4.1.4 Package 2: Framework for Participation and Education

The development of a framework for rural community participation and education included the following activities:

- Consultation with end users, target audience representatives and local community leaders and the establishment of ground rules for interaction between the Project team and the local community.
- Performing socio-economic assessments to identify under-represented groups/genders concerned with the Project goal and to establish the basis for their integration into the communication dialogue.
- Carrying out participatory livelihood analyses (including water use and water needs analysis) with rural families (men and women).
- Establish workshops, seminars and participatory surveys using the knowledge gained from activities 1 and 2.
- Recording, reporting and evaluation of the results of the workshops and seminars.

4.1.5 Package 3: Operational Strategy for Integrated Communications

An operational strategy for integrated communications between rural community members (including small-scale farmers), researchers, managers and extension workers was required. The following activities were related to this package:

- Development of communication strategies aimed at producing effective multi-channel communication from the farm level up to national level encompassing farmers, water user communities, appropriate NGO's, public bodies, extension services and research organisations.
- Implementation of the communication strategy to contribute to and present the outputs of the technical research findings.
- Recording and reporting of the findings of this phase of the research.

4.1.6 Package 4: Guidance on Monitoring and Intervention Strategies

Guidance on convenient and cost-effective data collection strategies, involving individual community members and community groups for the assessment of irrigation performance, water conservation and salinity control was needed to fulfil the Project goal. The following activities were related to this package:

- Assessment of the local capability to undertake resource monitoring and to interpret/disseminate as well as action the results.
- Development of guidelines and procedures for acquiring resource status data, processing the data and interpreting and distributing the results.
- Development of resource stress indicators, presentation of the basis for these and their dependence on future conditions.
- Distribution of the procedures and guidelines and the publication of the strategies.

4.2 Summary of Activities

4.2.1 Livelihood, Water Use and Environmental Surveys

Quantitative and qualitative livelihood surveys were conducted during the inception stage in the two of study areas originally selected for the Project. These included the communities of the Rosario/Mimoso and Campo Alegre study areas. A full livelihood survey for the Mutuca area was undertaken in July 2004. The full details of these surveys are given in the Inception Report (SD7) and in Supporting Documents SD5 and SD11. As mentioned in Section 4.1.2, only qualitative surveys, based on interviews, were undertaken for the two additional communities (Xukurú and Mimoso Seco). Details are provided in Supporting Document SD22.

The quantitative livelihood surveys had a strong participatory element, with interviewers selected from the participating rural communities and trained by Project team members. The qualitative surveys in the two additional study areas were undertaken by Project team members, since a fully participatory approach was not possible for reasons mentioned before.

A stakeholder analysis was also undertaken during the inception stage and findings are described in detail in the Inception Report (SD7).

During the inception stage, a well survey was undertaken for a representative number of wells in the Mimoso valley. The survey used questionnaire forms specifically designed for the Project. The survey linked in with the livelihood survey in this area to enable a better understanding of the role of groundwater in the livelihood of the rural families. The findings of the well survey are described in the Inception Report (SD7).

Water use and environmental surveys have been undertaken by MSc and PhD students from UK and Brazilian universities. The aim of these surveys was to obtain the baseline information required for the assessment of available water resources in the study areas.

4.2.2 Guidelines for Sustainable Water Resources Management

(i) Monitoring

Developing a community-led monitoring strategy to support long-term community based management of the available water resources in the area represented a key objective of the Project from the outset. The support that monitoring provides is two-fold. First, it provides a simple activity around which a community can develop a joint approach to understanding the state of the water resources and the likely impacts at any point in time. Second, it provides a long-term record that can be used to examine the success of cooperative strategies to conserve the water and to sustain the community during periods of drought. The basis for the cooperative strategies is established in a set of guidelines that uses the monitoring data to define the need for intervention in groundwater and surface water use. The guidelines are location specific and dependent on the physical conditions that prevail.

In the initial stages of the Project though, there was also a considerable need to gain a better understanding of the physical setting and the availability of the resource and its response to climate variation. For this reason, part of the monitoring programme was also targeted during the Project at developing this understanding. The development of the monitoring activity for this purpose was facilitated through a large number of postgraduate research projects undertaken by students from Brazil and the United Kingdom. Apart from the obvious advantage of low costs, a major advantage of engaging these students in the Project area lay in the training that each student received on the aspects of socio-economic development and community based water management that have been promoted within the Project. The knowledge that each of the students has acquired will allow them to develop the underpinning concepts of integrated technical and social development in their future careers.

Monitoring and Sampling Equipment and Installations

Prior to the commencement of the current Project, various monitoring and sampling equipment had been installed in the 3 catchments over a period of more than ten years, with most located in Rosario valley and least in Campo Alegre. Since the inception of the Project, new equipment has been installed in the three regions, to support improved understanding of the physical and climatic conditions and to develop trials to assist the development of new ways of managing the available water resources and to improve irrigation efficiency and irrigation financial returns. The additional instrumentation has provided new climate measurements, groundwater level and water quality monitoring in areas with inadequate coverage, and data from trial irrigation experiments. Tables 4.1 to 4.3 present a list of all previous and new installations and their purpose. Instrumentation installed during the Project period but supported by other projects is listed to indicate the integration of activity across the different water related programmes that are being undertaken in the area. Appropriate technologies were used in all cases involving farmer or community level participation, other than in the case of soil moisture measurements (where the tension measurements could not be performed with low technology systems).

Several basic climate instruments (predominantly rain gauges and evaporation tanks developed by Professor Ronaldo Freire for use by low income communities) were also provided to local schools in support of the educational programme.

Before the start of the Project, the groundwater resources of Rosário valley had been extensively studied during research carried out through MSc and PhD studies undertaken by students of the Federal and Federal Rural Universities of Pernambuco State, and Newcastle and Birmingham Universities, UK. These studies were largely concerned with understanding the groundwater resource in terms of the development of salinity problems as a result of groundwater exploitation for irrigation. Demonstration pilot areas for irrigation management and salinity control had also been installed and monitored.

Mutuca region had also been previously studied by researchers and students of the Federal and Federal Rural Universities of Pernambuco State and a network of piezometers had been installed, funded by CT-HIDRO/CNPq-Brazil. The aquifer is punctuated by numerous underground dams along the valley that were implemented by the Pernambuco State Water Resources Directorate and most of the previous work had been concerned with the functioning of these dams and the issues of groundwater exploitation and groundwater and soil salinity upstream of the dams.

Campo Alegre was the least known region, although had been previously visited by the members of the Technical evaluation team of the KaR Project, in connection with interests from Pernambuco State Rural Extension Service, formerly EBAPE, and which prompted support for the current Project by EBAPE. Little monitoring was being carried out in this area before the start of the Project.

The installation of groundwater monitoring and sampling equipment was carried out in each of the three areas for the following purposes:

- In Rosário Valley, new piezometers were installed across the main valley, at locations where high salinity gradients are observed, to improve the understanding of the salt migration mechanism between hill slope and valley. The groundwater salt balance suggested a strong contribution from this source that was not adequately quantified and could prove decisive in terms of developing salinity control guidelines to support farmer exploitation of the groundwater.
- In Campo Alegre, new piezometers were installed in the alluvial aquifer adjacent to the river, to investigate the groundwater conditions, the morphology of the aquifer and the groundwater potential of the aquifer and the contributing valley sides to support exploitation during drought periods. Groundwater and surface water quality and level monitoring were developed in existing wells, in the river at selected locations along the length of the catchment, and immediately upstream of the Pão de Açucar Dam to determine the rate of depletion of the reservoir. In each case salinity and water levels have been recorded. The monitoring of both the groundwater and surface water responses were important to understand the relationship between discharges from the surface reservoir in the valley (Pão de Açucar) and the transmission and losses of the released water downstream.
- In Mutuca, temporary and permanent piezometers were installed at many locations along the valley during the Project in order to assess the effectiveness of the underground dams located along the valley. The coarse soil texture in several places allowed successive installation and retrieval with relative ease. The principal aim was to establish the degree of control exerted by the dams on the groundwater retention in the aquifer. The piezometer studies were supplemented by resistivity tomography to establish the lateral and vertical extent of the aquifer. It became clear during the investigations that many of the dams were not fully functional. Salinity monitoring was also undertaken in the existing open wells to establish both the seasonal and spatial variability of the groundwater quality.

In each case, the prime goal for the monitoring was to address a specific question about the functioning of the aquifer system rather than to establish a permanent network of piezometers. It was clear from assessments in each of the three areas that in all cases the farmers could use their existing well network to provide adequate long term monitoring without the need to introduce additional monitoring points.

In addition to the groundwater/surface water monitoring, soil moisture monitoring was also performed at several selected demonstration points to develop an understanding for both the farmers and the technical evaluation team of the soil moisture content variation and soil drainage as a function of irrigation practices to improve application efficiencies.

Participatory monitoring

An important aim of the KaR Project was to motivate local farmers and the community as a whole to undertake monitoring of the water resources in the three areas in order for them to be able to manage groundwater consumption and to reduce the risk of either crop failure or water resource failure during periods of drought. Monitoring included groundwater levels, precipitation, evaporation, soil moisture and groundwater salinity.

Engagement of the communities was initiated early in the Project through the inclusion of several key members of the communities in the monitoring process. Training in the use of the equipment was undertaken and the recording and interpretation of the results was explained through the implementation of a monthly measurement programme. In these cases, the members of the community were adults and mostly farmers and their families.

The value of monitoring was discussed during the community workshops so that the communities could begin to see the need for sustained monitoring beyond the end of the Project and could begin to see the need to work together to develop, conserve and share the water resources. While the development of individual measurement skills and appreciation of the value of monitoring was relatively straightforward, the development of a community based monitoring programme with community level decision making has taken time and will need to be an ongoing process in the three catchments.

In Campo Alegre this community level integration has been substantially boosted with the new agreement between the Xukurú and the downstream farming communities to share the resources in the Pão de Açucar reservoir. The link between the distribution of the water resource and consumption in the upstream and downstream areas has been made in this case and this will drive the monitoring programme.

In the area of Mimoso Seco, the community is well established and working closely together. Again in this case, the community involvement is assured and the monitoring and the corresponding guidelines will develop.

In the cases of Rosario and the remainder of Mutuca valley, the development of water users associations within or alongside the existing farmers associations has been slower and the development of an integrated approach to management of the water resources has gained much less momentum. However, it is hoped that this will develop in time if additional efforts can be made by NGO’s and the state government in the region to support the process of development of local management of ground and surface waters.

To support longer term monitoring in the communities, educational programmes at rural school level have been encouraged through the provision of low cost climate data collection equipment and the training of teachers and health agents. Particular attention has been paid to the collection of evaporation and rainfall measurements to assess the available water in the soil. The collection methods have been based on simple and very low cost equipment developed by staff at the Federal Rural University, notably Professor Ronaldo Freire. Training sessions were carried out regularly on the use of these equipments for farmers, local teachers as well as their students within the framework of the environmental education programme.

As part of the participatory groundwater monitoring efforts, concepts about the operation of the groundwater system have been discussed and knowledge shared between the KaR Project team and the community members. As an example, a strong relationship between the depth to groundwater and the salt content in the water and on the soil is observed in the monitoring data. The farmers already had the sense that as the groundwater declines during the dry season, the salinity increases, and therefore could relate their experiences to the measurements. However, they did not understand the reasons for the link between these observations. Illustrations were used including the example of a cup with a fixed amount of salt mass to which different volumes of clean water were added to show how the salinity is affected by dilution. Examples in the field were also presented using conductivity meter readings. The concept of sodicity was much harder to explain, although explanations based on the soil colour and the soil hardness using a wood stick were given so that the community could at least appreciate the physical effects of a high sodium level.

(ii) Assessment of Groundwater Resource Availability Stress Indicators

Indicators of resource availability and stress can be defined as environmental attributes that measure or reflect the environmental status or conditions of change of a resource. In this Project, indicators have been applied to the groundwater (Belousova, 2003), and also to the soils to assist groundwater exploitation for irrigation and irrigation management at the farm level. Irrigation is the largest single user of the water at the present time in each of the three catchments. The ability of the whole community to withstand a drought depends on timely reduction of irrigation activity to preserve the groundwater for livestock and human consumption. While the need to reserve water for human consumption in periods of normal rainfall might be reduced if recommendations to increase the use of rooftop rainwater harvesting are implemented to provide the majority of domestic needs, there may still be a need to reserve some part of the groundwater to supplement these supplies during a drought period. It seems unlikely that an alternative source to the alluvial groundwater is justified for maintaining the farmed animals in the three catchments.

The main groundwater resource indicators identified are the electrical conductivity (EC), the sodium content and the depth to groundwater. While transmission and storage attributes of the aquifer might normally also be considered as important indicators for sustainability in terms of the magnitude of the available resource and the ease with which it replenishes, these indicators have been shown to have less importance in the three valleys by the detailed work on assessing these parameters carried out during and prior to this project (Montenegro, 1997; Hardisty, 2004). Local variability of the aquifer hydraulic properties is large but the degree of heterogeneity introduces a significant degree of homogeneity at the kilometre scale. Thus it has been possible to make reasonable estimates of these properties to provide initial assessments of available water at each pumping location in the valleys and correspondingly estimates of the resource deficit given the depth to water measured (i.e. the available storage for recharge waters) (Galley, 2005; Dane, 2005; Sholl 2005).

The EC indicates the salinity level in the groundwater and therefore the crop types that can be grown in any given season. It varies throughout the year in response to concentration and dilution processes and the flushing of salts from the weathered rocks forming the valley sides. Crop choice is therefore seasonal and this has been encapsulated in the guidelines that have been developed.

The sodium content indicates the risk of causing sodification of the soils during irrigation and the reduction in the suitability of the soils for crop production.

The groundwater level provides data on the available resource without further replenishment but is also indicative of the maximum daily yield from the open wells used by the farmers. It therefore provides a useful indicator of the risks to crop production from a lack of water in the short term as well as providing an indicator of the risks from extended drought periods.

Rainfall recharge plays an important role in determining the groundwater quantity and quality variation throughout each year and the risks at each stage of the year of water shortages. To facilitate the application of the three stress indicators in the three catchments, three 'seasons' are identified. These are:

- Season 1- From April to July. This is the main rainy season and dilution of the groundwater salinity occurs as the aquifer recovers due to recharge and the rivers flow, removing some of the salts.
- Season 2- From August to November. Rainfall is limited and recharge is negligible. Consequently the groundwater levels drop due to evapotranspiration from the irrigated and non irrigated areas. The salts concentrate in the soil profile and in the groundwater.
- Season 3- From December to March. Rainfall is sporadic but can be intense. This frequently leads to salt increases after an initial flush of salts into the alluvial aquifer leaching from the valley sides as result of the first storms as well as salinity increases from soils leaching. During this period the water table can start to rise as well as the salinity.

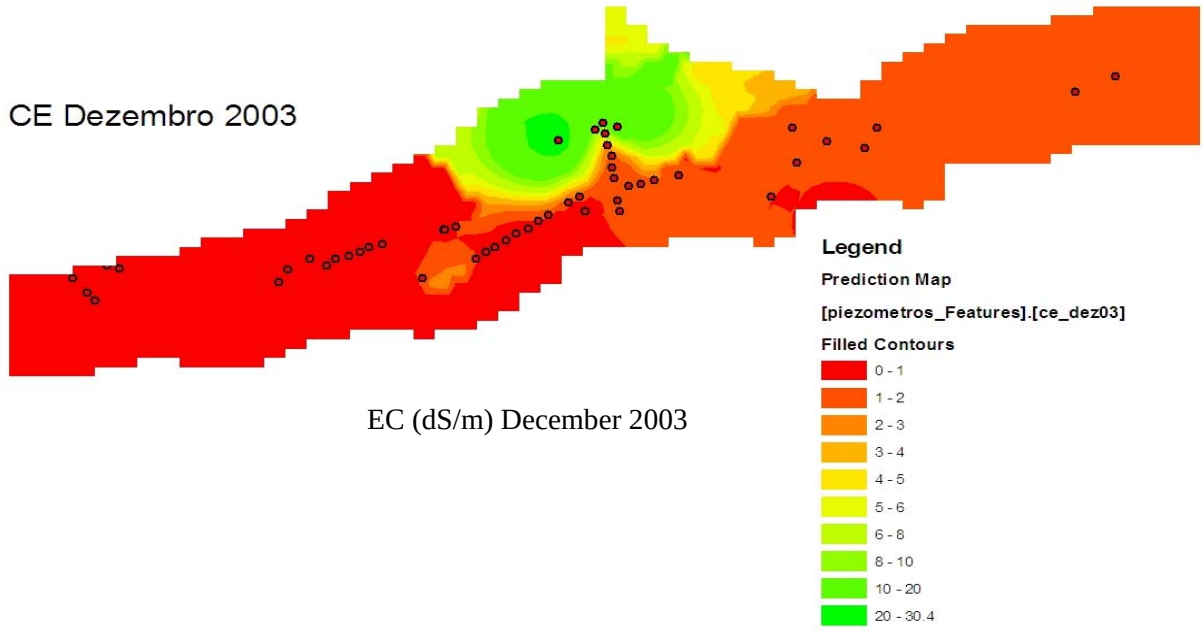
Sodium Risk and EC

Based on the results of the monitoring activities, sodium risk is low in Campo Alegre. This is largely due to the continual flushing of the aquifer by waters discharged from the Pão de Açucar dam which permit continued flushing of the salts in the aquifer system and the salts that are derived from the valley sides. In backwater regions of the shallow aquifer in Campo Alegre, high EC values are observed but the groundwater here is not used for irrigation and is localised.

In Mutuca, sodium values can reach high figures. However, the coarse soil texture allows a recharge dilution in Season 1 and this helps prevent development of sodicity issues within the remaining two seasons. Nevertheless the groundwater EC in Mutuca tends to be relatively high, particularly in the downstream portion of the valley and crop choices tend to be limited to relatively salt tolerant crops.

In Rosário, sodium and electrical conductivity can reach very high values, but these are in fact highly localised spatially (Figure 4.1). New piezometers were installed to identify the boundaries of the transition zone between the high salinity region and the remainder of the aquifer system and to validate the hypothesis that the zone of high EC is isolated from the rest of the alluvial valley. This did prove to be the case. It appears that the important feature here is the generally higher proportion of clay in the aquifer and soils in the high salinity region with the consequent reduction in flushing, higher evaporation under deeper water table conditions and slower lateral flushing by groundwater movement. Such conditions are not found at other locations in Rosário. The majority of the aquifer possesses relatively low salinity with a trend of increasing salinity downstream. This is indicative of the slow flushing of this aquifer due to groundwater throughflow down the valley. However, this does not explain the salinity distribution completely and it appears that flushing must also be taking place from this aquifer during flood events in Season 1 and discharges of groundwater to the normally dry river.

Figure 4.1: Electrical Conductivity (EC – dS/m) distribution in Rosário

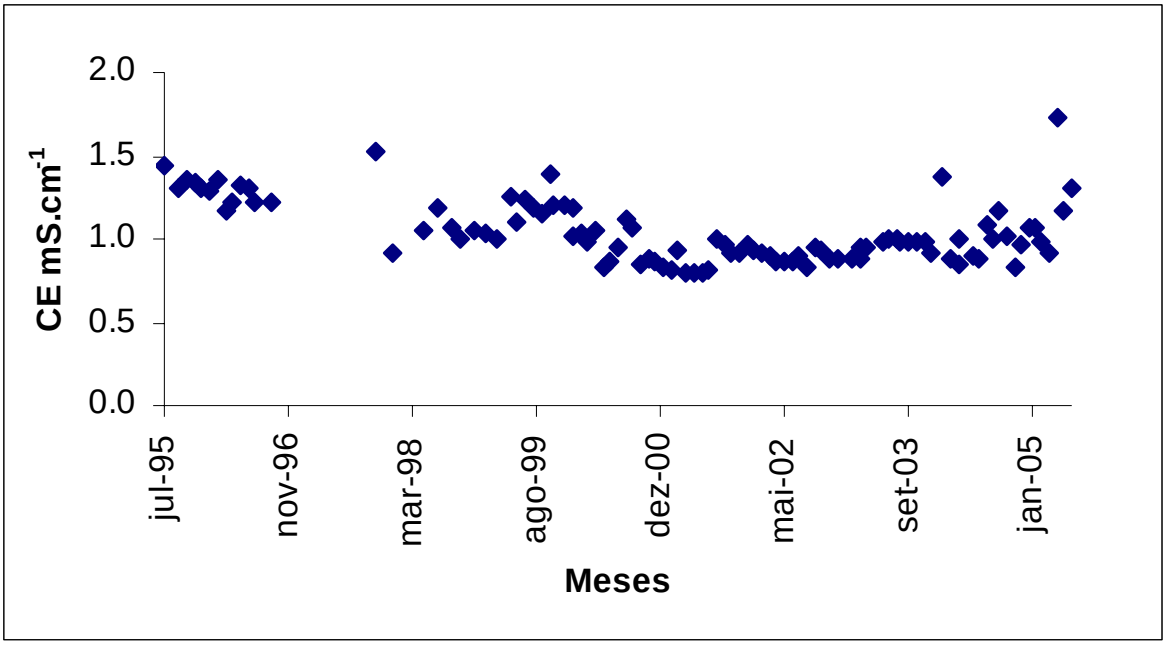


EC (dS/m) December 2003

Sodium management is complex and its measurement and control involve techniques usually not accessible to small scale farming enterprises. Work on this topic was carried out in the high salinity region of Rosário under a study by Stamford *et al.* (2003). However, outside of this region, sodification risk is very low in the three catchments and therefore its monitoring has not been extensively addressed in the guidelines for farmers working outside of the affected area.

Figure 4.2 exhibits the electrical conductivity variation over time for one monitoring well in Rosário. The main point to observe in this figure is that the salinity has generally lowered at this monitoring point during the period that records have been collected. Before 1995 there were serious concerns that the salinity would rise substantially due to the influence of the irrigation, but this has not occurred. The flushing of the aquifer of significant salts into the ephemeral river during the wet season provides the best explanation of this insensitivity to the extensive local irrigation practices. Nevertheless, areas with loam soils, where groundwater is less than 2m deep, are found to be at higher salinisation risk, notably in the dry seasons 2 and 3 when evaporation is at its peak and crop irrigation requirements are high.

Figure 4.2: Groundwater electrical conductivity versus time for Rosário



Note: Meses is Portuguese for month, while CE represents electrical conductivity

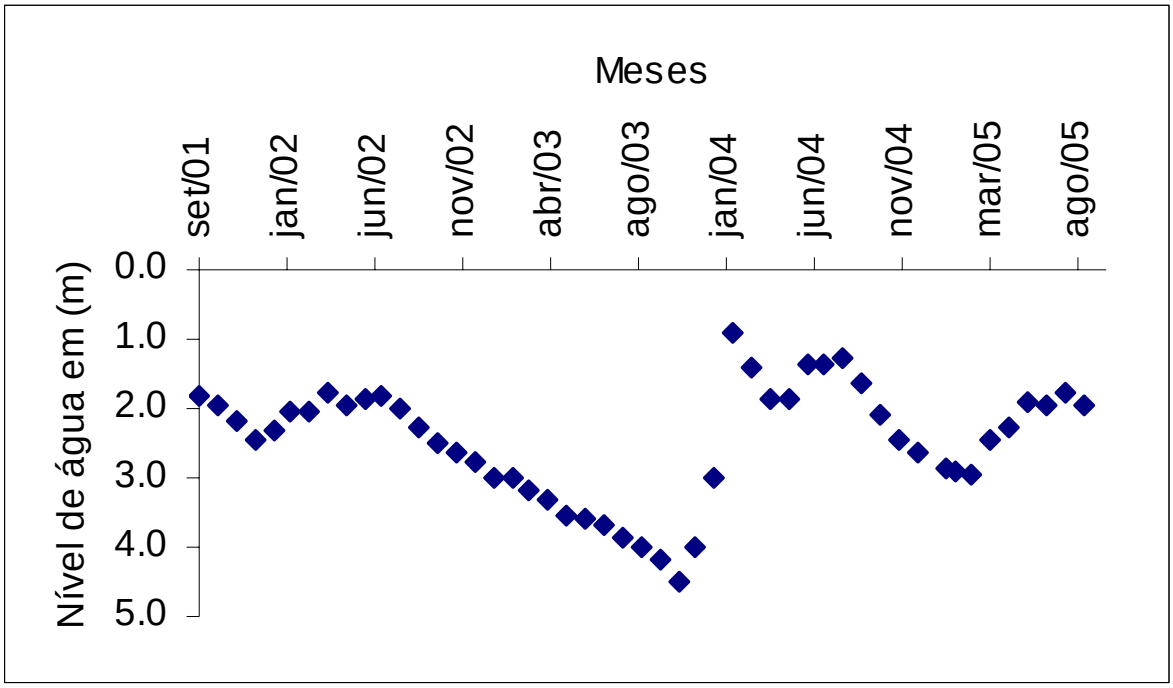
Depth to Groundwater

Figure 4.3 presents records of water table levels from the long term monitoring in Rosário that has continued during the project period. The substantial increase in depth to water table in the period 2002 to 2004 corresponds to a brief but significant drought period that created difficulties for irrigation in Mutuca and Campo Alegre but had a less pronounced effect in Rosário. The major consequence of the drought in Rosário was a marked increase in the use of the groundwater as a private water supply source for the town of Pesqueira. If the drought had continued for a further year, then it seems likely that irrigation areas in Rosário would also have had to be reduced. The sharp rise in early 2004 corresponds to the extensive flooding that took place across the region.

Although in typical years, groundwater recharge permits full recovery of the groundwater levels at the end of Season 1, the data in Figure 3.3 illustrate the susceptibility of the groundwater systems to low recharge years. The filling of the Pão de Açucar reservoir at the start of 2004 has provided a substantial buffer against drought for the communities in Campo Alegre, but irrigation in Mutuca and Rosário remain at risk from drought. Irrigation in Mutuca is the most susceptible as a result of the relatively smaller alluvial aquifer in the base of the valley. The higher salinity of the groundwater and also evidence from the field data collection exercises that have been carried out indicate that the majority of the groundwater dams in the Mutuca valley are not fully functional.

The indicators discussed in this section are used to support decisions based on the guidelines developed during the project. These are discussed in Section 4.2.5.

Figure 4.3: Water table depths in Rosário



Note: Meses is Portuguese for month, while the Y-axis represents depth to groundwater in metres

(iii) Evaluation of the Impacts of Groundwater Development and the Sustainability

Sustainability is a complex concept in any dynamic system that is affected by natural conditions, the social environment and the economics of local and global markets for products and services Thus, the concept of sustainability to which this Project has been working is the following. The local population should be able to establish practices to exploit the available water that collectively provides (on the basis of current understanding) a stable community with an acceptable quality of life and environment without the need for permanent external assistance. In this context groundwater development has to be seen within the context of the total physical and economic environment and not just in terms of agricultural productivity.

The three study areas are very different in their physical characteristics but are similar in terms of the climate and the farming practices that are undertaken. To understand the impacts of groundwater development and long-term sustainability in the region it is appropriate to consider each of the catchments individually. However, prior to presenting the particular findings for the three areas it is worth examining the general context and those factors that are common.

The climate of the three areas is essentially the same although it is clear from the data collected in the three catchments that micro-climatic variations do occur that locally affect the recharge timing and amount. Rainfall is on average 650 mm/year while potential evaporation is typically 1800 mm/year. The majority of the rainfall occurs in the period April to July and this is sufficient to generate almost total replenishment of the alluvial aquifers in a typical year: surplus waters discharge as surface flows.

Thus groundwater development for irrigation is constrained by the capacity of the aquifers in each of the areas and the rate at which these aquifers drain, both through evaporative flows and subsurface flows along the valleys. Land areas are not a constraint as the available land exceeds the water resources of the region, although neither are plentiful. Multi-annual variations in the precipitation introduce periods of low recharge that can extend over two or more years and these can lead to depletion of the groundwater to the extent that irrigation areas are reduced or crops fail. The irrigation areas allow the farmers to support their livelihoods during average years but in periods of reduced irrigation due to drought, incomes are not adequate and alternative income sources are needed.

This has generated three responses:

- The production of dryland crops that can be used for animal fodder such as the Palma
- The production of lace
- The migration of family members to the cities

The last of these is the least desirable since it withdraws labour from the region and therefore reduces the capacity of the communities to maintain and develop their environment. The production of lace is typically regarded as women's work, but progressively there is a shift in the community response to this that is allowing men to become involved, although the cultural shift is slow. Multi-skills development of the community is positive as it allows the farmers to maintain an income during periods of low irrigation but also to invest in development of their land during the drought periods to improve agricultural productivity during normal years.

Improvements in water use for irrigation through transitions to drip and micro-sprinkler irrigation have taken place in the past ten years and have been led by the research that has been carried out by the Federal Rural University (UFRPE) in the area. UFRPE, supported financially by government agencies, has been able to demonstrate, while carrying out research, the advantages of new irrigation methods and the water savings that can be made. While they have tended to work on the communal farms in support of the *Assentados* and equipment has been provided through equipment grants, the more established communities throughout the area have been able to observe the benefits of the new methods and to self-finance the introduction of these methods to their land.

In addition to the introduction of new irrigation methods and practices, recent innovations have been introduced aimed at supplying organically grown fruits and vegetables to the markets. The premium that exists in terms of higher crop values and the omission of costs of agro-chemicals and pesticides offers an opportunity to the farmers to improve the income from their land. The interest in organic agriculture arose since the inclusion of the Mimoso Seco and Xukurú communities in the Project. Both communities were strong advocates of organic agriculture and have promoted its use within their own communities. The Project has enabled effective dissemination of the benefits of organic agriculture, not only in terms of agricultural production, but also in terms of its benefits to human health and the environment (both in terms of the danger of exposure to pesticides, either directly or indirectly). The Project has shown the value of community initiatives and moving them into the research domain. This type of practice is now being introduced cooperatively between the communities and the UFRPE.

There is a clear need and desire for the University/community partnership to expand in the different physical domains in the region, and preferably to be complemented by an appropriate extension agency (preferably a local NGO) that can work with the communities to continue to improve their efficiency in terms of resource use and in terms of return on their investment. As well as the findings from the Project, the developments in the past ten years have provided a useful indicator that such developments will further improve the scale of the agricultural component of the regional activity.

Salinity in the groundwater is generated by the weathering processes in the basement rocks adjacent to and underlying the aquifers. It affects the types of crops that can be grown in each season and it requires management to minimise crop losses due to soil salinisation. Natural mechanisms for flushing the salts are apparent in each of the valleys and development of the groundwater resource to minimise water losses to expand irrigation could have a detrimental impact on these mechanisms. Clear guidance on options for retention of the groundwater is needed to minimise the risk of unwanted salinisation.

Potable water is partly derived from rainwater harvesting from rooftops and partly from groundwater. The size of the rainwater tanks appears to be small for most buildings, probably due to the small roof areas that contribute flows and many collection systems do not appear to be adequately maintained to prevent pollution of the water in the tank. There is considerable scope for improving these systems and establishing such systems for all domestic dwellings. There is even scope to do this for livestock watering. Groundwater could therefore be used to supplement rainwater (through blending) only during periods of drought, which would alleviate the problems of maintaining groundwater supplies for those dwellings at distance from the aquifer. It would reduce the need to constrain irrigation practices to retain water in the aquifer with sufficiently low total dissolved solids to be used without blending for drinking: in these circumstances, greater depletion of the groundwater by irrigation may be feasible.

In summary, the amount of ground water limits crop production but new methods can and are increasing yields. Irrigation alone is insufficient to sustain the community and other income sources have to be developed for the total system to be sustainable with an adequate living standard. Potable water need not be derived from groundwater other than during droughts and this could be a recommendation for future community development. Salinity affects the use of groundwater for irrigation and potable water. Approaches to maximising groundwater availability may impact on the salinity levels and care is needed to design systems to achieve a greater groundwater resource that do not degrade the water quality further by increasing the total dissolved solids.

Rosario

This valley has the largest groundwater resource of the three areas investigated. The total capacity of the aquifer is about 5 m^3. To date the groundwater exploitation has been in balance with the replenishment of the aquifer and salinity increases predicted as a result of irrigation practices have not arisen. However, during the extended drought up to the end of 2003, groundwater depletion was significant and indicated that even in this valley the agricultural activity could be curtailed by drought periods of several years. A growth in the use of the upper reaches of the valley to supply groundwater to the city is of potential concern as this will undoubtedly exacerbate the depletion of the groundwater. However, the value of the water as a potable water source far exceeds its agricultural value, realised through the market value of the agricultural produce. Unfortunately, the income derived from this market is not distributed among the farming community but resides with the farmer who owns the wells used for the abstraction. The community in Rosario does not work as a cohesive community and there is little awareness of the need to jointly manage the resource for the benefit of the whole community. Efforts to engage the community in the development of a water users association have met with little success. This reflects the nature of the community that was brought together through government land allocations relatively recently and who have little understanding of the limits of the groundwater resource and the degree to which it binds them together as a common good.

Opportunities exist to increase groundwater use in the valley by enhancing recharge in the late stages of Season 1 through over pumping for irrigation, when recharge is still occurring. In this way the total recharge entering the aquifer can be increased. However, there is a risk to this strategy in that the possibility exists for the salt extraction mechanism of groundwater fluxes to the river being disrupted and salinities rising to unacceptable levels in the longer term. Current models of the conditions in Rosario do not allow an assessment to be made of the balance point between increased exploitation and increased salinity to be made. However, modelling may not be needed in this case. The farmers could simply choose to carry out a full scale experiment by adjusting irrigation to expand crop production at the end of the wet season and to carry out water level and salinity monitoring to demonstrate the degree to which water levels are sustained by enhanced recharge and the degree to which salinities increase through a reduced capacity for salt discharge. The current evidence suggests that the effects of such a 'long-term' experiment would be reversible by returning to the current level of exploitation. The experiment would produce increased incomes in the short term and would provide guidance on the maximum increase in productivity that would arise in the long term from enhanced groundwater exploitation.

The type of experiment envisaged here demands long-term monitoring and it demands community management. The sustainability of Rosario in the long-term will be much enhanced if this can be achieved. At present, the continuity of the current situation appears assured but this should not be regarded sustainable as it is currently partly supported through external grant aid.

Campo Alegre

Prior to the start of 2004, the situation in Campo Alegre downstream of the Xukurú reservation was very poor. The aquifers are very small (max 20 m^3 usable groundwater /m of valley length in the exploitable sections of the aquifer) and were effectively drained. Aquifer material along the valley was being extracted for building materials for use outside the valley to increase incomes for some landowners. The situation dramatically altered after the floods of 2004. While severe damage was inflicted on many structures in the valley floor (weirs and bridges) by the flood waters, the alluvial materials were replenished and the aquifers were recharged. However, the major benefit was not the replenishment of these small aquifers but the total replenishment of the Pão de Açucar surface water reservoir in the Xukurú reservation which has a capacity of approximately 45Mm^3. This reservoir had been empty for many years previously. The dam was built to supply water to towns downstream of the Campo Alegre area and the river was used as the conduit for discharges from the dam to the water treatment reservoirs 20km downstream. The intermittent discharge of these waters replenished the minor aquifers when the reservoir was operational. Once the reservoir emptied the water Company decided to remove it from their operational plans and therefore at the present time all water in the dam is available for local use.

Longstanding distrust between the Xukurú and the Campo Alegre communities meant that the people in Campo Alegre could not influence the Xukurú to release waters from the dam to assist replenishment of the aquifers for use by the Campo Alegre farmers. This was compounded by the lack of control at the dam due to mechanical problems. However, intervention by members of the current Project brought the communities together and the water company provided a repair to the dams release pipework and water is being discharged to supply water to the aquifers downstream. The amount being discharged needs to be controlled to satisfy demand downstream without wastage. In this case the surface flows need only to carry to the aquifers used for irrigation in the downstream valley. The aquifers are therefore acting only as a buffer for surface water derived irrigation rather than as a 'true' groundwater resource. Nevertheless, the buffering capacity of the aquifers does allow the releases

from the dams to be adjusted progressively to achieve the right balance between demand and supply throughout the year.

The 'conflict' between the Campo Alegre and Xukurú communities in relation to releases from the Pão de Açucar reservoir was long-standing and clearly stemmed from misunderstanding and inability/unwillingness to communicate.

The action-orientated to approach to resolving this long-standing conflict was simple and included the following action from Project team members:

- A meeting with the Xukurú leaders on 19 November 2004, during which they were briefed on the Project, but more importantly they were listened to.
- A meeting with a farming family from the Campo Alegre community to brief them on the meeting with the Xukurú and to encourage the farmer to gauge the willingness of the Campo Alegre community to enter into discussion with the Xukurú
- The communication was established through inviting one of the Xukurú leaders to the Next Advisory Group meeting to present the point of view of the Xukurú community in regards to provision of water from the reservoir to the Campo Alegre farmers.
- Project team members provided advice on the technical issues related to the release of water from the reservoir.

From this time onward the Xukurú became an participating community in the Project.

Following these minor actions the conflict was resolved and over the next year continued communication between the two communities has resulted in a water-sharing agreement and the establishment of a Pão de Açucar Water User Group.

Modelling of the Pão do Açucar dam inflow and outflow suggests that it should be able to sustain the downstream irrigation even under drought conditions for a number of years (> 10 years for some parts of the valley but only 3 to 4 years for other parts) based on current irrigated land areas and about leakage from the reservoir (Galley, 2004). However, the current models for replenishment of the aquifer are based on very limited data and there is a need to carry out long-term monitoring to examine the response of the reservoir to climate conditions and there is a need to examine the impact of a growth in the irrigation demand through the exploitation of a greater area of land by each of the communities operating along the ribbon valley of the river. It is clear from visual field evidence collected since the start of 2004 that farmers are extending substantially the cropped areas by extending field areas up the valley sides. There will be a limit to this growth and the two communities will have to work together to establish the extent to which such growth can be allowed to continue. Current modelling is being refined to improve the assessment of the impacts of the developments on future sustainability.

Mutuca

Mutuca's alluvial aquifer capacity is greater than that in Campo Alegre but much less than in Rosario. Estimates of an approximate maximum 100 m^3 usable groundwater/m of valley length in the exploitable sections of the aquifer indicate the scale of the resource over the 15 km of the valley addressed in this study. The permeability of the alluvial material below the dry river is high and groundwater movement along the valley is relatively rapid under natural conditions.

It was chosen as one of many valleys in Pernambuco State in which groundwater dams would be introduced and there are 9 dams located at roughly equal spacing along the valley. These are low cost dams constructed using a waterproof membrane lining an excavation dug across the valley to the base of the alluvium and backfilled. The success of the dam depends both on the impermeability of the underlying hard rock, the ability to excavate to the hard rock and the competence of the membrane. Furthermore, its success depends on a lack of movement of the alluvial material during flooding. Evidence from piezometric and geophysical measurements suggests that the majority of the dams are not effective in retaining significant amounts of groundwater. In one case, this is because the dam does not intersect the main fluvial channel but in the other cases it seems likely that groundwater is leaking beneath the structure. Modelling of the water flows in the aquifer (Sholl, 2004) suggest that if the groundwater dams were fully functional that the current groundwater use could function adequately even during extended drought periods. In the current situation irrigation reductions would be needed as a result of drought. This assessment is based on water flows and volumes and not on considerations of salinisation. However, it does provide a useful argument for instating properly functioning dams in the future.

The salinity levels in the aquifer are high and current practices of both abstracting groundwater and irrigating upstream of a dam are potentially contributing to the salinity level. This situation could be made worse if inadequate flushing of the groundwater could not be achieved during the main recharge season. The design of replacement dams, both in terms of location and function would need to reflect this issue. At the present time, the irrigation in Mutuca valley is at or near its limit, but engineering options to increase its capacity and therefore sustainability are viable and should be considered in future planning.

In Mimoso Seco, at the downstream end of the study area, the community is well established and clear cooperation operates within the community. The farmers in this community are highly motivated not only to work together but also to develop their land and water as far as possible to improve living standards for their families. In this case, while groundwater availability cannot increase without the development of new retention dams, the farmers are expanding the use of the water and the value of the water by introducing micro-sprinklers and organic farming methods. Energy savings are being made by also reducing the applied irrigation water by altering land drainage patterns on the fields, irrigating in the early morning or late at night and altering the irrigation schedules to reduce leaching.

Similar development is not taking place further up the valley as the community is well dispersed and cooperation has not evolved to the extent achieved already in Mimoso Seco.

Mutuca requires further development to achieve sustainability and there is considerable benefit to be derived from detailed hydrogeological assessment and the engineering of new groundwater dams to achieve true sustainability of all the communities along its length with initial emphasis on development of the Mimoso Seco community.

(iv) Dissemination of Findings

The dissemination of findings has been at different levels. In terms of importance to the goal of the Project appropriate dissemination of knowledge and experience gained during the implementation of the Project to the participating communities has had first priority throughout. The dissemination process has been continuous since the start of the Project and has been along a variety of channels, most importantly the participatory monitoring, the Project workshops, the Advisory Group and the published guidelines for monitoring and irrigation management.

The inclusion of community members in the resource monitoring teams as well as the participation in field trials has been essential in the dissemination process. The direct transfer of knowledge was action orientated with participating community members gaining hands-on experience with monitoring methods and equipment, while at the same time acquiring an understanding of the meaning and need of monitoring in the context of sustainable resource management and utilisation.

The themed workshops have also proved to be a powerful platform for dissemination and knowledge, largely through the intra and inter-community communication that took place at those workshops. The impact of the seminars was enhanced through the involvement of community members in the preparation and presentation of topics relevant to the workshop theme. Furthermore, the inclusion of locally based NGO's has been a contributory factor to the uptake of messages by the communities.

The Advisory Group comprised community representatives, who were both highly respected by their community members and were knowledgeable about the technical issues related to water resources use and management. Furthermore they had expressed an enthusiasm for the Project aims and were 'hungry' for information and knowledge. The Advisory Group fulfilled an important role in the dissemination of Project findings to their communities. This dissemination was made effective through their roles within the communities and their desire to succeed in bringing about positive change to the livelihoods of their communities.

The guidelines on monitoring and irrigation management (refer to Section 4.2.5) are meant to be a 'permanent' output from the project, which will guide community members, through their water associations, in practising more sustainable use of their available water resources. It should be recognised that these guidelines will require update in the future when better understanding of the water resource systems is established through the continued monitoring of the water resource components.

Dissemination to locally based NGOs, municipal and state level government, and organisations has been achieved mainly through the participation of representatives from those organisations in the workshops and the Project seminars. Dissemination was also achieved through meetings with those organisations.

Dissemination to the world audience has been achieved through the attendance of international seminars and conferences, the publication of papers, the preparation of MSc theses and the publication on the Project web site.

An overview of the means of dissemination and the disseminated Project output is given in Supporting Document SD21.

4.2.3 Framework for Participation and Education

(i) Consultation and Establishment of Ground Rules for Interaction with Communities

Consultations were necessary so that the establishment of ground rules for interaction with the rural communities could be established. Consultations were in the form of:

- The collection of data to provide the baseline information about each of the participating communities. This was done through quantitative surveys in Rosário, Campo Alegre and Mutuca and qualitative interviews for Mimoso Seco and Xukurú. The collection of data was essential to enable the Project team members to understand the socio-economic, political and cultural settings of each of the communities.
- Themed workshops provided opportunities for the communities to exchange knowledge about the situation they were exposed to in regards to the themes being covered in the workshop. The participation of community members was very high in relation the identification of indicators concerning their communities and also through the presentations of some community members at the workshops. Here they were able to demonstrate and share their own knowledge about the themes.
- Field visits provided an opportunity for community members, especially the Advisory Group members, to view what was done in other areas and complement their knowledge. Their evaluation of these visits allowed them to judge their gained knowledge in the context of issues within their own communities. This contributed to the direction of some of the activities undertaken during the Implementation Phase of the Project.
- Seminars, two of which were held in Pesqueira during 2005 offered opportunities for community members to present their views on the Project. This provided further direction to Project activities and actions.
- The establishment of a Project Advisory Group was the most important means of consultation. The main goal of the establishment of the group was to "advise" Project team members on all aspects of the Project. The Advisory Group members led the discussions and took important decisions regarding the planning and implementation of the Project actions, including decisions on aspects of financing for those actions.

The consultations provided the basis for the identification and establishment of ground rules for interaction with communities. Given the participatory methodology adopted for the Project, the ground rules were established with due consideration of the specific characteristics and needs of each community, and also of their contribution and participation in the Project. The Advisory Group members played a major role in the establishment of the ground rules. The ground rules were of great importance to and an integral part of the empowerment process of community members.

The established ground rules include the following:

1. **Account for the importance of local traditional knowledge** – this was very relevant as it made community members feel they could contribute to the Project.

An experience of empowerment: local traditional knowledge and the academic sphere
Following the Project seminar in March 2005, the Project organised participation of some community representatives in an event sponsored by a College in the Belo Jardim Municipality in celebration of the World Water Day. The invitation was made by two of the teachers who are members of local NGOs and who had attended the Project seminar. The experience of the farmers as well as that of the teachers was very interesting as this was the first time community members had any involvement with events at the College. When asked about their experience, they said they never thought they would have the opportunity to speak to teachers and students as they had very little schooling and thought that what they had to say was of no interest to well-educated individuals. However, they were surprised by the great interest of the audience in their presentations and said that, through the Project, they discovered that they had knowledge to share. They felt empowered through the experience.

2. **Respect for all community members regardless of their age, gender and socio-economic status** – by respecting all community members without distinction on gender, age and socio-economic status, they all felt part of the Project and this contributed to a rise in the self-esteem and the empowerment of the under-represented groups such as women and the poorest in society.

3. **Account for gender differences in all of the actions which involve women and men** – this implied equal respect for women and men and for the contribution each of the genders give to society. Therefore, it was avoided to consider activities undertaken by men of higher importance such as is often the case with most activities related to agriculture.

4. **Consider the importance of the knowledge of elderly community members –** the elderly usually have a great deal of wisdom but sometimes do not have the opportunity to be heard. Effort was made to invite them to participate in Project activities.

The importance of the KaR Project and its participatory methodology through the eyes of a community leader

At one of the Advisory Group meetings, Agnaldo, a Xukurú indian and an elected city councillor gave his opinion about the difference of a development project such as the KaR Project, which is based on the use of a participatory methodology, and projects based on top-down approaches in which the supposed beneficiary communities have no participation. In his opinion, the KaR Project was very important because it empowered the beneficiaries, made them feel that the Project belonged to them and that they were part of the Project. He added that this Project made a difference to the livelihood of the communities by respecting the local traditional knowledge and not imposing anything on the community members.

5. **Encourage community participation in all of the actions without imposing their role –** when invitations for activities were made, it was avoided imposing the role of participants so that their performance could be spontaneous and they could feel confident about their contribution and rate it of high importance.

6. **Have transparency in all of the Project actions –** transparency was always stimulated as a means to achieve successful outcomes in all of the actions. This was very important for the implementation of all Project activities.

7. **Avoid raising false expectations in community members-** this was a very important rule and the success of the Project was partly a result of that. The goals and objectives of the Project were always made very clear so that false expectations were not raised by community members.

(ii) Identification of Under-represented Groups/Genders and Integration into the Community Dialogue

The Landless

The livelihood surveys undertaken during the Inception Phase indicated that landless women and men were an under represented group as they did not participate actively in community life. This lack of participation was attributed to the fact that this group has no longer any ties to the land and was always fully preoccupied, as a way of survival, with satisfying their basic household needs. The majority left their community early everyday to engage in paid labour at the nearby large landholdings. This group of landless individuals used to be part of the *"assentados"* group, and used to have access and control over land. Their small plots of land were insufficient to sustain a livelihood during drought periods and many families sold their land and migrated to cities in southern Brazil. As they did not succeed in their place of destination, they decided to return to their original communities and formed the landless groups. These groups are amongst the poorest of the poor and have a very low self-esteem.

For reasons mentioned above, the landless demonstrated little interest in participating in any of the Project activities and they were therefore "invisible". Part of the problem was the original focus of the Project on water for agriculture. The change in Project focus to water for rural communities enabled the Project to embrace this under-represented group. The Project could thus contribute to reducing their poverty stricken condition and improve their self-esteem and livelihood.

Project team members tried to involve the landless in the Project actions by paying particular attention to them through visiting their homes, discussing the Project with them and making them feel part of it. The local health agents played a major role in bringing this group into the communication dialogue as they work with all community members on a daily basis. This was a very successful strategy and the landless population was gradually incorporated in the Project, through attendance at the workshop sessions, where they were encouraged to participate in the discussions. They were also encouraged to participate in monitoring activities. At workshop evaluation sessions, some of the landless people indicated that the knowledge acquired was very beneficial and they expressed hope that this would help them find work more easily. The Environmental Education Programme, introduced at the rural schools located within the participating communities during the final year of the Project, also contributed highly to the inclusion of this under-represented group in the Project. This was achieved, indirectly, through the involvement of their children in the learning activities related to land and water, and the dissemination of the children's acquired knowledge to their parents.

Women

Another under-represented group includes the women in the participating communities. Their under-representation was identified during the livelihood surveys undertaken during and shortly after the Inception Phase. The survey sample was disaggregated by gender and thus included both women and men. The majority of women were not involved with agricultural production, although they clearly had interest in water in the context of their household needs. In most of the participating communities women's daily activities revolve around the household and involve lace-making. The latter is important as a complementary source of income for their household. It becomes particularly important in times of severe drought when income from agricultural production can become severely constrained. Women were initially not very interested in participating in the activities of the Project. This was largely due to their perception that the Project was related to agriculture and thus the Project activities were only of the interest to the men.

During the Inception Phase, several women leaders were identified, including health agents and they played a very important role in raising the consciousness of women about the need to be included the Project. It is important to note that, despite their involvement with lace making, women from the two more organised communities, i.e. Mimoso Seco and Xukurú, demonstrated a greater interest in the Project (from the time these two communities became part of the Project). This greater interest amongst the women of these two communities is attributed to the stronger social organisation and the stronger role of women in the community Associations. In the case of Mimoso Seco, women form the majority of the members of the Association.

To enable women to participate in the communication dialogue, it was made clear to them that the Project was not focussed only on water for agriculture. This expansion of focus was formalised through revisions to the Project log frame at the conclusion of the Inception Phase. Women became more interested in the Project activities and participated actively in the themed workshops that were held during the Project Implementation Phase. Of particular interest to women was the workshop on Theme 1: Water Storage and Use for Domestic Purposes. It is known that women play a major role in the collection and management of water for domestic use and the workshop was very useful to them as it discussed a series of methods for the treatment of water.

The majority of the health agents are women and they played a very important role during all stages of the Project. The health agents have a strong leadership position in their communities and work closely with community household members. They, therefore, contributed greatly to the inclusion of under-represented groups into the communication dialogue; the landless and women.

Teachers from rural schools also played a very important role in the inclusion of the under-represented groups in the communication dialogue, largely through their active participation in the establishment of the land and water focussed Environmental Education Programme. The majority of the teachers are women who have neither been exposed to the daily life of farmers, nor have they had the opportunity to understand the way of life of farmers and the important role of land and water in the farmer's daily livelihood. One of the aims of the Environmental Education Programme was to improve the gender balance in the rural communities. The Environmental Education Programme offered an opportunity to address this by including farmers in the education process. The women teachers now work closely with the men farmers, who act as teaching assistants. This was very important for the students as they were exposed to both the academic knowledge of the teachers and to the practical knowledge of the farmers. The added benefit of the education programme is the transfer of acquired knowledge from the students to their family members and this encourages the dissemination of Project messages.

The teachers as well as health agents played a major role on the integration of the under-represented groups into the communication dialogue.

(iii) Participatory Livelihood Analyses with Rural Families

The participatory livelihood analysis was a result of the quantitative surveys undertaken during the Inception Phase and at the beginning of the Implementation Phase (the Mutuca community), and of the qualitative data collection undertaken among the Mimoso Seco and Xukurú communities. Although the survey sample included individuals from each family, a woman or a man, the focus of the analysis was the family household as individuals were asked to provide data about the family or household unit and not about themselves only.

Detailed analyses of the livelihood surveys in the Rosário and Campo Alegre communities are given in the Inception Report and in Supporting Document SD5. The quantitative livelihood survey in the Mutuca community was undertaken in July 2004 and a detailed account of this survey is given in Supporting Document SD11. The quantitative livelihood surveys in the three communities were strongly participative and included members from the participating communities, who had been trained by Project team members and were assisted by community health workers. The surveys included a questionnaire and this was complemented through the use of in-depth interviews and life histories.

The surveys conducted in the two additional communities that joined the Project during the Implementation Phase were only qualitative. The surveys were carried out by Project team members only.

The data available through the surveys undertaken during the Inception Phase and shortly after provided an important basis for the actions undertaken during the Implementation Phase. The questionnaire was lengthy and covered several aspects of life at the community households. The areas covered by the questionnaire were:

- General information on the household
- General information on the interviewee
- Information on the work in which household members engaged
- Information on the health of household members
- Information on available water sources
- Information on drinking water and water treatment
- Information of water for household consumption
- Information on water availability and use for livestock
- Information on water availability and use for irrigation

In the context of the planning for the Project Implementation Phase, the most important data related to the socio-economic status of the household, particularly in relation to land ownership, to engagement in economic activities, to division of labour according to gender, to total income of the household and to literacy levels of the household members. The data allowed for better understanding of the dynamics of livelihood at both household and community levels. Other important information concerned the organisation of the community and the participation of the household members at the local Association. This indicated whether community members were organised and understood the importance of organisation to improvement of life at the community level. The information on health was also very valuable, especially for the understanding of water related health problems.

The information on water and water use provided important pointers to activities required during the Implementation Phase. Data were collected on sources of available water for both human consumption and other uses. Information was also available on the types of treatment used for water for domestic consumption, the amount of water used for multiple purposes, whether water was reutilised and also whether water was shared with neighbouring households. The data were very useful as one could understand how households and the community as a whole managed the available water. The collection of information on water took account of climatic conditions, in relation to seasonal variations and to longer term variations, including droughts.

The information described above provided the baseline data for the planning and preparation of all the activities undertaken during the Implementation Phase, including seminars, workshops, training sessions and the participatory monitoring. The findings were discussed with community members, particularly during the Advisory Group meetings so that the communities could understand the reasons why data were collected.

(iv) Workshops, Seminars and Participatory Surveys

Workshops

An introductory workshop was held in March 2004 during the Inception Phase. The workshop was aimed at introducing the Project to the three rural communities involved with the Project at that time. The workshop is described in Section 5.2 and Appendix D of the Inception Report (SD7).

The following themed workshops were held during the period from September 2004 to March 2005:

Theme I: Water storage and use for domestic purposes

Theme II: Water for farming, including irrigation

Theme III: Land management for improved water harvesting and retention

Theme IV: Institutional and organisational aspects of groundwater management

Each themed workshop was held at three locations, generally the Rosario, Mutuca or Mimoso Seco and Xukurú communities. Cross-community representation was established through involvement of community members in workshop presentations and discussions.

The workshop on Theme 1 had participation from health agents, while the Theme 2 workshop was believed to be too prescriptive and lacked community participation. Ideas for the Theme 3 workshop were exchanged amongst the team and generally accepted and applied to the remaining two workshops. Local participation through presentations by community members became a main focus. The change in workshop style contributed to an improved feeling amongst community members of being part of the Project and a genuine appreciation of being able to express ideas and opinions.

A detailed account of the workshops is given in Supporting Document SD10, while a summary of the evaluation by the Project team members is given in the following.

- Workshop on Theme I - Water storage and use for domestic purposes
  - Women expressed problems in relation to timing of attendance due to having to attend their normal household duties.
  - It was concluded that workshop sessions should be in the afternoon only.
  - The workshop was considered successful by the Project team members in terms of conveying the messages to the community members.
  - The workshop included a play, prepared and performed by women from the participating communities, particularly the health agents. The play had not only a positive impact on audience attention through its entertainment value, it also served to convey important messages to the community members, particularly in relation to water and health.

The lonely fight of a woman against the use of chemical pesticides
Geraldina, a health agent from Rosário, was involved with the Project since its beginning. She is a passionate objector to the excessive use of chemical pesticides and is well aware of their dangers human health, either through direct exposure during application, or indirectly through contamination of food and water. Her lonely fight against the use of pesticides had fallen on deaf ears for many years. The Workshop on Theme 3 allowed her to express her views to members from other communities, including those advocating the use of organic agriculture. At long last she was listened to and her opinions became valued. At the final evaluation seminar, she expressed, in emotional terms, here gratefulness to the opportunities the Project has given to health agents like herself in expressing their views on important health issues.

- Workshop on Theme II - Water for farming, including irrigation
  - Few women attended the workshop.
  - There was attendance from several *moradores* from the landless community in Rosário.
  - The workshop included field visits to irrigated plots, which was considered instructive by the workshop attendees.
  - Presentations on organic agriculture were well received.
- Workshop on Theme III - Land management for improved water harvesting and retention
  - The workshop was considered very successful and this was attributed to the involvement of community members in the delivery of material.
  - The involvement of community members in the delivery of material was seen as an important way of empowering the community members and in encouraging them to share knowledge and experience.
  - The presenters were members from different communities, which contributed to the goal of improved inter-community communication.

The moringa tree
Several moringa trees (*moringa oleifera*) were distributed through a draw involving community members during the Workshop on Theme I (Water Storage and Use for Domestic Purposes). The trees can be used in the treatment of water. The trees were planted by the recipients so that, once established, cuttings could be taken and distributed to other community members. Celina, a landless lady who attended the workshop and received a small tree, planted it in her backyard and took very good care of it. She is very proud of her tree, which is now the largest of all the trees distributed. She proudly shows visitors her tree and gives a good explanation of its merits. She knows the plant is originally from India and that it has several medicinal purposes besides treating water for drinking. She is willing now to distribute it among anyone who is interested and could even sell the cuttings. It is an example of community awareness building through simple, yet effective means.

- Workshop on Theme IV - Institutional and organisational aspects of groundwater management
  - The workshop was very productive and had strong participation from community members
  - The Xukurú were able to share the experience of their unique social organization with the non-indigenous communities. It gave them visibility and provided the other communities with much needed appreciation of the Xukurú way of life.

- The sessions which were attended by members from two communities (for example Xukurú and Campo Alegre) were more productive than the sessions with single community involvement. This showed the importance for communities come together to share experiences and knowledge.
- The workshop was an important step towards the establishment of improved community organization.

Seminars

The Project planning given in the Inception Report (SD7) included a seminar in Recife. This was given consideration during the Implementation Phase and it was concluded that such a seminar would largely exclude participation from local community members. To allow stronger participation from the community members, without compromising the aim to expose the Project to State organisation, two seminars were planned for March 2005 and November 2005, both in Pesqueira. The detailed accounts of the seminars are provided in Supporting Documents SD14 and SD23. A summary of the objectives, the attendance and the seminar findings are given in the following. In relation to the seminar held in November 2005, statements and quotes from presenters at the seminar are given to provide a flavour of the perception of community members and stakeholder representatives of the Project impact.

A seminar held on 15 March 2005 was planned by the KaR Project team members to discuss the progress of the Project thus far, disseminate the outputs and develop as well as strengthen partnerships with different stakeholders. The seminar consisted of presentations about the Project by the team members, presentations by community members about the impact of the Project on their livelihoods and presentations by guest speakers about their experiences in other areas. During the occasion, there was the launching of posters about the Project (supporting Document SD17) to be shared among different stakeholders. It also included the launching of an itinerant Exhibition with photographs and texts in relation to the different Project themes. The exhibition was planned to be shown at different events in the region with the objective of informing different sectors of society about the Project (rural communities, students, government officials, NGO activists).

The seminar was held at the São José Seminary in Pesqueira and counted with the participation of 83 people. Besides community members, there was the participation of representatives from the municipal government and neighbouring municipalities. There were also members of several NGOs. Besides the Project team members from Brazil, the Project Manager also attended the event.

The seminar was an important step in the dissemination of the Project to others in the Region. There was much interest by the participants in the presentations, especially the ones delivered by Prof. Ronald Freire on low cost monitoring equipment and Dr. Padilha on small-scale catchment management. The Seminar achieved its goal as it was to share the Project outputs and to strengthen partnership.

A final Project evaluation seminar was organised for 17 and 18 November 2005, again at the Seminary São José in Pesqueira. The seminar was attended by the Project team members from Brazil and the Project Manager from the UK, community members, representatives of the Municipal Government in Pesqueira, teachers, health agents, Xukurú representatives, representatives of partner institutions such as CARITAS, UFRPE, ConsuBitury and INFOC as well as of invited institutions such as, FUNTEPE, Renascer Project (related to the World Bank), CPRH and CPRM, which represented the State and Federal Governments as well as funding institutions. The total number of participants was 115 individuals. The Seminar was mostly conducted by the Advisory Group members and facilitated by Adélia Branco (the Project's Social Scientist).

The seminar aimed at providing an overview of Project activities and their impact on the participating communities. Particular importance was given to the views of community members in this regard. The seminar also provided an overview of the land and water focussed Environmental Education Programme, its introduction at ten rural schools located in the communities and the impact of the introduction of the programme on achieving the Project purpose and the sustainability of Project activities.

The second day of the seminar included a visit to one of the schools participating in the Environmental Education Programme. The visit is described and illustrated in Supporting Document SD14. It provided a clear impression to the visitor that, even at its early stages of implementation, the programme has had a very significant impact on both students and their teacher.

The seminar clearly highlighted the importance the Project has had on the participating communities and also on the related municipalities and State organisations. The quotes taken from presentations during the day illustrate clearly the perception of local community members and stakeholders on the project outcome.

Statements arising from the Project Seminar, held in Pesqueira on 17 November 2005

I identified, in the discourse of women and men involved in the KaR/DFID Project, a satisfaction not only because they were part of the Project, but also because they felt part of a successful initiative. Among other important aspects present in the various speeches delivered, it was highlighted the desire for continuation of the project with the same focus and following the same lines of action. I also noticed the great importance in regards to its goals and focus on education. There was a great exchange of knowledge among different parties. The project also contributed to introduce several changes on the livelihoods of the local population.

It is my understanding that the main elements which contributed to the success of the project were the legitimacy of the project from the effective participation of the involved parties, especially community members who gave their opinion about all aspects, including in decision-making. Once the population is involved to the extent they were, education plays a very important role as a permanent tool to multiply actions which, in this context, regard the important resource which is water.

Prof. Ricardo Ferreira, Diretor do INFOC

Due to the reliance on participative methodology, which is applied on this Project, I observed that the communities absorbed well all of the teaching and training done along the implementation of the Project. I also noticed that this was the most successful project among the ones in which I have participated and this is due to the high involvement of the communities in all of the actions of the Project. As a result of their participation, community members showed the desire to change, to exchange knowledge and to learn about practices that can be applied at their communities on a daily basis.

I believe that an important point about this work was that there was no paternalistic type of relationship involved and, on the contrary, there was a great intention to cause positive changes in the behaviour of the local population. It is more important to share knowledge about how to fish than to give the fish.

Prof. Ronaldo Freire, UFRPE

Quotes from Presentations at the Final Seminar

Maria da Paz said that the Project focus on education with a focus on water and land management provided the communities the opportunity to discussing their daily problems and try to seek solutions to them.

Socorro, a health agent from Campo Alegre: She shared the important experience she and other community members had in participating in the survey data collection. …… She said that this gave them a feeling of empowerment as they felt part of the project by giving their opinions.

Penha, a health agent from Mutuca recalled that the Project team members did not impose anything on them, on the contrary, encouraged them to be creative.

Geraldina, a health agent from Rosário said that as a member of the Advisory Group, this project provided satisfaction in many ways. They had the opportunity to visit other sites and to learn about the experiences and also to exchange ideas with people from other communities.

According to ***Seu Antônio, a farmer from Mimoso Seco***, it was only after participating in the Project that he realised that he was a knowledgeable person as usually people tend to rate the farmers experience and knowledge very low and of no importance. He believes the Project had a strong impact on the livelihood of community members.

Seu Djalma, a farmer from Rosario who practises traditional rain fed agriculture, mentioned his satisfaction about participating in the Project and said that he has never heard of a project such as this one before. He said that water and soil are very important for farmers and that before this Project, his neighbours never believed in him. But now, everyone believes he is doing things in the right way.

Agnaldo, a Xukurú leader and City councillor in Pesqueira said that the participation of the Xukurú in the Project had made other communities aware of the Xukurú organisation and that it brought the Xukurú closer to non- Xukurú people. It was an important way to solve conflicts and that if it were not for the Project, this would not have happened. He said the Xukurú were now sharing water from the Pão de Açucar Dam with Campo Alegre (downstream) and that this was due to the Project. He also said that he believes in the sustainability of the Project and that he will do his best to contribute to that.

Mercês Costa, President of the Bitury Water Users Council in Belo Jardim said that she views the Project as a very important initiative, especially because of its focus on empowerment and education.

Seu Djalma said that farmer participation in the Environmental Education Programme has been an important measure to raise the self-esteem of farmers, like him, who did not have the opportunity to spend much time at school. By involving farmers, the Project is also placing high value on local and traditional knowledge and this will contribute to students rating the rural areas as important and instead of migrating to cities, stay in their place of origin.

Antônio Guedes, the representative of the Renascer Project (World Bank supported) complimented the Project team and the community members and said that he believed the Environmental Education Programme will achieve sustainability as it was planted with solid roots.

Enjolras Medeiros, a geologist from CPRM, the Brazilian Geological Services, said he was impressed with the Project and the participative methodology used and he was sure that the Project was going to achieve sustainability due to the high involvement of community members.

Tereza Brandão, a specialist on Environmental Education from CPRH, the state Environmental Institution, said that she was impressed with the Advisory Group and the way it works. She had never seen anything like that in any other project.

Cleide Oliveira, the secretary of Education of the Municipality of Pesqueira said that since the teachers and students are all very involved, the Environmental Education Programme was probably going to achieve sustainability and that the municipality will continue supporting the actions.

Participatory Surveys

The main goal of the participatory methodology was to empower the communities by including them in all of the activities of the Project. This was done from the initial stage, i.e. the surveys undertaken in the Inception Phase, and continued throughout the Implementation Phase, i.e. the Workshops and Seminars as well as through other activities such as the establishment of the Advisory Group and the establishment of the Environmental Education programme at rural schools. The success of that can be seen though the reporting of all of the activities in the supporting documentation (Supporting Documents SD 10, SD 12, SD14 and SD15).

(v) Results of the Workshops and Seminars

The results of the Workshops and Seminars can be partly seen as the results of the Project itself as they constituted one of the main outputs of the Project. The high participation of community members in these activities had a great impact on the empowerment process of community members which took place gradually. It was during the Workshops, Seminar and Advisory Group Meetings that the need for the implementation of an Environmental Education Programme was identified. As it can be seen in the reports of the various Workshops, the community members participated by providing indicators about the specific situation of each of the communities. The same took place in the training sessions delivered for health agents and teachers.

The success of the Project can be seen though the result of the Final Evaluation Seminar, which took place in November 2005. At that occasion, the seminar presentations were prepared and presented by community members, teachers and health agents whereas Project team members participated as facilitators of the sessions (Supporting Document SD14).

4.2.4 Operational Strategy for Integrated Communications

(i) Development of Communication Strategies

The Operational Strategy for Integrated Communication was developed on the basis of three main aims of the Project:

- Develop and disseminate clearly understandable, culturally appropriate guidelines for sustainable groundwater resource management, targeted at water users within rural communities.
- Facilitate and increase understanding of the potential benefits from groundwater resource management and the implications of the overuse of the resource, in the context of seasonal and long-term variability in hydrological/climatic conditions.
- Empower community representatives (farmers, farmer representatives and other local groundwater users) in the active monitoring and collective management of the groundwater resource.

The development of the communication strategy aimed at achieving effective multi-channel communication from rural community level through to national level, encompassing farmers, water users, appropriate NGOs, public bodies, extension services, state institutions and research organisations.

The development of the operational strategy for integrated communication was intended as a process initiated at the grassroots (rural community) level. From this basis, it was intended to gradually expand through involvement of other stakeholders in its development. It was also recognised, particularly from the findings of the inception stage, that a strong participatory approach to the development of the strategy would be required to ensure its successful implementation.

The development of the strategy thus developed during its implementation. It improved and evolved gradually over time. This process of implementation and development is described in the following section.

(ii) Implementation of the Communication Strategy

The implementation of the strategy took place as a gradual process shaped by the needs and actions of all the stakeholders involved and also by the lessons learned during Project activities, particularly the workshops and field surveys. The participatory methodology utilised in the Project was an important mechanism for the elaboration of the strategy. Such a mechanism was initiated during the inception phase as the information collected set the basis for elaborating the strategy. The surveys done in the three communities, Rosário, Campo Alegre and Mutuca offered data about the population, about the use of water and about community organisation. The surveys also provided an opportunity to identify leaders at each of the communities. The data collection itself was done through a participatory methodology. The health agents at each community were the ones who helped identify the men and women that comprised the survey sample and the interviewers were community members trained to collect the data.

In order to develop proper integrated communication strategies, it was necessary to improve intra and inter community communication as well as communication between Project team members and the

communities. The lack of communication within the participating communities is due to the low level of social organisation and the low level of empowerment of the population. Improvement in communication was viewed as an important way to empower community members who up until that time, had never been exposed to a participatory project such as the KaR Project. The Project's community members had been exposed to in the past adopted a top-down approach to communication, giving the communities no opportunity to discuss the information being disseminated. Their only choice was to accept or not accept what was delivered. Moreover, the majority of past projects were paternalistic and instead of empowering the population, they aimed at providing palliative solutions to problems. The past approach had contributed to the low self-esteem of the rural community members, and had not contributed to a strengthening of the social organisation within the rural communities. Little attention had been paid to the role of women. Besides women health agents and teachers, there were very few women leaders.

Introductory workshops were held during the inception phase to introduce the Project to the participating communities (refer to the Inception Report). The workshops involved participation of community members as well as representatives from local government and extension workers. Although the workshops were considered successful, It was noted that the involvement of local government officials restricted the participation of the rural community members. Given the low level of empowerment and the weak organisational structure of the rural communities, it was noted that an important step in the process of communication strategy development was to start working with community members so that they would enhance their self-esteem and start their empowerment process.

The next step was to encourage communication among community members. To achieve this, it was necessary to recognise the importance of local traditional knowledge and to use this in the implementation of the communication strategy. The recognition of local knowledge served to empower farmers and other women and men at the communities and to help them feel confident to exchange knowledge among themselves. This also enabled them to develop a sense of belonging to the Project and a feeling that they had something of value to contribute to the Project (their own knowledge). At the first of the four themed workshops, which focussed on the Storage and Use of Water for Domestic Consumption (Section 4.2.3), a group of health agents from Mutuca prepared a theatre performance reflecting the workshop theme and presented it at the workshop sessions in the three communities.

The second workshop focussed on water use in farming, which is an activity undertaken mainly by men. It was noted that there was a clear difference in expression at this workshop, compared to the first. This was attributed to gender differences. It was noted that women are better communicators once given the opportunity, while the men follow their own routines as individuals. The latter does, however, not imply that the men have no opinions to share. It was recognised at the second workshop that there was a need to reconsider the format of subsequent workshops and encourage much stronger participation from community members.

The Project team members identified farmers to deliver talks about the methods they use in relation to aspects of land and water management and organic agriculture. These farmers had expressed their views on these issues during private discussions with Project team members and clearly indicated their frustration about not being able to communicate their ideas to other community members. Farmers from Rosário and Mimoso Seco (a community which was included as one of the pilot communities at a later stage) were invited to give presentations at the third workshop. The format of this and subsequent workshops was such that the local farmers became the main speakers, while Project team members played a lesser role in communicating the messages. By becoming speakers at the

workshops, farmers became empowered as the Project as well as their fellow community members acknowledged their local traditional knowledge. This resulted not only in a rise in the self-esteem of the individuals; it also raised the self-esteem of the communities as a whole.

By the time the fourth workshop, which was on the Institutional and Organizations Aspects of Groundwater Management, was held, two additional communities had become part of the Project: the Xukurú indigenous community and the Mimoso Seco farming community. Both communities differ from the others in their advanced level of community organisation and, as a result of that, had benefited significantly from several past projects. Invited speakers from the Xukurú indigenous community had the opportunity to share information about their strong social organisation in all of the four other participating communities. This was a way of improving the communication between the communities. The inclusion of the Xukurú indigenous group in the Project was very important because that group had been subject to discrimination due to their struggle for land. By participating in the Project, the Xukurú had the opportunity to change the long-standing negative view the other non-indigenous farming communities had about them.

An important achievement of the Project in regards to communication strategy and the inclusion of the Xukurú in the Project was the opportunity to solve tensions between the Xukurú and the Campo Alegre residents. The tension was a result of the fact that the Pão de Açucar reservoir is located in the indigenous land, which is upstream of the Campo Alegre community. There was a belief amongst the Campo Alegre residents that the Xukurú were unwilling to release water from the reservoir for downstream use. As the Xukurú became part of the Project, there was opportunity for leaders from both communities to discuss the problem and arrive at a solution. Water then started to be released to Campo Alegre and this not only improved greatly the relationship between the two communities, but also changed the view in general about the Xukurú people.

Once an intra and inter flow of communication involving the communities was established, other stakeholders such as extension service workers, NGOs representatives, and government officials increased their involvement in the Project and were involved in the implementation of the communication strategy. Staff members from CEDAPP and ConsuBitury NGOs had an active participation in the workshop sessions and had the opportunity to communicate about their work in other communities and this was another step towards the integration of the communication strategy.

Another important activity through which the communication strategy was developed was the establishment of an Advisory Group. The Advisory Group comprised community members representing each of the communities as well as health agents and teachers. The main objective of the Group was to make decisions about all that concerned the Project and to disseminate information among the other members of the communities. The Group had therefore an important function and played a very important role in all aspects of Project implementation, including communication. The Group had the opportunity to contact state representatives, representatives from NGOs and to visit other sites. Several discussions about the legal and institutional aspects of groundwater management took place and Group members had the responsibility to disseminate the information gathered to their own communities.

Health agents were given specific training sessions about water and health and this not only increased their knowledge on the subject, but enabled them to communicate the messages learnt to community members with whom they work on a daily basis.

The land and water focussed Environmental Education programme introduced at rural schools during the final year of the Project was one of the most important activities undertaken in the Project. It not only involved the training of the teachers so that they could transmit the knowledge to the students, but involved the participation of farmers who delivered training sessions to the students. This was a way of acknowledging the importance of local traditional knowledge and also of contributing to the sustainability of the actions implemented in the Project. Education is an important initiative to contribute to long-term changes. The local, state and national government were important partners in the Environmental Education programme as the Ministry of Education is encouraging the incorporation of Environmental Education in the curricula at both Rural and Urban schools.

The participatory monitoring activities in which community members, both women and men, as well as school students participate can be seen as an important part of the communication strategy. Once the local population learns about the importance of monitoring to their livelihood by internalising the knowledge about the use of monitoring equipment, that the point will have been reached where there is a clear understanding of the technical aspects of the Project. The active engagement of the population in monitoring activities can contribute to the sustainability of the Project.

The Guidelines on Monitoring and Interventions Strategies also comprise part of the communication strategy. However, the development of the monitoring guidelines absorbed the full Project period to be finalised. They will be incorporated into Statute of Farmers and Water Users Association in Mimoso Seco and serve as the basis for the establishment of Water Users Group involving the Campo Alegre and Xukurú residents.

The presentation of several papers at National and International Conferences was also part of the communication strategy and aimed at reaching a ‘world’ audience. The elaboration of a poster and of leaflets as well as the publication of a school textbook on environmental education to be utilised at the rural school were also part of the communication strategy.

(iii) Recording and Reporting

The discussions on the development and implementation of the communication strategy clearly highlight the gradual and integrated development process. The reporting of the strategy is embedded in the numerous documents included as supporting documentation to this report. In particular, Supporting Documents SD10, SD12, SD14, SD15 and SD21 contain aspects closely related to the development and implementation of the communication strategy. The development of the strategy is also closely linked to the activities described under the three other Project Packages.

4.2.5 Guidance on Monitoring and Intervention Strategies

(i) Assessment of the Local Capability

Technical

Throughout the period of the Project, the Project team has placed a great deal of emphasis on understanding the existing knowledge of the communities in relation to the water resources of the three catchments and their affect on the water resources. It was particularly important to define the capability of the communities not only in terms of existing knowledge but also in terms of their willingness to acquire new skills, to work together to achieve a common goal and to modify their traditional practices in the light of information learned through dialogue with the project team. Several features from this assessment have proved interesting and important for the development of the Project.

The communities clearly do have considerable knowledge about their environment and the impact of pumping groundwater for irrigation on the available groundwater and the quality of the groundwater. However, they do not express this knowledge in terms of the typical hydrological systems concept that we might choose to explain catchment water resources. Rather, they employ concepts about links between different components of the water resources that are defined in terms of a feeling that the connection exists and the type of response (for example an increase in salinity of the water as the groundwater resource is depleted). As such the communities do not have an integrated picture of their environment but they have a set of 'fuzzy' rules that provide an equivalent picture based on experience. While it was assumed that this was likely to be the case at the start of the Project, the evidence confirmed this assumption. So, rather than educate the adult community members in terms of water resource systems and catchment hydrology, the strategy adopted was to develop quantitative rules for managing the groundwater that mirror the fuzzy rules that are already intuitively used by the farmers. In support of longer term goals of educating the community in a more integrated understanding of the hydrology and hydrogeology of the catchments, concepts based on the hydrological cycle were identified for inclusion in the school's based environmental education programme. In this way, a longer term process of development of the community knowledge through interaction between the younger and older members of the community could be established.

The occurrence of the flooding in early 2004 generated an interesting step change in the responses during the well surveys. The later responses after the flooding implied that the community members adopt very short term thinking in relation to the environment. As soon as water resources in the area were plentiful, the deprivation that had been endured by the community prior to the flooding was largely forgotten and the communities immediately exploited the new water as rapidly as possible to ensure maximum benefit from its occurrence. This behaviour unwittingly magnified the impact of past drought periods, and reinforced the community opinion that not using the resource as soon as it was available meant that an opportunity was lost. The response suggested a lack of awareness of the groundwater resource as a common good so that the farmers effectively competed for the water rather than working to share and conserve the water. Unsurprisingly, the awareness of the need to share the surface waters in the Xukurú community was much stronger. The visual evidence of drawing water from a common resource is much clearer where surface waters are involved than where groundwater is being exploited. To take the Project forward and to develop guidelines for water conservation that would reject the existing strategy of the farmers in favour of a new strategy aimed at managing the water use to assist in drought alleviation required the common resource concept to be articulated. For

this reason different regions in the different catchments needed to be treated individually on the basis of both the natural separation of the groundwater bodies into different physical units and on the basis of natural communities through the farmers associations.

Discussions with the different associations existing in the three catchments produced clear differences between communities in the way that the farmers worked together. In the more established settlements in Mimoso Seco and the Xukurú reservation, community partnerships were strong and the need to work together to manage and develop the resources was much more appreciated. In the recently established settlements such as Rosario communal farm, the community partnerships were generally much weaker with each individual working independently as far as possible to achieve a living. Encouraging the development of water user associations in the more settled communities proved to be much easier than elsewhere. A targeted policy of developing the more settled community associations first was therefore adopted. The justification for this approach lay in the short timescale for the Project and the potential for the future existence of successful associations to provide impetus to other groups in the region to copy their example.

Technical skills in hydrological monitoring and recording observations were invested in a few individuals in the area who were employed through previous research projects by the Federal Rural University to monitor the groundwater levels and electrical conductivity and to record precipitation and evaporation data. Maintenance of equipment was not included as a duty of these individuals. These individuals were held in high regard by the communities in which they lived, partly because of the knowledge that they possessed but also because of the income that this activity generated on top of their normal farming income. This created two problems for the Project. The first was to dissociate the monitoring of the groundwater from the possibility of external funding. The second was to dissociate the monitoring from a research activity led by the Universities to a community activity for the benefit of the community. These two problems had to be overcome and a training programme introduced to the farmers on the methods of monitoring well in advance of a clear understanding of the community of the benefits of such monitoring. The approach taken by the Project team was to undertake surveys regularly and during each survey to involve the farmers in the monitoring through a participatory exercise. The time spent with the farmers was used to explain not only the use of the equipment and the methods of data collection but also to explore the reasons for the monitoring and the longer term goal of the Project to improve the sustainability of the farming in the catchments. The farmers were receptive to the approach and were able to assimilate the reasons underlying the monitoring programme.

Overall, the communities showed a high degree of interest to move to a more sustainable approach and in some communities the enthusiasm to improve the use of the resource and to intervene to ensure continuity of supply during droughts is very strong. However, it was also clear that considerable time is needed to build a long-term community structure in all the catchments that can deliver sustainability in the longer term.

Social

During the whole period of the Project, Project team members put a lot of effort into understanding the existing knowledge of community members in regards to a variety of issues related to socio-economic aspects. The basis for that was the survey undertaken at the level of each community and the qualitative collection of data.

Community members demonstrate a considerable understanding of health related issues and this is due to the important work of health agents. In some communities, they are aware of the importance of treating water properly to avoid water related diseases. Many of the households treat the water they drink, however, some of them, especially the poorer households don't. They do, however, not seem to have as much knowledge about the sources of contamination of water such as the heavy use of chemical pesticides. In some communities, such as the Mutuca village, the residents used to drink contaminated water from a well and this had a very negative impact on their health. Although the government provides chlorine for the water treatment, the quantity provided is not enough to be distributed among all community members. For this reason, the health agents teach alternative treatment methods. Another aspect is that community members do not seem to know what to do when something different from the ordinary routine takes place. After the flood in the beginning of 2004, there was a high incidence of water related diseases as a result of the consumption of contaminated water.

It is interesting to note that despite the weak social organisation found in many communities, there is a great deal of collaboration among community members. In times of drought, for example, drinking water is shared and therefore, those who have wells and cisterns usually provide water at no cost for those who do not have the facilities. This solidarity may be a result of the fact that most community members are kin-related. The same does not happen for water for irrigation and the explanation given is the high cost of energy to pump the water.

Education is an important area which concerned virtually all community members. All the school age children from every community attend school. The level of literacy is high among the adult population and the majority of the illiterate people are elderly community members. There is a great emphasis on keeping the children at school with the hope that they can have a better future. Teachers as well as health agents play an important role at the community level as they are considered leaders. Many community members will come to them to ask for advice on many issues.

Gender relations do not differ from those in other rural areas of the Brazilian Northeast. The "macho" culture predominates and women are expected to be subordinate and subservient. This is, however, not the case when women are the heads of their households. It was noticed that in several households women take most decisions and have a leadership role. Even in these cases, they are expected to demonstrate subordination outside the family level. Women play an important role in the economy of the household, especially in periods of drought. The majority of women engage in lace making and commercialise their products at the city market. This constitutes an important source of income for the household.

According to the gender division of labour, women are not expected to be involved in agricultural activities, particularly irrigation. The farmers said that agriculture involves heavy tasks and that women do not have enough physical strength for that. Some women, however, have their small plots and grow horticulture crops for the market. Women are considered to have better skills for retail selling than men. Thus, men are generally only in charge when they sell their products to middlemen.

The most organised communities, i.e. Mimoso Seco and Xukurú, have a better intra-community communication flow. Community members are very participative in all community activities and tend to collaborate with one another. There is not much community faction or rivalry and competition. In the case of the Xukurú indigenous reservation, this is a result of their ethnicity based ties. In the case of Mimoso Seco, this is due to their solid social organisation and, to a lesser extent, to kinship ties. In the less organised communities, particularly Rosário and Campo Alegre, there is not much intra-community communication flow. Community members tend to compete with one another and there are several community factions. In both communities, the Association does not function well, neither does it have the support of many members. Community residents are aware of this fact and the households always tend to behave individually rather than collectively. Due to the water scarcity problems in Campo Alegre, the residents demonstrated a desire to change and are trying to work on a more collective basis.

The inter-community communication flow has much improved during the implementation of the Project, especially as a result of the workshops and seminars, which brought community members from different areas together as well as the Advisory Group meetings as these provided representatives from each of the communities the opportunity of being together to discuss the Project as well as the problems in their communities. Except for Campo Alegre and Mutuca, which are located close to each other, there used to be little interaction between communities and therefore the communication flow was poor. This was particularly the case of the Xukurú indigenous community, which was discriminated by other farming communities as a result of their struggle for land. The communication among community members has greatly improved during the Implementation Phase of the Project.

The assessment of local capability was very important as the Project team was able to address community needs through the various Project actions and to contribute to a successful implementation of the Project.

(ii) Development of Guidelines and Procedures

Groundwater Guidelines

The groundwater use guidelines for the three catchments were developed in three stages. In the first stage, the identification of the primary stress indicators was undertaken (Mackay *et al.*, 2005) as discussed in Section 4.2.2 In the second stage, the relative importance of the indicators in each of the three catchments was assessed and catchment water balance models were developed to quantify the impacts of different development scenarios on the groundwater conditions along the length of the catchments (Galley, 2005; Dane, 2005; Sholl, 2005). Finally, the third stage was the translation of the quantitative results from the modelling into general and location specific recommendations for the future. Because of the need to develop location specific guidelines, the whole of the Project implementation period was required for these to be finalised.

The general guidelines that emerged from this process have been collated in Mackay *et al.* (2005). However, this document is a high level document that has little practical application at the community or farmer level and a fourth stage – translation into practical documentation for local application of the guidelines was required.

The development of a practical documentation set has been developed for the community in Mimoso Seco and will form part of the supporting documents of the Water Users Association created by this community. The applicability of the guidelines developed for this community will be tested and the guidelines refined in response to the comments of the association members. It is expected that the guidelines will provide a template for similar material to be distributed to the other communities in the three catchments. However, it has not been possible in the limited time during this Project to complete the trials of the guidelines or to produce local guidelines for the other regions in the three catchments and it will be necessary to seek further funding and/or the support of other agencies working in the area to complete this process.

The models that have been developed are not sophisticated tools but could not be used successfully without considerable knowledge of current water balance modelling methods for climate, soils, rivers and aquifers. Figures 4.4 a) to e) provide schematically the descriptions of one reach of the catchments and the flows modelled. This means that these tools are unlikely to be useable by community members directly and it is anticipated that staff in the Federal and the Federal Rural Universities in Recife will use them and continue to develop them through the future monitoring in the three catchments. This would improve the estimates of the information defining the properties of the catchments and would allow validation of the results as well as improving the guidelines for each catchment.

Figure 4.2.5 illustrates the use to which the models have been put. The results show the drawdown in the alluvial aquifer under three conditions:

(a) Drought, based on current irrigation practices in the vicinity of the groundwater dam Cafundo II located in the upper reaches of Mutuca valley. Current irrigation practices introduce some stress for the crops due to the difficulty of pumping sufficient water from the existing wells located upstream of the dam and cause little over pumping at the present time. During an extended but mild drought the drawdown is constrained by reductions in pumping to compensate for the low water levels.

(b) The provision of adequate irrigation by assuming that pumping can be enhanced to permit irrigation to the full crop water requirement

(c) The construction of a new dam to reduce flows past the existing dam.

Adequate irrigation would lead to severe problems, while reducing irrigation effectiveness as is practiced at present would lead to mild issues but significant crop productivity loss. The introduction of an improved dam would produce adequate water to sustain the irrigation at the dam. The complex interplay between the natural system, the engineering to control nature and the decisions that are made in relation to irrigation provide a reasonable degree of difficulty for defining simple, understandable yet effective guidelines for the farmers.

The strategy for designing the guidelines has been to work at the local level (initially for Mimoso Seco) and to provide the following:

- recommendations for a monitoring system that can indicate the status of the groundwater flows entering the region
- recommendations for a monitoring system that can indicate the residual resource at any time in the region
- recommended methods of estimating the risk of irrigating related to the time of the year and the provision of critical levels where actions should be taken

Supplementary information is provided in the guidelines on the equipment required for the monitoring, the methods of monitoring and the recording of the data. Additionally tables are prepared that indicate the residual resource. The resulting guidelines have to be used in conjunction with the irrigation guidelines to define the total irrigable area in each of the three seasons (early dry - 1, late dry - 2, and humid – 3) based on the available water.

- In all cases monitoring relates principally to the measurement of depths to groundwater at locations that are established for the purpose and maintained. Measurements are made in existing open wells rather than using new wells or monitoring points for reasons of economy and practicality. The timing of measurements is such that they occur just before pumping takes place (if the well is used for irrigation) and not less than 12 hours after pumping the well ceases. Data are collected on an approximately weekly basis. Measurements are to be made using a simple 'popper' and depth readings recorded from a defined and stable point on the lip of the well. Four locations would typically be identified for monitoring and the measurements would be undertaken by the farmers using the wells. Records are to be collated by a member of the water association. Methods for overseeing that the collection of data is continuous are left for the community to decide. The record keeper is trained in the evaluation of the data and will be tasked with informing the community about the current resource levels and the risks for future crop production depending on the time of year and the depths to water level. The farmers must decide collectively how to use the information and whether to risk failure of a crop, to reduce the irrigated area or to alter the cropping to a less demanding crop type. Sharing of the available water to ensure that the crops succeed in terms of water availability and that the whole community benefits is an essential requirement for the community to prosper from the knowledge that it acquires from the monitoring.

Figure 4.4: Illustration of the components of the water balance models

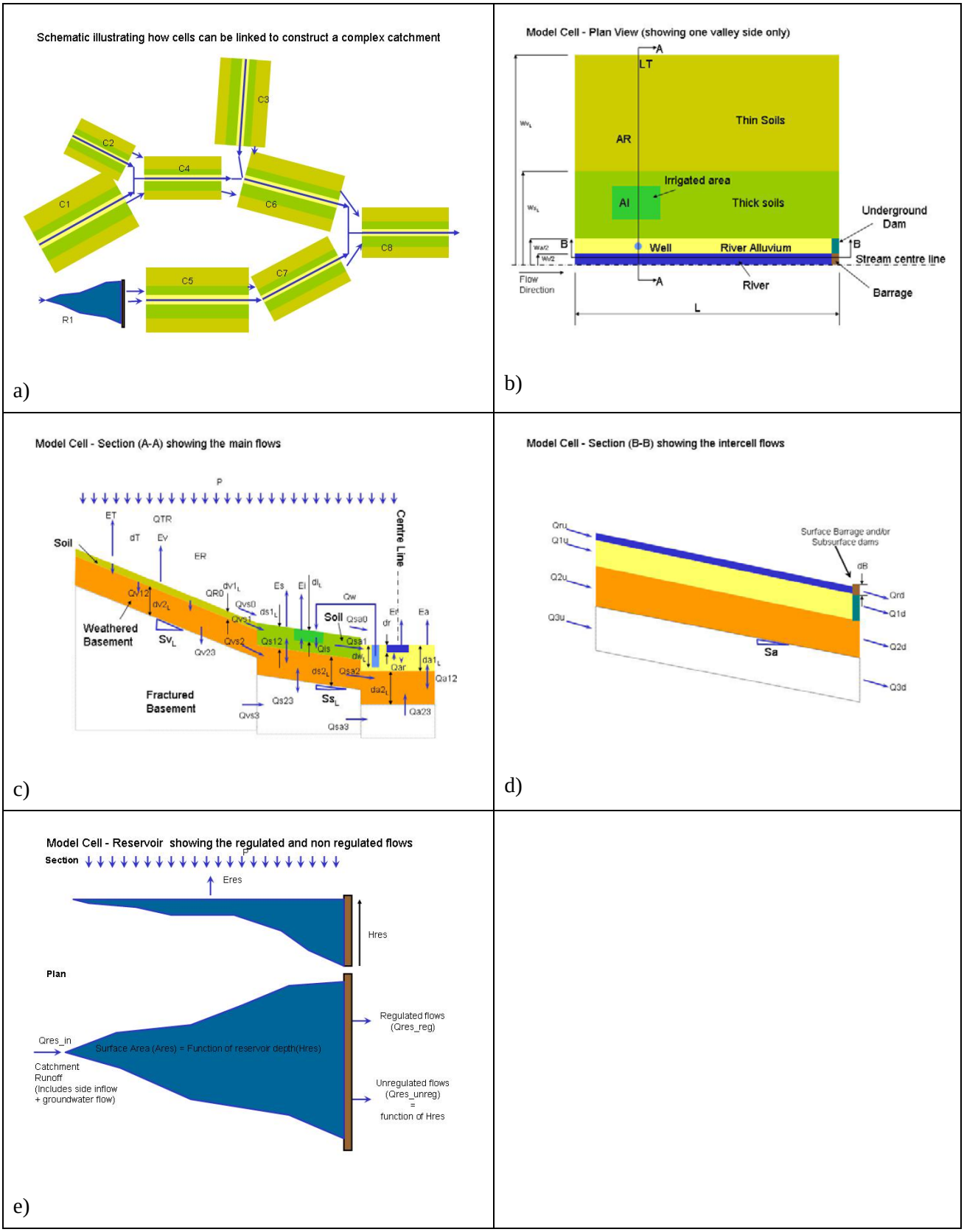
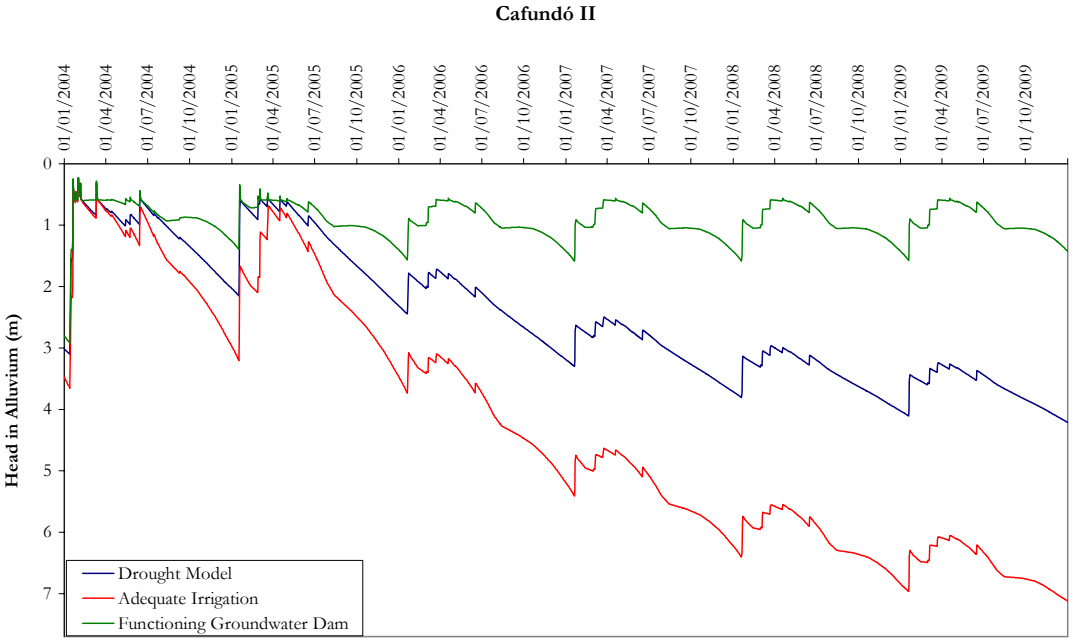


Figure 4.5: Variation in alluvial head



Cafundó II - 1st January 2004 to 1st January 2010.

Irrigation Guidelines

The guidelines and procedures for irrigation are detailed in Montenegro *et al.* (2005) and the main contribution to the developments of these guidelines during the Project are summarised here. Of the environmental variables related to the correct management of irrigation, evapotranspiration and precipitation were considered in the most detail in the guidelines developed for the farmers. These are essential terms for the estimation of crop water requirements. Within the scope of the Project, actions were carried out to simplify the estimation of the water need of the crops. In particular, the identification of appropriate equipment to the conditions of small scale agriculture was explored in detail.

Low cost equipment for rainfall and evaporation measurement created by Professor Ronaldo Freire at the Federal Rural University were installed and evaluated. These were found to be effective and were recommended to the communities during the participatory monitoring programme of the Project. The relevance of the monitoring, the meaning of the readings gathered and the processing of the readings to determine irrigation demand for the different crops were all addressed in the participatory exercises. These exercises provided a better understanding for the farmers of the value of the measurements of water use and their application. As the measurements could be made by each farmer on an individual basis, irrigation applications in each field could be readily incorporated in the rainfall totals to yield the crop demand for the following day.

In areas of low groundwater quality, the addition of excess irrigation water to provide a leaching fraction to remove salts in the soil profile is recommended. This is appropriate for soils with adequate drainage as in Mutuca but not where impediment layers are found or the water table is shallow. An alternatively solution for these more problematic locations is the partial or total exclusion of a leaching fraction ("incomplete leaching") and the exploitation of the natural recharge mechanisms in the rainy season to displace the excess salts. This relies on the land being fallow in this period or at least covered by a crop with a low crop water requirement. The physical situation relevant to this problem is uncommon in the three catchments but was found to be applicable to the high salinity region farmed in the Rosário catchment.

Within the scope of the Project, the potential for the rainfall to remove the accumulated salt from the previous growing season was verified. Incomplete leaching was found to have promise both for reducing groundwater demand and for salinity control. Therefore it has been included as a component of the guidelines and the conditions for its adoption have been identified. Further work will be required to assess whether the approach of incomplete leaching has advantages for general application to the irrigated areas of all three catchments. Additional research is also needed to show that salinity increases in the cropping period due to low irrigation application is not detrimental to the crop yield and also that the flushing of the salts to the groundwater does not lead to an overall increase in the salinity of the groundwater.

Trial areas were also instrumented to test the possibility of directly estimating crop water requirement from soil moisture measurements and therefore to more directly relate the irrigation demand, timing and duration to the conditions in the soils. Tensiometers at a range of depths were installed and the farmers were introduced to the information provided by the tensiometers and to the interpretation of the data produced to assess the need for irrigation on each day. This work is ongoing.

Crop choice depends primarily on the quality of the water, but also on the groundwater availability which depends on the well capacity and the time of year (a surrogate for depth to groundwater). Groundwater abstraction rates for most wells in the three catchments lie between 5 and 10 m^3/h For the three seasons (early dry - 1, late dry - 2, and humid - 3), information on the best crop to be planted has been tabulated.

As an example, Table 4.5 presents the most common crops (carrots, beetroot, green pepper, cabbage and tomato) in the catchments and the relationship between land area and well capacity for each for the early dry season (2). Cropping on any given field is not limited to a single crop per year, but in this case the farmers must consider issues related to disease control and to the exhaustion of the land. Additionally, the farmers have also to consider the market for these crops, which may not coincide with the optimal crop choice based on physical factors alone.

Crop production as a function of soil salinity has also been tabulated and the optimal timing of crop production identified. Irrigation timing throughout the day is also addressed in the guidelines. Assessments have been made of the extent to which farmers have traditionally considered the choice of crop, the water demands of the crop and the efficient use of water during cropping. The evidence from the assessments is that little consideration has been given to these matters and that previously crop failure has been accepted rather too readily as a consequence of a failure to plan ahead. The need for guidelines and the training in the use of these guidelines is important. Many of the farmers recognized this but did not know how to acquire the necessary information. While the guidelines are a step in the right direction, considerable work will now be needed over an extended period of time to develop the uptake of the guidelines within the communities in the three catchments.

The demonstration areas developed during the Project to develop and illustrate the concepts in the guidelines and the use of the field equipment were also used for general educational purposes: teaching the farmers, their families, the university students involved in the Project, the students from rural schools and the teachers and health agents in the area.

(iii) Development of Resource Stress Indicators

The discussions in sub-section (ii) of Section 4.2.2 as well as the previous sub-section on guidelines cover the development of resource stress indicators. The stress indicators are embedded in the guidelines for groundwater and irrigation guidelines. No further discussion is therefore included in this sub-section.

(iv) Distribution of Procedures and Guidelines and Publication of Strategies

Reference to published information has been given in the sub-section on the development of guidelines and procedures. Procedures and guidelines will be incorporated in a document attached to the statutes of established associations.

In Mimoso Seco the guidelines document will become a binding requirement for resource monitoring and utilisation. The legal procedures for inclusion of the guidelines have been undertaken with the assistance of the Jatauba Municipality.

The guidelines that relate to the communities of the Xukurú and Campo Alegre will be incorporated into the statutes of a Pão d'Açucar Water User Group. Community representatives are in the process of establishing the water user group, which will comprise representation from the two communities. The aim of the group is to ensure fair distribution of the available surface water resource from the reservoir and to ensure that the resource is used in a sustainable manner. Emphasis is placed by the Xukurú on limiting harmful chemical pesticides.

The community of Rosário and Mutuca have a less advanced organisational structure and establishment of water user associations will require follow-up activities beyond the current Project. Guidelines have been prepared for those communities and these are available for consultation. The continued presence of the main research bodies (the two universities from Recife) will in part contribute to the uptake of the guidance by those communities.

4.3 Environmental Education

4.3.1 Introduction

A participative environmental education programme, targeted at younger as well as older community members and with a major focus on water and land, has been introduced during the final year of the Project Implementation Phase. One of the main characteristics of this Environmental Education Programme is that although it is being implemented within the existing school systems, it involves local farmers, who work with the teachers in the dissemination of knowledge to the students. Such participation not only empowers the farmers themselves, but acknowledges the importance of local knowledge.

4.3.2 Aims of the Programme

The newly introduced environmental education programme aims to achieve improved awareness and knowledge about:

- Catchment hydrology and the need for community based decisions about water
- Methods for water harvesting, water storage and issues for water quality and health
- Techniques of land management to improve water resource use and retention
- Appropriate ways of monitoring and interpreting the data to regulate water use
- Organic agriculture

The programme includes participation of local farmers and builds into existing curricula for environmental education at local schools in the participating rural communities. It has strong practical and participative components. Expected outcomes include:

- Established monitoring facilities, managed and maintained by the communities
- Appreciation of the need for and benefits of environmental education and monitoring
- Active involvement in monitoring activities, data analysis and dissemination
- A successful example of an approach to participatory environmental education that can be replicated and adopted on a wider scale

Many of the elements imparted to students are of both applied scientific and social science nature, and hence of relevance to the broader curriculum being followed in schools.

Communities benefit from the project, particularly since the education is focussed on both young and adult community members. Enhanced knowledge strengthens the appreciation of resource vulnerability and the need for resource management that assures sustainability.

4.3.3 Rationale for Introduction of the Programme and its Potential Impacts

Education is one of the most important and powerful means to achieving livelihoods improvement. Where projects have a limited lifetime, actions achieved through education stay and provide an important continuum. Although the inclusion of environmental education was not one of the original Project components, its introduction was seen as an opportunity to give Project outputs a much longer ‘shelf-life’. The emphasis placed on land and water, which plays a crucial role in the livelihoods within the rural communities, provided a clear win-win situation. The land and water focussed environmental education programme provides the cornerstone for long-term, sustainable integrated water resources management (IWRM). In particular:

- The programme underlines the Dublin-Rio principles and develops both an appreciation and understanding that:
  - Water is a finite and vulnerable resource. Essential to sustain life, development and the environment
  - Water management should be based on a participatory approach
- The programme aims at building knowledge of the inter-relationship between water, land and human society, this in the context of climate variability and human and environmental needs. The scientific understanding of the natural land and water system is one of the essential requirements for sustainable IWRM.

- Participation of students in resource monitoring and inclusion of adults in the teaching of important local and traditional knowledge instils a feeling of ownership of actions that contribute to sustainable water use and management.
- Continuous knowledge exchange is encouraged through the introduction of practical projects that involve students as well as their families.

An important impact in social terms is that this Programme highlights the relevance of aspects related to rural livelihood. Historically, the educational model followed by both rural and urban schools has been heavily modelled on urban life. This has had a very negative impact on rural students, particularly those who inhabit the drought prone areas of Northeast Brazil, as it contributed to out migration.

In terms of economic impact, the Programme teaches the students the limitations of their environment in regards to land and water and prepares them to monitor the available resources as well as how to manage them in a sustainable manner. By learning such skills, the students develop interest in staying on the land and in avoiding inappropriate use of water which leads to degradation of the resource. By managing the resources properly, they can increase their family income, which can lead to an improvement in their livelihood.

In ecological terms, the Programme teaches the students how to promote the sustainable use of land and water resources and promotes an appreciation of the local and traditional knowledge disseminated by farmers.

It is important to mention that by interacting with local farmers, teachers have the opportunity to learn and appreciate the importance of traditional knowledge, which is not normally acquired in the school setting. The students are the ones who most benefit as it contributes to an empowerment process of those exposed to a rural way of living.

The theoretical knowledge of the teachers, i.e. the one acquired through formal education, integrated with the practical knowledge of the farmers (acquired through informal means) is very important. This gives visibility to local, traditional knowledge and contributes to the empowerment of those exposed to rural life. Beyond that, the teachers, who are in the great majority women, are exposed to a whole new set of traditional agricultural knowledge transferred by the farmers, who are in the great majority men. Such integration is very important and gives credibility to the Programme.

4.3.4 Introduction of the Programme

The introduction of environmental education is not a novelty. One sees its introduction in the school curriculum in many parts of the world. The originality of the Environmental Education Programme introduced in the rural communities covered by the Project is in its focus on land and water as a livelihood issue that involves both young and adult members of the communities.

The process of introduction of the programme during the Project included the following steps:

- Themed workshops on sustainable water resources development with participation of adult community members
- Working with local education authorities and teachers to integrate the new education components in school's curricula

- Delivering training sessions to the teachers so that they could acquire the knowledge to transfer to the students (refer to Supporting Document SD16)
- Preparation of the educational package though participatory workshops involving local community members and local community artisans
- Preparation of a training manual to be used as guidelines by the teachers and of a publication for the students (refer to Supporting Document SD13)
- Preparation of a textbook for the school students (a copy is enclosed with this report)
- Trial application of the educational package in ten rural schools. Practical components are being monitored and community response evaluated throughout the trial
- Student led field studies programmes, covering:
  - Installation, maintenance and monitoring of rain gauges[*1].
  - Monitoring groundwater levels and groundwater salinity
  - Monitoring domestic (student's household), animal and irrigation water use
  - Logging and interpretation of the monitoring data
  - Community level dissemination by the students.

[*1] - The rural university in Recife has developed a low technology rain gauge, which is both accurate and low cost (~$0.50). Many gauges can be installed at low cost.

The idea is innovative on three counts. First, it involves participation of local community members with the evaluation of water resource use and management problems/issues, the preparation of the educational programme and its delivery. Second, it introduces environmental education in a way that generates data needed to better understand and manage the resource. Third, it introduces concepts of community water governance to a much younger audience than previously trialled.

The involvement of students is effective for two reasons: firstly, they will become the community members responsible for the sustainable management of resources, and, secondly, they will disseminate the knowledge acquired at school to family members, relatives and friends.

Lastly, the involvement of local farmers in the dissemination of information along with the local teachers acknowledges the importance of traditional knowledge and empowers the farmers themselves, most of whom have not had access to formal education.

The programme has been received with great enthusiasm by local education authorities and by teachers. Given the Brazilian Government's drive towards wide-spread introduction of environmental education, the Project initiative has provided the necessary focus and momentum to carry it into the future. Its success will no doubt lead to the adoption in areas not covered by the Project.

The initiative has been accepted as a local action at the 4th World Water Forum, held in Mexico in March 2006.

Table 4.1: Rosario – Devices for field monitoring and knowledge transfer

Area	Devices /Instruments	Observations	Installation date	Coordinates		Details	Funding Agency
				UTM (E)	UTM (N)		
Rosário - FNSR	1. Class A Tank	Evaporation	2002	735139	9071388		UFRPE/CNPq
	2. Automatic weather station	Climate info.	2002	735139	9071388		UFRPE/CNPq
	3. Simple Rain gauge [1]	Rainfall	2003	735139	9071388		UFRPE/CNPq
	4. Simple Evaporation Tank[1]	Evaporation	2003	735139	9071388		UFRPE/CNPq
	5. Piezometers (70)	NA / CE	1995			See Monitoring and Analysis Report Tables	ODA(DFID)/ UFRPE
	6. Piezometers (30)*	NA / CE	2005			See Monitoring and Analysis Report Tables	DfiD KaR project
	7.Tensiometers:	Soil water tension					
	Vivaldo's Area		2004 -2005	735668	9071304	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Paulo's Area		2004 -2005			10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Nido's Area		2004 -2005	736262	9071342	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project

Table 4.1 (cont)

Area	Devices /Instruments	Observations	Installation date	Coordinates		Details	Funding Agency
				UTM (E)	UTM (N)		
Rosário - FNSR	1. Class A Tank	Evaporation	2002	735139	9071388		UFRPE/CNPq
	2. Automatic weather station	Climate info.	2002	735139	9071388		UFRPE/CNPq
	3. Simple Rain gauge [1]	Rainfall	2003	735139	9071388		UFRPE/CNPq
	4. Simple Evaporation Tank[1]	Evaporation	2003	735139	9071388		UFRPE/CNPq
	5. Piezometers (70)	NA / CE	1995			See Monitoring and Analysis Report Tables	ODA(DFID)/ UFRPE
	6. Piezometers (30)*	NA / CE	2005			See Monitoring and Analysis Report Tables	DfiD KaR project
	7.Tensiometers:	Soil water tension					
	Vivaldo's Area		2004 -2005	735668	9071304	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Paulo's Area		2004 -2005			10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Nido's Area		2004 -2005	736262	9071342	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project

Table 4.2: Campo Alegre - Devices for field monitoring and knowledge transfer

Area	Devices /Instruments	Observations	Installation date	Coordinates		Details	Funding Agency
				UTM (E)	UTM (N)		
Rosário - FNSR	1. Class A Tank	Evaporation	2002	735139	9071388		UFRPE/CNPq
	2. Automatic weather station	Climate info.	2002	735139	9071388		UFRPE/CNPq
	3. Simple Rain gauge [1]	Rainfall	2003	735139	9071388		UFRPE/CNPq
	4. Simple Evaporation Tank[1]	Evaporation	2003	735139	9071388		UFRPE/CNPq
	5. Piezometers (70)	NA / CE	1995			See Monitoring and Analysis Report Tables	ODA(DFID)/ UFRPE
	6. Piezometers (30)*	NA / CE	2005			See Monitoring and Analysis Report Tables	DfiD KaR project
	7.Tensiometers:	Soil water tension					
	Vivaldo's Area		2004 -2005	735668	9071304	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Paulo's Area		2004 -2005			10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Nido's Area		2004 -2005	736262	9071342	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project

Table 4.3: Mutuca - Devices for field monitoring and knowledge transfer

Area	Devices /Instruments	Observations	Installation date	Coordinates		Details	Funding Agency
				UTM (E)	UTM (N)		
Rosário - FNSR	1. Class A Tank	Evaporation	2002	735139	9071388		UFRPE/CNPq
	2. Automatic weather station	Climate info.	2002	735139	9071388		UFRPE/CNPq
	3. Simple Rain gauge [1]	Rainfall	2003	735139	9071388		UFRPE/CNPq
	4. Simple Evaporation Tank[1]	Evaporation	2003	735139	9071388		UFRPE/CNPq
	5. Piezometers (70)	NA / CE	1995			See Monitoring and Analysis Report Tables	ODA(DFID)/ UFRPE
	6. Piezometers (30)*	NA / CE	2005			See Monitoring and Analysis Report Tables	DfiD KaR project
	7.Tensiometers:	Soil water tension					
	Vivaldo's Area		2004 -2005	735668	9071304	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Paulo's Area		2004 -2005			10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Nido's Area		2004 -2005	736262	9071342	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project

Table 4.3 (cont)

Area	Devices /Instruments	Observations	Installation date	Coordinates		Details	Funding Agency
				UTM (E)	UTM (N)		
Rosário - FNSR	1. Class A Tank	Evaporation	2002	735139	9071388		UFRPE/CNPq
	2. Automatic weather station	Climate info.	2002	735139	9071388		UFRPE/CNPq
	3. Simple Rain gauge [1]	Rainfall	2003	735139	9071388		UFRPE/CNPq
	4. Simple Evaporation Tank[1]	Evaporation	2003	735139	9071388		UFRPE/CNPq
	5. Piezometers (70)	NA / CE	1995			See Monitoring and Analysis Report Tables	ODA(DFID)/ UFRPE
	6. Piezometers (30)*	NA / CE	2005			See Monitoring and Analysis Report Tables	DfiD KaR project
	7.Tensiometers:	Soil water tension					
	Vivaldo's Area		2004 -2005	735668	9071304	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Paulo's Area		2004 -2005			10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project
	Nido's Area		2004 -2005	736262	9071342	10, 20, 30, 40, 60, 80, 100, 120 cm depth	DfID KaR project

Table 4.4: Maximum areas (ha) recommended for the early dry season

Crop	ETc	Discharge Rate (m^3/h)			
		5	7.5	10	12.5
Banana	4.83	0.66	0.99	1.32	1.66
Batata Doce	4.26	0.75	1.13	1.50	1.88
Beterraba	5.12	0.63	0.94	1.25	1.56
Cebola	5.97	0.54	0.80	1.07	1.34
Cenoura	6.25	0.51	0.77	1.02	1.28
Feijão de Corda	5.40	0.59	0.89	1.19	1.48
Fruteira	3.13	1.02	1.54	2.05	2.56
Goiaba	3.13	1.02	1.54	2.05	2.56
Jerimum	4.83	0.66	0.99	1.32	1.66
Mamão	5.68	0.56	0.84	1.13	1.41
Maracujá	5.68	0.56	0.84	1.13	1.41
Maxixe	4.83	0.66	0.99	1.32	1.66
Melancia	4.83	0.66	0.99	1.32	1.66
Melão	4.83	0.66	0.99	1.32	1.66
Milho	4.83	0.66	0.99	1.32	1.66
Pimentão	5.40	0.59	0.89	1.19	1.48
Pepino	4.83	0.66	0.99	1.32	1.66
Repolho	5.40	0.59	0.89	1.19	1.48
Tomate	4.83	0.66	0.99	1.32	1.66

5 Project Findings

- Successful integration of social and technical Project contributions.
- A strong participatory approach and full inclusion of the communities in all Project activities has been successful.
- Through active participation, community members, local teachers and health agents have been empowered and have developed the interest and skills to continue the Project activities.
- Improved understanding of water resource availability in the context of climate and land management and active participation of local communities in water resources monitoring.
- Water and land resources management concepts and participatory monitoring have been included as components of an Environmental Education Programme. The programme has been implemented at 10 rural schools with municipal government support and involvement of teachers, education specialists, health agents, as well as local farmers. Farmers are involved in teaching activities and in the preparation of the educational material, thus recognising their traditional knowledge.
- The inclusion of the two additional communities in the Project has enhanced community awareness of social organisation (already well established in those two communities) as well as organic agriculture. This has resulted in other communities embracing social organisation principles as well as practicing organic agriculture.
- Resolution of conflict between the indigenous Xukurú community (owners of the Pão de Açucar Reservoir) and local farmers in downstream Campo Alegre has resulted in water sharing and active participation of the Xukurú in the Project. This has resulted in the establishment of a Water User Group with representation from the two communities. This has been an important action towards sustainable water resources management in this catchment.
- The inclusion of the Xukurú in the Project has given them the opportunity to express their beliefs and explain to the other communities their social organisation and their willingness to share available water resources. This has benefited neighbouring communities, particularly the Campo Alegre community. It has also, to a major extent removed the animosity between the Pesqueira municipality and the indigenous community.
- Guidelines for sustainable water resources management have been developed in relation to resource monitoring and usage, and in relation to water use and water saving in rainfed and irrigated agriculture. However, there is clearly a requirement to ‘translate’ the guidelines in a ‘language’ appropriate for use by the rural communities. Guidelines are being incorporated in the statutes of water user association in three of the five communities.
- The diversity of social structures within the five participating communities has had an impact on the degree of uptake of the Project messages. The communities with better established social organisation have benefited more from Project activities than the others.
- The diversity clearly highlights the need to approach communities in ways that consider their social structure. It is clear that more time and effort is required to bring the poorly organised communities to the level of the better organised ones. Steps towards achieving this have, however, been successfully taken.

- The land and water focussed Environmental Education Programme was conceived at the start of the final year of the Project. Its implementation at ten rural schools has been so successful that three municipalities in the region have embraced it and will introduce the programme at all rural schools in those municipalities. The provision of low cost monitoring equipment by the Rural University of Pernambuco has allowed students to participate in monitoring.
- The final Project seminar held on 17 November 2005 was attended by representatives from the rural communities, NGO's and representatives from Recife based organisations. During the seminar, the success of the project was voiced by many of the community representatives. The establishment of a Project Advisory Group, comprising representatives from all participating communities, as well as the organisation of teachers in the environmental education initiative have contributed to active cross-community collaboration and participation. The Project has valued opinion of the rural communities to the extent that Project activities have changed direction in response to community wishes. This has had a powerful impact on the way the Project has been perceived by the rural communities and on their commitment to continue with the activities started during the Project.
- The inclusion of MSc students from UK and Brazilian Universities has contributed significantly to the hydrological and hydrogeological understanding of the catchments within which the five participating communities are located.

6 Conclusions and Recommendations

6.1 Conclusions

The duration of the KaR Project has been short and actual implementation of key Project activities. Activities such as the establishment of the land and water focussed Environmental Education Programme, and the capacity building amongst the rural communities, have been undertaken mainly during the final year of the Project. Although tremendous progress has been made, there is clearly a need to keep the momentum of the initiatives going and to disseminate and implement the Project findings to other communities. In the recommendations an outline of proposed follow-up activities is given.

The successful implementation of projects of this type depends on adopting the following set of ground rules:

- Account for the importance of local traditional knowledge
- Respect all community members regardless of their age, gender and socio-economic status
- Account for gender differences in all of the actions which involve women and men
- Consider the importance of the knowledge of elderly community members
- Encourage community participation in all of the actions without imposing their role
- Have transparency in all of the project actions
- Avoid raising false expectations with community members

The Project actions have demonstrated that, once the population is listened to and is given voice, projects of this type can be successful and contribute to improvement in the livelihoods of the beneficiary communities.

Groundwater is a precious resource which has to be managed properly, especially in areas where there is scarcity of water such as in the Brazilian semi-arid region. Environmental Education focussed on land and water is a very valuable tool to promote sustainability of actions regarding the management of these resources. During the implementation of the Project many lessons were learned which will be shared making use of opportunities such as the 4th World Water Forum in Mexico, where experiences from different parts of the world are exchanged. Appropriate land and water focus in Environmental Education Programmes will, in the long-term, lead to an enhanced understanding of resource availability and vulnerability. This should be seen as one of the major pillars supporting the long-term sustainable use of land and water resources.

The successful actions that have arisen from the Project can be implemented in various other regions, in Brazil and other parts of the world, where vulnerable and scarce resources impact on rural livelihoods and on the environment. Adjustments to the distinct cultural settings may be required. However, the underlying principles have to be preserved, that is: guaranteeing the proper management of land and water resources so that livelihoods can be improved in the future and the impacts of extreme water scarcity can be minimised. One of the most important lessons learned, which needs to be shared, is the importance of the full inclusion of community members in all dialogue and actions.

Improved rural community understanding of their water and land resources is fundamental to improved livelihoods and long-term community stability (reduction in out-migration). With practical environmental knowledge the communities will appreciate the need for local prioritisation and co-operation in water use management and can manage effectively their resources to reduce waste, avoid overuse and provide continuity of drinking water during droughts. Such knowledge will contribute to poverty alleviation as well as reduce environmental degradation. It is believed that the educational framework, which is community based and sensitive to local conditions, can contribute to achieving t The duration of the KaR Project has been short and actual implementation of key Project activities. Activities such as the establishment of the land and water focussed Environmental Education Programme, and the capacity building amongst the rural communities, have been undertaken mainly during the final year of the Project. Although tremendous progress has been made, there is clearly a need to keep the momentum of the initiatives going and to disseminate and implement the Project findings to other communities. In the recommendations an outline of proposed follow-up activities is given.

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6.2 Recommendations

It is recommended that financial resources are identified and made available for follow-up activities within the communities and to introduce the initiative of the Project to other communities and municipalities in the region.

Immediate and longer-term follow up activities are recommended. These relate to environmental education, to community capacity building in land and water resources management, and to institutional strengthening. The immediate follow-up activities, which should ideally follow on from the current Project are to a large extent inter-related. These include:

(a) Extending and strengthening the land and water focussed environmental education programme. This would require external support from locally based technical and educational specialists. It would involve local teachers and teaching co-ordinators as well as local farmers as the main drivers for extension and strengthening of the initiative within the local communities involved with the KaR Project. The farmers would act as supply teachers in relation to the practical aspects of the programme. The aim is to introduce the programme to a wider area, while the strengthening relates in particular to the monitoring activities included in the programme to ensure that monitoring results can contribute to better understanding of available water resources.

(b) Additional capacity building within the five rural communities is required to achieve the long-term aim of self-reliance and community management of land and water resources. The external support could come from local technical experts involved with the KaR Project, while local community members could play a key role in the process. Support could also be available from continued academic research undertaken by the Brazilian universities, which would run in parallel with the proposed activities.

(c) Community organisation varies significantly in the five communities. The importance of organisation is in the adoption of and belief in the guidelines for sustainable resource management developed during the KaR Project, and also in the acquisition of financial support, which often depends on the existence of strong and formal community organisation. Again these activities would require local expertise and community support.

It is proposed that the project is led by the two NGO's based in Belo Jardim, INFOC and ConsuBitury. The activities of INFOC focus on sustainable development, water, gender and environment, while ConsuBitury focuses on institutional development. Faculties within UFRPE involved with extension services would be part of the Core Team. Local community representatives and teachers would also form part of the Core Team. Collaborating teams would comprise representatives from the municipalities, SECTMA, CPRH and the technical faculties within UFRPE and UFPE. A proposed team structure is shown in Figure 6.1. The project would closely liaise with municipalities (in regards to the environmental education) and with the federal and rural universities of Pernambuco (in relation to the capacity building for sustainable resources management). It is further proposed that the locally based experts that worked for the KaR Project are included in the project. Their knowledge of the KaR Project activities and their familiarity and trust with the local communities would be important assets.

It is believed that successful implementation of a follow-up project would take about three years and, in relation to the environmental education programme, the project should ideally start in early 2006. A staged approach could be adopted for the project, with initial focus on the five rural communities involved with the KaR Project, and expansion of the environmental education programme to rural schools within the Pesqueira, Jatauba and Belo Jardim Municipalities. Those municipalities have already expressed a keen interest in expanding the programme. Expansion is also anticipation for the Xukurú indigenous community.

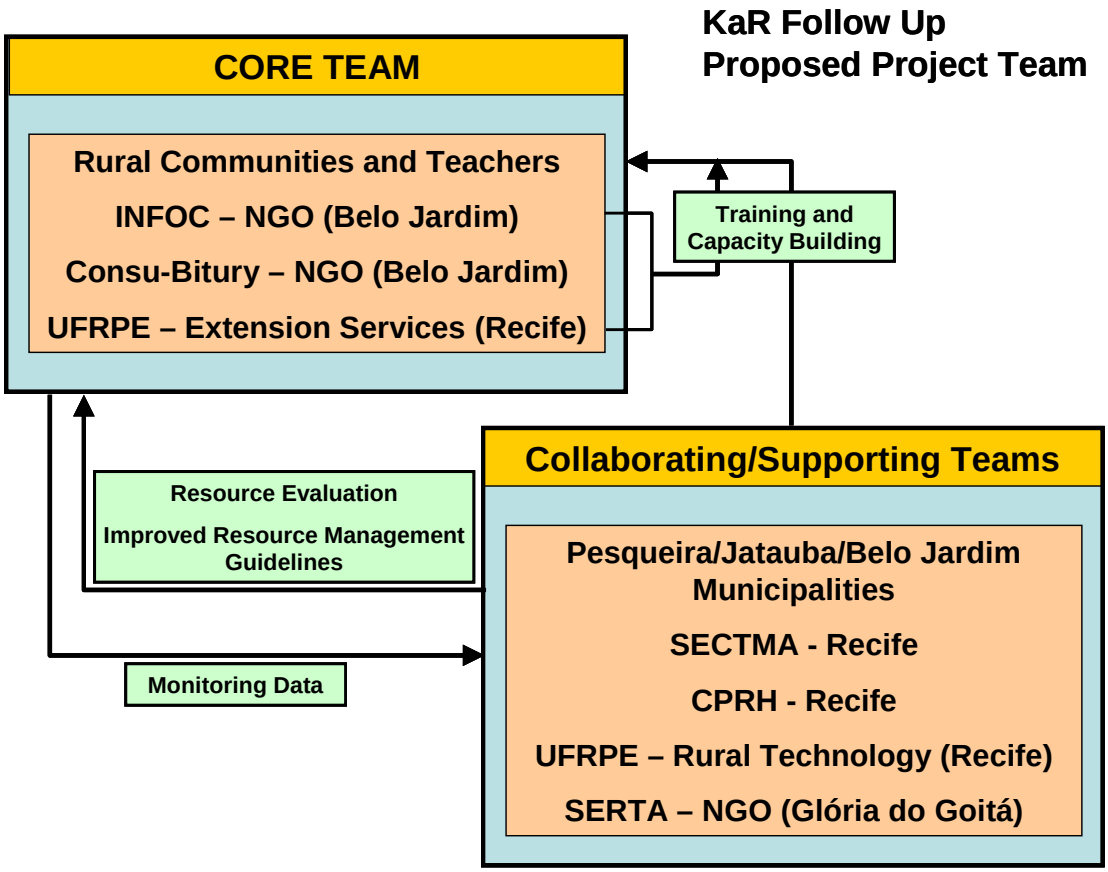
The longer term follow-up activities would relate to the dissemination of the environmental education programme and the capacity building initiative to communities in areas beyond those included in the KaR Project. These activities would be on a larger scale and involve the lessons learned from the initiatives implemented during the KaR Project and the local scale activities listed above.

The success of the follow-up activities in Brazil as well as similar activities elsewhere in the world will, in our opinion, depend on the following:

- Adoption of an inclusive and participative approach similar to the one adopted for the KaR Project.
- Use of locally based experts with experience of the type of work involved with the activities and with knowledge of the local communities.
- Inclusion of community members (teachers, health agents, farmers) in the project activities.
- Establishment of a Project Advisory Group, which should include representatives from participating communities.
- Encouragement of cross-community communication and knowledge sharing in relation to project activities.
- Strong and transparent project management in respect of project administration, financial control and technical issues (technical in the broader sense of project activities).
- Establishment of a culture of reporting, knowledge management and pro-active dissemination of project finings.
- Clearly established targets and milestones.
- Adequate monitoring and evaluation of project progress and outputs.

A clearly defined log frame setting out the goal and purpose of the project, the project outputs and related activities will be required.

Figure 6.1: Proposed Team for Follow-up Activities



References

ALMEIDA, Thaísa Alcoforado de; COSTA NETTO, Manoel Leal; MONTENEGRO, Suzana Maria Gico Lima; MONTENEGRO, Abelardo Antônio de Assunção; BRANCO, Adélia de Melo. **Utilização de águas subterrâneas em aluviões no Agreste pernambucano**. In: XIII CONGRESSO BRASILEIRO DE ÁGUAS SUBTERRÂNEAS, 2004, Cuiabá. Anais do XIII Congresso Brasileiro de Águas Subterrâneas. 2004. v. único, p. 1-19. 2004.

MONTENEGRO, Abelardo Antônio de Assunção; MONTENEGRO, Suzana Maria Gico Lima; BRANCO, Adélia de Melo; ALMEIDA, Thaísa Alcoforado de; COSTA NETTO, Manoel Leal. **Gerenciamento participativo para garantia da sustentabilidade hídrica em aluviões sob uso agrícola do semi-árido brasileiro.** In: XVI SIMPÓSIO BRASILEIRO DE RECURSOS HÍDRICOS, João Pessoa. 2005

MONTENEGRO, Abelardo Antônio de Assunção; MONTENEGRO, Suzana Maria Gico Lima; ALMEIDA, Thaísa Alcoforado de; COSTA NETTO, Manoel Leal. **Uso de águas subterrâneas para a sustentabilidade da pequena agricultura no semi-árido do nordeste do Brasil.** In: 7º SIMPÓSIO DE HIDRÁULICA E RECURSOS HÍDRICOS DOS PAÍSES DE EXPRESSÃO PORTUGUESA, 2005, ÉVORA, APRH, Lisboa, 2005

MACKAY, Rae; MONTENEGRO, Abelardo Antônio de Assunção; MONTENEGRO, Suzana Maria Gico Lima; VAN WONDEREN, Jan. **Alluvial aquifer indicators for small-scale irrigation in north-east Brazil**. In: VII th IAHS Scientific Assembly, 2005, Foz do Iguaçu. IAHS Publication. 2005.

Appendix A Revised Log Frame

	Narrative summary	Measurable indicators	Means of verification (MoVs)	Important assumptions
Goal	Reduce poverty in water scarce, semi-arid areas through sustainable use of groundwater resources, leading to a reduction in resource degradation and security in food production for the rural poor.	Uptake of guidelines by the water users should reflect in changing management and utilisation of the groundwater resource.	Feedback from post-project monitoring to be undertaken by the local collaborators.	
Purpose	Building the capacity of local communities in semi-arid areas to achieve the sustainable use of groundwater resources for agricultural production and domestic needs. Long-term sustainable use of the groundwater resource, through local management of the resource by the end-users, will lead to: 1. Improved social standing in the local community (empowerment and participation in the management process) 2. Reduced vulnerability and better livelihood outcomes through more secure water supply for domestic and animal needs, and more secure food production (particularly during severe drought periods) 3. Reduction of harmful environmental impacts of over-exploitation of the groundwater resource (soil and water salinisation and stress on natural vegetation imposed by groundwater level decline)	1. Established groups of participants in the three trial areas. 2. Agricultural production in trial areas 3. Salinity patterns over the trial areas. 4. Water consumption for different purposes in the trial areas. 5. Uptake and implementation of guidelines in rural communities across the wider region. 6. Greater water security for domestic purposes. 7. Interest in the results of the research by potential beneficiaries from areas outside of the pilot areas	1. Documented records of communications between the user groups and the working teams. 2. Enquiries from other regional bodies. 3. Reports 4. Published papers and web site	

Outputs	1. Clear understanding of livelihood framework for rural families in the study areas (men and women), and the role of groundwater in this 2. Guidelines for sustainable resource management for groundwater use for domestic and farming purposes (particularly for irrigation). 3. A Framework for rural community participation and education. 4. An operational strategy for integrated communications between water users, researchers, managers and extension workers. 5. Guidance on convenient and cost-effective data collection strategies, involving individual community members and community groups for the assessment of irrigation performance, water conservation and salinity control.	1. Publicity materials for community level distribution. 2. Participation of communities in monitoring. 3. Participation of local leaders in promoting the research activities and outcomes. 4. Acceptance and implementation of guidelines by the beneficiaries. 5. In-country open meetings and workshops to reach the local farming community (potentially co-ordinated through local radio). 6. Project reports and guidance documents. 7. Contributions to international meetings, publications in scientific and engineering literature and dedicated web site for international distribution	1. Produced materials including farm level monitoring records, meeting records and attendance, publications and web-based materials. 2. Reports	(Output to Purpose) 1. Beneficiaries engage in the communication process, with strong support from local leaders/institutions, NGOs and local/state government. 2. Active engagement of the beneficiaries in the implementation of the guidelines and in monitoring of responses to water management. The success of this engagement requires continuous monitoring and regular consultation. 3. Willingness of all parties to work together to achieve the project purpose. Good communication between the parties and adequate understanding of sustainable water management issues need to be ensured. 4. Sufficient data exist already to support the assessment of resource reliability and responsiveness to farmer practices. 5. The successful engagement of local beneficiaries in monitoring of the resource will depend on appropriate knowledge transfer and ability of beneficiaries to undertake the monitoring tasks.

Activities	1.a. Review current monitoring arrangements and implement new monitoring systems and schedules	1.a. Integrated data base on existing and required monitoring points. Installation records for new monitoring points, and ongoing records from them.	(Activity to Output) 1.a. Adequate access to existing monitoring records and sites.
	1.b. Assess groundwater resource availability in each trial area and determine indicators of groundwater stress	1.b. Briefing reports provided through the project workshops.	1.b/c Data can be collated on the alternative irrigation strategies under consideration by the farmers and the socio-economic basis for the implementation of these strategies.
	1.c. Evaluate the impacts of groundwater development and the sustainability of the resource under different operational conditions and usages, and the timing requirements for intervention.	1.c. As for 1.b.	
	1.d. Disseminate the findings arising from 1a-1c through the communication channels created to address output 3 and the resources developed under activity 2.	1.d. Published materials produced by the project teams.	
	2.a. Consult with end users (including the Xukuru indigenous population), target audience representatives and local community leaders and establish the ground rules for interaction.	2.a. Records of meetings between work teams and users.	2.a. Current good communications between the project team and the local community facilitate the consultation process.
	2.b. Perform socio-economic assessments aimed at identifying under-represented groups/genders concerned with the project goal and establishing the basis for their integration into the communication dialogue (including the Xukuru)	2.b. Working reports on the socio-economic assessments.	2.b. Suitable representatives of under-represented groups can be identified.
	2.c Carry out participatory livelihood analyses with rural families (men and women)	2.d. Flyers for workshops, participation lists and workshop reports.	
	2.d. Establish workshops, seminars and participatory surveys using the knowledge gained in 2.a. and 2.b.	2.d. As per 1.d.	
	2.e. Recording, reporting and evaluation of the results of the workshops and seminars.		
	3.a. Development of communication strategies aimed at producing effective multi-channel communication from the farm level through to national level encompassing farmers, water user communities, appropriate NGO's, public bodies, extension services and research organisations.	3.a. Prepared reports on the approach to and development of the strategies.	3.a. Identification and engagement of appropriate level interactions with all representative groups in formulating the communication processes.

	3.b. Implementation of the communication strategy to contribute to and present the outputs of the technical research findings. 3.c Recording and reporting of the findings of this phase of the research. 4.a. Assessment of local capability to undertake resource monitoring and to interpret/disseminate the results 4.b. Development of guidelines and procedures for acquiring resource status data, processing the data and interpreting and distributing the results. 4.c. Development of resource stress indicators and the presentation of the basis for these and their dependence on future conditions. 4.d. Distribution of the guidelines and procedures and publication of the process.	3.b. Records of communications between represented groups. 3.c Output reports. 4.a. Database of community representatives met and education/training needs assessments for those willing to participate in the research. 4.b Manuals and other information sources generated describing the techniques adopted for the assessment. 4.c Final report of the groundwater resource evaluation and monitoring studies. 4.d Final production of the guidelines.	3.a/b. This assumes the adequacy of knowledge transfer and knowledge management at al levels. It also assumes that there is the willingness of all parties involved to actively participate in this process. 4.a. The willingness of the local farmers and water user communities to carry out the additional tasks required by monitoring and to acknowledge the need for such monitoring. 4.b. Sufficient resources are available to maintain the equipment base and the training requirements needed to introduce the local participants to the proposed methods. 4.c. Adequate information can be gathered through the project to assess the hydrological and water management interactions in a sufficiently robust manner for implementation by the water users. 4.a-c. There will always be the risk that the assessment of sustainable resource availability will results in under or overestimates. It will be necessary to monitor the impacts of resource utilisation after completion of the research. Regular re-evaluations of resource availability can then be undertaken. The University of Pernambuco will be in a position to undertake this further work and we will seek potential sources of funding during the project.
			A.i Pre-conditions

Appendix B MSc Theses

B.1 Introduction

Seven students from Birmingham University undertook field studies in the Project area as part of their MSc dissertations. They have provided valuable contributions to the understanding of the water resources systems in the three catchments studied during the Project. The abstracts of their MSc reports are given in the following sections. All material produced by the studies is included on the enclosed CD.

B.2 MSc Thesis of Carolyn Walker - 2004

Rainfall/Recharge/Runoff Assessment of the Campo Alegre Region, Pesqueira, NE Brazil

Water resource issues are a limiting factor in terms of social and economic advancements in the Northeast of Brazil. This study focuses on factors influencing the rainfall/recharge/runoff relationships on the hillslopes of Campo Alegre with the hope of identifying methods of enhancing replenishment of soil and underground water stores.

Rainfall simulation equipment used in five fields consisted of a 1.5 m, later adjusted to 75 cm, tall frame supporting rows of sprinklers over a 2.75 m long x 1.5 m wide plot. Initial rain rates of approximately 15 $mmhr^{-1}$ were insufficient to generate runoff. Equipment developments produced rain rates between 100 and 200 $mmhr^{-1}$, which were very capable of runoff production. Improvements included increasing the sprinkler head density, lowering the frame, fitting a filter and variable pressure pump, and using hanging sprinklers. Runoff observed was of the infiltration excess type.

The soil moisture measuring instrumentation employed was tensiometers, located at 10, 30 and 50 cm deep in each plot. These displayed hydrostatic conditions in surface soil during rainfall simulation in a number of cases, which were assumed to be anomalous results possibly due to bypass or macropore flow. Tensiometer data indicated that surface organic matter amendments delay infiltration by around half an hour due to its large moisture holding capacity, therefore reducing the proportion of rainfall becoming lost through runoff.

Vegetation cover significantly decreased the occurrence of surface ponding by reducing the kinetic energy of raindrops. Soil type was very influential, with soils of higher clay content experiencing increased ponding, decreased infiltration rates, and delayed drainage. Evidence was displayed of soils increasing in thickness downslope. Shallow bedrock and a cemented layer at depth may have been responsible for apparent ‘ponding-up’ incidents.

Existing exploitation of runoff in the area through a reservoir collection system seemed ideal for storing water and allowing it to slowly infiltrate into the soil and fractured rock below.

B.3 MSc Thesis of Peter Milmo - 2004

A Water Use Assessment of the Mutuca Valley, NE Brazil

The Mutuca Valley of north-east Brazil represents one of many aquifers in the region confined to a shallow alluvial deposit in the ribbon valley bottom. The aquifer represents a valuable resource of water to the local communities, supplying the water requirements for domestic and agricultural use. The groundwater resources however, are very fragile depending on constant recharge to maintain the groundwater levels, and are beset with salinity problems.

To improve the available resources, government funding has allowed experimental implementation of underground dams, to improve the aquifer storage for the different groundwater users. These dams function to different degrees and complicate the downstream distribution of groundwater storage.

Field work has been carried out to provide an understanding of the aquifer and the available resources present, but also the level to which the local communities are dependent on the available groundwater for various uses. An understanding of the aquifer has included an appraisal into the efficiencies of different dams and the water quality of the groundwater stored. Using the fieldwork data, a lumped parameter model has been constructed on Visual Basic to simulate the various flows within the system and provide a basic water balance for a single year. This model has then been extended for use in modelling the likely groundwater scenario following a drought.

B.4 MSc Thesis of Rachel Hardisty - 2004

Piezometer Installation and Hydraulic Testing in the Campo Alegre Region, Northeast Brazil

Part of a valley approximately 90 m wide and 350 m long was studied in Campo Alegre, Pernambuco State, NE Brazil. 17 piezometers were installed with slug tests being carried out at 33 different depths and locations in order to study the hydraulic parameters of the system. The hydraulic conductivity of the aquifer was found to be very variable even at scales of less than 15 m, with a periodicity in the system of approximately 75 m. The mean hydraulic conductivity was found to be 5.27 m/d.

Water level monitoring in the field indicated that the hydraulic gradient was nearly zero (approximately 0.0007 towards the south) and that water levels quickly responded to rainfall.

The alluvium in the valley was of very limited extent, with a maximum observed thickness of only 7 m. The sediment was generally unsorted and texturally immature. Sandy sediment was limited and silty sediment was dominant. Modelling of the area for the dry season gave a potential maximum pumping rate of 80 m^3/d assuming that the well was 7 m deep in the valley centre but the poor water quality of a local well suggests that the potential for serious exploitation of the aquifer for agricultural irrigation is low.

B.5 MSc Thesis of Brian Last – 2004

Modelling a Groundwater Dam in an Alluvial Ribbon - Valley in Pernambuco, Northeast Brazil - Flow and Salt Transport Modelling

Geophysical and hydrological investigations were carried out in the area around a groundwater dam in a shallow ribbon-valley alluvial aquifer in a drought-prone area of North-Eastern Brazil with the objective of quantifying its operational characteristics.

A resistivity imaging survey using the Wenner array aimed at delineating the bedrock topography unexpectedly revealed a buried paleochannel which by-passes the dam. The path of the channel through the area was mapped. The thickness of the alluvial material overlying crystalline basement was found to be in the range 0-15 m and highly variable.

Slug tests using existing piezometers and a pump test on an abstraction well yielded hydraulic conductivity estimates in the range 1 – 50 md^{-1}.

Analysis of historical water levels and electrical conductivity data showed that a lag of the order of 150 days exists between the main precipitation events and an increase in groundwater salinity. A simple hillslope transport theory based on the Sloan and Moore (1984) approach is presented which shows that a large proportion of the lag can be attributed to the hillslope travel time during which salts are leached out.

An insight into the recharge characteristics of the system was gained from analysis of historical climatic and soil suction data. The conclusions from this study, together with the climatic and hydraulic data, the geometry derived from the geophysical survey and the hillslope transport concept, were integrated into a numerical flow and transport model of the system using GroundWater Vistas.

Design recommendations are made for an experimental programme to test the validity of the model.

B.6 MSc Thesis of Katie Dane – 2005

Sustainable Management of Groundwater Resources in Rosario-Mimoso valley, Northeast Brazil

In semi-arid Northeast Brazil irrigation is necessary for successful agriculture. Irregular precipitation and high potential evaporation mean surface water resources are often not reliable. Therefore it is essential for local farming communities to understand and be able to sustainably manage their groundwater resources.

The alluvial aquifer in the 8km Rosário-Mimoso valley has a potential water capacity of 6,000,000m^3. At current abstraction rates, the valley's water demands are 140,000m^3year^{-1}; 90% of which is used to irrigate 16ha of cultivated land.

The alluvium overlying basement material was found to have an average thickness of 16m using electrical imaging. Initial estimates of the hydraulic conductivities of the alluvium and underlying basement were yielded from pump and slug test results. An estimate of specific yield was calculated from simple drainage experiments. River discharge tests show rainy season surface water flows to be in the region of 2,000 – 200,000 m^3day^{-1}.

A numerical water balance model, populated by data sourced fieldwork, historical datasets and literature, shows natural groundwater flows range between 270,000 to 35,000,000m^3yr^{-1} and are generally large in comparison to irrigation demands. Drought simulations reveal current day abstraction rates can be sustained for at least two years without recharge. Reduction of irrigation demands has an insignificant effect on the long term sustainability of the groundwater resource. Different engineering solutions are discussed. Increased upstream economic abstraction during drought periods was not found to have a significant effect on downstream groundwater users.

B.7 MSc Thesis Emilie Galley – 2005

Campo Alegre: the Water Balance of an Alluvial Valley in Semi-arid Northeast Brazil

The alluvial valley of Campo Alegre, in semi-arid northeast Brazil, is part of an international research project into poverty alleviation and the management of groundwater resources. This study quantifies the resource using a lumped catchment model populated by field data and existing data.

Resistivity imaging and field observations along the 9 km stretch of the Ipojuca River reveal a small alluvial aquifer, 9 m deep (range 3-16 m; becoming shallower downstream) and 50 m wide. Pump tests and specific yield tests suggest a relatively high hydraulic conductivity (10-80 m/d) and a specific yield of 0.23. Resistivity imaging and a slug test suggest the underlying weathered basement has a thickness of at least 4 m and a hydraulic conductivity of 0.006-0.05 m/d. The exploitable groundwater resource is 890,000 m^3.

The water balance is currently dominated by surface water from two sources: the Pão de Açucar reservoir (catchment area of 480 km^2) releases 4000 m^3/day at full capacity, and the Cana Brava tributary whose modelled average discharge of 2400 m^3/day is concentrated during the wet season. The 14.2 hectares of irrigated land draw annually draw 134, 000 m^3 of water from the river, less than 10 % of the water released from the dam. In contrast model shows groundwater along the Ipojuca River are less than 10 m^3/day.

Modelling suggests that under after 16 years of drought the reservoir leakage would have declined to 450 m^3/day and that groundwater levels start to fall rapidly after 3-13 years, furthest downstream being affected first. Given current abstraction rates, the aquifer could sustain current water extraction groundwater levels immediately downstream of the confluence of the Cana Brava tributary.

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Modelling the Hydrological Cycle of a Semi-arid, Alluvial Valley in Northeast Brazil

The alluvium in the valley of the River Fundão, near the town of Mutuca in Pernambuco, Northeast Brazil, is the principal aquifer, supplying over 250 families with water. The semi-arid climate, with annual rainfall and evaporation of 500mm and 2500mm, respectively, creates the potential for drought conditions, which result in the migration of families away from the area, to poor, crime stricken favelas on the outskirts of Brazil's major towns and cities. As part of an on going project (KaR), to reduce poverty in water scarce areas, through the sustainable use of groundwater resources, a lumped catchment model for the valley was created. Fieldwork was carried out over a five week period to populate the model, which once complete was used to simulate various scenarios in order to assess the groundwater resource system. The key scenario was assessing the ability to have a sustainable resource during times of drought. The outcomes of which showed that had the groundwater dams, which were constructed as part of a Brazilian Government scheme in the 1990's, been functioning correctly, the groundwater resource would be highly sustainable, even after five years of drought.