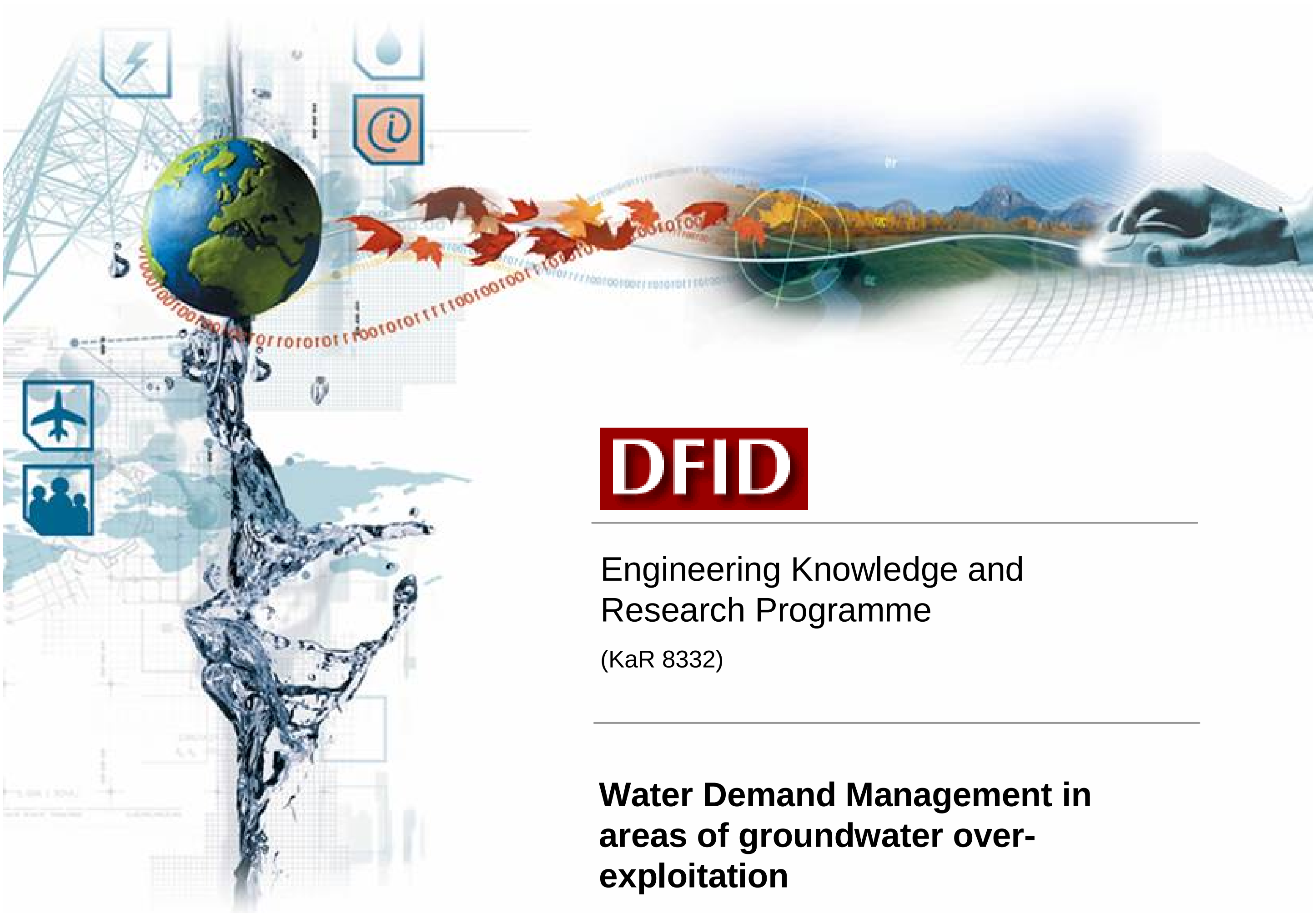

DFID

Engineering Knowledge and Research Programme

(KaR 8332)

Water Demand Management in areas of groundwater over-exploitation

REPORT ON CASE STUDIES

MAIN REPORT

January 2005

BLACK & VEATCH

Black & Veatch Consulting

in association with

VRV Consultants (P) Ltd, Chennai, India

Jouzy & Partners, Amman, Jordan

REPORT ON CASE STUDIES

MAIN REPORT

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REPORT ON CASE STUDIES

MAIN REPORT

S. SUMMARY

S1. Background

This Report has been prepared in support of Project No R8332, Water Demand Management in Areas of Groundwater Over-exploitation which is being undertaken and funded as part of the UK Department of International Development (DFID)'s Knowledge and Research Programme. The initial concept for the research was developed by Black & Veatch Consulting Ltd in line with the DFID agenda on poverty alleviation and within the context of the UN Millennium Development Goals.

The purpose of the research is to:

- develop water demand management strategies for controlling groundwater abstraction in areas where aquifers are being over-exploited, ensuring the long-term livelihoods of the vulnerable and poor are safeguarded; and to

- discuss and disseminate the findings with potential end users of the research (Donor agencies, Government and agencies involved in water management)

Case studies have been undertaken in Chennai, India and Shoubak - Al Jafr in Jordan. This "Case Study" report presents the findings which have been discussed with stakeholders at a workshop in Chennai and at meetings in Amman in November 2004. Based on the studies, generic water demand management strategies will be developed and made suitable for dissemination to potential end-users of the research (Donor Agencies, Government agencies, NGOs and agencies involved in water management).

The research project started with initial studies in November 2003. The final report will be available in draft in November 2005.

Black & Veatch Consulting Ltd is leading the research and providing inputs on water resources, hydrogeology, economics, community, poverty and gender issues, and strategy development.

The main research collaborators are:

- VRV Consultants Ltd., Chennai and the Centre for Poverty Alleviation (CUPA), Chennai in India; and
- Jouzy & Partners, Amman and JOHUD, Queen Zein Al Sharaf Institute (ZENID) in Jordan

The following Government institutions, donor and other principal agencies have provided advice and access to data in support of the studies and we acknowledge with thanks the assistance they have given:

In India: The Ministry of Finance, The Department of Public Works, The Department of Municipal Administration and Water Supply, Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), The Institute of Water Studies, World Bank, Asian

Development Bank, DFID, Delhi, Madras School of Economics and several NGOs in Tamil Nadu.

In Jordan: The Ministry of Planning, The Ministry of Water and Irrigation, The Ministry of Agriculture, UNDP, USAID, EU, GTZ, The University of Jordan

S2. Water demand management and livelihoods

"Water demand management" has become an important element in integrated policies of water resources development. Multilateral and bilateral funding agencies involved in the water sector recognise the need for a better understanding of water demand management. The International Water Demand Management Conference in Jordan, June 2004 demonstrates the importance with which it is regarded in the Middle East and the intense effort that is being made to understand the complexities of water resource management.

Water demand management - controlling and influencing the amount of water used by consumers in areas where there is a scarcity of water resources - raises issues for communities, water providers and regulators for which there is rarely a simple solution.

The management of water demand becomes of key importance once the available water supply can no longer meet the demand for water and the supply options are neither economically nor technically viable. An understanding of supply augmentation and water quality improvement options and their costs, therefore, is a prerequisite to the identification and evaluation of appropriate water demand management measures.

Building on the work of others, three categories of water demand management measures, technical, allocative and other socio-economic measures, have been examined together with associated supporting measures (or policy instruments). In addition, it has become clear that water demand management measures must be seen in a wider context which includes consideration of a country or region's macro-economic policy and future development, its strategic water security and its dependence on "virtual water".

The aim of the research project is to develop strategies for water demand management which take into account the impact on the livelihoods of the vulnerable and poor.

From the Case Study fieldwork in India and Jordan, some common indicators of poverty in relation to water became apparent and the development of a methodology to assess vulnerability was found to be necessary. A methodology has been developed and applied to the case study areas which uses a number of key indicators to define the vulnerability of groups within the study areas. The first priority for developing a vulnerability assessment methodology was therefore to integrate stakeholder priorities (community and institutional priorities) in a single framework.

Because of the complex nature of relating poverty, competing water demand interests and multiple institution involvement and their priorities, multi-criteria analysis has been used as the principal methodological guide. The procedure developed depends on simple rating and ranking systems.

S3. Features of the Case Study areas

The case studies areas in Chennai, India and Shoubak - Al Jafr, Jordan both suffer from groundwater over-exploitation. They are different in size and character; the principal features are described below.

India

The population of the project area is about 7 million of which about 4.5 million live in the Chennai Metropolitan Area and the remainder in the rural areas including the areas overlying the A-K aquifer to the north of Chennai.

Domestic and industrial water supplies for the area come from a variety of sources which include surface water run-off collected in large but shallow reservoirs, groundwater abstracted from the A-K and southern coastal aquifers and from the city area, surface water transferred from the Krishna river in Andhra Pradesh (when this is available), groundwater pumped from aquifers surrounding the city which is then transported by tanker lorries to the city. The last three years' rainfall has been well below average and there has been insufficient water to supply the city via the distribution network. At present, water from the treatment works is delivered to water distribution centres and then supplied by tanker to consumer households or communal tanks at the end of the street.

In the rural areas, paddy rice (two or three crops per year) is the dominant crop, irrigated mainly from groundwater. Other crops grown include sugar cane, groundnuts and vegetables. Change is taking place in rural Thiruvallur and Kancheepuram. Labour is leaving the land and turning to alternative employment opportunities, such as the construction industry, local factories sited in peri-urban districts of Kancheepuram and Thiruvallur, and weekly migration to Chennai Metropolitan Area. Abolition of inter-state tariffs has introduced a higher level of competition, with cheaper and better quality agricultural products being transported from other Indian states.

The urban poor are classified as low-income or slum resident groups and comprise nearly 1.5 million, about one-third of the Chennai Metropolitan Area population. Focus group meetings indicated that low income households' (monthly income Rs 3,300) consumption of water was 34 lcpd. The demand for water and the increasingly expensive supply options indicate that further demand management options will have to be considered and the impact on vulnerable groups will have to be considered both in the city and rural areas.

Jordan

The populations of the study areas in Shoubak and Al Jafr are about 13,000 and 12,000 respectively, settled in small villages in Shoubak but concentrated in and around the town in Al Jafr. Annual rainfall in Shoubak is abut 250 mm/yr but Al Jafr is a desert area which has no surface water resources.

Shoubak is an important fruit growing area with over 2,000 ha of drip irrigated fruit farms which have been established since the 1980s. In Al Jafr, there is a government farm of 250 ha which was set up to settled nomadic Bedouin where they can grow fodder crops and some olives. This is surface irrigated using groundwater. A number of other farmers are active in the Al Jafr area growing vegetables and olives using groundwater supplied through drip systems, some growing crops using plastic mulch and cloches.

Water supply in Shoubak is provided through the Water Authority and supplies are used by householders for both domestic water supply and to water gardens.

The aquifers at Shoubak and Al Jafr are over-exploited and restrictions will be required on both aquifers if agriculture in these areas is to be sustainable.

In the Governorate of Ma'an in which Shoubak and Al Jafr lie, 21% of the population is estimated to live below the poverty line (less than JD 156 per family per month) and this percentage is similarly reflected in the Case Study Area.

S4. Findings to date

India

The Chennai Case Study has revealed some interesting insights into the management of water both at the public supply authority and community levels. Water supplies to the city are limited, unreliable and have been seriously affected by the poor monsoon rainfall of 2002 and 2003.

The A-K aquifer, to the north of Chennai has traditionally been used to provide water for irrigated agriculture, but in 1969, wellfields were developed to supply water to the industrial area of Manali and, from 1987, new wellfields were established to supply water to Chennai city. The aquifer is currently over-exploited, by a combination of municipal abstractions and agricultural use which exceeds the sustainable yield. This has resulted in depletion of groundwater levels; saline intrusion now penetrates up to 12km from the coast.

The water supply situation is complex and exacerbated by the recent drought conditions but it is clear that managing the demand is an essential ingredient of any water policy for the area if the domestic, industrial and agricultural sectors are to be satisfied. A Water Master Plan, which introduces a demand management policy, is required for the area.

The studies to date have defined the vulnerable in the Chennai Case Study area and their current status with regard to water. The research continues with impact studies of introducing water demand management measures on the poor and vulnerable and the development of strategies which would protect these groups from any negative impacts that might arise from their introduction.

This theme was introduced at the Workshop held in Chennai on 20 November 2004.

Jordan

The studies in Shoubak and Al Jafr have demonstrated different characteristics and a range of water supply and management issues.

The principal issues relate to the over-abstraction of water from the aquifers: (i) in Shoubak where the fruit farmers are abstracting more than the renewable resource in the area; and (ii) in Al Jafr where there is a significant drop in the water table and a deterioration of the quality of the water for both domestic and irrigation water supply. Further work is required to confirm the current abstractions from these aquifers and to determine appropriate demand management options which would be effective in allowing sustainable abstraction from the aquifers.

The studies to date have defined the vulnerable in the Case Study area and their current status with regard to water. The research continues with impact studies of introducing water demand management measures on the poor and vulnerable and the development of strategies which protect these groups from negative impacts from their introduction.

PART I INTRODUCTION

1. THE RESEARCH PROJECT

1.1 Background and objectives

The project is part of the UK Government Department for International Development (DFID)'s Knowledge and Research Programme. The initial concept was developed by Black & Veatch Consulting Ltd in line with the DFID agenda on poverty alleviation and within the context of the UN Millennium Development Goals.

Groundwater is the principal source of both irrigation and domestic water supplies in many arid and semi-arid countries. However, many of these countries are already consuming more water than is available from renewable resources. In some areas, over-abstraction of groundwater is leading to saline intrusion and deteriorating water quality.

Demand management of water is required if these aquifers are not to be over-exploited. A variety of measures can be applied to achieve sustainability. These may have long-term benefits but their introduction may have negative impacts on the livelihoods of some sections of the community.

In the irrigation sector, technical solutions (e.g. reducing evaporative losses in existing systems), regulating water use (e.g. crop restrictions) or introducing market influences (e.g. water tariffs) can be considered. In the domestic/municipal water supply sector corresponding technical, allocative and market influences may be introduced. Where water supply is limited, measures may be adopted by and within communities to manage demand.

The poor (vulnerable farming families and domestic consumers) may be adversely affected by the introduction of water demand management measures with poverty increasing as a result. Some groups who are unable to afford the technical solutions for water conservation may be negatively affected by water quotas and crop restrictions and may be unable to meet the cost of water tariffs. Others, however, may benefit from re-allocation of the available water.

Strategies are required to ensure that, when water is short, the poor are protected and that an enabling environment is provided in which the vulnerable can escape from poverty and a climate is created in which their aspirations can flourish and be met.

The purpose of the research is to:

- examine water demand management strategies for controlling groundwater abstraction in areas where aquifers are being over-exploited, ensuring the long-term livelihoods of the vulnerable and poor are safeguarded; and to
- discuss and disseminate the findings with potential end users of the research (Donor agencies, Government and agencies involved in water management)

The research takes into account DFID objectives set out in Government White Papers Eliminating World Poverty: A Challenge for the 21st Century (1997) and Eliminating World Poverty: Making Globalisation Work for the Poor (2000) and recognises the sustainable livelihoods approach promoted by DFID.

1.2 Research programme

The research project started with initial studies in November 2003.

Other key dates are:

Inception Report, Knowledge Review and draft "Case Study Report"	June 2004
Workshops to discuss issues raised in the draft "Case Study Report"	November 2004
Final "Case Study Report"	December 2004
Water demand management strategies (draft)	March/April 2005
Water demand management strategies (discussion with Stakeholders)	September 2004
Dissemination of findings and Final Report	November 2005
Research contract completed	June 2006

This "Case Study" report was presented to stakeholders at a workshop in Chennai and at meetings in Amman in November 2004. General strategies will be developed and made suitable for dissemination to potential end-users of the research (Donor Agencies, Government agencies, NGOs and agencies involved in water management) in 2005.

The final output will be developed and prepared in a form suitable for dissemination both as a bound document and on a web-site. The studies and dissemination of findings are being carried out over a two year period. The Final Report will be available in November 2005.

1.3 Research organisations and collaborators

Black & Veatch Consulting Ltd is leading the research and providing inputs on water resources, hydrogeology, community, poverty, gender issues, economics and strategy development.

The main research collaborators are:

- VRV Consultants Ltd., Chennai and the Centre for Poverty Alleviation (CUPA), Chennai in India; and
- Jouzy & Partners, Amman and JOHUD, Queen Zein Al Sharaf Institute (ZENID) in Jordan

The following Government institutions, donor and other principal agencies have provided advice and access to data in support of the studies and we acknowledge with thanks the assistance they have given:

India

Government	Funding Agencies	Other Agencies
Ministry of Finance, Tamil Nadu	World Bank	Madras School of Economics, Chennai
Department of Public Works, Tamil Nadu	Asian Development Bank	The Megha Foundation, Chennai
Department of Municipal Administration and Water Supply, Tamil Nadu	DFID	Sadhana Rural Foundation, Chennai
Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) – Metrowater		
Institute of Water Studies, Chennai		

Jordan

Government	Funding Agencies	Other Agencies
Ministry of Planning	USAID	University of Jordan
Ministry of Water and Irrigation	EU	
Ministry of Agriculture	GTZ	
	JICA	

2. THE CASE STUDIES

2.1 Choice of case study areas

Two "Case Study" areas were selected after discussions with Government officials in India and Jordan, one based in Chennai, Tamil Nadu and the other in the Al Jafr - Shoubak region in Jordan.

Groundwater over- exploitation is prevalent in Tamil Nadu, India. Supply options are unreliable and north of Chennai the quality of water in the principal aquifer is affected by saline intrusion. In Jordan, many aquifers are being depleted because of the heavy use of water for agriculture.

The locations of the Case Study areas are shown on the maps above thus: *

3. PURPOSE OF THE REPORT

This Case Study Report, is submitted in support of Project R8332, Water Demand Management in Areas of Groundwater Over-exploitation, a EngKaR contract between DFID and Black & Veatch Consulting Ltd.

This report is aimed at demonstrating a deeper understanding of the research subject following discussions with collaborators and other stakeholders, data collection and fieldwork. The report is supported by a Knowledge Review (abstracts of the principal existing publications that are relevant to the research).

The draft report findings were discussed at a workshop in Chennai and at meetings in Amman in November 2004 and comments received from stakeholders have been incorporated in this Report.

PART II WATER DEMAND MANAGEMENT & SUSTAINABLE LIVELIHOODS

1. WATER DEMAND MANAGEMENT

Water demand management - "…the implementation of policies or measures which serve to control or influence the amount of water used". UKWIR/ESA (1996)

1.1 General

"Water demand management" has become an important element in integrated policies of water resources development. Multilateral and bilateral funding agencies involved in the water sector (e.g. World Bank, USAID, GTZ) recognise the need for a better understanding of water demand management. The International Development Research Centre (IDRC), Canada regards water demand management in Africa and the Middle East as one of its priority research areas (Ref 1). The International Water Demand Management Conference in Jordan, 30 May - 3 June 2004 (Ref.2) demonstrates the importance with which it is regarded in the Middle East and the intense effort that is being made to understand the complexities of water resource management.

Controlling and influencing the amount of water used by consumers in regions where there is a scarcity of water resources raises issues for communities, water providers and regulators for which there is rarely a simple solution.

There have been a number of attempts to categorise water demand management measures including those by James Winpenny, 1994, (Ref. 3), Professor Tony Allan, 1999, (Ref. 4) and David B. Brooks, 1997, (Ref. 5) and P. Magheira, S Taha et al, 2004, (Ref. 6). They recognise that water demand management must be seen in the context of the technical and economic viability of available water supplies and its quality, national and regional water strategies, the dependence of a region on "virtual water" and other socio-economic factors.

1.2 Supply augmentation, water quality improvement & demand management

The management of water demand becomes of key importance once:

- the available water supply can no longer meet the demand for water; and
- the supply options are neither economically nor technically viable.

An understanding of supply augmentation and water quality improvement options and their costs, therefore, is a prerequisite to the identification and evaluation of appropriate water demand management measures.

Although it is not the purpose of this research project to examine supply and water quality improvement options in detail, the table below lists the options that often exist.
Measures that could be taken to secure improved quality of water sources are listed on the right of the table and these measures may often prove of higher priority than those which aim to develop a new source of water. This generic list of measures may not be fully comprehensive but includes the principal options that have been identified on the basis of the Case Studies in Tamil Nadu and Jordan and from earlier studies in the Sultanate of Oman (Ref. 7).

Table II.1 Water supply augmentation and water quality improvement options

COMPONENTS OF WATER SUPPLY AUGMENTATION				COMPONENTS OF WATER QUALITY IMPROVEMENT			
Domestic/municipal		Agriculture		Domestic/municipal		Agriculture	
SD1	Develop additional groundwater (wellfield)	SA1	Develop additional groundwater (wellfield)	QD1	Sewage collection/reticulation system	QA1	Pollution control (reduction in use of pesticides/fertilisers, control on pollutatnt disposal)
SD2	Desalination plant (a) seawater (b) brackish water						
SD3	Blending of water supplies			QD2	Construct sewage treatment plant		
SD4	New water treatment facilities	SA2	Treat/use wastewater				
SD5	Improve/extend water distribution system (fixed infrastructure)	SA3	Improve/extend water distribution system (fixed infrastructure)				
SD6	Improve/extend water distribution system (tankers)	SA4	Retention dams & reservoirs				
SD7	Retention dams & reservoirs	SA5	Aquifer recharge: a) dam/tank b) well	QD3	Wellfield protection zones (a) Community source protection (b) Government implemented		
SD8	Aquifer recharge: (a) dam/tank b) well	SA6	Increased abstraction from surface water resources		**Industrial/commercial**		
SD9	Increased abstraction from surface water resources	SA7	Rainwater harvesting	QD4	Pollution control by: a) providing collection stations		
SD10	Rainwater harvesting	SA8	Trans basin transfer (import)	QD5	Controlled landfill and tipping		

1.3 Water demand management and supporting measures

In categorising water demand management measures, we have drawn principally on the work of Winpenny, Allan and Brooks. These authors discuss water demand management from different viewpoints but there is some consensus on the classification of measures, particularly on the division between "technical" and "allocative" measures (see Annex B) and we have built on this.

The table below shows the principal categories of demand management measures we have identified and how these have been classified as those affecting the domestic, municipal and industrial provision of water and those affecting irrigated agriculture.

The three categories of measures shown below (technical, allocative and other socio-economic measures) can only be implemented with supporting or enabling measures (or policy instruments). These associated measures are shown as a separate category at the bottom of the table.

There is a wider context within which water demand management measures for any particular area should be viewed, beyond their relationship to water supply and quality options. This context includes consideration of a country or region's macro-economic policy and future development, its strategic water security and its dependence on "virtual water".

Table II.2. Categories of water demand management measures

Category	WDM Measure	
	Domestic/municipal & industrial water	**Agricultural water**
Developmental and technical measures	**DT** Physical changes to the infrastructure which reduce losses in the supply system, improve water use by consumers and re-cycling of water in industrial systems.	**AT** Physical changes to the irrigation infrastructure or introduction of more water efficient systems (drip or sprinkler systems) and improved water management which reduces water consumption.
Allocative, financial and market based measures	**DA** Re-allocation through inter-sectoral and intra-sectoral water quotas and allocations and through water tariffs	**AA** Re-allocation through inter-sectoral and intra-sectoral water quotas and allocations, land use and cropping pattern changes, water tariffs and water markets
Other socio-economic measures	**DS** Community level management of water and measures relating to population	**AS** Establishment of water users' associations to improve water management and measures relating to population
Supporting/enabling measures	**SD** Measures required in support of the implementation of those above (e.g. legislation, regulation, public awareness campaigns, community level mobilisation and institutional changes)	**SA** Measures required in support of the implementation of those above (e.g. legislation, regulation, improved extension services and institutional changes)

[Note: The following codes are used above for generic measures: DT – Domestic Technical; AT – Agricultural Technical; DA – Domestic Allocation; AA - Agricultural Allocation; DS – Domestic Socio-economic; AS – Agricultural Socio-economic; SD - Supporting Domestic; SA – Supporting Agriculture].

We have found that there is often some confusion in the literature between water demand management measures, by which the demand is influenced, and the supporting measures (e.g. legislation, institutional changes) which are required to bring about the change, and we make a clear distinction here.

The diagram (Figure II.1) shows the principal supporting or enabling measures that may have to be considered and applied in implementing demand management measures. These may be applied by different institutional levels or groups (e.g. through public administration or community intervention).

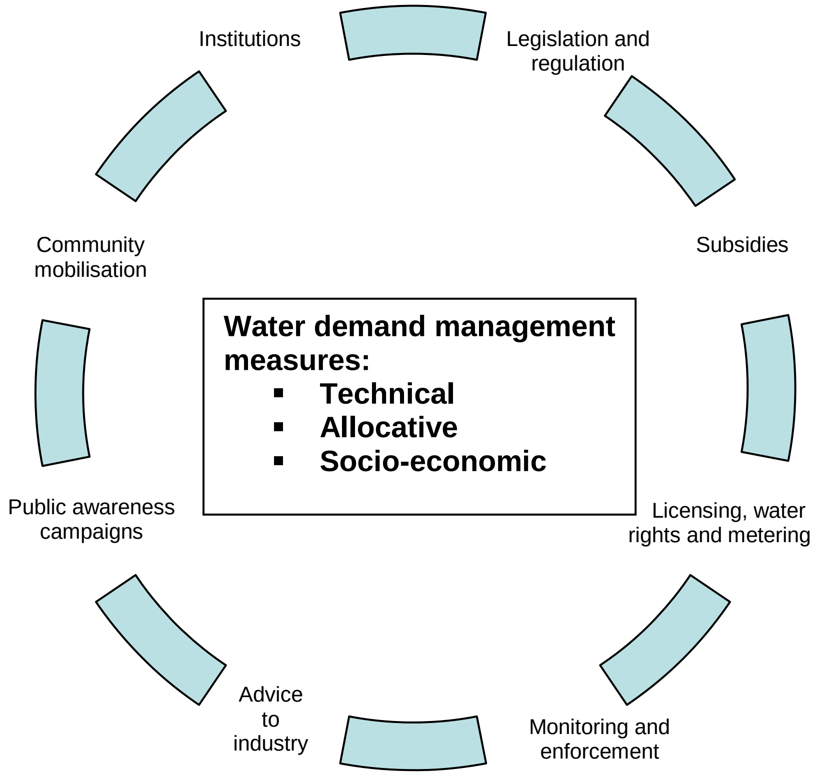


Figure II.1 Water demand management supporting measures

The ultimate purpose of demand management is to control or influence the amount of water used and Figure II.2 illustrates how such measures might be brought to bear on the demand for water so that it does not exceed the available supply.

It shows how demand management measures can contribute to the solution when the available water (including treated poor quality water) cannot meet the demand.

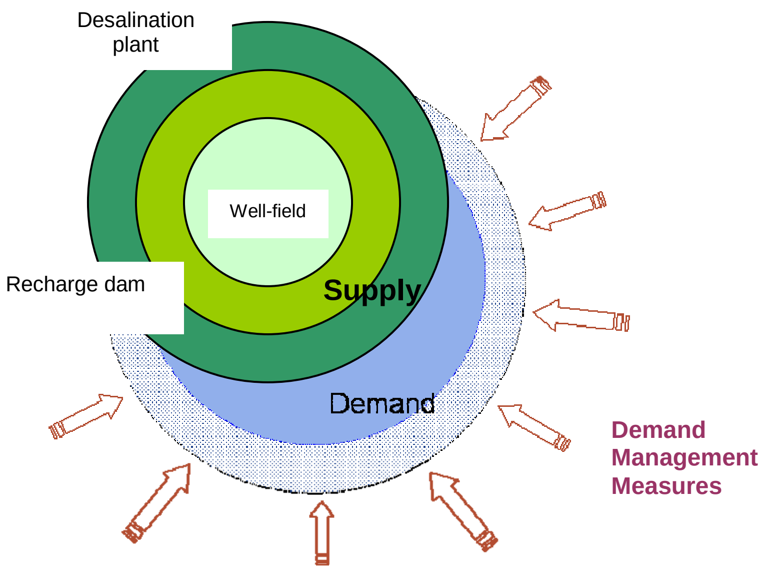


Figure II.2 Purpose of demand management

In Figure II.2 overleaf, the three concentric circles show examples of a number of supply options of increasing unit cost. As the cost of supply increases or water resources become limited, measures are required to control or influence the demand for water.

1.4 The wider context

There is a wider context within which water demand management measures for any particular area should be viewed, beyond their relationship to water supply and quality options. This context includes consideration of a country or region's macro-economic policy and future development, its strategic water security and its dependence on "virtual water". The issue of "virtual water" has become one of increasing interest and importance to regions were renewable resources are limited, see for example Allan, J.A, 1998, (Ref. 8) and P. v Hofwegen, 2004, (Ref. 9).

1.5 Demand management options

The research to date has identified a range of demand management measures that could be adopted and which fit within the three generic categories described above. These are listed in the table below.

Table II.3A Water demand management measures

	WATER DEMAND MANAGEMENT			
		Domestic/municipal		**Agriculture**
Developmental and technical measures	DT1	Reduce consumer water losses	AT1	Improve efficiency of surface irrigation systems
	DT2	Water saving devices and fittings	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT3	Recycling of industrial water		
	DT4	Use of "grey" water		
Allocative, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land use change and control	AA3	Land use change to control:
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population density regulation	AS2	Population density regulation
	DS3	Migration	AS3	Migration

Table II.3B Supporting or Enabling Measures

		Domestic/Municipal		Agricultural
Supporting or enabling measures	SD1	Community mobilisation (DS1)	SA1	Increase Extension Services (AT1, AT2, AA5)
	SD2	Public-Private-Community Participation (DS1)	SA2	Public awareness (AT2, AA1, AA2, AA4, AA5, AA6)
	SD3	Public awareness campaign to reduce wastage (DT1, DT2, DT4, DA1 & DA2)	SA3	Subsidy introduction (AT2a)
	SD4	Encourage industry to recycle water (DT3)	SA4	Metered agricultural wells (AA1, AA2, AA7)
	SD5	Metered water supply (DA3)	SA5	Legislation & regulation (AA1, AA2, AA3, AA4, AA5, AA6, AA7)
	SD6	Legislation & regulation (DT2, DT3, DA1, DA2, DA3, DS2)	SA6	Monitoring and enforcement (AA1, AA2, AA4, AA7)
	SD7	Institutional – community agreements	SA7	Licensing/registration, water rights and associated legislation (AT1, AT2, AA1, AR2, AR3, AR7)

A distinction is made in the table above between those measures where:

(i) Additional water supply options begin to become technically or economically impractical.

In these instances, developmental and technical measures (DT & AT) or allocative, financial and market based measures (DA & AA), may be considered. The measures would be implemented through regional or central government institutions, making use of the appropriate policy instruments (shown as supporting or enabling measures at the bottom of the table).

and

(ii) The supply of water is already limited or unreliable.

In these instances, in addition:

(a) other socio-economic measures may be adopted. The measures may arise spontaneously or may be encouraged at community level. For instance, community may take action or be encouraged to manage the demand of the community either to ensure:

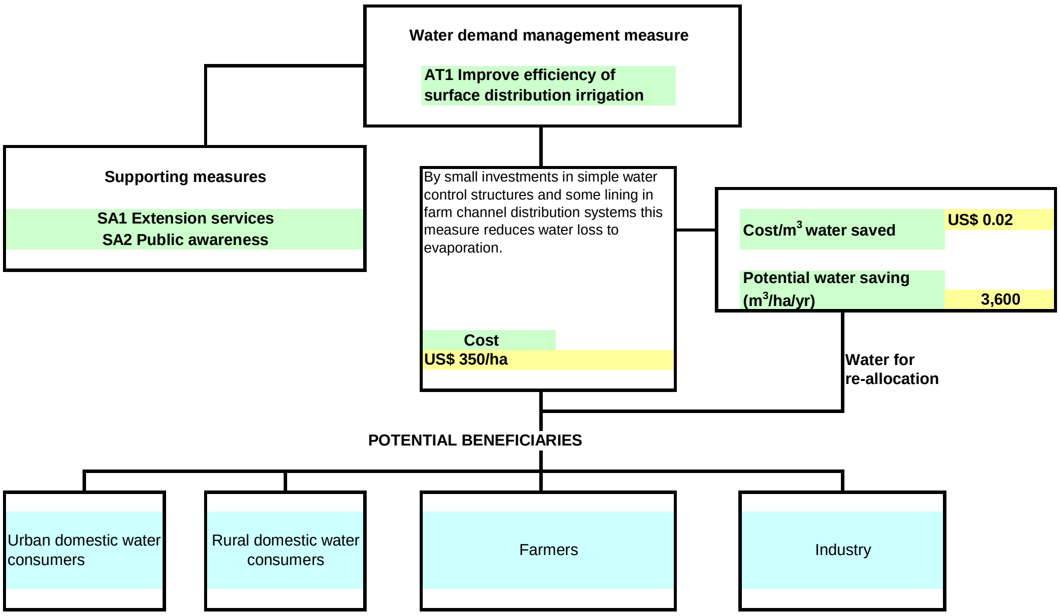
- at least the limited quantity of water reaches the community;
- an equitable (or other) level of distribution of the limited water available is made;
- access to other diverse sources of water; or

(b) people may move to less water scarce areas (e.g. farmers or farm labour may migrate or move to other employment.

1.6 Potential water savings & the cost of water saved by demand management

The introduction of a water demand management measure will normally have a cost and provide water savings, thereby, either contributing to sustainability of a resource or making water available for other consumers. The measure may have an impact on individuals and communities by providing a re-allocation or redistribution of water. In Figure II.3, an example is given of a water demand management measure, the supporting measures required, its cost, the cost of water saved and the potential water savings by introducing the measure.

Figure II.3 Impact of water demand management measure – example



In this example, water may be saved by reducing evaporative water losses on the farm. The water may then be available either to reduce the over-exploitation of an aquifer or for increasing the agricultural cropping intensity or for transfer to beneficiaries in urban areas or elsewhere. Where the water is pumped from the ground by the farmer, the investment in water saving infrastructure may also be offset by reduced pumping costs.

Examples of the costs and benefits of a number of water demand management measures are discussed in Annex F of this report.

2. LIVELIHOODS AND VULNERABILITY

2.1 The sustainable livelihoods approach

The aim of the research project is to develop strategies for water demand management which take into account their impact on the livelihoods of the vulnerable and poor.

The Sustainable Livelihoods Approach (SLA) has its roots in the work of Conway and Chambers, 1991 (Ref. 10), subsequently developed through the work of NGOs such as Oxfam and Care International, and prioritised by DFID since 1997 (Ref. 11).

Over the past ten years, the SLA has experienced several interpretations and broadened its intellectual and practical applications over a number of sectors. In general, it is based on addressing the following[1]:

- the priorities of the poor;
- a responsive and participatory approach in addressing the needs and concerns of the poor;
- adopting a holistic view towards poverty reduction;
- the need for multiple partnerships across sectoral divisions;
- the sustainability of approaches;
- flexibility of approach to enable adjustments to be made to changing circumstances.

A "livelihoods approach" towards poverty and water use is also interpreted as a "people-centred approach" rather than a technical approach, R. Calow & A. Nicol (Ref. 12). Numerous case studies have been sponsored by DFID, to support and refine this approach based on experience and best practice. The SLA has proved helpful in several ways, including:

- improving integration of people-centred project planning and implementation;
- enhancing an understanding of the complex dimensions of poverty;
- encouraging flexibility during the course of project implementation, based on realities on the ground;
- supporting new development initiatives;
- encouraging inter-disciplinary working.

Simultaneously, the SLA has encountered obstacles which are no less significant in determining whether or not the concept has a viable application in the broader development context. Key limitations identified by development practitioners and listed by Allen & Sattaur (Ref. 13) include:

- missing links: the SLA fails to make sufficiently explicit the links between poverty, power relations, gender, environment and human rights;
- over-intellectualisation of SLA, and lack of practical and simple tools and methodologies to support implementation under existing project and budget cycles;
- holistic working in a sectoral environment is difficult at best and distinctly discouraged in some circumstances;
- monitoring and evaluation: it is difficult to attribute livelihood outcomes to specific project interventions;
- difficulty in translating the concepts;
- oversimplification of complex realities;
- expectations raised beyond the competence of communities/institutions/projects to meet them.

The Case Studies in India and Jordan exhibit conditions where both SLA strengths and weaknesses are reflected. Adopting a people- and poverty-centred approach for this section of the Case Study analyses has enabled identification of links between poverty, water and livelihoods impact. These links emerge from analysis of the fieldwork data described in Annex D.

[1] An excellent review of the strengths and weaknesses of the SLA is by Catherine Allen & Omar Sattaur, *Sustainable Livelihood Approaches: Engaging with SL or just best development practice?*, Paper presented at Bradford Workshop, 29-30 May 2002.

Fieldwork investigations also confirmed the multiple and complex issues relating to water demand management as well as to poverty analysis in different rural and urban contexts.

Demand management is as much a social and political issue as a technical one. Developing, implementing and enforcing water demand management options that are people-centred is almost a contradiction in terms. Governments throughout the world are often reluctant to force people to curtail abstraction, foreseeing huge social and economic impacts on large sections of the population, or at the least, on small sections of the population with high levels of social and political influence. Water related legislation and regulation, to be effective, has to have tacit agreement or, at least, the understanding of those to whom it applies.

While the Sustainable Livelihood Approach encourages and enables people's needs to be integrated into planning and management of water resources, it cannot substitute this for the current realities of water management and delivery responsibilities

2.2 Water-Poverty links

Water scarcity is caused by multiple factors. To address these factors, a variety of responses must be taken at multiple levels. Integrating differing water demand interests has always been a challenge that frequently leaves the poor worst off. Aquifer use and management usually involve a number of agencies which cross administrative and political boundaries. Moreover, it is not unusual for different types of water users to ignore the fact that other people's water needs are not met, provided their own needs are satisfied.

A feature of water demand management is that different priorities may be placed by different water managers and users on different aspects of managing demand. This sometimes leads to a polarisation of attitudes and, in some cases, to a lack of integration in determining rights, roles and responsibilities. Those least able to argue their case or bring their needs to the attention of decision-makers, are least well served. Characteristics of water-poverty links have been described by Arthur McIntosh in a recent Asian Development Bank publication[2] (Ref. 14).

Poverty, in itself, is also a highly complex issue. The relationship between water and poverty is characterised by the nature of the links between water availability, water demand, and the ability of individual households to use their different assets most effectively. Water users with greater economic, social or political weight access water and influence demand management strategies more effectively than those without. It is, thus, important for the water needs of the vulnerable to be adequately represented in strategic planning for water demand management. This then begs several questions:

- how are poverty and vulnerability defined in relation to water demand?
- what methodologies will allow vulnerability assessments to be incorporated in sector planning?
- how can the needs and interests of the vulnerable be protected in implementing a sector plan?

2.3 Vulnerability assessment

There is no "one-link is universal" in relating water to poverty. Poor communities in some locations experience severe inequities in relation to water access; others do not. Some

[2] Arthur C. McIntosh, *Asian Water Supplies: Reaching the Urban Poor*, Asian Development Bank and International Water Association, ADB 2003

may experience water shortages, but vulnerability impacts may be reduced by a supportive community or through social networks.

From the Case Study fieldwork in India and Jordan, some common indicators of poverty in relation to water became apparent and the development of a methodology to assess vulnerability highlighted several issues:

- the dimensions of poverty are highly complex;
- there are significant rural/urban differences, for which planning processes need to account;
- vulnerability, in relation to water resources, sometimes relates to socio-economic differences in a community, but may affect entire communities regardless of socio-economic differences;
- the higher the socio-economic status of water users, the higher the expectations for water supply;
- issues of resource management, demand management and supply management cannot be separated. Actions relating to one affect management of another. Integration of management systems is needed to develop a balanced system that can meet basic water needs;
- water/poverty links include: political issues; social issues; economic issues; gender issues; and technical issues;
- the more complex the assessment methodology, the less likely it is to be adopted.

The SLA provides a useful basis for defining poverty and vulnerability in relation to water demand and use in terms of an asset base. For the purposes of this study we have, therefore, defined the poor and vulnerable as: **those households whose basic needs of food, shelter, health, livelihood and sense of empowerment, outstrip the resources available to meet those needs and consequently are more likely to experience harmful or negative impact as a consequence of water shortage.**

During fieldwork in both India and Jordan, the five key SLA assets, (human, financial, socio-political, natural and physical) were evaluated. Examples are given in the table below of lack of assets and their impact on the poor and vulnerable.

ASSET	EXAMPLE OF ASSET LACK ENCOUNTERED DURING RESEARCH	EXAMPLE OF IMPACT ON POOR AND VULNERABLE
HUMAN	Absence of working adult males in proportion to number in household	Children taken out of school to wait for water deliveries.
FINANCIAL	Daily wage labour dependent, below local average monthly income.	Unable to purchase water storage facilities, overhead tanks.
SOCIO-POLITICAL	Low levels of knowledge, use of tools and technologies, no effective social or political influence.	No power to influence water service providers.
NATURAL	No ownership of water resource.	Heavily dependent on external water suppliers, location determines quantity and quality of supply.
PHYSICAL	No land or property, poor quality housing.	No space or right to install borewell.

2.4 The Poor and Vulnerable in Survey Areas

Based on the above definitions, the most vulnerable were identified as follows:

Chennai (see Annex D, D2.4.5):

- elderly persons living in high rise apartments blocks in notified slum areas
- women-headed households from low income groups with no adults of working age
- women of child-bearing age
- low income groups in particularly densely populated inner city localities
- residents of areas with poor public supply
- non-formalised slum dwellers
- households dependent on daily wage earning

Jordan (see Annex D, D3, 3.4):

- women-headed households with no working adult males
- women of child-bearing age in households with no water-storage facilities
- elderly persons with no working adults to assist
- families with little or no education and reduced work options

2.5 Incorporating Vulnerability Assessment in Sector Planning

Because of the complex nature of relating poverty, competing water demand interests and multiple institution involvement and their priorities, multi-criteria analysis (Ref. 15) was used as the principal methodological guide. The procedure developed depends on simple rating and ranking systems and was arrived at after several steps. It became apparent that this system required fine-tuning depending on the audience. This took the form of two-phases.

The **first phase** was conducted with communities (see Annex C). This was developed based on an analysis of fieldwork output, and provided critical information on (i) the sort of person most vulnerable to water shortages; (ii) indicators which could be used to determine impact.

The **second phase** comprised impact evaluation with sector planners. The methodology was pilot tested in the Chennai workshop (November 2004), using six simplified Vulnerability Indicators, compared to the ten more detailed Indicators used at community level.

The identification of indicators is discussed in detail in Annex C and their application to the Case Study Areas in Parts III and IV below.

While decision-makers need appropriate information about the scope and extent of vulnerability in relation to water, and appropriate ways of obtaining that information, developing the methodology proved a good learning exercise on how not to develop over-theoretical models. It led to an assessment of well-being in relation to water which could help planners evaluate the conditions they confront, alert them to issues likely to cause difficulties in future, and adjust plans accordingly.

Armed with this knowledge, planners can determine the most relevant priorities for an area or for a target group. For instance, it

- makes subsequent planning of WDM measures more relevant to different communities, integrating pro-poor strategies into the planning process;
- can generate higher interest and ownership of actions and results with target groups;
- is more cost-effective, channelling funds and resources most appropriately;
- accommodates the needs of different water users, taking account of localities, socio-economic group and gender;
- enables qualitative and community-based comparisons to be made in a methodologically sound fashion.

Different water users have different priorities and apply different indicators to determine levels of satisfaction. These can include, among others, technological indicators, health, livelihoods and quality standards. During the Case Studies, it was apparent that the focus shifted depending on the stakeholder consulted. The first priority for developing a vulnerability assessment methodology is, therefore, to integrate stakeholder priorities (community and institutional priorities) in a single framework.

PART III TAMIL NADU CASE STUDY

1. THE CASE STUDY AREA

1.1 Description of the area

The Case Study area is centred on the city of Chennai in the north-eastern corner of Tamil Nadu State. The Chennai area is characterised as forming part of a coastal plain with hills in the west and a gentle slope towards the east and the shore of the Bay of Bengal. The ground elevations vary from 150m above sea level in the west to just above mean sea level along the coast.

There are four rivers flowing through the study area and these are grouped together to form the Chennai Basin Group. These rivers are from north to south the Araniyar, Koratalaiyar, Cooum and Adayar. The Araniyar and Koratalaiyar are the main rivers and originate in Andhra Pradesh to the north, whereas the Cooum and Adayar originate from surplus flows within Tiruvallur and Chembarambakkam taluks and drain through the Chennai Metropolitan Area.

The climate is subtropical with mean annual temperatures of 24^{o}C (min.) to 33^{o}C (max.). The hottest and driest part of the year is April to May when the temperature may exceed 40^{o}C. The average total rainfall varies between 1000mm/annum in the west and 1215mm/annum in the east and is provided by the south west monsoon from June to September and the north east monsoon from October to December. Most of the rainfall occurs as the result of one or two tropical depressions formed in the Bay of Bengal. The NE monsoon is usually the wetter of the two, providing about 50% of the annual total rainfall. The SW monsoon is more erratic and provides about 40%. The remainder of the year provides about 10% of the annual rainfall.

1.2 Economic background

Tamil Nadu

Tamil Nadu consists of 30 districts covering a geographical area of 130,000 km^2 with a total population of 62.41 million (2002). The surface area of Tamil Nadu covers 4% of the India but population comprises 6% of that of the country.

The GDP of Tamil Nadu in 2001-2002 was Rs 1,309.2 billion at current price. The annual growth rate of the state GDP was 5.9% in the period 1993-2002.

The Primary sector (agriculture, forestry and fishery) plays an important role in the State's economy but its contribution to the economy has reduced from 26% in 1993 to 18% in 2002 due to the growth rate of the Tertiary sector (business and services). During the period 1993-2002, annual growth rates were 0.8%, 5.7% and 8.5% per annum for the Primary, Secondary (Industry and construction) and Tertiary sectors respectively.

GDP per capita in 2002 was Rs 13,055, equivalent to about US$ 650. Summary details are given in Table III.1.

Tamil Nadu's Tenth Five Year Plan (2002 - 2007) proposes to expand the agricultural sector at a rate of 4% per annum. The target for overall growth rate of GDP is 8% during this period with a reduction of poverty level from 21% in 1999-2000 to 10% in 2007.

The net area sown in Tamil Nadu in 2001 was about 5.3 million ha of which about 2.9 million ha (55%) is irrigated from canals, tanks, wells and other sources to grow principally paddy and sugarcane crops. Main agricultural production outputs were paddy (7.37 million tons), total cereals (8.55 million tons), groundnut (1.36 million tons) and others such as cumbu, rag and cholam with about 300-400 thousand tons each crop.

Export values by sea and by air through Tamil Nadu were Rs 269.8 billion in 1999-2000 (occupying 17% export value of all India) and Rs 117.4 billion in 2000-2001 (occupying 6% export value of all India)

Table III.1 Selected Economic Indicators Tamil Nadu State

(Rs billion - Fixed prices 93-94)

	Sectors	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
I	PRIMARY	135.50	151.21	131.07	129.70	141.22	153.52	146.82	150.42	144.50
1	Agri-forest-fish	132.43	147.90	127.97	126.77	138.11	150.67	143.77	146.88	140.93
2	Mining & quarrying	3.07	3.31	3.10	2.93	3.10	2.85	3.05	3.54	3.58
II	SECONDARY	166.01	189.37	209.23	207.62	212.53	210.76	239.38	247.65	258.21
III	TERTIARY	214.25	239.27	260.04	286.87	324.42	354.44	371.69	393.14	412.14
IV	GDP	515.76	579.85	600.35	624.19	678.17	718.71	757.90	791.21	814.86
V	POPULATION ('000)	57,670	58,340	58,992	59,624	60,235	60,821	61,381	61,913	62,416
VI	GDP/capita (Rs)	8,943	9,939	10,177	10,469	11,259	11,817	12,348	12,779	13,055
VII	GDP growth (%/year)	-	12%	4%	4%	9%	6%	5%	4%	3%

Source: Statistic hand book, Tamil Nadu 2002

Case Study area

Most of the activities in the Case Study area are centered on the city of Chennai. Most of the farming communities comprise marginal farmers who depend on jobs in the city for their livelihood. There has been a trend for the last 10 years of sending young people to the city for work and investing in better education for their children for better income and improved social position. This has resulted in a shortage of labour for agricultural activities especially at peak season demand.

There are about 18,000 small scale industries, 124 large and medium industries of various disciplines. These provide good employment opportunities for the basin population as well as to the migrants from other parts of the Tamil Nadu.

The area has great potential to attract tourists. The area is well connected by roads and rail. The Chennai harbour and Meenambakam airport provide major facilities to tourists and from other economic activities.

2. WATER RESOURCES – POLICY, INSTITUTIONS & LEGAL FRAMEWORK

2.1 Water Policy

The Ministry of Water Resources, Government of India formulated a "National Water Policy" in September 1987 as a basis for overall planning and development of water resources.

Many of the general policy items of Central Government have been absorbed into the Tamil Nadu State water policy.

In 1993, the Government of Tamil Nadu formed a Water Resources Control and Review Council (WRCRC) to formulate water management strategies and to develop and implement a water policy. The power and functions of the WRCRC are to:

- establish allocation priority norms for water use for different sectors (taking as a given that "the provision for drinking water has the highest priority");
- formulate water management policy and, after acceptance, implement and monitor;

- examine the impact of extraction, utilisation and conservation of water by its users;
- formulate water policies for State and basin water development, control and management;
- establish principles, standards and procedures for allocation of water under licences, preparation of comprehensive regional and river basin plans and for formulation and evaluation of water policy and related land resources projects using technical, economic, social, legal and environmental criteria;
- serve as an advisory and co-ordinating body for the State in water related matters;
- review and approve State and river basin master plans; prioritisation of different sectional water needs;
- review and approve macro planning, distribution management and water resources taking into account the water needs of different sectors;
- review and approve for publication an annual assessment of the adequacy of supplies of water necessary to meet the present and the projected State and basin water requirements;
- issue orders as may be necessary to carry out its functions.

Based on the national water policy of the Government of India (1987), the Government of Tamil Nadu formulated the Tamil Nadu Water Policy. The Institute of Water Studies (IWS) drafted the policy in January 1994 and this was approved in July 1994. IWS was appointed to act as the implementing agency for the policy. The ultimate aim of the policy was to develop a State Water Plan.

In addition, the water policy encourages participatory approaches to field level problems; training is considered as an integral part of water management. The Government of Tamil Nadu's Water Policy accepts that water rates should be given a purpose; they should be such as to convey the scarcity value of the resource to the users and foster a sense of economy in water use.

Importantly, the river basin is seen to be the unit of water management and for water resources planning. The policy accepts the need for State Framework Water Resources Basin Plans. These are being prepared for each of the seventeen river basins. Four of the basin plans have been prepared (2003). The Case Study Area comes within the Chennai Basin (Araniyar, Kortalaiyar, Cooum and Adayar rivers). The Chennai basin plan is still to be prepared.

2.2 Institutions

(a) Government Institutions

The principal organisations involved in the development and management of water resources in the Case Study Area are:

- Water Resources Organisation, Public Works Department;
- Tamil Nadu Water Supply and Drainage Board;
- Agriculture Department;
- Agricultural Engineering Department;
- Revenue Department;
- Chennai Metropolitan Water Supply and Sewerage Board;
- Rural Development Department;
- Pollution Control Board;
- Department of Municipal Administration; and
- Fisheries Department.

2.3 Legislation and regulations

Government of India legislation

The two principal Central Government Acts relating to the Case Study area are those listed below:

- Inter-State Water Disputes Act No 33 of 1956, and as Amended
- Rivers Boards Act No 49 of 1956 as Modified [relates to inter-State rivers]

These are relevant in the way that they relate to the supply of water to Tamil Nadu from Andhra Pradesh and in particular to the Krishna river supply which is the subject of an agreement between the State Governments.

Tamil Nadu legislation and regulation

There are a number of State of Tamil Nadu Acts relating to the Water Sector and the Study Area. These are concerned mainly with water abstraction, use of water from government managed schemes and pollution. The key legislation relating to the case study area is as follows:

Chennai Metropolitan Area groundwater (Regulation) Act no 27 of 1987 and as Amended

Chennai Metropolitan Water Supply and Sewerage Act, Tamilnadu Act No 28 of 1978 as modified 31 August 1981

Tamilnadu Water Supply and Drainage Board Act No 4 of 1971 and as Amended

Tamilnadu Panchayat Act No 35 of 1958 as Amended

Details of these, which deal principally with regulation of abstraction of water, and other relevant regulations are given in Annex G

3. WATER RESOURCES DEVELOPMENT

3.1 Water resource availability

The water supply to Chennai city is derived from both surface water and groundwater sources. The study area is shown on Figure III.1.

Surface Water Development

The first organised public water supply was put into operation in 1772 and was designed to supply 0.635 million litres per day (Mld) from a cluster of ten shallow wells. The water supply of Chennai city was for many years obtained solely from these shallow wells and it was not until 1866 that a public water supply scheme was adopted. The scheme combined the city water supply with irrigation of 3500Ha and commenced in 1872. The surface water flow from the Koratalaiyar river was diverted to Cholavaram and then to Red Hills reservoirs located some 20km to the northwest of the city. Further development, which took place after 1907, which included construction at Red Hills, an underground conduit to convey water to the city and extensions at Kilpauk Water Works provided a design supply of 160lpcd.

To meet the increasing demand for water in the city, the irrigation supply from the reservoirs was discontinued sometime during the 1940's or 50's. The treatment capacity of Kilpauk Water Works was increased to 190Mld and the Sathyamurthy Dam was constructed between 1940 and 1944 across the Koratalaiyur river to form a third reservoir at Poondi.

The current storage capacity of these reservoirs are as follows: Poondi - 91.49 Mm^3; Cholavaram - 24.95 Mm^3; and Red Hills - 93.44 Mm^3

In 2000, water from Chembarambakkam reservoir (103.21 Mm^3), which is located some 25km to the southwest of Chennai city, was also utilised for city water supply.

In March 2004, due to insufficient rainfall, only water from dead storage is available from all the reservoirs. Only 10 to 15Mld from the dead storage in the Red Hills reservoir is being diverted to the city, treated at Kilpauk Water works and put into the distribution system.

Groundwater Development

In the 1950's, the water supply was augmented by groundwater supply from shallow wells within the city boundaries, particularly in the suburbs. Further groundwater development occurred after 1968 based on a UNDP/PWD study, which recommended development of well fields in the Araniyar-Koratalaiyar (A-K) aquifer to the north of the Chennai Metropolitan Area.

The A-K Basin aquifer comprises alluvial deposits of an old buried channel of the Palar river. This aquifer extends from the vicinity of Poondi reservoir to the north east of Chennai to the Minjur area to the north of the city over an area of roughly 750km^2, which includes the course of Koratalaiyar river and the lower reaches of the Araniyar river. Groundwater occurs under unconfined or confined conditions in the A-K Basin. In its lower part, roughly downstream of Tamaraipakkam, the aquifer is layered and further downstream it is confined. An impervious base of Gondwana formation comprising shale, clay, underlies the alluvium. Recharge into these alluvial aquifers is mainly from precipitation, flow through the river beds, water bodies and return flow from the irrigated fields. The quality of water is generally good.

Based on the UNDP/PWD study recommendation, three well fields, Tamaraipakkam, Panjetty and Minjur were developed in 1969, with a designed total capacity of 125Mld (Tamaraipakkam 50Mld, Panjetty 42.5Mld and Minjur 32.5Mld). The groundwater from these well fields mainly supplied water to the industrial area at Manali, which is to the north of Chennai city, contributing only a little to the city supply.

To meet the additional demand in the early 1980s, CMWSSB (Metrowater), with the assistance of UNDP, reassessed the groundwater potential in the A-K Basin and looked for new sources. This resulted in the commissioning of three new well fields during 1987, with a designed total capacity of 55Mld (Poondi 28Mld, Flood Plains 13.5Mld and Kannigaiper 13.5Mld). The total designed capacity from all six well fields is 180Mld. However, the maximum reported abstraction from these six well fields was 120Mld in the year 1987, when the additional three well fields were made operational.

A second groundwater source is utilised for public supply to parts of the the city. This aquifer is located to the south of Chennai city and extends along the coast of the Bay of Bengal for about 20 km between Thiruvanmiyur and Muttukadu. The groundwater from this aquifer is pumped from 22 dug wells and supplied to the southern part of Chennai city.

3.2 History of water resource studies

There have been a number of studies carried out since the early 1980s. These are summarised below in chronological order. Further details are given in Annex E.

1. Hydrogeological and Artificial Recharge Studies, Chennai, UNDP/CMWSSB Studies (1982-91)

2. Groundwater Resources and Development Potential of Chengai MGR District, Central Ground Water Board (1991)

3. Groundwater Resources and Development Prospects in Chennai District, Central Groundwater Board (1993)

4. Hydrogeological and Sea Water Intrusion Studies between Thiruvanmiyur and Muttukadu by RITES – CMWSSB (1995-96)

5. State Frame Work Water Resources Plan of Tamil Nadu, Public Works Department (1998).

6. Groundwater Exploration in Tamil Nadu and Union Territory of Pondicherry Central Ground Water Board (1998)

7. A profile of Thiruvallur District, Tamil Nadu Water Resources Organisation (Public Works Department), 2000

8. Second Chennai Water Supply Project, Scott Wilson Piesold, for CMWSSB (2002)

The consultancy services for the Second Chennai Water Supply Project, to reassess the groundwater potential and transferable water rights in the A-K basin, was awarded to Scott Wilson Piesold (SWP). In Phase I of the study, the firm has carried out a hydrogeological investigation to establish a sustainable yield for Chennai City water supply of 100 Mm^3 per year or 270Mld. On establishing this sustainable yield, Phase II of the study, which includes presentation of proposals for introducing transferable water rights in the A.K basin has been started.

3.3 Development and current use of water resources

Surface sources

The main source of water supply to the city of Chennai is from three reservoirs namely Poondi, Cholavaram and Red Hills, located to the northwest of the metropolitan area. These reservoirs receive surface water flows during monsoon rains, particularly during the North East monsoon, from a system of anicuts and canals as well as from their direct catchment areas. Chembarambakkam reservoir, to the southwest of Chennai city, has also been included in the Chennai water supply system since 2000.

The water supply to the city from these reservoirs depends upon the storage available. The appreciable increase in water supply during 1996 to 2002 is attributed to the additional storage available in the reservoirs due to contributions from the Krishna Water Scheme.

Groundwater sources

The City gets its groundwater supply from two main sources:

(i) Well fields in the Araniyar-Koratalaiyar (A-K) Basin
(ii) Southern Coastal Aquifer.

(i) Well Fields

There are six well fields in the A–K Basin extracting groundwater. The locations of these well fields are shown on Figure III.1.

The Tamaraipakkam, Panjetty and Minjur well fields were established during 1969 and the other well fields, Poondi, Flood Plains and Kannigaiper were established in 1987. There are 74 bore wells in the six well fields. The major part of the extraction from these well fields goes to the industrial area at Manali Town

The average extraction from the 21 production wells is 20Mld (7.3Mm^3/yr).

Due to the limited supply of surface water and ground water from the six wellfields available to CMWSSB, agricultural wells are now being hired from farmers to extract groundwater to manage the current severe drought situation. This system of renting agricultural wells was started in April 2001 and at present about 60Mld (21.9Mm^3/yr) is being extracted from these wells.

Where it is not possible to get a cluster of bored wells, groundwater from two or three wells is collected and transported to the city by tankers/lorries. At present around 50Mld (18.3Mm^3/yr) is supplied to the city in this way from villages within a 100km radius of Chennai city.

(ii) Southern Coastal Aquifer

This aquifer, to the south of Chennai city, extends along the coast of the Bay of Bengal for about 20 km between Thiruvanmiyur and Muttukadu. The groundwater from 22 shallow open/dug wells is pumped to the Thiruvanmiyur head works for further distribution to the southern part of Chennai city. Presently about 3.5Mld (1.28Mm^3/yr) is being extracted from these wells.

4. THE ABSTRACTION AND MANAGEMENT OF GROUNDWATER

4.1 Historical trends

Groundwater in the A-K Basin

Groundwater is abstracted from the A-K basin for both irrigated agriculture in the basin area and for transfer to Chennai City for domestic and industrial consumption.

A summary of the abstraction and management of water used for the city water supply from the six well fields of the A-K Basin up to March 2004 is given below.

Poondi

The total depth of the aquifer ranges from 24 to 35m and the average aquifer thickness is 31m.

At the start of operation in 1988 the average water level was 19.3m below ground level. The water level declined to a low of 22.5m by 1993. There was gradual recovery from 1994 onwards. This was partly due to reduced abstraction of groundwater in 1998 and 1999, when an additional source of surface water from the Krishna Water Scheme was put online. Due to insufficient rainfall from 1999 onwards, lack of surface water storage in the reservoirs and a return to the earlier higher abstraction rates, the water level in the well field started to decline again and the average water level in March 2004 was 24.3m below ground level.

The maximum annual abstraction from this well field was 16.38Mld (6Mm^3/yr)in 1994. The present average annual abstraction from this well field is 10Mld (3.65Mm^3/yr).

Tamaraipakkam

The total depth of the production wells ranges from 28 to 38m, with an average aquifer thickness of 35m. The average water level during 1969 at the start of operation was 12.8m below ground level and since then it fell until 1993 but improved again to 1999. The average water level during 1999 was 2m above the 1969 level.

Due to insufficient rainfall since 1999, lack of surface water storage in the reservoirs and twice the normal abstraction from the wellfield in 2000 the water level in most of the production wells has now fallen below the minimum required pumping level. The average water level for the month of March 2004 was 30.8m, which is the lowest recorded level in the past three decades. The maximum abstraction from this well field was during the year 1969 (34.2Mld), the initial year of operation, and second to this was during the year 2000 (32.2Mld).

Flood Plains

The total depth of the production wells range from 29 to 36m and the average aquifer thickness is 35m. The average water level during 1988 at start of operation was 21.5m below ground level and then there was a slight decline until 1993 when like other well fields, it started showing an improvement until 1999. Due to the reduced abstraction over the period 1993 to 1999, the water level during 1999 was nearly 8m above the 1988 level. However, due to insufficient rainfall since 1999, lack of surface water storage for supply and the above normal abstraction in 2000, the water level has fallen and in March 2004 was 32.2m below ground level. The average water level in 1988 (21.5m) was more or less maintained and it had not fallen below the 1988 level until 2000. The average water level in March 2004 is 32.2m below ground level. Since the average depth of the aquifer in this area is 35m, the water column available for pumping is not sufficient and hence no production wells in this well field have been working since September 2002. The maximum pumped quantity was achieved in the initial year of operation in 1988 (9.12Mld), after that it has gradually reduced and finally during 2002, it was only 0.69Mld.

Kannigaiper

The average thickness of aquifer in this area is 33m. The average depth to water level during 1988 was 22m and this was maintained until 1999. Since 2000, there has been a gradual depletion and the water level in March 2004 was 31.8m. Since there was not sufficient water column for pumping, none of the wells has operated since December 2002. The maximum annual abstraction from this wellfield was during 1988 (9.42Mld). Since the initial year of operation the quantity abstracted has gradually reduced and finally during 2002 the abstraction was only 0.72Mld.

Panjetty

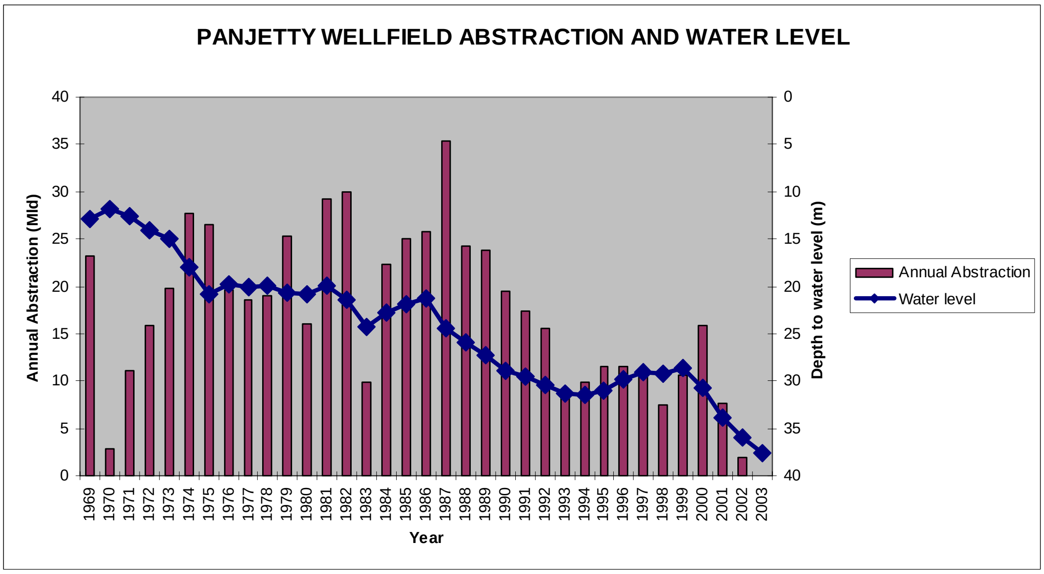
The average water level during 1969 was 12.9m and it is shows a gradual depletion since then with some minor short-term fluctuations until 1993. Then as with the other wellfields there was a slight recovery of water level up to 1999. The water level in March 2004 is 39.4m below ground level and the average thickness of the aquifer is 42m. None of the production wells has operated since December 2002. The maximum abstraction achieved was 35.36Mld during 1987 and the lowest extraction was 1.99Mld during 2002.

Minjur

About 22 wells have been constructed in the Minjur area since 1969. At present only eight wells are operational and all the other wells have been abandoned due to salinity. Even though this part of the aquifer has the highest groundwater potential because of thicker aquifer and larger saturated thickness, the quantity abstracted is restricted due to the threat of seawater intrusion. The average water level during 1969 was 11.8m below ground level and was below Mean Sea Level. The ground elevation of this well field area ranges from 2.9 to 12.2m above MSL. The average water level has fallen to 23.8m during 1993. Due to the continuous depletion of water level and progressing seawater intrusion, the abstraction rate has been gradually reduced since 1987. Because of this measure and the above normal rainfall, the water level rose again to 16.2m during 1999 (i.e. 7m rise). However, due to the requirement to supply water during drought conditions, the abstraction has been slightly increased. The maximum withdrawal from this well field during 1978 was 28.42Mld, but at present the withdrawal is limited to 10Mld. The average water level during March 2004 is 30.2m below ground level.

Graphs showing annual abstraction and annual rainfall plotted against average depth to water level are given in Annex E. A typical situation is illustrated in Figure III.2.

Figure III.2 Panjetty wellfield – abstractions and water level



Southern aquifer

Groundwater from this aquifer is being extracted by 19 shallow open/dug wells with a total depth ranging from 7.75 to 11.60 m. There are eight wells in the Neelangarai area and eleven wells in the Akkarai area. Abstraction from individual wells ranges between 0.06 to 0.50Mld. The wells are located along the coastal area between the East Coast Road and the Bay of Bengal. Groundwater abstracted from these wells is pumped to the Thiruvanmiyur head works for further distribution. Presently about 3.5Mld is being pumped from these wells.

4.2 Current groundwater resource abstractions (2002-3)

The A-K Basin

The average abstraction from the 21 operational production wells in the six wellfields is now 20Mld (7.3Mm^3/yr).

Due to the limited stored quantities of surface water and decreasing yields from the wellfields, agricultural wells are hired from farmers to extract groundwater to manage the current severe drought situation. At present, there are 15 collection sumps in the A-K basin and there is a proposal to have more. Each collection sump supplies about 5 to 8Mld. This system of hiring agricultural wells was started in April 2001 and at present about 60Mld (21.9Mm^3/yr) is being extracted from these wells.

In addition, around 50Mld (18.25Mm^3/yr) is collected from village wells within a 100km radius and transported to the city by tankers and lorries.

Southern aquifer

Groundwater from this aquifer is being extracted by 19 shallow open/dug wells located along the coastal area between the East Coast Road and the Bay of Bengal. Presently about 3.5Mld is being extracted from these wells.

4.3 Groundwater source availability

The A-K Basin

A number of estimates have been made of the annual recharge to the A-K aquifer. The UNDP study in 1987 estimated that the annual recharge to the A-K Basin was 450Mm^3.

This included recharge from rainfall, infiltration from river beds and irrigation returns. The UNDP study also gave an estimate of average annual abstraction of 350Mm^3 over the period 1980 to 1984.

Based on these figures they concluded that during normal or above normal rainfall recharge exceeds consumption. The UNDP study also made estimates for well field areas for the same period (1980 to 1984). The average recharge for this period was calculated to be 367Mm^3 and abstraction 354Mm^3. In dry years such as 1982, where recharge was estimated as 172Mm^3 and pumping abstraction was estimated as 382Mm^3, the difference was met from groundwater storage.

In the SWP study, the A-K aquifer was modelled and estimates were made of the annual recharge to the aquifer. The annual recharge for the period 1970 to 2002 was calculated and varied from a low of 209Mm^3 in 1974 to a high of 585Mm^3 in 1976 with an average over the whole period of 350Mm^3. The calculated total annual abstraction (irrigation and municipal) from the aquifer varied from a low 260Mm^3 in 1995 to a high of 430Mm^3 in 1980 with an average over the whole period of 344Mm^3.

An inspection of the average depth to water level plots for all six wellfield areas shows that there was an overall increase in depth to water level indicating over abstraction was taking place.

The modelling of the aquifer has indicated that, for City water supplies, a yield of 100Mm^3/year under normal rainfall conditions and 70Mm^3/year during drought periods is sustainable. For planning purposes, the SWP study has recommended that the sustainable yield for the A-K Basin aquifers should be taken as 70Mm^3/year.

4.4 Treatment and distribution

There are two water treatment plants at present treating the raw water from the three reservoirs Poondi, Cholavaram and Red Hills: 270 Mld Kilpauk water works and 300 Mld Treatment plant at Red Hills. A third treatment plant (530Mld) is under construction and situated beside the Chembarambakkam reservoir.

CMWSSB is in the process of implementing a Water Supply and Sewerage Master Plan that will;

- endeavour to meet the water demand for the projected population of Chennai city for the year 2021 and
- ensure equitable distribution of water throughout the city.

Apart from four existing water distribution stations, located at Kilpauk, K.K. Nagar, Southern Head Works and Anna Poonga a further 12 additional water distribution stations were planned as part of the master plan for utilisation of additional supply from Krishna river. Out of the 12 stations, five stations at Valluvarkottam, Triplicane, Choolaimedu, Kannaparthidal and Ekkattuthangal were taken up under HUDCO funding and are now completed. The balance of seven stations, Koluthur, Vyasarpady, Patel Nagar, Pallipattu, Mylapore, Nandanam and Velachery were taken up under World Bank assistance as part of the Second Chennai Water Supply Project.

At present, the water from the treatment works is delivered to the Water Distribution Stations by the transmission mains and is then being supplied to the surrounding areas only by tanker lorries, due to shortage of water.

CMWSSB (Metrowater) decided to expand its area of operation around the city into the Adjacent Urbanised Area (165km^2) and in the Distant Urbanised Area (142km^2) expecting the receipt of Krishna water. The work was to be undertaken in two phases.

Due to the prevailing drought condition, there is not sufficient water even to meet Chennai city's requirements. Therefore, the water supply to the AUA and DUA will be undertaken when there will be enhanced water storage in the four surface water reservoirs from rainfall and Krishna water transfers.

The diagram below (Figure III.3) illustrates the water balance in the study area for a normal year and, in parenthesis, for a dry year. The figures given are approximate and are based on the recent studies by SWP and others.

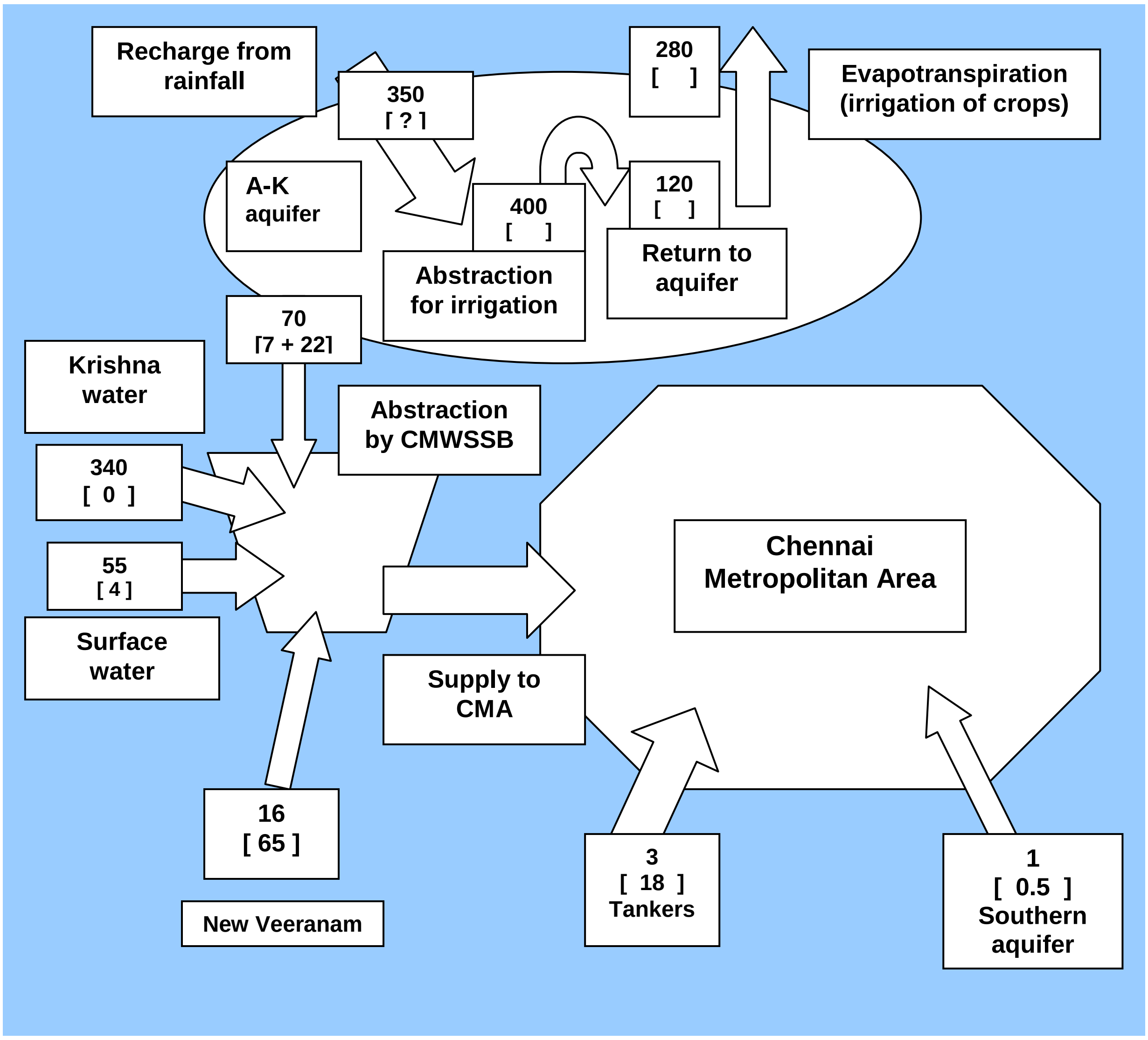


Figure III. 3 Study area water balance during normal year [and dry year] (Mm^3/yr)

5. THE POOR AND VULNERABLE

5.1 Surveys undertaken

Site Selection and Focus Group Discussions (FGDs)

Discussions were first held with Government and non-government agencies to determine areas within the study area which were: (i) under significant stress due to over-extraction; (ii) serve as primary domestic and irrigated water sources for dependent communities and urban consumers. Within the Study area, which includes the Araniyar/Koratailaiyar (AK) aquifer within the Chennai Basin and the Chennai Metropolitan Area (CMA), urban and rural locations were selected for fieldwork representing five location types;

- slum localities in CMA
- prosperous localities in CMA

- designated industrial zones of peri-urban areas of CMA in Thiruvallur and Kancheepuram districts
- rural sites overlying AK aquifer
- rural sites in the AK basin

The locations of Focus Group Discussion sites surveyed are shown on maps in Annex D. 153 (46 rural agriculturally-dependent and 107 urban domestic households were represented in the Focus Groups with an overall average household size of five. Three industries, one large business and one small enterprise were also interviewed.

Demography of the Survey Areas

The population of Chennai Metropolitan Area (CMA) and peri-urban areas is given in Table III.2. The overall urban growth in CMA and its two neighbouring districts has been 35% in the last decade, reflecting CMA overspill and growth of a peri-urban area which supports industries and, increasingly, residential areas.

Farm land in peri-urban districts are now giving way to housing plots, boosted by the presence of the metropolitan area as a work location, proximity to good communication and transport facilities, and better availability of water. The latter is a strong factor in house and land values.

Table III. 2 Urban growth rates, 1991-2001

District/ Metropolitan Area	Urban Growth Rate '91-'01	Total Population 2001	Total Urban Population 2001
Chennai Metropolitan Area	13.07%	4,343,645	4,343,645
Kancheepuram	55.77%	2,754,756	1,500,082
Thiruvallur	36.05%	2,877,468	1,534,966

There is regular urban migration from peri-urban districts, on a weekly or daily basis, creating a weekly water demand bulge which may not be reflected in official figures. There are also scores of informal and uncounted squatter colonies of semi-permanent nature whose residential status has not been formalised as have those termed as "slum dwellers".

The poor, classified as low-income or slum resident groups, officially totalled 1.4 million in 2001[3]. This is approximately one-third of the total 2001 Census population of the CMA.

Poverty in the Survey Areas

Tamil Nadu prepared a Human Development Report (TNHDR) in 2002, in co-ordination with the Union Planning Commission, which prepared the first all-India Human Development Report in March 2002. In the foreword to the TNHDR, the Chief Minister points out that development objectives are defined not just in terms of an increase in GDP or per capita income but more broadly in terms of enhancement of human well-being (indicated by factors such as attainment of education, health, life expectancy, access to safe drinking water, sanitation facilities).

Development of a national and state perspective on human development, and by association, poverty alleviation, is a positive step taken. The next step is to link these perspectives to practical poverty alleviation targets and pro-poor actions to reach them. A

[3] Sources: Tamil Nadu Slum Clearance Board 2001 and Continuing Education Department, Corporation of Chennai, 2004

key action was the establishment of the Tamil Nadu Slum Clearance Board in 1984, which continues to play an important role together with the Public Works Department in implementing various housing, slum improvement and rehabilitation and resettlement programmes to improve living conditions of urban slum families.

However, the needs of the poor outstrip resources available, and under circumstances of stress, such as the current water shortage, whether households can meet their daily needs highlights key poverty issues. These were identified first through wealth ranking exercises, which provided community criteria of socio-economic differences.

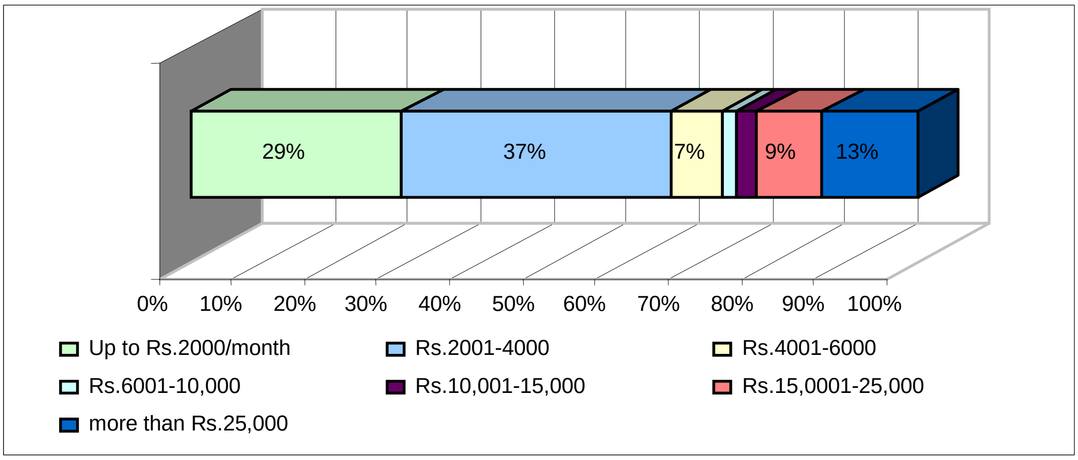
From such criteria it was possible to make the links where and how water stress is experienced by the poor as compared with other income groups. In Chennai, key features relating water and poverty include:

- lack of human assets (too few adults mean no-one is available to wait for water deliveries)
- lack of financial assets (insufficient household funds to pay for direct water connections, water storage facilities, independent borewells, or bulk purchase)
- lack of socio-political assets (no power to influence service providers)
- lack of natural assets (dwellings are rented, small and in crowded areas. There is no space to install borewells and tankers cannot negotiate the narrow lanes)

Poor urban localities are characterised by crowded conditions and large number of families in small spaces. This means a higher dependence on external water providers, particularly via piped supplies to street tapstands and handpumps, as larger water transport (ie. tankers) cannot negotiate the narrow lanes.

Figure III.4 shows income classification of the total number of Focus Group participating households.

Figure III.4 Representative income categories, FGD respondent households

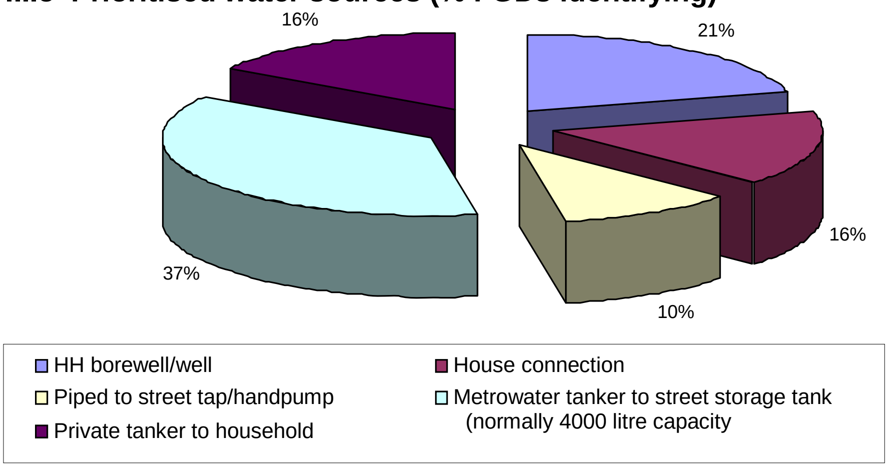


5.2 Domestic water use, Chennai

Diversification of Sources

Thirteen separate domestic water supply sources were identified. The most favoured are shown in Figure III.5.

Figure III.5 Prioritised water sources (% FGDs identifying)



Rainwater harvesting methods have been made compulsory by state government, although all respondents expressed frustration that since implementing recommended measures there has been very little rainfall. Among low-income households, 43% of respondents are implementing simple forms of rainwater harvesting, such as catching and storing rooftop runoff. 100% of high income households have installed improved guttering and well recharge equipment.

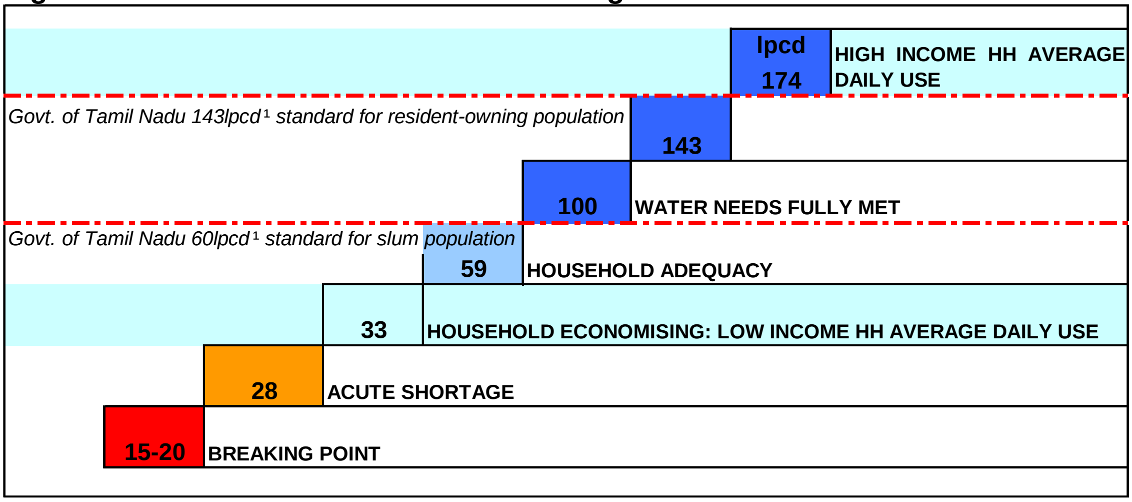
Water Security

Figure III.6 illustrates differences in water security between households from different income groups, and the proportionately greater vulnerability of the poor. Boxed numbers show average household water consumption rates according to Focus Group respondents, though some localities in CMA are reported to receive only 10 litres per person per day. North Chennai is worst affected.

Respondents were asked what constituted water security to them, and how much less could they manage with before their condition became worse than it was at the time of the survey. Poor households were easily able to identify stress levels. High income households could not identify these as easily and already considered their present situation one of acute shortage, despite average consumption being 31lpcd over Metrowater's standard for higher income households.

There appears to be no shortage of water supply for those that can pay for it. Not only can higher income households afford the more expensive bottled water as well as regular tanker deliveries, they can achieve economy of scale with storage tanks which are filled regularly (on average every 3-4 days, depending on storage capacity). Prosperous localities are also better served by roads which can accommodate large private tankers.

Figure III.6 Water Stress Thresholds among FGD Households



1: lpcd = average number of litres used per person per day

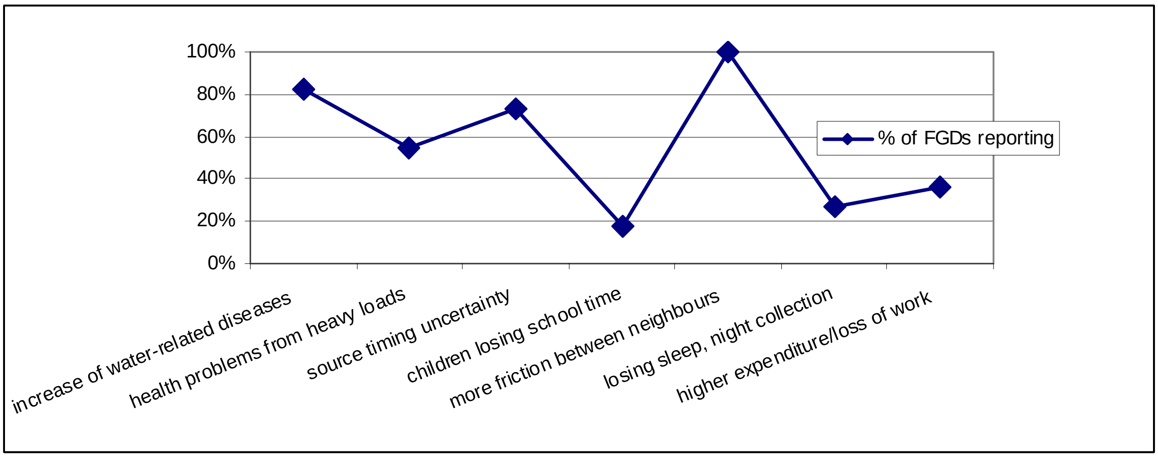
Many household wells in all parts of Chennai have been dry for some 2-3 years. For those with financial capital and land space, existing bores are deepened or new ones dug. The difference in well depth (depending on location) ranges between 25-40ft. five years ago, up to 80ft. at present.

Household connections in all FGD locations have been cut off for the past 2 years, with the exception of one high income locality. All FGD respondents said water supply from direct connections and wells decreased in the past three years, while dependence on tanker delivery and bottled water has increased by 81% and 54% respectively.

All FGD respondents said they took 1-2 hours daily in fetching or waiting for water. One particularly poorly served area (Taramani) and some households in Pullianthope reported spending more than 4 hours a day in fetching water. Reports of water problems are summarised in Figure III.8.

Figure III. 7
Water collection from Syntex tank, Chennai

Figure III.8 Focus Groups reporting increases in water problems in the past year



Costs

Basic costs of domestic water supply and water connections are set out in Tables III.3. The price varies from location to location, and the sort of payment differs from area to area; prices given are averages from all used sources.

Table III.3 Recurrent household domestic water costs

Type of water supply	Average price per litre
Private tanker	Rs. 0.06
Metrowater tanker load to shared street Syntex tank subsequently distributed to households by pots	Rs. 0.02
Tricycle trip to water loading station (including tricycle hire charge)	Rs. 0.08
Bottled/Canned water	Rs.1.20

The cost of a household water connection is well beyond the means of poor households. The average monthly household water expenditure of respondents (excluding costs, such as waiting times, livelihood impact, electricity charges for pumping, energy consumed in water treatment (e.g. boiling)) was calculated as a proportion to total monthly disposable income. Low income households (consumption 34 lcpd; income Rs 3300) pay about 4% and middle income families (consumption 110 lcpd; income RS 7,500) around 1% of their income on water.

Conflicts

All households said they experience higher levels of conflict over water, sometimes between communities and water authorities or controllers of supply, but primarily between each other over distribution. The importance given by focus groups to types of problem, were inequity of distribution 44%; irregularity of supply 20%; failure of supply, 12%; water quality 12% and water quantity 12%.

Most households attempt to resolve water shortage difficulties by complaining direct to Metrowater, either collectively or individually. However, many FGDs pointed out their dependence on intermediaries to address their needs and their powerlessness to effect any change independently. Some of the poorest areas have resorted to direct action by blocking roads.

Coping Strategies

Higher income households respond to shortages from their normal supply sources by purchasing more bottled water and paying for private tanker delivery.

Low income households cannot afford to purchase more and cope by spending more time looking for alternative water sources. This involves longer distances to collect water from a wider number of supply sources. Many slum areas have been re-built as tenement blocks, and carrying buckets of water up flights of stairs is laborious. Intensive labour in accessing domestic water automatically represents a water management technique; if water is easily available from a tap, people tend to use this more freely and with less regard to amounts used.

Poor households are also the first to start making economies in their time, budgets and water use. 57% of poor FGD respondents said water shortages have had a negative impact on livelihoods. Livelihood impacts include:

- loss of wages due to non-attendance at work while waiting for water supplies
- loss of work opportunities due to irregularity of water delivery timing
- loss of work due to illness from water-related diseases
- reduced labour capacity due to poorer nutrition
- higher expenditure for medical treatment
- higher expenditure to purchase meals outside (no time to prepare food at home)
- higher expenditure for water purchases
- higher expenditure to local water distributors
- high levels of customer dissatisfaction with water supply managers

Of those households already economising, women are the first in the family to do without. The most vulnerable are:

- the elderly who cannot afford to hire domestic help, particularly those living in blocks of flats
- women-headed households from low-income groups with no adults of working age (women earn less than men, they have responsibility for the children, they have responsibility for the domestic budget which includes water costs)
- women of child-bearing age (burden of carrying heavy loads)
- low income groups in particularly densely populated inner city localities relatively inaccessible to large vehicles
- those residing in poorly served areas
- non-formalised slum dwellers
- households dependent on daily wage earning

The most serious limitations of water shortages from the point of view of poor respondents are inequity of distribution of existing water supplies and timing uncertainty of deliveries, regardless whether the supplier is Metrowater or from a private source.

Satisfaction Levels

Overall satisfaction levels proved lower among high income households than middle and low income households. Expectations among the poor are very low and are related to their perceptions of empowerment. Poor respondents felt their only strength was in numbers and through direct action. Expectations concerning competence and representation of local leaders were correspondingly low.

Dealing with Change

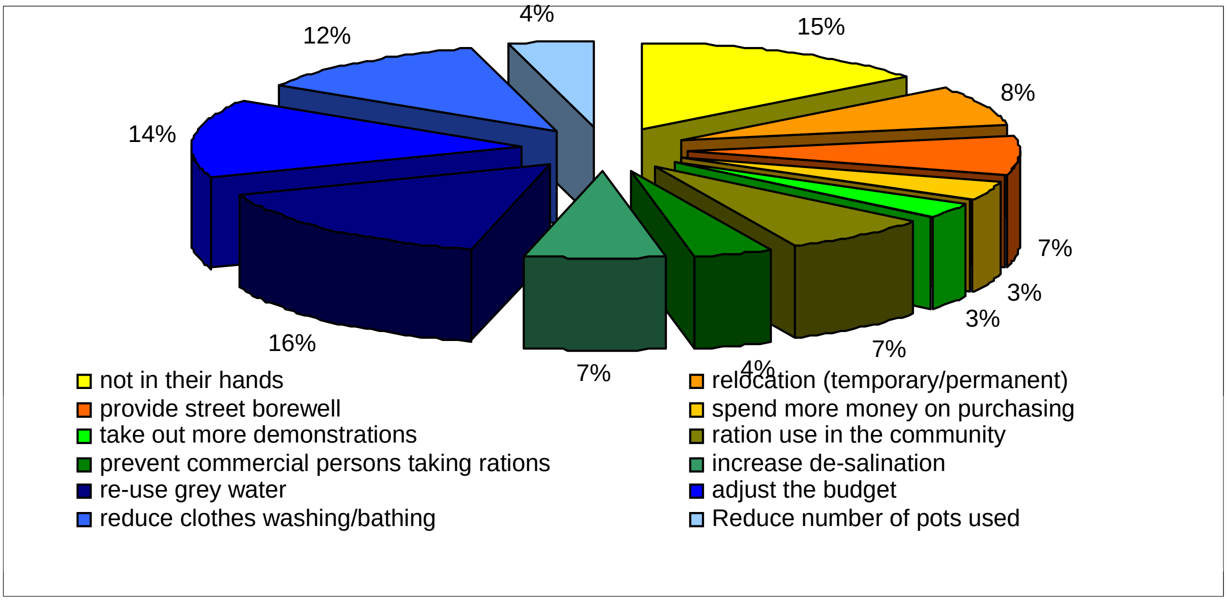
The water supply situation has become worse in Chennai over the past two years. Household economies and coping strategies thought to be temporary have now become established.

Respondents were asked the question: "If water supply stays the same or becomes even less, what methods will you adopt to cope with this?"

Responses fell into roughly three categories:

- how to obtain more water, revealing low levels of awareness about causes of groundwater scarcity (yellow wedges)
- how to deal with current water access grievances, indicating dissatisfaction levels about the equity of existing water supplies and improving neighbourhood water demand management (green wedges)
- how to manage with less water, implying acceptance of a worsening situation and adopting household water demand management measures (blue wedges)

Figure III.9 Respondent attitudes to dealing with water quantity changes (%FGD responses)



5.3 Agricultural water use, Chennai

In the six FGD locations in the AK basin, approximately 92% of households own or rent land for agricultural purposes. Of the 46 agriculturally-dependent respondent households in the FGDs, landholdings averaged 14 acres per household. The smallest average landholding was in Pandeswaram (2 acres), the largest in Jothinagar (40 acres). The majority of land is cultivated (89%); very little has been left fallow as a consequence of water shortage. The lowest rate of cultivation was in Orakkad, at 62% of landholdings.

The principal crops are all water-intensive. Paddy is the most important, with 86% of FGD locations cultivating. Sugar cane is also grown together with fruits (mangoes, guava, banana) and pulses. Increasingly, farmers are cultivating low water-intensive and high profit crops such as groundnut and green gram. 66% of farmers practised three cropping seasons, the remaining 34% two seasons.

Diversification of Sources

The main source of irrigation water is farmer-owned borewells (66%). 17% of FGDs identified some farmers sharing or purchasing water from another's well. Only 17% of FGDs reported dependence on traditional rainfed tank irrigation.

In the FGD locations, most farmers do not practise water-saving techniques, though a small number in two villages do water their fields via pipes to reduce evaporation. Two households use drip irrigation for fruit trees. No-one used sprinkler irrigation, or mulching as a means to reduce water loss. Only one farmer pipes rainwater to recharge his well.

Water Security

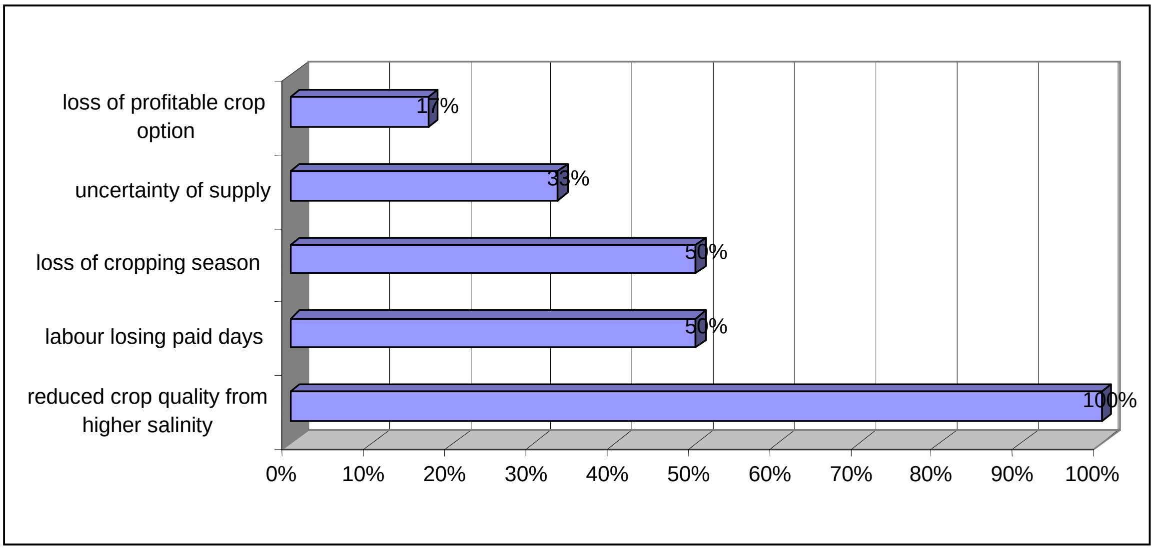
67% of households said irrigation water was regularly available, and average pumping time per household was 17 hours a day. One FGD reported borewells dry up to six and nine months of the year. The other FGDs stated borewells are never dry, but perceive a decrease in water availability. A third of FGDs complained about uncertainty of water supply. FGD responses to questions about borewell water quality indicated that groundwater quality is variable, even within the same village. (17% reported very saline water; 50% slightly saline water; and 33% good to very good water). Most farmers have deepened their wells in the last five years by an average of 40 feet. Some villages are involved in selling water to urban suppliers, both to Metrowater and private suppliers.

Conflicts

There is virtually no conflict between farmers and government, though there is much grumbling, particularly over the failure to maintain the tank system and to construct rainwater catchment checkdams. Farmers from all villages complain of the demise of tank irrigation due to lack of maintenance or alternative use by cultivators or sand extractors, both of which they regard as illegal. Excessive pumping from river beds by both Metrowater and private companies is also a grievance.

Other identified shortcomings relating to groundwater as illustrated in Figure III.10.

Figure III.10 Key shortcomings with groundwater (% FGDs identifying)



Coping Strategies

Despite the stated availability of irrigation water, 66% of FGDs claim water problems (overdraft of the aquifer and poor water quality) have affected their livelihoods. However, they acknowledged that livelihood decline was set in train by other factors such as non-availability of agricultural labour, and water difficulties have simply accelerated the process. Livelihood impact in the rural context is not all directly attributable to water problems, nor as severe as it is in the urban context. Even so, there are livelihood impacts which include reduced productivity, reduced crop quality, reduction in area planted and increasing debt., and farmers have adopted corresponding coping strategies.

Satisfaction levels

There are much higher levels of confidence among farmers as water-users than among urban dwellers. Despite their stronger sense of empowerment compared with urban dwellers, satisfaction levels over aspects of water are universally low. Those with higher dependence on tank irrigation are least satisfied with both availability, quality and quantity of tank water. However, most farmers no longer depend on tank irrigation and are independent with their own borewells. FGD results on satisfaction levels with borewell water indicated that more than 80% were dissatisfied with water quality and 50% with water quality and availability.

Dealing with Change

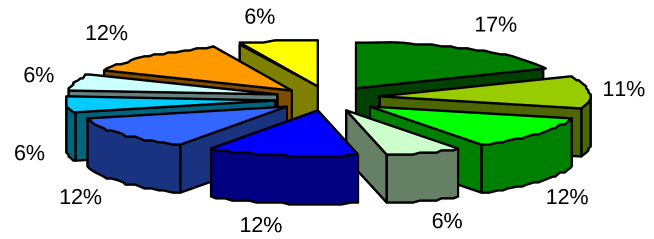
Change is taking place in rural Thiruvallur and Kancheepuram. Labour is leaving the land and turning to alternative employment opportunities, such as the construction industry, local factories sited in peri-urban districts of Kancheepuram and Thiruvallur, and weekly migration to Chennai Metropolitan Area. Abolition of inter-state tariffs has introduced a harsher level of competition, with cheaper and better quality agricultural products being transported from other Indian states. On top of this has come several years of low rainfall and an ever-increasing urban demand for water. The combination has proved an unhappy one for farmers in Thiruvallur and Kancheepuram, many of whom see the future, for their children if not for themselves, as an urban one.

The impact has not really been felt so much by the poorest landless agricultural workers. Presented with alternatives, they are increasingly leaving the land. The impact is most felt by marginal farmers with few financial and human assets to work the land, who find themselves increasingly indebted with no apparent way out. Water scarcity and decreasing quality is pushing them into a state of economic unviability, and landowners reported distress sale of cattle due to non-availability of fodder.

During the period of fieldwork, Tamil Nadu state declared a moratorium on bank loans for six months, in an effort to support farmers until harvests were in. Despite these efforts, state agricultural production targets are maintained without compromise, reflecting a need to improve co-ordinated water demand management across sectors. Respondents also complained the agricultural sector has been run down through lack of traditional irrigation infrastructure maintenance, and failure to promote water saving land use methods such as transfer to profitable drought resistant crops and promotion of water saving irrigation techniques. Some forward-thinking farmers have pursued these alternatives and report positive and profitable results.

FGD respondents were fairly gloomy about the future of agriculture in their villages. When asked the same question as urban water users about water supply levels and standards remaining the same or becoming worse, replies reflected an approximate balance between those who want to stay on the land and improve agricultural opportunities (green wedges), and those who would choose to give up agriculture as a way of life (blue wedges). A small proportion responded on the relationship between rural groundwater supplies and urban demand (yellow wedges).

Figure III. 11 Respondent attitudes to dealing with groundwater situation (% of FGD responses)



Industrial Water Use

Industry is an important water user in Chennai, 40 large industries accounting for CMWSSB's main sources of revenue. Some industries re-use wastewater and have installed on-site recycling plants for the purpose. Madras Fertiliser Ltd. and Chennai Petrochemical Corporation Ltd. are the best known, having set up their own tertiary treatment plants to reuse secondary treated water, resulting in a saving of 19Mld.

However, wastewater recycling is not pursued as actively as it might, and both large and small industries are responsible for major contamination of both ground and surface water sources. Hundreds of small industries discharge untreated effluent directly into waterways, such as the Cooum River and Buckingham Canal, and FGDs reported significant variability in borewell quality depending on proximity to contaminated sources.

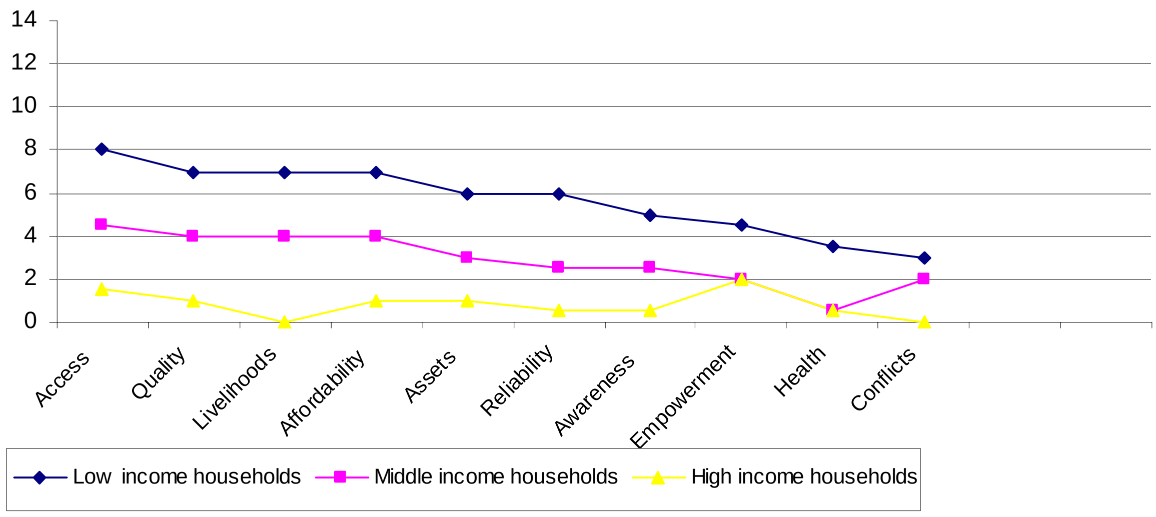
5.4 Vulnerability assessment, target groups identified

On the basis of the methodology described in Section II.2 above and in Annex C, a test assessment of vulnerability was prepared for Chennai for socio-economic categories of low, middle and high income households.

Using fieldwork data collected from Focus Group Discussions, an assessment of how respondents in different localities might have assigned values, was made. A certain amount of external judgement combined with community assessment is needed with this exercise in any case, as some sections of the community may project their situation as better or worse than it actually is.

The result of the vulnerability appraisal for Chennai is given below.

Figure III.12 Vulnerability assessment, Chennai



The chart shows that the highest impact for poor and middle income households is "access", followed by "poor water quality", "impact on livelihoods" and "affordability". For high income households, all these issues have some, but not much impact. The highest rated issue for rich households is empowerment, with low presence of effective community representation and inadequate ability to protect the water source.

Overall, we can see that low income households are severely affected at all levels in comparison with high income households. Middle income families are also affected, though to a lesser degree.

The rating and ranking exercise can be employed to evaluate vulnerability in relation to a variety of water demand management priorities and this theme was discussed during the Workshop held in Chennai in November 2004. In complex water demand management situations, this enables vulnerability assessment to be incorporated into overall planning to manage a situation with multiple types of water users and multiple reasons for water scarcity.

The methodology is simply a way to systematise and record qualitative observations and judgements related to water and vulnerability. There is nothing fixed about the rank or rate of indicators. Indeed, it is expected that different stakeholders will assign ranks and weights in different ways. It is through comparison of these differences that planners can be alerted to critical differences, enabling them to adjust their planning accordingly.

It should be stressed, however, that this exercise does not replace other qualitative and quantitative information gathering exercises. Indeed it can be more valuable when taken in conjunction with other tools, to enhance understanding of any given situation. Further details are given in Annex C.

6. WATER DEMAND MANAGEMENT

6.1 Current management strategies

The water resources development of Chennai and the agricultural areas to the north of the city are described in Section III.3. The demand for water for domestic, industrial and agricultural use exceeds the available supply. Water supply to the Chennai Metropolitan

Area (CMA) is currently inadequate and unreliable. The Chennai Metropolitan Water Supply and Sewerage Board (CMWWSB), Metrowater is now looking at ways of increasing resources. These include:

- increased abstraction rights from the A-K aquifer, an aquifer which is currently over-exploited and which is used extensively for irrigated agriculture;
- desalination of seawater and blending with existing supplies;
- construction of recharge dams;
- rainwater harvesting;
- further water transfers from Andhra Pradesh (from Krishna river);

Although a wide range of supply options are being considered by the Government of Tamil Nadu to provide water for Chennai, a number of issues arise with regard to the water supply for domestic and industrial use and provision of water for agriculture in the area. These include:

- unreliability of monsoon rainfall
- unreliability of supply from inter-State water transfer
- over-abstraction from A-K aquifer, falling groundwater levels and saline intrusion
- competition for water between agriculture and city water supply requirements
- inequity of domestic water supply distribution between different socio-economic groups in Chennai
- expanding urban population (1.3 % per annum)

Further consideration will have to be given to introducing appropriate water demand management measures. The potential options for the domestic, industrial and agricultural sectors are given in Table III.4 below.

Measures in place include those shaded [green box] below. These are:

- changing land use; well buy-out or rental by CMWSSB from farmers (the transfer of water rights is now under consideration); and

- in response to the shortages, communities within the City in some areas have taken on an informal role in managing the demand from domestic users by organizing equitable distribution and in effect implementing a quota system at community level;

In addition, some sectoral and intra-sectoral water demand quotas are planned by CWMSSB (e.g. for Chennai Metropolitan Area: 60lpcd for slum population, 143 lpcd for residential population, 133 lpcd for commercial organisations with 18,000 l/ha/day for institutional/industrial demand, although these can not be met at present);

6.2 Demand management options

If we look at the range of options which could be considered or encouraged, a first step would be to define inter-sectoral and intra-sectoral water allocations and quotas more precisely (measures DA1/AA1, DA2 and AA2 shaded [light blue box] below).

Table III.4 Water demand management options - Chennai

	WATER DEMAND MANAGEMENT			
	Domestic/municipal		Agriculture	
Developmental and technical measures	DT1	Reduce consumer water losses	AT1	Improve efficiency of surface irrigation systems
	DT2	Water saving devices and fittings	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT3	Recycling of industrial water		
	DT4	Use of "grey" water		
Allocative, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land use change and control	AA3	Land use change and control by: a) land purchase b) re-zoning/classification c) well buy-out (transfer of water rights)
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population density regulation	AS2	Population density regulation
	DS3	Migration	AS3	Migration

The basic steps in this process are:

(i) define the priority demands (e.g. domestic water quotas per capita, population and demographic trends; industrial demands; environmental demands)
(ii) calculate an appropriate allocation for the priority demands
(iii) determine the supply options and sustainable yields
(iv) calculate the water availability for other uses (i.e. principally agriculture)
(v) define the allocations to the different water using sectors.

With priority being given to domestic water supply, it is important that this water is distributed with minimum loss and wastage. Items DT1 Reduction of consumer water losses, DT2 Water saving devices and fittings and DT3 Recycling of industrial water become of importance here and DA4 water tariffs may become an instrument in controlling these.

The current domestic water situation in Chennai is extremely serious, especially with regard to the poor and vulnerable. Community Level Management, is an essential ingredient of the water demand management approach with consideration being given to equity of distribution.

Thereafter, further consideration could be given to measures AA3 to AA7:

- Change land use by: a) land purchase b) re-zoning/classification; c) well-buy outs/transfer of water rights
- Crop area prohibition;
- Change cropping patterns by: a) extension b) tax c) market support;
- Introduction of water markets;
- Water tariffs: a) volumetric b) on power to pumps c) area based

Some of these measures are already being introduced in one form or another (e.g. water rights at some sites are effectively being transferred to CMWSSB through agreements with farmers to buy or lease their rights to water abstraction). In addition, the change in farming patterns in areas using the A-K aquifer may favour a more co-operative approach to water abstraction which might be strengthened through the encouragement of farmer groups or water users organisations.

Supporting measures

Implementation of the measures above would require supporting or enabling measures (or policy instruments), a summary of which is given in Section II.1.

The legislation and regulation for the abstraction of groundwater in Tamil Nadu is described in Annex G. Legislation was introduced in 1987. Sectoral water allocations and water quotas have not been introduced as yet and these would require further licensing and legislation, metering of abstractions and the introduction of monitoring and enforcement measures. Currently piped domestic water supply is metered but abstractions from agricultural wells are not. Supporting measures given in Table II.3B all have their place and need considering alongside the corresponding demand management measures described above.

7. IMPACT OF DEMAND MANAGEMENT OPTIONS

7.1 Introduction

The Chennai Case Study has revealed some interesting insights into the management of water both at the public supply authority and community levels. Water supplies to the city are limited, unreliable and have been seriously affected by the poor monsoon rainfall of the last few years.

The A-K aquifer, to the north of Chennai has traditionally been used to provide water for irrigated agriculture, but in 1969, wellfields were developed to supply water to the industrial area of Manali and, from 1987, new wellfields were established to supply water to Chennai city. The aquifer is currently over-exploited, abstractions exceed the sustainable yield and saline intrusion now penetrates up to 12km from the coast.

Currently, studies are being undertaken to establish the sustainable yield of the aquifer so that up to 100 Mm^3/year could be supplied to the city. There is competition for water for domestic/industrial water supply and for irrigation.

The other sources of water supply to the city are from surface water run-off via reservoirs, inter-State transfer of water from Andhra Pradesh (Krishna River), tanker supplies from borehole supplies outside the A-K aquifer. A pipeline from Veeranam (230 km south of Chennai) has recently been constructed to supplement supplies. A desalination plant to serve Chennai is also planned. Rainwater harvesting has been introduced to the city to improve recharge to the city aquifer. A wide variety of supply options have been considered, but the provision of water is becoming increasingly expensive.

The water supply situation is complex and exacerbated by the recent drought conditions but it is clear that managing the demand is an essential ingredient of any water policy for the area if the domestic, industrial and agricultural sectors are to be satisfied. A Water Master Plan, which introduces a demand management policy, is required for the area.

At this stage of the Research Project, we can only point to demand management measures that should be considered and their potential impacts. These measures were discussed with stakeholders and at the Workshop in Chennai in November 2004 so that an appropriate strategy can be developed.

7.2 Water provision, savings and unit costs of water saved

Some preliminary cost estimates of components of a number of water supply options, based on data made available in Chennai, are given in Table III.5.

Table III.5 Cost of components of water produced (Rs/m^3)

Option	Description	Cost of Water (Rs/m^3)	Water made available at
SD1/SA1	Develop additional groundwater (wellfield)	6.1	at head of distribution system
	Develop additional g.w. and supply to city (Veeranam)	17.7	at head of distribution system
SD2	Desalination	45.0	at plant
SD4	New water treatment facilities	2.9	at treatment plant (cost of facility only)
SD5	Extend water distribution system	7.4	average for city supply system
SD6	Extend tanker distribution		
SD7/SA3	Retention dams and reservoirs	11.0	at aquifer
SD8/SA4	Aquifer recharge (dam)		
SD9/SA5	Increased surface water diversion		
SD11/SA7	Trans basin water transfer		
SA2	Treat/use wastewater	2.2-2.9	at treatment plant (cost of facility only)

Where demand management measures are introduced, there is a cost in so doing and, where agriculture is curtailed, an amount saved per hectare of land can be estimated. The table below gives some initial estimates of the cost of water saved and potential savings per hectare for a number of demand management measures which could be adopted in the Case Study area.

Table III.6 Cost of components of water produced (Rs/m^3)

Option	Measure	Cost of water saved (Rs/m^3)	Quantity of water saved (m^3/ha)	Water made available at
DD1	Reduce consumer water losses			
DD2	Water saving devices and fittings			
DD3	Recycling of industrial water	36		plant
DA1	Improve efficiency of surface irrigation systems	0.54	3,600	aquifer
DA2	Introduce sprinkler irrigation	3.5-10.9	269 - 676	aquifer
	Introduce drip irrigation	9.7-13.0	676	aquifer
AR3	Change land use	0.09	22,208	aquifer
AR4	Crop area prohibition			
AR5	Change cropping pattern		8,320	aquifer

These estimates will provide a starting point for developing demand management strategies. Supporting details and source references are given in Annex F.

7.3 Impact of water demand management measures on poor and vulnerable

The studies to date have defined the vulnerable in the Chennai Case Study area and their current status with regard to water. The research continues with impact studies of introducing water demand management measures on the poor and vulnerable and the development of strategies which would protect these groups from any negative impacts that might arise from their introduction.

PART IV AL JAFR-SHOUBAK CASE STUDY

1. THE CASE STUDY AREA

1.1 Description of the area

The two case study areas, Al Jafr and Shoubak, are in the Al Jafr basin. The basin is located in the southern part of the Hashemite Kingdom of Jordan between latitudes 19°30'N and 20°30'N and longitudes 35°30'E and 37°00'E. The location of the project area is shown on Figure IV.1.

The Al Jafr basin is to the east of the Wadi Araba and Southern Ghors rift valley system and is part of the Central Jordanian Plateau. The basin shows a centripetal drainage pattern with all wadis draining from the surrounding highlands to the central desert playa at Al Jafr. The ground elevations vary from 1200m above sea level in the western highlands around Shoubak to 860m above sea level at Al Jafr.

The central part of the basin is a peneplain with occasional hills and weakly incised wadis with intermittent flows resulting from local precipitation that is usually intense and caused by scattered storms.

The climate varies between semi-arid desert for most of the basin with a Mediterranean type climate in the highlands in the west. The basin plateau of the eastern desert is hot in summer and cold in winter. The temperature may reach more than 40°C during summer days and drop to a few degrees below zero in winter, especially during the night. In the highlands, the climate is more temperate, cold and wet in the winter with temperatures reaching a few degrees below zero during the night and hot dry summers with temperatures reaching 35°C at midday.

The average total rainfall varies between 300mm/annum in the west and less than 40mm/annum in the east and is provided by winter rainfall from October to May with the majority falling in January and February. Snowfall does occur once or twice a year in the highlands with up to 75 days of frost. The mean annual potential evaporation rate varies from 1150mm/year in Shoubak to 2500mm/year in Al Jafr. The annual rainfall varies significantly about the mean value and in a cycle between 1 and 5 years, with drought periods that continue for 3 to 5 years.

The water supply to the Al Jafr – Shoubak areas is derived from both surface water from a limited number of spring sources in the western highlands and groundwater sources.

Demands for water supply in Shoubak come primarily from a number of small villages where water is required for domestic water supply and garden irrigation. Rainfed agriculture is confined to the winter season when wheat and barley are grown, yields of which are variable and dependent on the rainfall pattern. The irrigated agricultural sector is dominated by large fruit farms (about 2,000 ha) in the east of the study area which rely on groundwater.

Al Jafr relies on groundwater for domestic and agricultural use. There is a surface irrigated farm run by the Ministry of Agriculture to support settlement in the area. There are a number of vegetable and fruit farms in Al Jafr using groundwater and applying water principally by drip irrigation.

Case Study Area Shoubak – Al Jafr

Location of Case Study Area Shoubak & Al Jafr Figure IV.1

1.2 Economic background

General

The population of the The Hashemite Kingdom of Jordan country was 5.33 million (2002) with the density varying from 3.1 person/km^2 in Ma'an Governorate to 586.5 person/km^2 in Irbid Governorate. The capital, Amman, serves 2.03 million, nearly 40% of the country's population.

The economy of Jordan is mainly dependent on the tertiary sector which consists of trading, business and services (73%). This is followed by the secondary sector (22%) which consists of manufacturing, construction, electricity, gas and water. The primary sector, which consists of agriculture, hunting, forestry & fishing (2%) and mining & quarrying (3%) contributes a small portion to GDP (5%).

Real GDP growth rates have grown from about 3% per annum in 1998 to 5% in 2002. GDP per capita was US$ 1,762 in 2002. The annual inflation rate is 3.3% per annum and the official un-employment rate is 16%.

Phosphate represents a significantly natural resource of Jordan and export is expected to expand considerably as pressure continues on world wide agricultural productivity. Other materials such as glass, sand, potash and bromine have shown significant growth. Tourism also presents a major source of income generation of foreign exchange.

The total agricultural area of Jordan is 260,000 hectares, 75,000 ha of which are irrigated. The remaining 71% area is rain-fed with field crops prevailing. Vegetables and fruit trees are usually irrigated and many Jordanian farmers are well experienced in drip and sprinkler irrigation.

Availability of good agricultural land and water is limited in Jordan; however the country exports high quality agricultural commodities (vegetables and fruit) with an export value of 92 JD million (2002). Jordan imported about 636,000 tons of wheat & barley and about 36,800 tons of fruit with total value of 93 JD million in 2002.

Shoubak - Al Jafr

(Shoubak District and Al Jafr Sub-District)[4]

The Case Study areas, Shoubak District and Al Jafr Sub-District, are in the Ma'an Governorate (population 104,000, 2% of the kingdom's population). The populations of Shoubak District and Al Jafr Sub-District were 13,075 and 11,850 respectively in 2002.

The Ma'an Governorate contributes about 5 % to fruit production and 8% to the vegetable production of the nation. The total area cropped (2002) in Ma'an Governorate was about 263,000 dunum of which about 94,000 dunum (36%) of the crops are irrigated, the remainder are rain-fed with generally low and variable yields depending on the rainfall.

In Shoubak District a total of 101,386 dunum are cropped each year (19,867 dunum of these crops are irrigated and 81,521 dunum rely on rainfall). In Al Jafr the total area cropped is 40,479 dunum, all of which are irrigated.

Land use details in Ma'an Governorate and those in the areas of study (Shoubak and Al Jafr) are given in the Table IV.1 below.

[4] Shoubak is one of the four Districts of the Ma'an Governorate. Al Jafr is one of the five Sub-Districts of Ma'an District.

Table IV.1 Land use in Shoubak District, Al Jafr Sub-District and Ma'an Governorate - 2002

Crops	Irrigation	Trees	Ma'an Governorate	Shoubak District	%	Al Jafr Sub-district	%
Fruit trees							
	Irrigated	Olives	15,392	1,969	13	1,597	10
	Irrigated	Grapes	3,275	300	9	957	29
	Irrigated	Others*	33,124	17,187	52	1,540	5
	Non-irrigated	Olives	2,123	353	17		
	Non-irrigated	Grapes	589	200	34		
	Non-irrigated	Others	1,091	3	0		
Vegetables							
Winter			8,727			7,980	91
Summer	Irrigated		18,562	409	2	14,410	78
Field crops							
Winter	Irrigated		14,099			12,944	92
	Non-irrigated	Cultivated	161,677	80,240	50		
		Harvested	145,330	70,183	48		
Summer		Cultivated	4,305	725	17		
		Harvested	3,501	510	15		
Clovers/alfalfa	Irrigated		1,085			1,051	97
Total	Irrigated		94,266	19,867	21	40,479	43
	Non-irrigated		169,035	81,521	48		
Grand total			**263,299**	**101,386**	**39**	**40,479**	**15**
Fruit trees			21.1%	19.7%		10.1%	
Vegetables			10.3%	0.4%		55.3%	
Field crops			68.6%	79.7%		34.6%	

* Apples, stone fruits etc
Source: Agricultural statistics, Department of Agriculture, Ma'an Governorate.

The survey carried out by the research team during April 2003 in Shoubak and Al Jafr showed that farm sizes in Shoubak are generally smaller than in Al Jafr.

In Shoubak, 40% of farming households interviewed had less than 5 ha; 28% of households had more than 10 ha. Meanwhile, in Al Jafr most farming households interviewed had more than 5 ha of land and 46% of households more than 10 ha.

However, irrigated land is only a small portion (37%) of the farmed agricultural land in Shoubak since rain-fed wheat/barley is widely cultivated. The information on irrigated land in Al Jafr is affected by the number of nomadic households using the Department of Agriculture's Farm who do not cultivate and irrigate their land regularly.

Net irrigation water requirement for irrigated crops are estimated to be about 1000 m^3/dunum/year for fruit trees, 500-700 m^3/dunum for vegetables and 430 m^3/dunum for wheat and barley field crops.

1.3 Institutions

The primary Government Ministry responsible for water matters is the Ministry of Water and Irrigation. The Ministry was formed in 1992, under Law No 54/1992. Its main purpose is to centralise the national management of water resources which were previously regulated by multiple agencies (WAJ, JVA, Ministry of Agriculture and Ministry of Health). The MWI has responsibility for distributing and regulating the water resources in Jordan and for settling disputes between agriculturalists and water supply authorities.

The Water Authority of Jordan (WAJ) is responsible for construction, operation and maintenance of water supply and sewage facilities and for national water resources management plans.

The Jordan Valley Authority from 1977 has been the prime authority for planning and implementing water supply services in the Jordan Valley. Subsequently, JVA extended its role to infrastructure development in the Valley (to include water electricity, land and municipalities).

The Ministry of Agriculture is responsible for the promotion of agriculture and the provision of advisory services.

1.4 Legislation and regulations

The principal laws, ordinances and regulations relating to the abstraction, use and conservation of water in Jordan are:

- Water Authority Law No 18 of 1988 and Amendments thereof, Law No 62 of 2001
- Municipal Wastewater Law No 12 of 1977
- Underground water control By-Law No 26 of 1977

The most recent legislation relating to the abstraction of groundwater in Jordan is By- Law No. (85) of 2002: Underground Water Control By- Law, issued in pursuance of Articles 6 and 32 of the Water Authority Law No. 18 of 1988.

2. WATER RESOURCES DEVELOPMENT

2.1 Water resource availability

The water supply to the Al Jafr and Shoubak areas is derived from both surface water from a limited number of spring sources in the western highlands and from groundwater sources.

The Al Jafr basin is a completely contained depression with a catchment area of around 13,500km^2. The total surface water runoff of the catchment is reported to be between 22Mm^3/year (Ref. 16, JICA) and 15Mm^3/year of which 10Mm^3/year flows as floods into the Al Jafr depression where they either evaporate or infiltrate into the ground (Ref. 17, Kdhier). There are no perennial stream flows. There are proposals to augment the recharge to the aquifer by the construction of recharge dams at six locations across the wadis in the Western Highlands (Ref 16, JICA). One earth-type dam to harvest the annual runoff in Wadi Jurdaneh for watering of livestock has been constructed.

Base flow in the form of spring discharge in the western highland is used for irrigation. The Ministry of Water and Irrigation (MWI) Data Bank has provided discharge data for the main springs in the area. The mean annual spring discharge was reported as between 0.75Mm^3 (Ref. 16, JICA) and 1.3Mm^3 (Ref. 17, Kdhier). The long term records show that there has been a general reduction in spring flow in recent decades with a number drying up completely. These include Nijil-Shoubak (G0572), Jerba el Kabira (G0554) and Udruh (G0552) that have all dried up since 1989.

Groundwater is the major source of water in Jordan. The aquifers of Jordan are divided into three main systems or complexes:

- Deep sandstone aquifer complex
- Upper Cretaceous carbonate aquifer complex, and
- Shallow aquifer complex

The Upper Cretaceous carbonate aquifer system forms the major regional aquifer system of Jordan and this is so in the Al Jafr basin. It is essentially continuous and contains productive aquifers throughout the country.

Four aquifers have been recognised within the Upper Cretaceous sequence. The main one is the Amman - Wadi Sir (B2/A7) which extends throughout most of the country. The others are the Na'ur (A1/2), the Hummar (A4) and the Rijam (B4) and are of importance locally throughout Jordan. In the Al Jafr basin the Hummar is not well developed.

The B2/A7 and the underlying older Kurnub (Lower Cretaceous) and Disi sandstones (Cambrian to Ordovician) form the deeper aquifers in the Al Jafr basin and are separated from each other by thick aquitards. A hydrogeological profile across the Al Jafr basin, taken from Khdier (1997), is included in Annex E. In the central part of the basin, the overlying thick impervious argillaceous unit of the Muwaqqar (B3) Formation confines the B2/A7, while in the surrounding higher areas to the west it is unconfined. The different aquifers within this unit are considered to be in hydraulic continuity. The aquifer has an average thickness of 100m, 40m of Amman (B2) and 60m of Wadi Sir (A7). In general, the aquifer thins to the south and thickens to the north.

Within the outcrop area of the B2/A7 aquifer system in the Western Highlands a recharge mound has developed which is divided by tectonic and morphological features in to three flow systems (Ref 18, Bender H and Duerbaum). The largest part of the recharge area drains eastward towards the Al Jafr basin. The flow system of the Nijil – Shoubak area drains north and that of the Wadi Musa area to the west of the surface catchment divide to discharge as springs and seepages along the base of the A7 aquifer on the escarpment above Wadi Araba.

Several tectonic structures such as the Arja-Uweina flexure act as flow barriers to the eastward direction of ground water flow. The presence of the hydraulic barriers is indicated by the marked head drop across the structures. The JICA study records piezometric levels in the Western highlands of 1200 to 1500m, while they are as low as 800 to 900m immediately east of the Arja-Uweina flexure. In the central part of the Jafr basin the piezometric elevations are reported to be between 750 and 800m with a nearly flat hydraulic gradient.

Eastward of the flexure the groundwater of the B2/A7 aquifer is confined by the impervious marl of the Muwaqqar (B3) horizon.

The main groundwater aquifer in the centre of the basin area is the B4 Formation of the Belqa group, consisting of thin beds of chert, limestones, clays and marls with a total thickness of 20-25 metres. In the central part of the basin the B4 is saturated under water table conditions, whilst in the surrounding areas it is unsaturated.

Recharge to the B4 aquifer takes place from surface runoff from the highland of Shoubak. Direct recharge to the saturated part of the aquifer in the centre of the basin is negligible because the surface area of the playa where the flood water collects is covered by very fine sediments which do not allow rapid infiltration and groundwater recharge.

The groundwater flow in the B4 and B2/A7 aquifers is generally from west to east. In the deeper aquifers, the groundwater flows in a generally northerly direction with components towards the northeast and northwest.

2.2 History of water resource studies

Groundwater investigations in Jordan began in the early part of the 20th century. There have been several regional studies that included water resource evaluation for the Al Jafr Basin.

- Muhammad M Abu-ajamieh (1967). A quantitative assessment of the groundwater potential of the Rijam Formation aquifer in the Jafr Basin, Natural Resources Authority. (Ref 19)

- Bender and Duerbaum (1969) reported on the exploration and exploitation of groundwater in the Arja Uweina area for an irrigation project. This work was carried out in cooperation with the Natural Resources Authority of Jordan and the UN Special Fund Sandstone Aquifer Project. (Ref 18)

- The UNDP study (1970) Sandstone Aquifer Project defined the general outlines of the hydrogeology of the region. (Ref 20)

- Agrar-und-Hydroteknik (1977) compiled all the available data on geology, hydrology and groundwater for compilation of the National Water Master Plan of Jordan (WMP). (Ref 21)

- Howard Humpreys Ltd. (1986) studied hydrogeology and hydrochemistry of the Mesozioc-Cainozoic aquifer of the Ma'an-Shidiya-El Jafr region. (Ref 22)

- Japanese International Co-operation Agency (JICA) with the cooperation of WAJ (1990) conducted a study of the Wadi Hasa and Jafr basin. The study included drilling new observation boreholes and groundwater mathematical modelling. (Ref 16)

- Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) (1991) and WAJ cooperated on a technical study of the groundwater resources of Southern Jordan. (Ref 23)

- Kamel M. Khdier's doctoral thesis (1997) was an assessment of regional hydrogeological framework of the Mesozoic aquifer system of Jordan. (Ref 17)

The bodies responsible in the past for monitoring/reporting on water resources in the Al Jafr basin include the Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ) and the Ministry of Agriculture (MoA). The MWI Data Bank provided water resource data for this project. In 2002 there were 190 wells in the Al Jafr basin as a whole extracting 25Mm^3. Of these, there were 32 for domestic supply, 20 industrial, 122 irrigation and 5 for domestic private use.

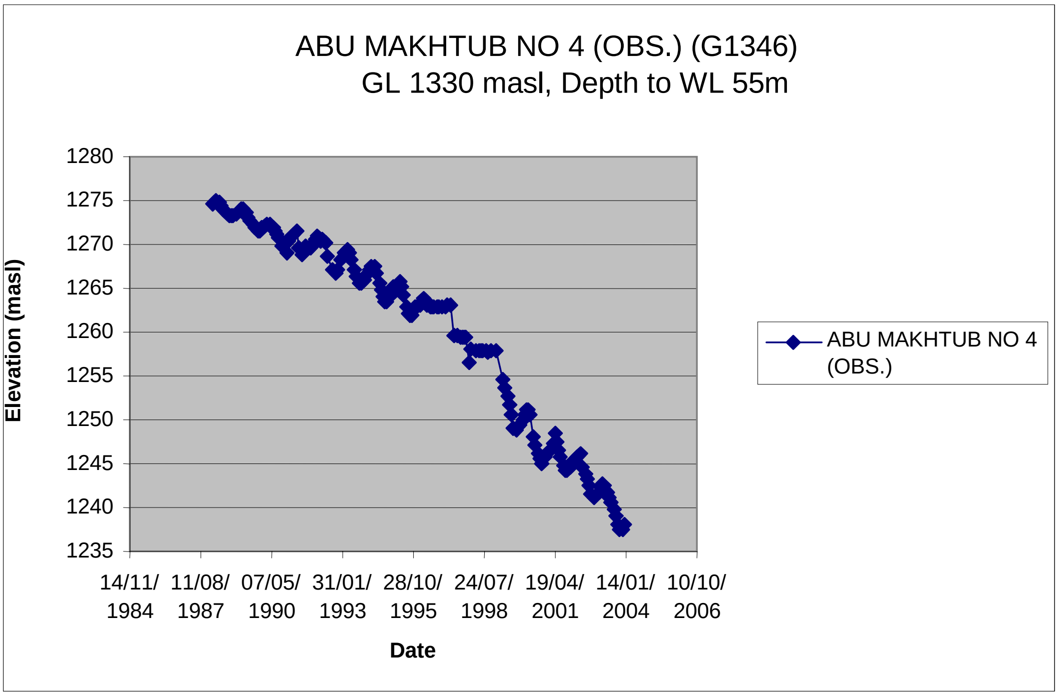
2.3 Development and current use of water resources

Shoubak area

The agricultural farms 5 to 10kms to the east of the villages of the Shoubak area are the main abstractors of groundwater from the aquifer. The locations of the agricultural areas and the wells are shown on Figures IV.2 and IV.3.

The observation well Abu Makhtub No. 4 (G1346) some 7kms to the southeast of Shoubak has provided a record of the water table in the area of agriculture from 1988 to 2003 (Figure IV.4). Over that period the water level has fallen 40 metres. Over the period 1988 to 1996, the average annual decrease in water level was 1.5m/year. Since 1994, the average annual decrease has doubled to 3m/year.

Figure IV.4 Record from observation well Abu Makhtub No. 4 (G1346)



The domestic supply for the Shoubak area is supplied by six wells belonging to WAJ. A 68kms long pipeline from Shoubak supplied Tafila until May 2003, when the replacement wellfield at Wadi Hasa came online. The water is pumped directly into supply. Each village is divided into zones to ensure delivery at the end of the pipelines. The wells are pumped for 10 hours per day during the winter and 24 hours per day in the summer. The summer supply is reported to be given every third day for about 5 hours.

A pipeline from the Ail pumping station (WAJ) supplies the Udruh, Jarba and Menshiye area at a rate of 1200m^3/day during the summer and 500m^3/day from November to the end of March.

JICA estimated the B2/A7 abstraction in western highlands to be 9.36Mm^3/year. No significant regional drawdowns have been recorded except in the Shoubak wells. The Western Highlands are the major recharge area for the aquifer.

East of the desert highway the groundwater in the confined aquifer is untapped, until the well field for the Shadiya industrial area is reached.

The JICA study (1990) reported that an estimated 3.3Mm^3/year was being used for irrigation in the Shoubak area. Based on the abstraction records held in the MWI Data Bank, the total annual agricultural abstractions from the fruit farms in a 25km^2 area located 8 kms to the south east of Shoubak (shown as the northern farms, shaded cells in Table IV.2 below) varied from 2.9Mm^3/year to 4.6Mm^3/year between 1996 and 2001.

Shoubak fruit farms

There are more than twenty-three specialised fruit and vegetable farms in Shoubak abstracting water for irrigation of apples, apricots, other stone fruit and vegetables. Irrigation of fruit trees (97% of the area under crops) is by drip systems; vegetables (3%) are also irrigated by drip systems in plastic greenhouses or under cloches.

Table IV.2 Large farms – Shoubak

	Name	Total area (ha)	Apples (ha)	Stone fruits (ha)	Vegetable (ha)	Olive (ha)	Pistacch-Aleppo (ha)	Other (ha)	Pump capacity (reported) (M3/hr)
1	Sabeeh Al Masry	171	120	8	12				120
2	Abu Al-Haj Farm	400	170	10		40	10	130	180
3	Salem Jarrar	80	60	2					45
4	Khalil M. Al-Jilany	75	65	10					55
5	Mohammed F.Ali	59	50	9					85
6	Khalid Alean & Majed Hashlamoony	170	130	25					205
7	Mohammed Samoor Al-Jazy	62	45	17					70
8	Essa Jarda Al-Tarawneh	60	48			7			45
9	Yusri Al-Jazy	65	45	10		10			65
10	Zuhair Zanooneh	45	35	5		5			95
11	Samir Mahmood	36	34	1		1			44
12	Nafith Al Hashlamoony	55	40	10		5			50
13	Essa Al-Masry	40	30	3		7			55
14	Bassam Abdullah	19	15	4					55
15	Abdel Hameed Al Hashlamoony	175	125	40					125
16	Al-Tilal	20	16	4					16
17	Hassan Salem & Kholy	127	85	25		6			250
18	Khalid Alean & M,Hashlamoony	40	30	10					55
19	Saleh R. Al-Jazy	25	7	3	3				85
20	Kasib Sofouk Al-Jazy	80	30	10	10				80
21	Ganim (Farah)	73	60	13					115
22	Abdul Hameed Al-Hashlamoony (small)	45		35	10				100
23	Al-Jabra Co-operative	110	25		15				150

(Source: Field survey, 2004)

The first of the farms was established in the early 1980s and development has continued since then, although it is now being limited by the need for licences from MWI to drill or deepen wells to abstract more water from the aquifer. The total area of these farms is 20,320 dunum (2,032 ha). Currently about 62 percent of the area is under drip irrigated apples and 90 percent of the total area is cultivated.

The recorded abstraction of water from the aquifer is discussed in Annex E and the abstraction by the northern farms, those shaded thus ▭ in Figure IV.2 is recorded by the MWI as between 2.9 and 4.6 Mm^3/year between 1996 and 2001.

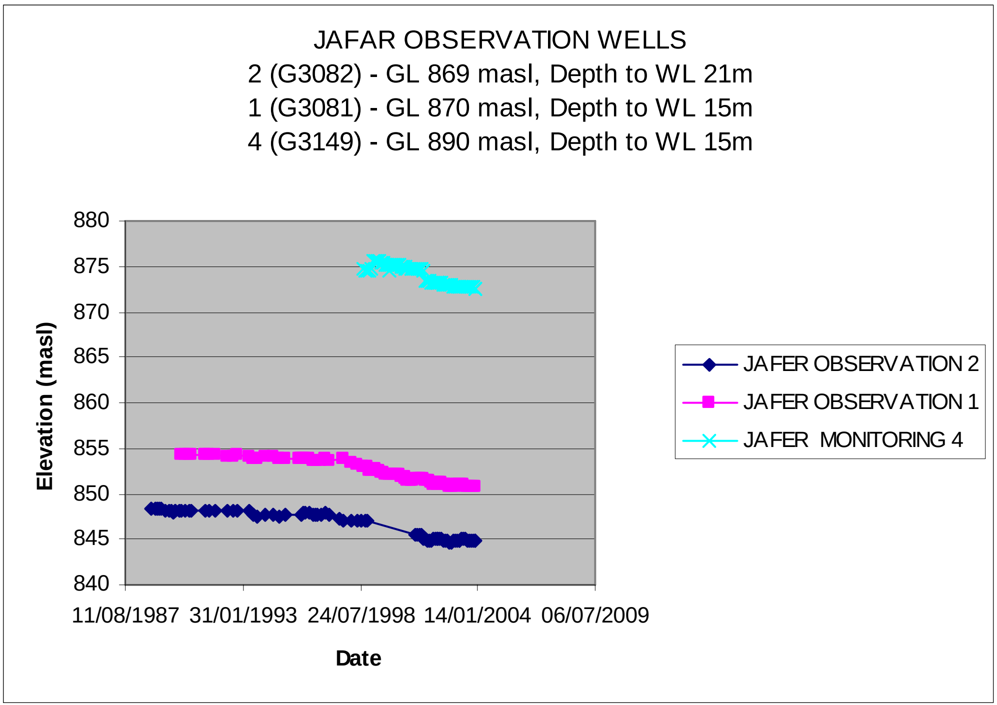
Based on the areas under cultivation in the northern farms of Shoubak, listed in Table IV.2, and the potential evapo-transpiration (the full water requirements of the crops – see Annex F) for the fruit and vegetables, the total water consumption would be between 7 and 9 Mm^3/year. These figures indicate either that the fruit trees and vegetables are not being provided with sufficient water or that abstractions from the aquifer are greater than those being recorded. A combination of these explanations probably applies.

Al Jafr area

The Jafr basin is desert area that has no permanent surface water resources. Present groundwater use for all purposes in the basin is 8Mm^3/year for domestic, 10Mm^3/year for agriculture and 7Mm^3/year for industry (WAJ, 2002). As the safe yield of renewable groundwater is estimated to be around 9Mm^3/year, the overdraft is 16Mm^3/year.

In 1964 groundwater was developed in the Al Jafr area to provide water for both domestic and agricultural uses. The shallow Rijam (B4) aquifer was exploited using wells up to 50m deep. Prior to 1967, abstractions were just over 1Mm^3/year. In 1990, five boreholes were used to withdraw 2Mm^3/year. Each borehole abstracted between 864 and 3629m^3/d with an average of 2400m^3/d. Water levels monitored since 1964 show water level decline 0.1m/yr to 0.36m/yr in those 16 to 22 years, corresponding to a fall of water level in the 10 to 20 years of 2 to 7 metres.

Figure IV.5 Jafer Observation wells



Based on the record supplied from MWI for Jafer Observation Well 2 (G3082) for the period 1988 to 2003 the decline between 1988 to 1997 was 0.5 metre and then until 2003 was a further 3 metres (Figure IV.5). This response indicates that the average annual abstraction exceeds the natural recharge.

Two wells, Jafr 29 (G3020), 50 metres deep and pumping from the B4 aquifer, and Jafr 30 (G3175), 60 metres deep also pumping from the B4 aquifer, supply domestic water to the town of Al Jafr.

We understand that the pumps run for 17 hours per day in winter and 22 hours per day in the summer. The water is pumped to an overhead storage tank (capacity of 55m^3) and is delivered to 400 connections that are fitted with water meters.

Five boreholes (Jafr 17, 18, 19, 20 and 23) supply the Government Ministry of Agriculture (MoA) farm of 250 hectares. Jafr 18 is reported now to be used by the ostrich farm within the farm area. The recorded abstraction for the period 1994 to 2001, based on the MWI Data Bank, varied between 0.55 and 1.15Mm^3/year.

Within a 5km radius of the farm there are forty-six wells abstracting groundwater either from the B4 or B2/A7 aquifer. The net effect of this abstraction is a lowering of the water level.

3. THE POOR AND VULNERABLE

3.1 Surveys undertaken

Survey areas were selected in Shoubak and Al Jafr for Focus Group Discussions (FGDs) to include:

- a minimum of 10 separately representative households per Focus Group

- as equal as possible a proportion of male and female respondents (more female participants were included in Domestic Water FGDs, and more male in Agricultural FGDs)

There was difficulty in obtaining a minimum of 10 representative households in each group, and it proved impossible to interview the poorest households in Al Shoubak[5]. However, an employment survey recently carried out by the Household Surveys Directorate[6], indicates that 10% of the population of Ma'an earns less than JD100 per month, while 68% earns between JD100-200 per month. Respondents from this income category were well represented in Shoubak. Respondents from all socio-economic levels were included in FGDs in Al Jafr.

Focus Group selection criteria included areas where populations are dependent on groundwater for both domestic and agricultural use (all fieldwork sites were rural). In Shoubak, five locations were selected based on the following criteria:

- locations experiencing water stress;
- settled communities, with livelihoods depending partly or wholly on agriculture;
- domestic water users;
- a range of socio-economic levels, representing low, middle and high income households;
- formerly nomadic communities, now settled.

One FGD was sited in Udruh sub-district, also dependent on the Shoubak aquifer. In addition, separate interviews were conducted with large agricultural investors in Shoubak, owning substantial fruit and vegetable farms.

The survey areas in Shoubak are shown on Figure IV.2. The FGDs in Al Jafr were all conducted in or close to the town. One hundred households were represented in the FGDs (63 domestic, 37 agricultural), overall average household size is 8 persons (7 in Al Shoubak, 9 in Al Jafr).

Population density is low in Ma'an Governorate, with less than 3 persons per square kilometre. This reflects the limitations of natural and economic resources in the area. In the survey area, population distribution is characterised by division of clans belonging to different tribes. The Hawettat tribe is dominant in Al Jafr, with its main clans of Al Tawaiha, Al Damanieh, Al Nawasra, Al Ftinah and Al Darawsheh. In survey locations in Al Shoubak, the Al Jazy clan (also from the Hawettat tribe and originally from Al Jafr area, but settled in Shoubak) was the only settled Bedouin community interviewed. Other communities included Al Zubariyah – Al Habahbieh; Al Juhaier – Al Tawara; Al Baq'a – Al Qunmieen; Bir al Dabagat – Al Amareen.

3.2 Poverty in the Survey Areas

Substantial work has been undertaken in Jordan on defining poverty and developing poverty alleviation strategies. Jordan compares well with other countries over income levels and GDP per capita, despite having the highest population growth rate in the Middle East[7] (Ref. 23).

5 *Communities were often reluctant to co-operate without some material benefit to themselves through a subsequent project.*

6 *Employment and unemployment Survey 2003: Annual Report, Household Surveys Directorate, January 2004, Table 7.2, p. 121*

7 *Poverty Alleviation for a Stronger Jordan: A Comprehensive National Strategy*, Jordan Poverty Alleviation Program, Ministry of Social Development, The Hashemite Kingdom of Jordan, May 2002

According to a Report published in 2000[8] (USAID Ref. 25), poverty is not so much due to unemployment as to low income resulting from low participation in the labour force and low wage levels in the Kingdom. Poverty levels are taken from 1999 World Bank definition of JD313.50 per person per year. Based on this criterion, approximately 21% of the population of Ma'an Governorate is estimated to live below the poverty line. This compares with an overall estimate of 11% for the Kingdom of Jordan as a whole, making Ma'an the governorate with the second highest poverty concentration in Jordan and the lowest Human Development Index.

Local perceptions of poverty in Shoubak and Al Jafr were sought through a rapid wealth ranking exercise, which provided community criteria of socio-economic differences. The official national poverty line is taken as an income of JD156 or less per month for a family of five persons. Communities rated it as slightly lower at JD120 or less per month.

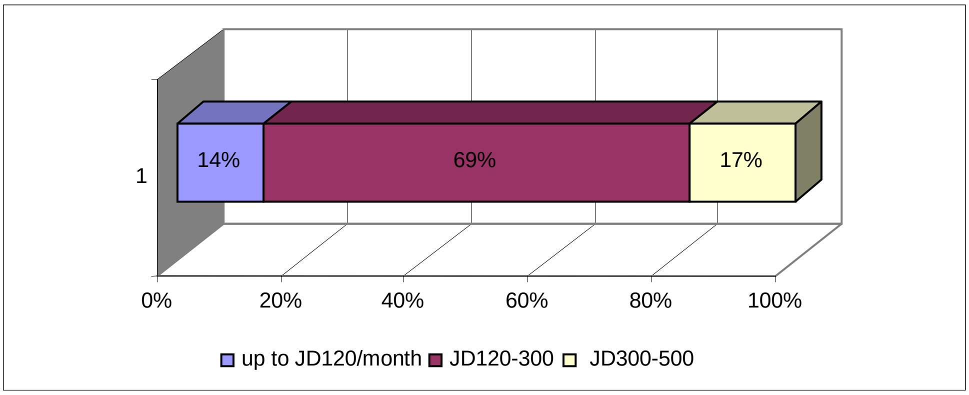
National and regional poverty alleviation strategies focus heavily on providing statutory services (education, domestic water supply, health facilities) as well as on targeting employment opportunities. Coupled with a recently begun process of administrative devolution from Central to Governorate level, the intention is to encourage people to remain living and working in the regions rather than migrate to Amman.

Poverty is characteristically higher among households in rural areas, among households with large numbers of children and among households with low educational levels. Female-headed households are particularly prone to low income and poverty, especially as there are strong cultural restrictions to obtaining paid work outside the home. In Al Jafr[9], poverty is also seen as caused by:

- loss of pasture and decrease in animal resources
- high cost of fodder
- having many wives and large families
- refusal to accept certain types of work (e.g. agricultural labouring)
- comparative remoteness of the area, leading to high transportation costs

Income classifications of FGD households are shown in Figure IV.6

Figure IV.6 Representative income categories, FGD respondent households



[8] USAID, *Poverty Levels in Jordan*
[9] Participatory Rapid Appraisal, Al Jafr Department of Social Development, 2003

3.3 Domestic water Use

All households in Shoubak and Jafr rely on piped water to the house supplied from a well belonging to the Water Authority of Jordan (WAJ). In Al Zubayriya, management of the well has been taken over by a society composed of village members. 10% of respondents in this village also purchase bottled water, particularly for young children or in times of illness. In Al Jafr, 40% of respondent households in the FGD representing low income households estimate they need to take water from neighbours during the summer. Approximately 17% of poor households in Shoubak take water from neighbours.

Domestic water is commonly used to irrigate home gardens (On average, each household has 0.85 dunums of home garden, with rich households having an average of 1.39 dunums). Gardens are important features of women's livelihoods in which they cultivate vegetables, herbs, grapes, and a few fruit trees (apples, apricots and olives), as well as raising livestock such as chickens and a few goats. No-one uses rooftop rainwater harvesting methods.

All respondents in Al Jafr said there is no problem of water security either in winter or summer. Some poorer households have difficulties in summer when water is pumped alternate days. This is because they cannot afford storage facilities, and must take from their neighbours. However, all agreed this posed no difficulty as neighbours were always willing to assist.

In Shoubak, the seasonal picture is somewhat different. In winter, three of the four FGD locations receive water 2-3 times a week. In summer the situation is more acute; Al Baq'a, which normally receives water daily in winter, receives it 2-3 times a week, while Juhaier receives it weekly, and Bir el Dabagat once every 2 weeks.

Adequate access to water for the poor appears to be guaranteed, even if it is in smaller amounts. Community co-operation is strong in both Shoubak and Al Jafr with neighbours willing to allow access to their supply.

Sixty-two percent of the households interviewed own water storage facilities. No-one could tell how much water they used as everyone rushes to fill tanks and irrigate gardens as freely as possible when the water is flowing. Households estimated an average of 25% of their domestic water use goes to irrigate the garden.

All FGDs in Shoubak reported the quantity of water piped to the house has increased in the past 3 years. The opposite is the case in Al Jafr, where all FGDs reported the amount has decreased.

Costs

Costs vary depending on whether a water supply is managed by a village society or by the water authorities. Summer bills are some 59% higher than winter bills.

Table IV.3 Water expenditure (figures rounded)

Income and expenditure	Low income	Middle income
Average monthly HH income	JD120	JD120-300
Average monthly HH expenditure on water	JD6	JD11
% monthly disposable income spent on water costs	5%	5%

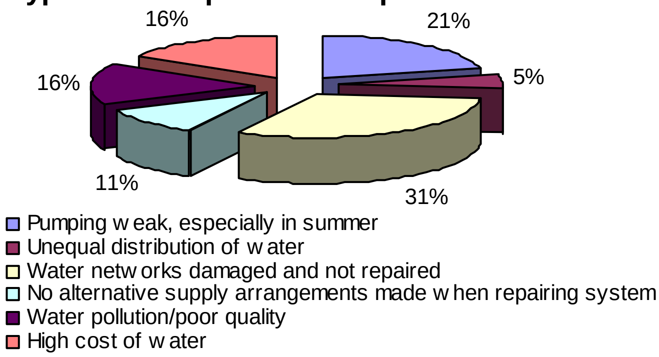
The methodology of determining broad income brackets is explained in Annex D, Section D3.3. All domestic FGD participants were subsequently asked which income bracket their household fell into. They were also asked what was their monthly expenditure on water. Table IV.3 reflects aggregated and averaged costs from these primary data.

With the exception of one household, all FGD respondents said they could afford to pay connection charges. Almost all households could afford to pay their water bills.

Conflicts

All FGDs confirmed there has been conflict over water. 57% of FGDs reported conflict between neighbours concerning distribution and equity of water, while all focus groups reported conflict between communities and water authorities. One FGD indicated that there had been problems between landlord and tenant in allocating water costs for shared facilities. Figure IV.7 shows the relative importance placed by focus groups on types of water-related problem.

Figure IV.7 Type of water problems important to FGDs



Most households attempt to resolve water difficulties by complaining through local leaders, or try and sort things out with each other. All FGDs pointed out their dependence on intermediaries to address their needs and their willingness to bypass local water authorities to go straight to higher authorities in Amman if need be. 57% of FGDs said they complained individually, 86% collectively.

Coping Strategies

85% of FGDs said that water difficulties have affected their livelihoods. For domestic water supplies, this has had a higher impact on women than on men, as the home garden is women's responsibility and one of the few ways in which they are able to earn some money. Livelihood impacts include:

- higher medication costs to treat water-related illness
- restriction on cultivating fruit and vegetables in the home garden and the associated higher cost of purchasing fruit and vegetables
- increased gas expenditure to boil water
- higher cost in buying household items such as soap, shampoo, etc.

There is fortunately a strong sense of corporate community responsibility which provides a valuable and welcome safety net for poorer households. Some of the richer families lend animals to poorer families so they can use the milk. This is particularly important in Al Jafr, where livestock is an important feature of the local economy. In Shoubak, subsidised animal fodder is available from government outlets. Local shops also extend monthly credit.

In Al Jafr, the Social Development and National Aid Fund calculate they provide cash and occupational rehabilitation for about 27% of households[10].

The poorest families look to government employment and the army to obtain regular income. The most vulnerable are:

- women-headed households with no working male adults and several small children
- women of child-bearing age in households with no water storage facilities (burden of carrying heavy loads)
- elderly people with no working adults
- families with little or no education and reduced work options

Vulnerability is also location-specific, with some areas such as Juhaier experiencing seasonal difficulties, while others such as Mansourah experience year-round problems.

Satisfaction Levels

For Al Jafr and Al Shoubak combined, 45% of FGD respondents were not satisfied with summer access to water, although 100% were satisfied with winter access. 71% were unsatisfied with the quality of water.

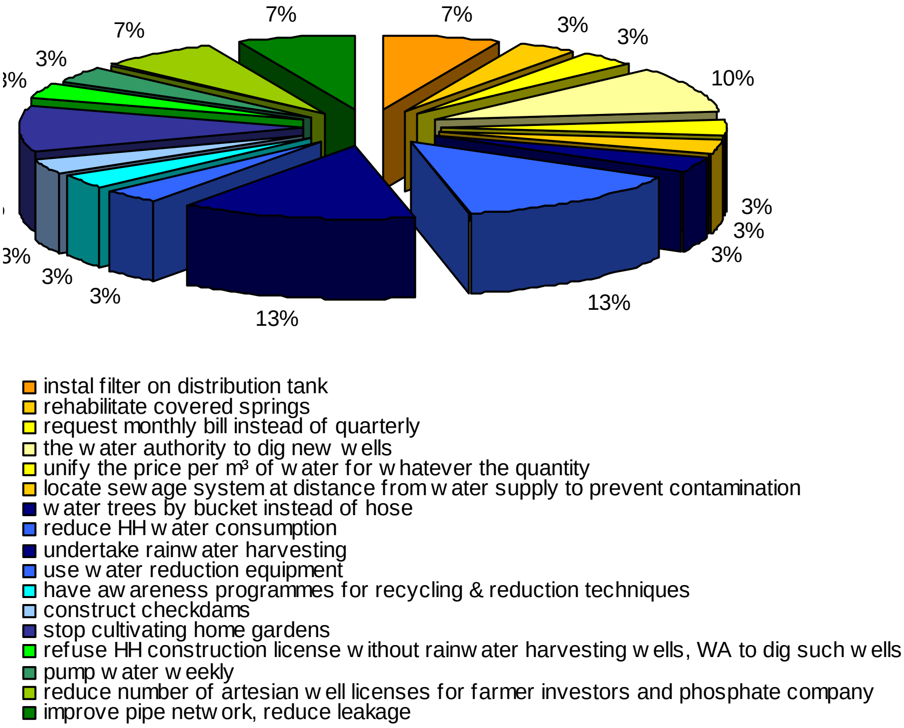
Dealing with Change

According to FGD respondents, the domestic supply situation has improved over the past three years. Figure IV.8 reflects the relative popularity of different suggestions by respondents on how to improve the water situation. These fell into approximately three categories:

- actions reflecting low levels of awareness about causes of groundwater scarcity (yellow wedges)
- actions that could be undertaken by government (green wedges)
- actions that could be undertaken by the household (blue wedges)

[10] Department of Social Development PRA, Al Jafr, 2003

Figure IV.8 Respondent attitudes to dealing with water quantity changes

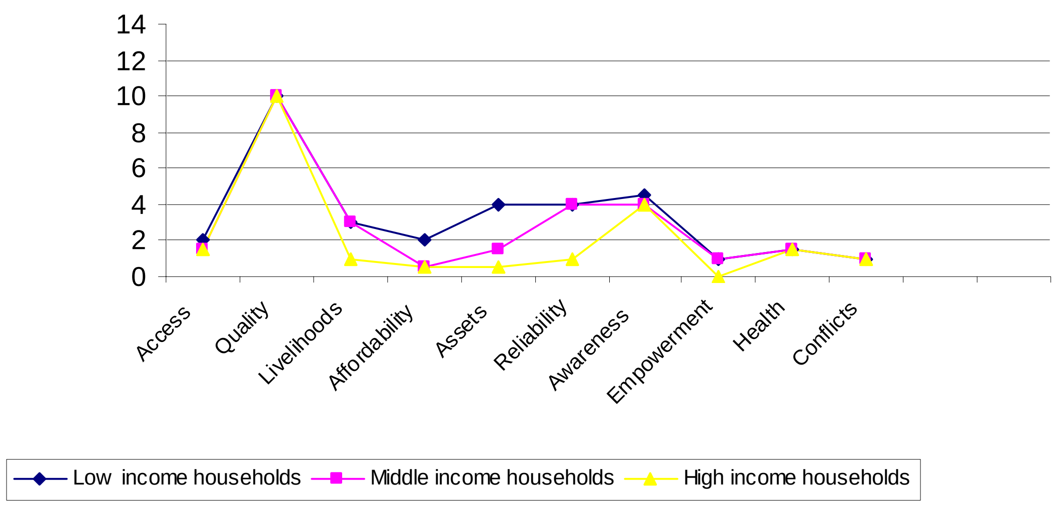


3.4 Vulnerability assessment, target groups identified

On the basis of the methodology described in Section II.2 above, a test assessment of vulnerability was prepared for Al Jafr with different socio-economic categories of low, middle and high income households.

Using fieldwork data collected from Focus Group Discussions (FGD), an assessment of how respondents might have assigned values, was made. This resulted in the following vulnerability appraisal for Al Jafr.

Figure IV.9 Vulnerability assessment, Al Jafr



In Al Jafr, the vulnerability assessment shows far fewer impact differences between socio-economic groups. There is a reasonable standard of access for all households, and the fact that primary sources of livelihood are not water-dependent indicates a relatively low livelihood impact, though there are some differences between rich households compared to middle and low-income families. The greatest impact differences are to be seen in levels of asset ownership (e.g. water storage tanks), where rich and middle-income households are less affected than low-income households, and supply reliability, where rich households are less affected than middle and low-income households.

Location-related vulnerability is also apparent, with all income groups being equally affected by poor water quality.

3.5 Agricultural Water Use

In the five FGD locations in Al Jafr and Al Shoubak, approximately 33% own land. Of the 37 respondent households in the FGDs cultivating land, landholdings averaged 16.5ha per household. However, sizes vary widely, with the smallest landholding being 0.5 ha and the largest 150 ha. Landholdings among high income households in Al Jafr are particularly large.

Livestock, particularly sheep, are an important part of the domestic economy. Sheep and goats are important for women's income, as are home gardens attached to the house. In Shoubak, there are, in addition, 23 large specialised farms principally producing apples, apricots and other stone fruits and some vegetables.

The FGDs were undertaken in areas outside these large fruit farms and details below refer to FGD respondents living and working outside these farms.

Diversification of Sources

The main sources of irrigation water are: (i) farmer-owned wells, (ii) wells belonging to a society or co-operative, (iii) wells belonging to the water authority in Shoubak, (iv) wells belonging to the Ministry of Agriculture in Al Jafr, and (v) natural springs in Shoubak. Farmers may use more than one water source.

Farmers in Al Jafr and Shoubak demonstrated different levels of familiarity and use of water saving techniques.

In Shoubak, non-Bedouin farmers have been settled agriculturalists for generations, are familiar with making the most of what little moisture they have and practised drip irrigation and mulching.

Water Security

In Shoubak, there are few complaints from farmers about water security. Farmers noted, however, that some springs have dried up and water levels overall have fallen. All agricultural Focus Groups agreed the quality is very good for agricultural purposes. Most farmers depend on rainfed agriculture in the winter and on wells in the summer. Farmers will admit to one or two licensed artesian wells on their land, but all acknowledged that a far higher number of unlicensed wells are used in reality.

In Al Jafr, farmers saw no change in quantity, but significant worsening of water quality with higher levels of salinity. There was no seasonal difference in quality in any of the fieldwork locations.

All farmers are well aware of the impact that extensive extraction by the large fruit farms in Shoubak and by the phosphate company in Al Jafr, is having on their water sources. However, this does not necessarily stop farmers from continuing to pump water for their own purpose, quite extensively in some instances.

Figure IV.10 Small and large farms, Shoubak

Not everyone could specify differences in well depths, but all Shoubak FGDs confirmed deepening their wells in the last five years. Respondents in Al Jafr reported that there are 74 private working wells.

Conflicts

60% of FGDs reported conflicts over water. Of these, 40% were between farmers and water authorities and 60% between farmers.

Grievances with water authorities focused entirely on water pricing. However, at the time of fieldwork it was announced that the Council of Ministers had amended the regulation governing the use of groundwater in the country, reducing the price of water extracted from licensed wells from JD0.25/m^3 to JD0.05/m^3.

Disagreements between farmers were principally over the amount of water taken by an individual, the water schedule, and the tail end of the distribution network suffering from low pressure (Al Zubayriya, Al Jarba).

Coping Strategies

Both Shoubak and Al Jafr have always been arid and water-poor areas. Farmers are accustomed to adopting coping strategies, particularly in years of periodic drought. 60% acknowledged water problems have affected their livelihoods. Three principal coping strategies were identified, the most popular option being to reduce the cultivated area (50%), followed by decreasing the amount of water given to trees or to quit agriculture altogether and seek other forms of income generation (25% respectively).

Livelihood impact for farmers appears to be limited, though all farmers would like to cultivate more land than they are currently able to do. All respondents said agriculture is not the main or most important source of household income. Most households depend primarily on income from a salaried family member, or from government support.

Satisfaction Levels

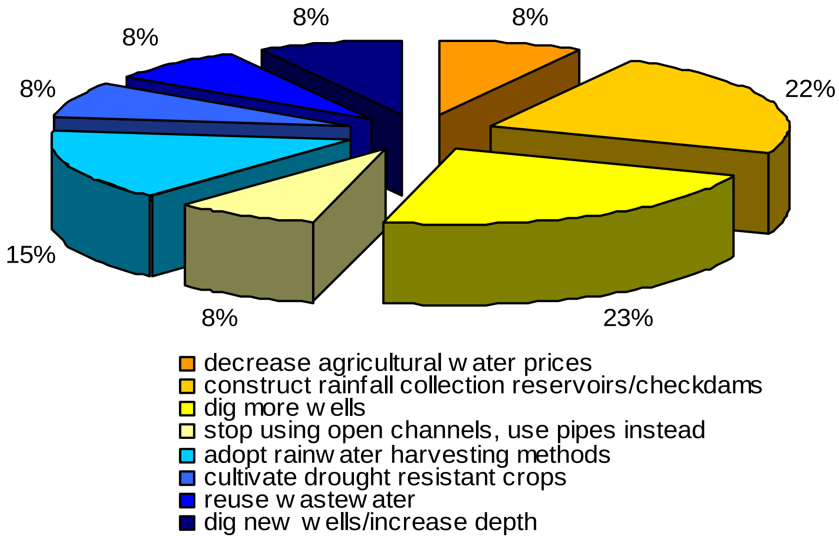
Satisfaction levels are fairly high for all categories. Those not satisfied with the quantity are mainly those accessing water from a co-operative or Ministry of Agriculture wells.

Dealing with Change

There has been little change in Shoubak and Al Jafr, and most farmers feel it is the government's responsibility to sort out their water problems. Although there are high levels of awareness of the impact of large-scale water extractors from both aquifers, the main response appears to be a desire to do the same. Attitudes towards aquifer use reflect short-term thinking, and there are very low levels of awareness about aquifer capacities and how it will affect them in both the immediate future and long-term.

When asked about water supply levels and standards remaining the same or becoming worse, responses reflected actions which could be undertaken at community level (blue wedges) and at government level (yellow wedges). Farmers consider the responsibility is more that of government than that of farmers.

Figure VI.11 Respondent attitudes to dealing with groundwater situation (% of FGD responses)



4. DEMAND MANAGEMENT OPTIONS

4.1 Current management strategies

In Jordan, a national water demand management approach has already been considered. The approach taken within the Ministry of Water and Irrigation's Water Resources Management Master Plan (2001) is outlined in Annex B. The demand for water for domestic and industrial use is given priority and as the demand for agricultural water from groundwater sources exceeds the renewable resource, demand management measures are required in this sector.

Many of the measures, discussed in Part II, (page 9) are included in the MWI's approach (e.g. allocation to sectors, measures for reduction of groundwater abstraction, improvement measures for unaccounted for water, institutional and legislative improvement), and there are lessons to be learnt from the approach adopted. However, we consider that some development of this process is required to provide a logical strategy which could be made more generally applicable to regions where there is a shortage of resources. Particular applications to the Case Study area of Al Jafr-Shoubak need further elaboration.

Although the range of supply options listed in Part II, including the Ma'an Wastewater Re-use project, have been considered by the Jordanian Government to provide sufficient water for the Shoubak and Al Jafr areas, a number of issues arise with regard to the water supply for domestic and industrial use and provision of water for agriculture in the area. These include:

- unreliability of rainfall (and lack of rainfall in the mostly semi-arid and arid region)
- over-abstraction from the aquifer, falling groundwater levels and increased salinity
- competition for water between agriculture and the Water Authority of Jordan

These have to be seen in the context of the The Jordanian Water Resources Management Master Plan (2001). The principal policy thrust has been given to measures for reducing irrigation water consumption and to reducing consumption for Municipal, Industrial and Tourism (MIT) uses.

The aquifers in Shoubak and Al Jafr are both being over-exploited with deterioration of water quality in Al Jafr. In Shoubak, controls on abstraction are required in the agricultural sector (particularly in the area of the large fruit farms where the abstractions are currently unsustainable). In Al Jafr, the abstractions for agriculture are again having an impact on the aquifer water levels and the quality of the water being abstracted is deteriorating having an effect on the abstraction for domestic water supply.

The range of demand management options for the domestic, industrial and agricultural sectors are given in Table IV.4.

Further examination of options is required for the two areas but a first step is to determine more accurately the sustainable yields of the aquifers and agree on sectoral allocations.

The areas shaded thus:

indicate measures which are applicable and could be considered.

Table IV.4 Water demand management options – Al Jafr-Shoubak

	WATER DEMAND MANAGEMENT			
	Domestic/municipal		Agriculture	
Developmental and technical measures	DT1	Reduce consumer water losses	AT1	Improve efficiency of surface irrigation systems (Al Jafr MoA farm)
	DT2	Water saving devices and fittings		
	DT3	Recycling of industrial water	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT4	Use of "grey water"		
Distributive, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land use change and control	AA3	Land use change and control by: a) land purchase b) re-zoning/classification c) well buy-outs (transfer of water rights)
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population density regulation	AS2	Population density regulation
	DS3	Migration	AS3	Migration

5. IMPACT OF DEMAND MANAGEMENT OPTIONS

5.1 Introduction

The studies in Shoubak and Al Jafr have demonstrated different characteristics and a range of water supply and management issues.

The principal issues relate to the over-abstraction of water from the aquifers: (i) in Shoubak where the fruit farmers are abstracting more than the renewable resource in this area; and (ii) in Al Jafr where there is a less obvious but significant drop in the water table and a deterioration of the quality of the water for both domestic and irrigation water supply.

Further work is required to confirm the current abstractions form these aquifers and to determine appropriate demand management options which would be effective in rendering the aquifers sustainable.

At this stage of the Research Project, we can only point to demand management measures that should be considered and their potential impacts. These measures will be developed in early 2005 so that an appropriate strategy can be developed.

5.2 Water provision, savings and unit costs of water saved

Some preliminary cost estimates of components of a number of water supply options, based on data made available in Jordan, are given in Table IV.5. These costs are based on schemes that have been studied or implemented in Jordan and are not all relevant to the Case Study areas. Derivation of these figures is described in Annex F.

Table IV.5 Cost of components of water produced (JD/m^3)

Option	Description	Cost of Water (JD/m^3)	Water made available at
SD1/SA1	Develop additional GW	0.07-0.09	at wellhead
	Develop additional surface	2.60	at dam outlet
SD2	Desalination	0.70-1.40	at plant
SD4	New water treatment facilities		
SD5	Extend water distribution system	0.66	at consumer (transfer to Ma'an and distribution)
SD7/SA3	Retention dams and reservoirs	2.60	at dam outlet
SD8/SA4	Aquifer recharge (dam)	0.084	in aquifer
SD11/SA7	Trans basin water transfer	0.476-1.155	Amman from Jordan river, from Lebanon
SA2	Treat/use wastewater	0.364	at treatment plant

(*Source: Annex F)*

Where demand management measures are introduced, there is a cost in so doing and, where agriculture is curtailed, an amount saved per hectare of land can be estimated. The table below gives some initial estimates of the cost of water saved and potential savings per hectare for a number of demand management measures which could be adopted in the Case Study area.

Table IV.6 Cost of components of water saved (JDs/m^3)

Option	Measure	Cost of water saved (Rs/m^3)	Quantity of water saved (m^3/ha)	Water made available at
DT1	Reduce consumer loss	0.22-0.25		at supply
DT2	Recycling of industry water	0.364		at plant
AR3	Change land use	0.02-0.77	3,500-8,000	aquifer
AR4	Crop area restriction	0.02-0.77	3,500-8,000	aquifer
AR5	Change cropping pattern			

5.3 Impact of water demand management measures on poor and vulnerable

The studies to date have defined the vulnerable in the Case Study area and their current status with regard to water. The research continues with impact studies of introducing water demand management measures on the poor and vulnerable and the development of strategies which would protect these groups from negative impacts which could arise from their introduction.

Glossary of terms (as used in the text)

General

Stakeholder	An individual or a governmental, non-governmental or private organisation which has an interest in, would participate in or be affected by the implementation of measures (relating to water resources development)

India:

A-K aquifer	Aquifer underlying the Araniyar, Kortalaiyar river basins
Chennai basin	River basin comprising Araniyar, Kortalaiyar, Cooum and Adaiyar rivers
Panchayat	Elected local body at village level (it may include one or more villages)
Rupee	1 US$ = 45 Indian Rupees
Taluk	Administrative sub-division of a district

Jordan:

dunum	1 dunum = 0.1 hectares
Jordanian Dinar (JD)	1 US$ = 0.71 JD

Abbreviations and Acronyms

General:

DFID	Department for International Development, UK
ESA	Environmental Services Association
FAO	Food and Agriculture Organisation, Rome
FGD	Focus Group Discussion
ha	hectare (10,000 m^2)
HP	Horse-power
JICA	Japanese International Cooperation Agency
lpcd	litres per capita per day
MLD	Million litres per day
m^3	cubic metres
Mm^3	Million cubic metres
NGO	Non-governmental Organisation
UKWIR	UK Water Industry Research
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WDM	Water Demand Management
WHO	World Health Organisation
yr	year

India:

A-K aquifer	Araniyar-Kortalaiyar aquifer
AED	Agricultural Engineering Department (Tamil Nadu)
CMA	Chennai Metropolitan Area
MWSSB	Chennai Metropolitan Water Supply and Sewerage Board (also referred to as Metrowater)
IWS	Institute of Water Studies (Tamil Nadu)
TWAD	Tamil Nadu water Supply and Drainage Board
WRCRC	Water Resources Control and Review Council (Tamil Nadu)
WRO	Water Resources Organisation, Public Works Department (Tamil Nadu)

Jordan:

JD	Jordanian Dinar
JVA	Jordan Valley Authority
MIT	Municipal/Industrial/Touristic (sectoral water demand in Jordan)
MWI	Ministry of Water and Irrigation (Jordan)
JVA	Jordan Valley Authority
MIT	Municipal/Industrial/Touristic (sectoral water demand in Jordan)
MWI	Ministry of Water and Irrigation (Jordan)
WAJ	Water Authority of Jordan
WIS	Water Information System

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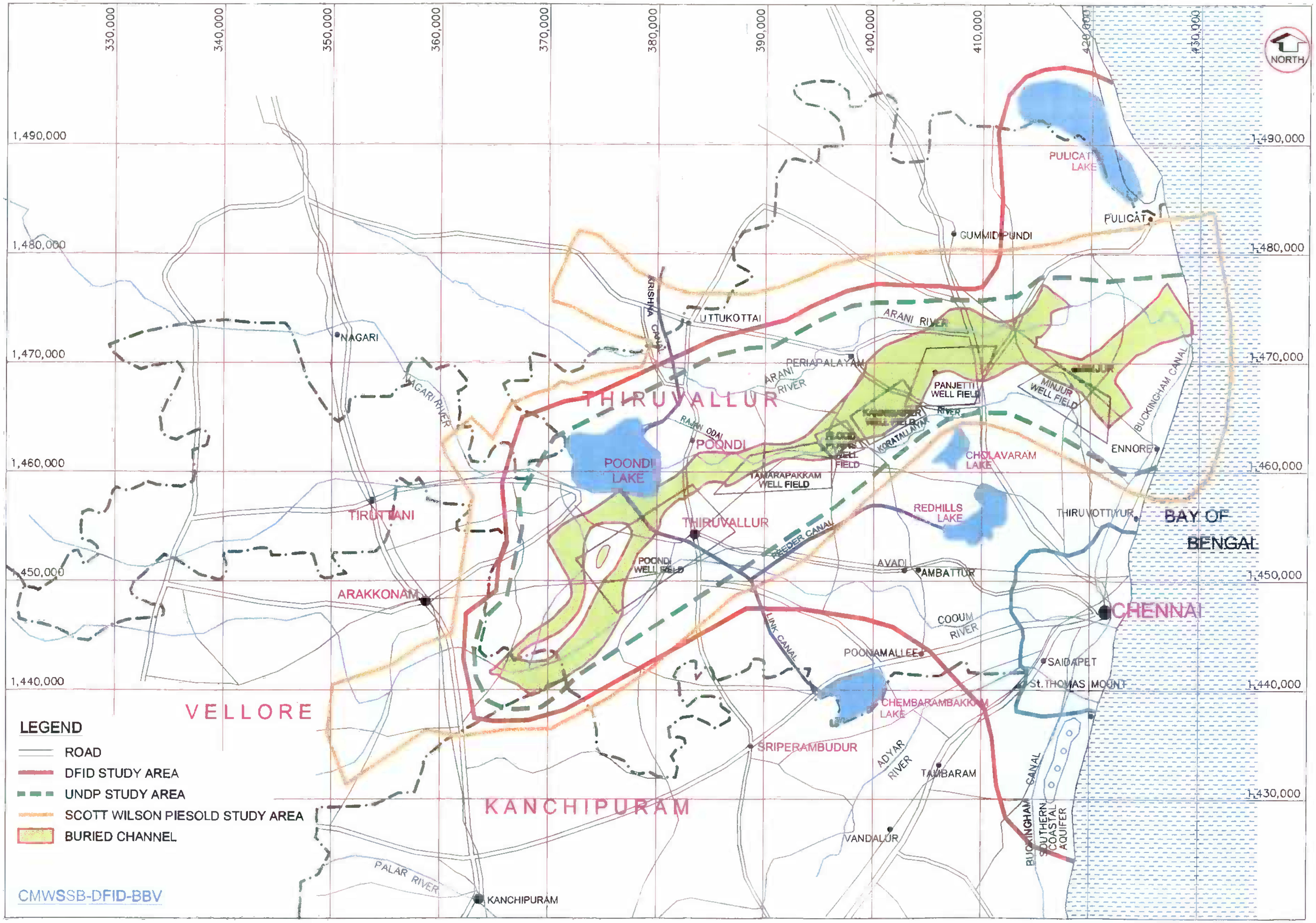
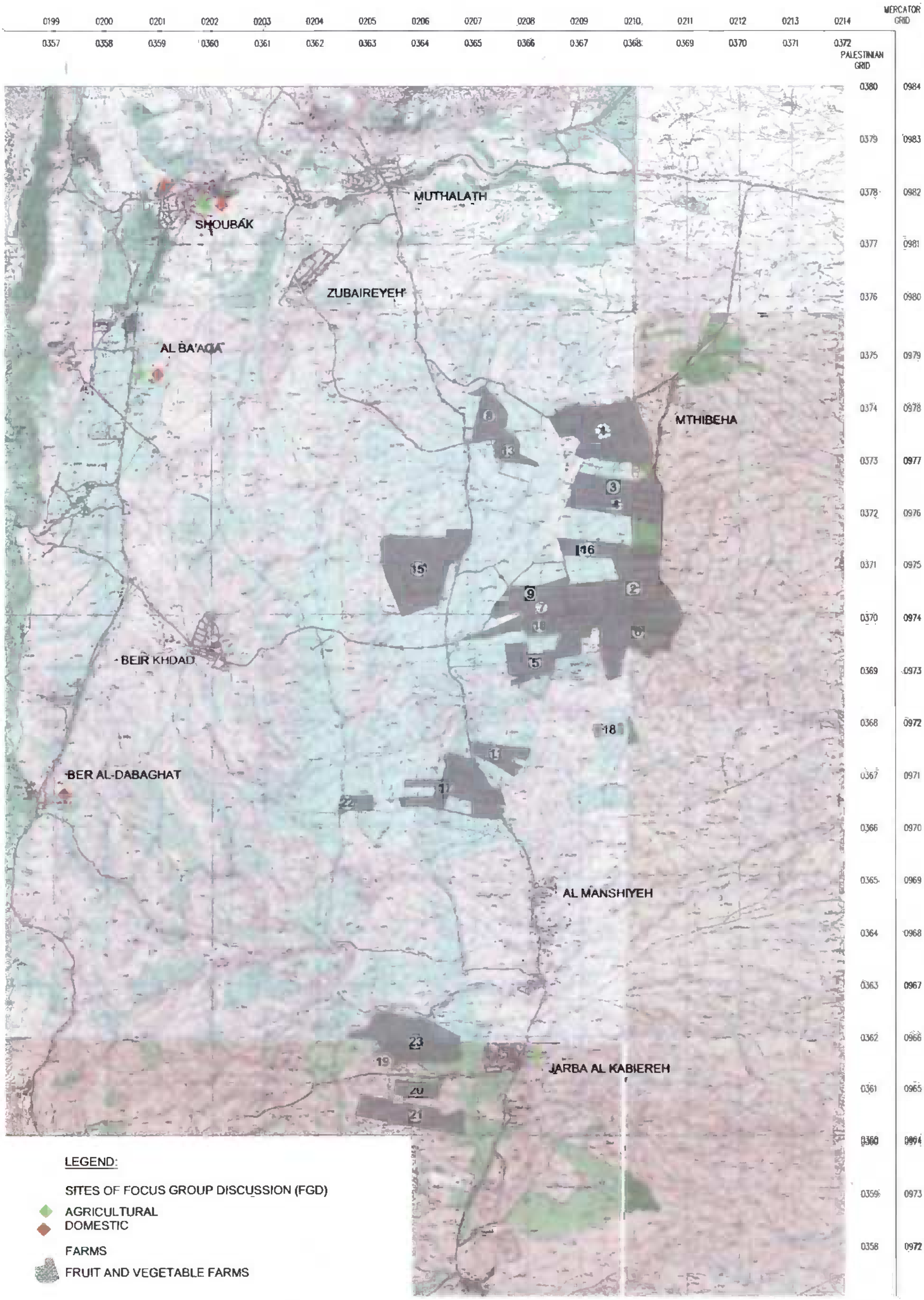


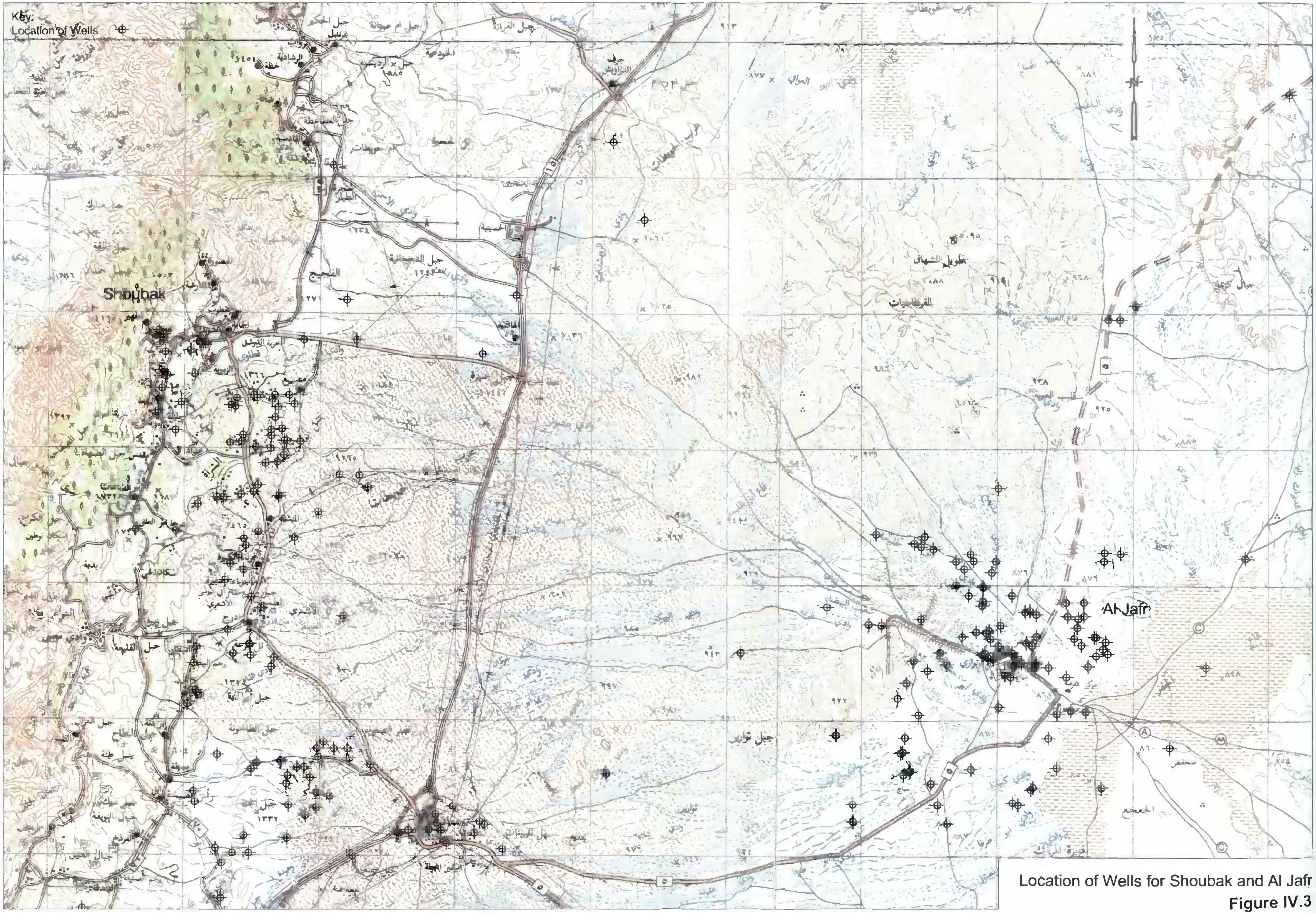
SOURCE-CMWSSB

STUDY AREA

Study Area - Chennai
Figure III.1



Agricultural Areas - Shoubak
Figure IV.2



Location of Wells for Shoubak and Al Jafr

Figure IV.3

DFID

Engineering Knowledge and
Research Programme

(KaR 8332)

Water Demand Management in areas of groundwater over-exploitation

REPORT ON CASE STUDIES

ANNEXES A TO D

January 2005

BLACK & VEATCH

Black & Veatch Consulting

in association with

VRV Consultants (P) Ltd, Chennai, India

Jouzy & Partners, Amman, Jordan

REPORT ON CASE STUDIES – JANUARY 2005

ANNEXES A - D

This Document contains Annexes A to D of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

Annex A – Approach to the Study

Annex B – Water demand management

Annex C – Sustainable livelihoods approach

Annex D – Focus group discussions – Methodology & results

The Annexes support the Main Report, which is bound separately, and are followed by the following Annexes which are also bound separately

Annex E – Water Resources
Annex F - Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

REPORT ON CASE STUDIES – JANUARY 2005

ANNEX A APPROACH TO THE STUDY

CONTENTS

PREFACE

This Document on the "Approach to the Study" forms Annex A of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

The Report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B - Water demand management
Annex C – Sustainable livelihoods approach
Annex D – Focus group discussions – Methodology & results
Annex E – Water Resources
Annex F – Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken, one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

Annex A describes the background to the study, the methodology adopted by the study team and the programme of work.

ANNEX A APPROACH TO THE STUDY

A1. BACKGROUND TO THE STUDY

A1.1 Background

The research project is part of the UK Government Department for International Development (DFID)'s Knowledge and Research Programme. The initial concept (Ref. 1) has been developed in line with the DFID agenda on poverty alleviation and in support of the International Millennium Goals.

The project recognises DFID's strategies for achieving International Development Targets and their overall strategy for water which includes:

(i) improving the management and allocation of water resources; and
(ii) ensuring activities in water contribute to and are guided by Poverty Reduction Strategies.

The research takes into account DFID objectives set out in Government White Papers Eliminating World Poverty: A Challenge for the 21st Century (1997) (Ref. 2) and Eliminating World Poverty: Making Globalisation Work for the Poor (2000) (Ref. 3). It is being undertaken within the context of the UN Millennium Development Goals, the DFID strategy for poverty reduction and the sustainable livelihoods approach.

Groundwater is the principal source of irrigation, domestic and industrial water supply in many arid and semi-arid countries. However, many of these countries are already consuming more water than is available from renewable resources. In some areas, over-abstraction of groundwater is leading to saline intrusion and deteriorating water quality.

Management of the demand for groundwater is required if the aquifers are not to be over-exploited. A variety of measures can be applied to achieve sustainability but their introduction may have negative impacts on the livelihoods of some sections of the community.

In the irrigation sector, technical solutions (e.g. reducing losses in existing systems; promoting modern irrigation systems), regulating water use (e.g. water quotas; crop restrictions; cropping pattern or land-use changes) or introducing market influences (e.g. water tariffs; water markets) can be considered. In the domestic/municipal water supply sector corresponding technical, allocative and market influences may be introduced.

The poor (vulnerable farming families and domestic consumers) may be adversely affected by the introduction of water demand management measures with poverty increasing as a result. Some groups who are unable to afford the technical solutions for water conservation may be negatively affected by water quotas and crop restrictions and may be unable to meet the cost of water tariffs. The livelihoods of landless and tenant farmer families may become further impoverished by the impact that the introduction of demand management measures has on the actions of their landlords.

Strategies are required to ensure that the poor are protected, ones which provide an enabling environment in which the vulnerable can escape from poverty and a climate in which their aspirations can flourish and be met.

The purpose of the research is to:

- examine water demand management strategies for controlling groundwater abstraction in areas where aquifers are being over-exploited, ensuring the long-term livelihoods of the vulnerable and poor are safeguarded; and to
- discuss and disseminate results with potential end users of the research (Donor agencies, Government and agencies involved in water management)

Examples of the problem arise in Tamil Nadu, India where aquifers are being over-exploited, where the quality of water is affected by saline intrusion and where the supply options are unreliable and in Jordan where aquifers are being depleted because of over-use of water for agriculture.

Two “case study” areas were chosen, one based on Chennai, Tamil Nadu and the other in the Al Jafr - Shoubak region in Jordan. General studies are also being made on the basis of reports and literature from other countries where aquifer depletion and demand management are issues.

The overall conclusions of the research will provide strategies for approaching demand management issues and at the same time address the impact of these strategies on the human, natural, physical, financial and social livelihoods of the vulnerable and poor.

The Case Study Report was discussed with stakeholders at workshops and meetings in Chennai and Amman in November 2004 before strategies are developed. The strategies will be made suitable for dissemination to potential end-users of the research within the countries where research has been undertaken and to a wider audience for incorporation in future projects in South Asia, Middle East and North Africa.

The final output will be developed and prepared in a form suitable for dissemination both as a document and on a web-site. The studies are being carried out over a period of two years (with intermittent inputs in each country) and will be followed by a six-month period for dissemination of findings.

The following Government institutions, donor and other agencies have provided advice and access to data in support of the studies:

India:

Tamil Nadu Government
Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) – Metrowater
Ministry of Finance
Department of Municipal Administration and Water Supply (MAWS)
Department of Public Works (PWD)
Institute of Water Studies, PWD
Tamil Nadu Water & Drainage Board (TWAD), Department of MAWS

Funding Agencies
World Bank, Asian Development Bank, DFID

Other agencies
Madras School of Economics
The Megha Foundation
Sadhana Rural Foundation

Jordan:

Hashemite Kingdom of Jordan
Ministry of Planning
Ministry of Water and Irrigation
Water Authority of Jordan
Ministry of Agriculture

Funding Agencies
USAID; EU; GTZ; JICA, UNDP

Other agencies
University of Jordan

Black & Veatch Consulting Ltd is leading the research and providing inputs on water resources, hydrogeology, community, poverty, gender issues, economics and strategy development. The collaborating organisations are:

In India:
VRV Consultants (P) Ltd., Chennai
Centre for Urban Poverty Alleviation (CUPA), Chennai

In Jordan:
Jouzy & Partners, Amman
The Jordanian Hashemite Fund for Human Development,
Queen Zein Al Sharaf Institute (ZENID), Amman

The research project started in November 2003. The final report will be available in draft in November 2005.

A2. APPROACH

A2.1 Inception Phase and Case Studies

After initial preparations, the Black & Veatch research team made visits to India (11 – 26 November 2003) and Jordan (2 -17 December 2003).

The purpose of the project and the potential "Case study" areas were discussed with Ministries in India and Jordan and suitable study areas were identified in Chennai - Tamil Nadu and in the Al Jafr – Shoubak region in Jordan. This period was followed by a consolidation period during which the Black & Veatch team reviewed previous studies and available data. The in-country collaborating consultants and NGOs continued with data collection. A literature search was started. A project website was established in March 2004 (http://www.groundwater-poverty-KaR.co.uk).

India (First visit, November 2003)

Inception meetings were held and Sub-Consultant Agreements were signed with collaborating Consultants (VRV Consultants Ltd and Centre for Urban Poverty Alleviation). Meetings were then held with the following to explain the purpose of the research and agree on a suitable study area:

Minister of Finance, Government of Tamil Nadu, The Honorable C. Ponnaian

Chief Secretary, Government of Tamil Nadu, Ms Lakshmi Pranesh IAS

Secretary, Department of Public Works, Govt of Tamil Nadu, Mr N.S.Palaniappan IAS

Secretary, Municipal Administration & Water Supply, Govt of Tamil Nadu, Mr L.N.Vijayaghavan IAS

Chennai Metropolitan Water Supply & Sewerage Board, Mr V Thangavelu IAS

It was agreed that the case study area should include the area south of the Tamil Nadu – Andhra Pradesh boundary, the District of Tiruvallur covering the A-K aquifer and the Chennai Metropolitan area.

Field visits were made to examine the conditions in the study area. Discussions were held with women's and farmers' groups to gather initial information sufficient to define the work required to identify: (i) poor and vulnerable groups; (ii) the participatory surveys and Focus Group Discussions (FGDs); and (iii) data collection required. NGOs visited included Literacy Project, Corporation of Chennai; The Megha Foundation (Saranalaya Children Home); Sadhana Rural Foundation, Somangalam.

Data were collected on Water Resources Development and an initial list of potential water demand management measures was prepared for the case study area for further discussion and evaluation.

Fig 2.1 Location of the Case-study Area in India .

Jordan (First visit, December 2003)

Inception meetings were held and Sub-Consultant Agreements were signed with the collaborating Consultants (Jouzy & Partners). Meetings were held with the following to explain the purpose of the research and agree on a suitable study area:

Ministry of Planning, Directorate Water & Environment, Director, Dr Kamal Khdier

Ministry of Water & Irrigation, Secretary General, Dr Sa'ad al Bakry; Director, Water Resources and Planning Directorate, Mr Edward Qunqar

Meetings were also held with:

USAID, Director, Office of Water Resources & Environment, James Franckiewicz

British Embassy, Development Officer, Ms Rana Saifi

EU Delegation, Mr Mario Rizos

WEPIA (Water Efficiency and Public Information for Action), Ms Mona Grieser

Near East Foundation, Country Director, Hajem Halaseh

CARE International, Programme Manager, Liam Maquire

JOHUD (Queen Zein Al Sharaf Institute for Development), Director, Ms Eman Nimri

Centre for Strategic Studies, Director, Dr Mustafa Hamaneh

The following potential study areas were visited on the advice of the Ministry of Water & Irrigation: Azraq, El Duleil, Upper Mujib and Al Jafr. After further discussions, the Ministry asked the Consultants to study the Al Jafr/Shoubak area. This is an area in southern Jordan where part of the aquifer is heavily used by fruit farmers and where there is both a settled and a semi-nomadic rural population with significant livestock.

Fig 2.2 Location of the Case Study Areas in Jordan .

An initial field visit was made to examine the conditions in the study area. Discussions were held with the local Consultants on the gathering of initial information, identification of poor and vulnerable groups and the participatory surveys and data collection required. After discussions with suitable collaborating NGOs, JOHUD (Queen Zein Al Sharaf Institute for Development) were appointed. An agreement was made between Jouzy & Partners and JOHUD for their assignment.

An agreement was also made with Professor Elyas Salameh, University of Jordan, to prepare a paper on the Shoubak - Al Jafr Case Study area and to contribute to project workshops on the project.

UK (January – March 2004)

The Black & Veatch team, on return to UK, consolidated the initial findings, drafted notes for local consultants to continue with the identification of poor and vulnerable groups, stakeholders and institutions, applicable legislation and regulation, data for the case study areas for water resources, hydrology, hydrogeology, water supply and treatment facilities.

An initial list of potential water demand management measures was prepared for the case study area for further discussion and evaluation.

On 16 March 2004, an outline of the research was presented at the International Commission on Irrigation & Drainage (British Section) one day Research Day meeting at HR Wallingford, UK.

India (Second visit, March 2004)

The purpose of the second visit was to;

(i) extend the team's understanding of the ground and surface water resources in the Chennai region and water supply and demand management issues;

(ii) undertake Focus Group Discussions (FGDs) in the Study area;

(iii) collect data on water policy, institutions and legislative issues;

(iv) collect and examine data on costs and economic aspects of development; and

(v) meet with stakeholders and donor agencies.

During the visit, 22 FGDs were held with a range of water users (domestic, agricultural and industrial) - see Annex D.

Details were collected of existing and ongoing developments for water supply to the Chennai Metropolitan Area and a review made of Water Resources Development Projects (see Annex E).

DFID, Asian Development Bank and World Bank offices in Delhi were visited to update resident staff there on the research project activities and to advise them on the plans to hold a one-day workshop in Chennai in November 2004 at which the Case Study Report and approaches to water demand management would be discussed.

Jordan (Second visit, April 2004)

The purpose of this visit was to;

(i) examine the water resources, and the water supply and demand management issues in the Shoubak and Al Jafr area;

(ii) undertake Focus Group Discussions (FGDs) in the study area;

(iii) examine data on water policy, institutional and legislative issues;

(iv) collect and examine data on costs and economic aspects; and

(v) meet with the Ministry of Planning, Ministry of Water & Irrigation and the Ministry of Agriculture

During the visit 12 FGDs were held with a range of water users (domestic and agricultural) - see Annex D. The Shoubak area is strongly influenced by water abstraction by large apple and stone fruit farms. These were identified and a selection of these farms were visited to investigate details of water use and farm economics. Details are given in Annex F.

Details were collected of existing and ongoing water resources development in the Shoubak and Al Jafr areas and of national strategies and future plans for water supply and management (see Annexes E & G).

Case study report

The Case Study Report, of which this is Annex A, was submitted in draft to DFID and to selected stakeholders in India and Jordan in June 2004. The Draft Report, together with a supporting "Knowledge Review", was submitted to DFID with an Inception Report in mid-June 2004. Issues and themes identified in the Report were developed at a workshop and meetings held in Chennai and Amman in November 2004. .

A2.2 Workshops and dissemination of findings

Dissemination and communication – Workshops

A workshop was be held in Chennai on 20 November 2004 and meetings were held in Amman in November 2004 to explain the findings of the research and to illicit views from stakeholders and end users during the research process so that their views could be incorporated. Proving the soundness of the findings from the Tamil Nadu and Jordan "case studies" will be important and will allow us to develop water demand management strategies which can be made relevant not only to the "Case Study" areas but also to other aquifers in other parts of the world.

The one-day workshop in Chennai in November 2004 was attended by representatives from Ministries, donor agencies, regional and local government departments, and agencies working in the water and social sectors.

Following submission of the Case Study Report, the research team will develop the results of the case studies to determine water demand management strategies which are applicable specifically to the study areas and which can be made relevant to other over-exploited aquifers.

Once these strategies have been developed, further meetings and a workshop will be held to discuss them. The provisional date for the workshop is September 2005.

Final Report & Guideline on identification of target beneficiary groups

The Final Report will be prepared after the 2005 workshop and, after discussion, will be presented in a form which suits the requirements of DFID. It will contain the findings of the research and be tailored to suit its incorporation in stakeholder policy documents.

In addition, a short advisory guideline on the identification of poor and vulnerable groups will be prepared. This will be developed on the basis of the "case studies" but made applicable, as far as possible, to a wider range of situations and areas where either groundwater or surface water is being over-exploited.

Dissemination of findings through website

The creation of the web-site http://www.groundwater-poverty-KaR.co.uk and the use of information and communication technologies will form a part of the dissemination process. The precise requirements will be discussed with DFID. The web-site will provide appropriate information for DFID Partners, linked to other relevant and complementary sites. We have created this site to raise awareness of the programme and to draw contributions and comments from other potential end-users and stakeholders.

The potential target audiences interested in the research are:

(i) Government Ministries and Departments who are involved in the management of the abstraction of groundwater and in the introduction of demand management measures;

(ii) Multilateral and bilateral funding agencies (e.g. World Bank, Asian Development Bank, DFID, USAID, EU, SDC) who are supporting work in this field, and

(iii) Agencies involved in poverty reduction strategies.

In addition, the work undertaken during the research period on the identification of poor and vulnerable groups and on the development of appropriate livelihoods approaches will be of interest to NGOs and agencies working in this area.

To meet their needs, we propose the following strategy for dissemination of findings:

- Identification of potential end-users and target organisations: (i) during the Inception Period (Oct 2003 – June 2004); (ii) while WDM Strategies are being developed (January 2005 – May 2005); and (iii) during June 2005 when the plan for the delivery and discussion of findings is prepared.
- Discussion with target audiences to identify best forums and format for dissemination of the findings. In addition, after discussion with DFID, we will finalise the details of published material and ITC required, develop and distribute this in appropriate publications and websites.
- We anticipate feed-back from the workshops and have allowed for disseminating the outcome of them and for following up with end-users and target organisations during late 2005.

The promotion pathways of the research would be as follows:

- Local and central government, institutions and agencies, including NGO will be encouraged to participate during the period of the research activities.
- Reports, advisory notes, workshops and seminars prepared and delivered during the research programme.
- Research results and reports will be disseminated at meetings, national and international conferences and to bilateral and multilateral funding agencies. They would be distributed to institutions in countries where similar conditions apply, making use of new information and communications technology

Target audiences would be encouraged to extend public awareness and information campaigns to communities who would be affected by future demand management measures.

A3. PROGRAMME OF WORK

The programme of work is attached.

Key dates are:

Inception Report with “draft Case Study Report”	15 June 2004
Workshop and meetings to discuss issues raised in the “Case Study Report”	November 2004
Case Study Report (Final)	January 2005
Development of Water Demand Management Strategies	January-May 2005
Workshop to discuss Water Demand Management Strategies	September 2005
Dissemination of findings and Final Report	November 2005
Research contract closure date	June 2006

Abbreviations and acronyms

DFID	Department for International Development
EU	European Union
FGD	Focus Group Discussion
JOHUD	The Jordan Hashemite Fund for Human Development
KaR	Knowledge and Research (as in DFID KaR Programme)
NGO	Non-governmental Organisation
SDC	Swiss Development Co-operation
USAID	United States Agency for International development
WDM	Water Demand Management
ZENID	Queen Zein Al Sharaf Institute

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1. Water Demand Management in areas of groundwater over-exploitation, DFID Engineering Knowledge and Research Programme, Competitative Component – Bid Round 2003/04

2. Eliminating World Poverty: A Challenge for the 21st Century, UK Government White Paper (1997)

3. Eliminating World Poverty: Making Globalisation Work for the Poor, UK Government White Paper (2000)

REPORT ON CASE STUDIES

ANNEX B WATER DEMAND MANAGEMENT

CONTENTS

PREFACE

This Document on “Water Demand Management” is Annex B of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B - Water demand management
Annex C – Sustainable livelihoods approach
Annex D – Focus group discussions – Methodology & Results
Annex E – Water Resources
Annex F – Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

Annex B which follows describes the background to the introduction of water demand management measures, a range of options that could be applied and the application of water demand management to the Case Study areas in Tamil Nadu and Jordan.

ANNEX B WATER DEMAND MANAGEMENT

B1. WATER DEMAND MANAGEMENT – DEFINITION & CONTEXT

Water demand management - "…the implementation of policies or measures which serve to control or influence the amount of water used". UKWIR/ESA (1996)

B1.1 Background

The need to manage the demand for water has become of increasing importance throughout the world. In ten countries in the Middle-East region alone water consumption already exceeds the renewable water resources (Ref. 1). In 1989, the Council of the Organisation for Economic Co-operation and Development (OECD) endorsed the role of "water demand management" as an element in integrated policies of water resources development. It recommended that Member countries should develop and implement effective demand management policies in all areas of water services through making greater use of:

- demand forecasting;
- appropriate resource pricing for water services;
- appraisal, reassessment and transferability of water rights;
- non-price demand management measures; and
- integrated administrative arrangements for managing demand.

Multilateral and bilateral funding agencies involved in the water sector (e.g. World Bank, USAID, GTZ) recognise the need for a better understanding of water demand management. The International Development Research Centre (IDRC), Canada regards water demand management in Africa and the Middle East as one of its priority research areas (Water management in Africa and the Middle East: Challenges and opportunities; Ed: Rached, E et al, 1996) (Ref. 1).

However, controlling and influencing the amount of water used by consumers raises complex issues for communities, water providers and regulators in regions where there is a scarcity of water resources.

There have been a number of attempts to categorise demand management measures. James Winpenny's "Managing water as an economic resource", (1994) (Ref. 2) groups them, as follows:

- Direct interventions
  Investment, spending programmes and targeted interventions to encourage the use of water-efficient and water saving measures

- Incentives
  Policies, market and non-market based measures which influence the behaviour of users directly by providing them with the incentives for using the resource more carefully

- Enabling conditions
  Changes to institutional, legal and the economic framework

A selection of typical measures within these overall groups is listed in Table B.1.1 and this forms a base from which a more comprehensive grouping and listing of measures, given later in this Annex, has been developed.

Table B1.1 Water demand management categories and measures

Category	Measure
Direct interventions and technical measures	*For example:* Leakage control Water efficient user appliances Industrial recycling, water re-use Canal lining
Incentives aimed at re-allocation	*Market based:* Active use of water tariffs Pollution charges Groundwater markets Surface water markets Auctions Water banking *Non-market based*: Restrictions Quotas, norms and licences Exhortations, public information
Enabling conditions (or supporting measures)	Institutional and legal changes Utility reforms Privatisation Macro-economic and sectoral policy

Based on Source: “Managing water as an economic resource”, Winpenny, J.,1994

The introduction of water demand management measures, however, can be socially and politically divisive. Professor Tony Allan (Allan T, 1999) (Ref. 3) discusses three key aspects of water management policy with respect to water use efficiency and national water security. He discusses:

- "productive efficiency" (technical efficiency of the water or irrigation system);
- "allocative efficiency" (economic efficiency or the consideration of which activity brings the best return to water); and
- trade in "virtual water" (relating to national/regional relationships within the global hydrological system).

These broadly match Winpenny’s general categories listed in Table B1.1 above. Professor Allan asserts, however, that engineers and scientists are likely to prioritise these three aspects in quite different ways from politicians. Whereas the former are likely to order the priorities in terms of their economic significance when water is scarce in any particular country, viz: (i) virtual water; (ii) allocative efficiency; and (iii) measures to improve productive efficiency, politicians will generally assign the reverse order for reasons of political expediency.

"Re-allocation of water is a profoundly political act", Professor Allan says. There are political implications and trade-offs to be considered when advocating this option. Improved productive efficiency is normally seen as the most welcome by politicians as increased investment in infrastructure and training provides a solution and the interests of manufacturers are served. Politicians find the option of water re-allocation less attractive.

The third of Professor Allan's categories requires an understanding of the global factors affecting future water supplies and the overall economic strengths which could secure further supplies of "virtual water" for a region or country. The recent e-Conference 'Virtual Water Trade' – Conscious Choices, 2004 (Ref. 4) includes a useful discussion on the subject.

B1.2 Supply augmentation, water quality improvement and demand management

The management of water demand becomes of key importance once the available water supply can no longer meet the demand for water and when the supply options become either technically difficult or economically unviable. It is important, therefore, to have a clear idea of supply options and their costs before considering significant water demand management measures.

A list of potential supply measures for increasing supplies for domestic/municipal use and for agriculture is given in the Table B1.2 below; potential measures for improving water quality are given in Table B1.3. Not all these measures will necessarily apply or be relevant to any one area or region.

Table B1.2 Water supply options

	WATER SUPPLY AUGMENTATION			
		Domestic/municipal		Agriculture
Developmental and technical measures	SD1	Develop additional groundwater (wellfield)	SA1	Develop additional groundwater (wellfield)
	SD2	Desalination (a) seawater (b) brackish water		
	SD3	Blending of water supplies		
	SD4	New water treatment facilities	SA2	Treat/use wastewater
	SD5	Improve/extend water distribution system (fixed infrastructure)	SA3	Improve/extend water distribution system
	SD6	Improve/extend water distribution system (water tankers)		
	SD7	Retention dams & reservoirs	SA4	Retention dams & reservoirs
	SD8	Aquifer recharge: a) dam/tank b) well	SA5	Aquifer recharge: a) dam/tank b) well
	SD9	Increased abstraction from surface water sources	SA6	Increased abstraction from surface water sources
	SD10	Rainwater harvesting	SA7	Rainwater harvesting
	SD11	Trans basin water transfer (import)	SA8	Trans basin water transfer (import)
			SA9	Cloud seeding

Many of them will, however, have been considered or adopted before demand management measures (*which serve to control or influence the amount of water used)* become an over-riding necessity.

Table B1.3 Water quality improvement options

	WATER QUALITY IMPROVEMENT			
		Domestic/municipal		**Agriculture**
Developmental and technical measures	QD1	Sewage collection/reticulation system	QA1	Pollution control (reduction in use of pesticides/fertilisers, control on pollutant disposal)
	QD2	Construct sewage treatment plant		
	QD3	Wellfield protection zones (a) Community source protection (b) Government implemeted		
		Industrial/commercial		
	QD4	Pollution control by: a) providing collection stations		
	QD5	Control landfill and tipping		
	QD6	Pollution control by: a) disincentives for polluters b) incentives for clean technology		

The supply of water may be restricted on account of its quality or susceptibility to pollution. In Table B1.3 above, a number of measures that could be taken to secure a improved quality of water are listed and these measures may prove of higher priority than searching for new supplies of water. The relative costs of supply and water quality improvement measures and the contributions that they can make to increase the water availability must be borne in mind, of course, when considering them or comparing them with demand management options. Typical costs of supply options are given in Annex F.

B1.3 Water demand management and supporting measures

The categories and water demand management measures suggested by Winpenny and Allan are broadly confirmed by others working in this field (D.B.Brooks, 1997 (Ref 5); Hamid A.Bakir, 2001 (Ref. 6). We have used the Winpenny categories as a starting point and built on these in the light of the case studies undertaken in Tamil Nadu, Jordan and elsewhere.

Table B1.4 lists the categories we have selected and the demand management measures included in each category. These are further classified as those affecting the domestic and municipal provision of water and those affecting irrigated agriculture. The three categories of measures can only be implemented with supporting measures. The associated supporting measures are shown as a separate category at the bottom of the table.

Table B1.4 Water demand management categories and measures

Category	WDM Measure	
	Domestic/municipal water	**Agricultural water**
Developmental and technical measures	**DT** Physical changes to the infrastructure which reduce losses in the supply system, improved water use by consumers and re-cycling of water in industrial systems.	**AT** Physical changes to the irrigation infrastructure or introduction of more water efficient systems (drip or sprinkler systems) and improved water management which reduce water consumption.
Allocative, financial and market based measures	**DA** Re-allocation through inter-sectoral and intra-sectoral water quotas and allocations and through water tariffs	**AA** Re-allocation through inter-sectoral and intra-sectoral water quotas and allocations, land use and cropping pattern changes, water tariffs and water markets
Other socio-economic measures	**DS** Community level management of water and measures relating to population	**AS** Establishment of water users' associations to improve water management and measures relating to population
Enabling or Supporting measures	**SD** Measures required in support of the implementation of those above (e.g. legislation, regulation, public awareness campaigns, mobilisation and institutional changes)	**SA** Measures required in support of the implementation of those above (e.g. legislation, regulation, improved extension services and institutional changes)

[Note: The following codes are used above for generic measures: DT – Domestic Technical; AT – Agricultural Technical; DA – Domestic Allocation; AA - Agricultural Allocation; DS – Domestic Socio-economic; AS – Agricultural Socio-economic; SD - Supporting Domestic; SA – Supporting Agriculture].

Table B1.4 gives the broad list of generic measures that could be adopted under each category. During the studies we have examined these measures in more detail to develop a more comprehensive list of measures that could be taken to control water demand. These are discussed in Section B.2

The purpose of demand management measures is to control or influence the amount of water used and the diagram below illustrates how these measures (represented by the arrows) might be brought to bear on the demand for water so that it does not exceed the available supply.

It shows how demand management measures can contribute to the solution when the available water (including treated poor quality water) cannot meet the demand.

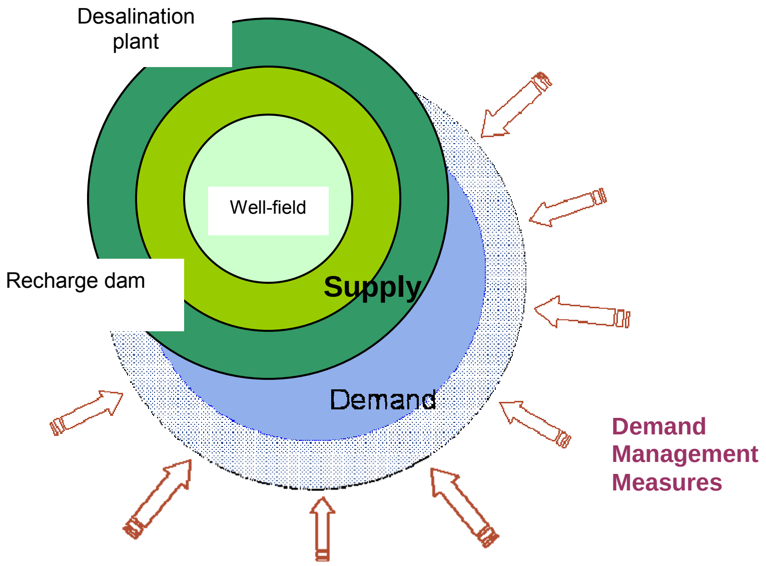


Figure B1.1 Demand management

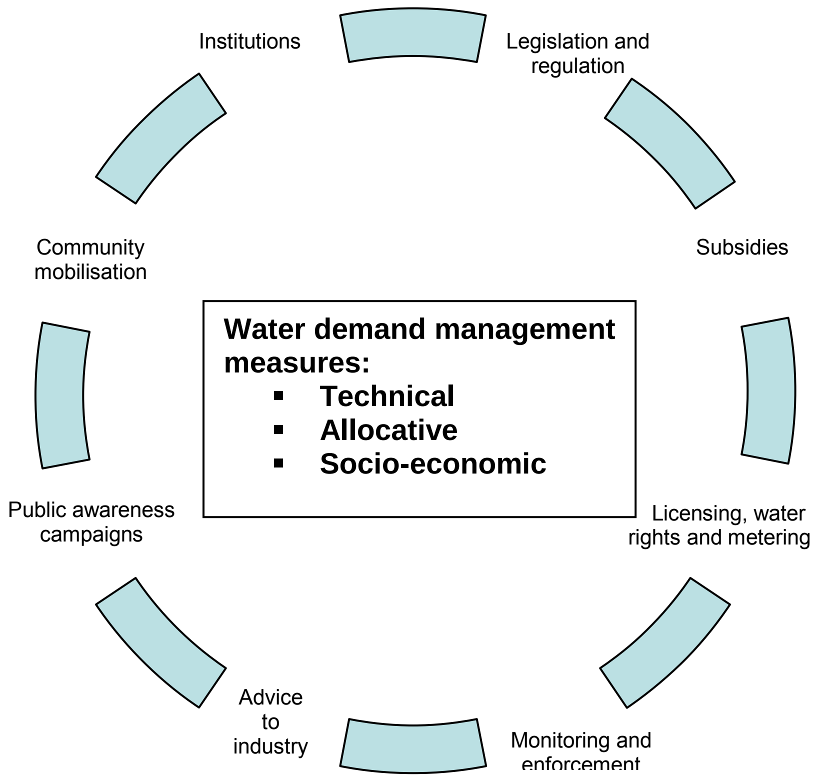
The three concentric circles show examples of a number of supply options of increasing unit cost. As costs become increasingly high or water resources become limited, measures are required to control or influence the demand for water.

B1.4 The wider context

The introduction of water demand management measures should be seen not only in relation to water supply and quality options but also in a wider context which includes consideration of a country or region's macro-economic policy, its strategic water security and, for instance, its dependence on "virtual water".

In addition, demand management measures should be seen in relation to the supporting (or implementing) measures described in Table B1.4.

The diagram below shows how, in implementing water demand management measures, a range of enabling or supporting measures (SD and SA in Table B1.4) has to be considered and applied in implementing demand management measures. These may be applied at different levels (e.g. through public administration or community intervention).



These are discussed further in Section B2.1.

B2. DEMAND MANAGEMENT – OPTIONS

B2.1 Demand management options

Table B2.1 gives a list of the potential water demand management options that have been identified during the study and which could be applied to control or influence the amount of water used by consumers.

These are categorised in the three principal classes described in Table B1.4. A distinction is made between those where:

- Water supply options begin to become technically or economically impractical or where the supply is unreliable. In these instances:
  (a) developmental and technical measures (DT & AT) or
  (b) allocative, financial and market based measures (DA & AA); may be considered, and

- The supply of water is already limited or unreliable. In these instances, in addition,
  (c) other socio-economic measures; may be adopted

In the first of these, (a) and (b) above, measures may be considered and implemented through regional or central government institutions, making use of the appropriate policy instruments (shown as associated supporting measures at the bottom of Table B2.1).

Table B2.1 Water demand management measures

	WATER DEMAND MANAGEMENT			
		Domestic/municipal		Agriculture
Developmental and technical measures	DT1	Reduce water losses	AT1	Improve efficiency of surface irrigation systems
	DT2	Water saving devices and fittings	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT3	Recycling of industrial water		
	DT4	Use of "grey" water		
Distributive, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land use change and control	AA3	Land use change and control
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population distribution	AS2	Population distribution
	DS3	Emigration	AS3	Migration
Supporting and enabling measures	SD1	Community mobilisation (DS1)	SA1	Increase Extension Services (AT1, AT2, AA5)
	SD2	Public-Private-Community Participation (DS1)	SA2	Public awareness (AT2, AA1, AA2, AA4, AA5, AA6)
	SD3	Public awareness campaign to reduce wastage (DT1, DT2, DT4, DA1 & DA2)	SA3	Subsidy introduction (AT2a)
	SD4	Encourage industry to recycle water (DT3)	SA4	Metered agricultural wells (AA1, AA2, AA7)
	SD5	Metered water supply (DA3)	SA5	Legislation & regulation (AA1, AA2, AA3, AA4, AA5, AA6, AA7)
	SD6	Legislation & regulation (DT2, DT3, DA1, DA2, DA3, DS2)	SA6	Monitoring and enforcement (AA1, AA2, AA4, AA7)
	SD7	Institutional – community agreements (DA1, DA2, DS2)	SA7	Licensing/registration, water rights and associated legislation (AT1, AT2, AA1, Ar2, AR3, AR7)

In (c) above, the measures may arise spontaneously or may be encouraged at community level. In these instances a community may take action or be encouraged to manage the demand for different sections of the community either to ensure:

- at least the limited quantity of water reaches the community;
- an equitable (or other) level of distribution of the limited water available is made;
- access to other diverse sources of water; or
- people may move to less water scarce areas (e.g. farmers or farm labour may migrate or move to other employment).

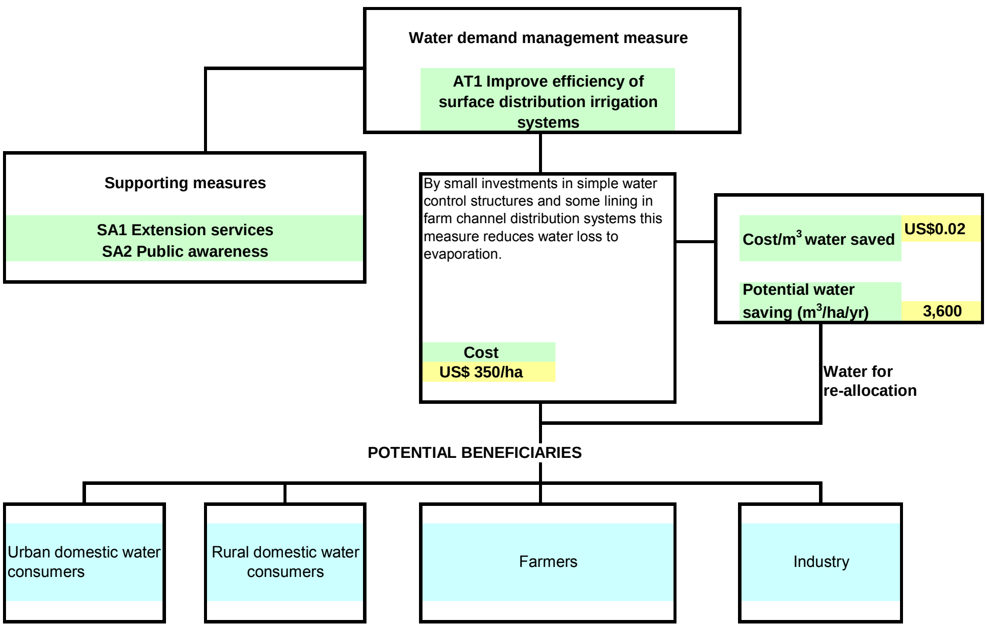
Community management is discussed further in Annex D.

B2.2 Potential water savings & the cost of water saved by demand management

The introduction of a water demand management measure will normally have a cost and provide water savings. In addition, the measure will have an impact on individuals and communities by providing a re-allocation or redistribution of water. In the figure below, an example is given of a water demand management measure, the supporting measures required, its cost, the cost of water saved and the potential water savings by introducing the measure.

The diagram shows some of the groups which may benefit or lose on account of the measure being introduced. The groups affected are discussed in Annex D.

Figure B2.1 Impact of water demand management measure – example



In the example shown above (Figure B2.1), water may be saved by reducing evaporative water losses on the farm. This water may then be available for transfer to beneficiaries in the city or for increasing the cropping intensity. Where the water is pumped from the ground by the farmer, the investment in water saving infrastructure may also be offset by reduced pumping costs.

B3. THE TAMIL NADU AND CHENNAI CASE STUDY

The water resources development of Chennai and the agricultural areas to the north of the city are described in Annex E. The demand for water for domestic, industrial and agricultural use exceeds the available and reliable supply. Water supply to the Chennai Metropolitan Area (CMA) is currently inadequate and unreliable. The Chennai Metropolitan Water Supply and Sewerage Board (CMWWSB), Metrowater is now looking for further resources from the A-K aquifer, an aquifer which is already over-exploited and which is used extensively for irrigated agriculture.

B3.1 Water supply

The principal sources of water are from:

- Wellfields in the A-K aquifer
- Surface water storage reservoirs
- Water transfers from Andhra Pradesh (the Teluga Ganga Project with diversion by canal from the Krishna river which has delivered in the past but which have been curtailed during the recent drought)
- Veeranam reservoir 230 km south of Chennai supplemented by water from wellfields in Panruti, Neivili, through Veeranam pipeline: project near completion, May 2004)
- Seawater RO desalination (New Tirupur Area Development Corporation proposed and planned to provide 300,000 m^3/day to CMWSSB)

The nominal service areas are as follows:

Chennai Metropolitan Area (CMA)	1178 km^2
Chennai City Area	170 km^2 (all in present operations area)
Adjacent Urban Area (AUA)	164.6 km^2 (10 km^2 in present operations area)
Distant Urban Area (DUA)	142.1 km^2

The total supply to Chennai City from all above sources (surface & groundwater) is currently, during years of normal rainfall, 350-400 MLD; this includes 50MLD to industry. This is equivalent to 128 -146 MCM/yr; or, for a 5 million population 70 – 80 lpcd.

The 1991 Master Plan envisaged a demand of 1418 MLD (518 Mm^3/yr) in 2003 and 1980 MLD (723 Mm^3/yr) in 2021 for the CMA. This demand was calculated for the City plus AUA plus DUA on the basis of 60lpcd for slum population, 143 lpcd for residential population and 133 lpcd for commercial organisations with 18,000 l/ha/day for institutional/industrial demand and a population of 6 million in 2003.

Surface and groundwater supply (including the present supply from Teluga Ganga) is:

- during normal years 350-400 MLD (2003)

and with planned improvements below would be:

- Teluga Ganga (Stage I) – from Krishna River (Andhra Pradesh) and Chennai WS augmentation 910 MLD (2005)
- Teluga Ganga Project (Stage II) 1440 MLD (2007)

The following infrastructure projects are under construction or in the pipeline:

	Rs Crores	Yield	Planned Completion Date
Chennai Water Supply Augmentation Project I (Groundwater from (i) Coleron river-bed and (ii) wellfields in Panruti (Neivili))	720	180 MLD	(June 2004)
Chennai Water Supply Augmentation Project II (proposed checkdams across rivers Kosastalaya and Palar to improve the storage capacity of Ambattur, Korattur and Rettai Eri lakes)	110	40 MLD	(June 2004)
Sea water desalination (proposed) DBOOT basis	1,500	300 MLD	(Dec 2005)
A-K river basin (studies ongoing)		200 MLD	(Apr 2007)
2nd Chennai project (WB assisted)	779		(Mar 2004)
Chembarambakkan treatment plant (partly French assisted)	200		(Dec 2004)
3rd Chennai project (Proposed)	750	50 MLD	
Total	4,059	770 MLD	

In addition, there are plans for a tertiary treatment/RO sewage treatment plant (50MLD) to be constructed to supply industries in the Manali area.

Rainwater harvesting (water collected from the rooftop and led to a soak-away to recharge the aquifer under Chennai) was introduced in 2001 and is now mandatory for all properties in Chennai.

Despite these plans, the water shortages in Chennai are acute (particularly during years of drought). Water is supplied by tanker to all households. Supplies are limited to one or two days per week in some locations. Water supply available to the poorer sections of the community is about 35 l/c/d. Details are given in Annex D and E.

Although the full range of supply options given in Table B1.2 have been considered by the Government of Tamil Nadu to provide water for Chennai, a number of issues arise with regard to the water supply for domestic and industrial use and provision of water for agriculture in the area. These include:

- unreliability of monsoon rainfall
- unreliability of supply from inter-State water transfer
- over-abstraction from the A-K aquifer and falling groundwater levels
- saline intrusion to the A-K aquifer (now up to 12 km from the sea)
- competition for water between agriculture and city water supply requirements
- expanding urban population (1.3 % per annum)
- inequity of domestic water supply distribution between different socio-economic groups in Chennai

B3.2 Demand management

Potential measures

To address these issues, consideration must be given to introducing appropriate water demand management measures. In Table B3.1, the range of options is listed for the domestic, industrial and agricultural sectors that may be applicable in Chennai.

Table B3.1 Water demand management options - Chennai

	WATER DEMAND MANAGEMENT			
		Domestic/municipal		Agriculture
Developmental and technical measures	DT1	Reduce water losses	AT1	Improve efficiency of surface irrigation systems
	DT2	Water saving devices	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT3	Recycling of industrial water		
	DT4	Use of "grey" water		
Distributive, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land development control	AA3	Change land use by: a) land purchase b) re-zoning/classification c) well buy-out (transfer of water rights)
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population distribution	AS2	Population distribution
	DS3	Migration	AS3	Migration

A first step would be to address measures DA1/AA1, DA2 and AA2 and define inter-sectoral and intra-sectoral water allocations and quotas.

See [ ] above.

This process comprises:

- defining the priority demands (e.g. domestic water quotas per capita, population and demographic trends; industrial demands; environmental demands)
- calculating an appropriate allocation for the priority demands
- determining the supply options
- calculating the water availability for other uses (i.e. principally agriculture)
- defining the allocations to the different water using sectors.

In Chennai, the A-K aquifer is already under stress. The abstractions both for the agricultural and the domestic/municipal sectors have depleted the aquifer and saline intrusion is occurring. The CMWSSB have agreements to abstract from the aquifer and these are discussed in Annex E. If the aquifer withdrawals are to be sustainable, measures are required to limit abstraction to a sustainable level to allow the groundwater resource to recover.

Measures AA3 to AA7 could be considered:

- Change land use by: a) land purchase b) re-zoning/classification; c) well-buy outs/transfer of water rights
- Crop area prohibition;
- Change cropping patterns by: a) extension b) tax c) market support;
- Introduce water markets;
- Water tariffs: a) volumetric b) on power to pumps c) area based

Some of these measures are already being introduced in one form or another (e.g. water rights are effectively being transferred to CMWSSB through making with farmers to buy or lease their rights to water abstraction). Others should also be examined. In addition, the change in farming patterns in the A-K aquifer may favour a more co-operative approach to water abstraction which might be strengthened through the encouragement of farmer groups or water users organisations.

With priority being given to domestic water supply, it is important that this water is distributed with minimum loss and wastage. Items DT1 Reduction of consumer water losses and DT3 Recycling of industrial water become of importance here and DA4, water tariffs, may become an instrument in controlling these.

The current domestic water situation is discussed in Annex D especially with regard to the poor and vulnerable. Here, measure DS1, Community Level Management, is an essential ingredient of the water demand management approach with consideration being given to equity of distribution.

The areas shaded thus:

indicate measures which are applicable but which would not be of the highest priority in this area. Spontaneous migration and population movement already take place but the overall population continues to grow and demand for water increases.

Supporting measures

Implementation of the measures above would require supporting or enabling measures, a summary of which is given below.

The legislation and regulation for the abstraction of groundwater in Tamil Nadu is described in Annex G. Legislation was introduced in 1987. Sectoral water allocations and water quotas have not been introduced as yet and these would require further licensing and legislation, metering of abstractions and the introduction of monitoring and enforcement measures. Currently piped domestic water supply is metered; abstractions from agricultural wells are not.

The other supporting measures given in the table above all have their place and need considering alongside the corresponding demand management measures given in Table B3.1 above.

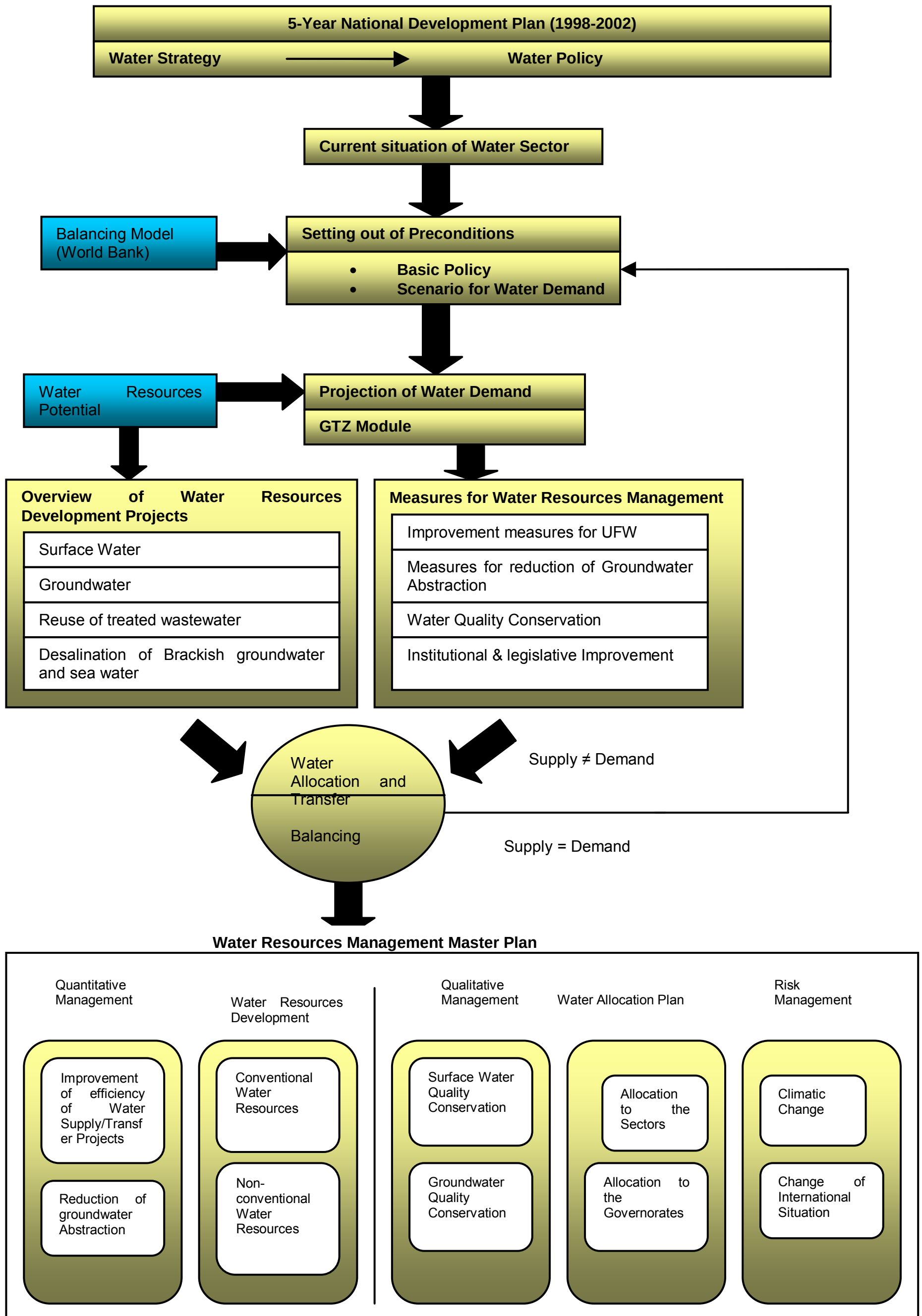
Community mobilisation is a supporting measure which may be appropriate where there is already a shortage of supply and where inadequate supplies must be managed appropriately to meet the demands of different sections of the community. This is a feature of the Chennai poor.

Table B3.2 Demand management supporting measures - Chennai

		Domestic/municipal		Agriculture
Supporting or Enabling measures	SD1	Community mobilisation (DS1)	SDA1	Increase Extension Services (AT1, AT2, AA5)
	SD2	Public-Private-Community Participation (DS1)		
	SD3	Public awareness campaign to reduce wastage (DT1, DT2, DT3, DT4, DA1, DA2)	SDA2	Public awareness (AT1,AT2, AA1, AA2, AA4, AA5, AA7)
	SD4	Encourage industry to recycle water (DT3)	SDA3	Subsidy introduction (DA2a)
	SD5	Metered water supply (DA4)	SDA4	Metered agricultural wells (AA1, AA2, AA7)
	SD6	Legislation & regulation (DA1, DA2, DA3, DT3)	SDA5	Legislation & regulation (AA1, AA2, AA3, AA4, AA5, AA6, AA7)
			SDA6	Monitoring and enforcement (AA1, AA2, Aa4, Aa7)
	SD7	Institutional – community agreements	SDA7	Licensing/registration, water rights and associated legislation (AT1, AT2, AA1, AA2, AA3, AA7)

B4. JORDAN AND THE AL JAFR - SHOUBAK CASE STUDY

Water resources development in Jordan is discussed in Annexes E and G. In Jordan, a countrywide demand management approach has already been considered. The flow diagram below shows the approach that has been taken within the Water Resources Management Master Plan (2001). The demand for water for domestic and industrial use is given priority and currently the demand for agricultural water from groundwater sources exceeds the renewable resource.



Source: Study on Water Resources Management in Jordan, MWI, Jordan 2001

The flow diagram shows the basic steps that have been adopted in arriving at the Water Resources Management Plan and the context within which it has been developed. Many of the actions or measures that are discussed in B1 above are included (e.g. allocation to sectors, measures for reduction of groundwater abstraction, improvement measures for unaccounted for water, institutional and legislative improvement), and there are lessons to be learnt from the approach adopted. However, we consider that some development of this process is required to provide a logical strategy which could be made more generally applicable to regions where there is a shortage of resources.

B4.1 Water supply

Although the range of supply options listed in Table B1.2 above have been considered by the Jordanian Government to provide sufficient water for the Ash Shoubak and Al Jafr areas, a number of issues arise with regard to the water supply for domestic and industrial use and provision of water for agriculture in the area. These include:

- unreliability of rainfall (and lack of rainfall in the mostly semi-arid and arid region)
- over-abstraction from the aquifer, falling groundwater levels and increased salinity
- competition for water between agriculture and the Water Authority of Jordan

B4.2 Water demand management

The Jordanian Water Resources Management Master Plan (2001) addresses water demand management issues. The principal policy thrust has been given to measures for reducing irrigation water consumption and to reducing consumption for Municipal, Industrial and Tourism (MIT) uses. In Table B4.1, the range of options is given for the domestic, industrial and agricultural sectors and these match the measures being considered by the Jordanian Government

The areas shaded thus:

indicate measures which are applicable to the Study Areas of Shoubak and Al Jafr. The first priority, however, is to establish the sustainable yields of the aquifers and to control the over-abstractions which have led to draw-down of aquifer water levels and deteriorating quality of water.

Table B4.1 Water demand management options – Al Jafr-Shoubak

	WATER DEMAND MANAGEMENT			
	Domestic/municipal		Agriculture	
Developmental and technical measures	DT1	Reduce consumer water losses	AT1	Improve efficiency of surface irrigation systems
	DT2	Water saving devices and fittings		
	DT3	Recycling of industrial water	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT4	Use of "grey water"		
Distributive, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
			AA3	Change land use by: a) land purchase b) re-zoning/classification c) well buy-outs (transfer of water rights)
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA3	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population distribution	AS2	Population distribution
	DS3	Migration	AS3	Emigration

Glossary of terms (used in this Annex)

Aquifer — a geological stratum which stores or transmits groundwater

Available (water) — the amount of water that could be delivered by current infrastructure, through interception of the natural water resource, from desalination and as treated wastewater.

Consumption: — for the purposes of this it is the amount of water withdrawn from the hydrological cycle for human, agricultural and livestock uses.

From the point-of-view of water supply companies, consumption is conventionally considered as the amount of water delivered to consumers and it includes wastage on their premises. (The disposal of wastewater to the ground, however, will provide return water to the groundwater resource).

Consumptive use (of crop) — the amount of water used productively by a crop through evapo-transpiration;

Crore — ten million

Indigenous: — applied to all sources of water that are available within the State; in contrast with "virtual water" that is used in production of imported foodstuffs and goods.

Lakh — one hundred thousand

Measure — a technical, financial or institutional procedure that can be considered as part of the water resource management programme.

Natural — applied to water resources that form part of the hydrological cycle.

Recharge — the volume of water that infiltrates into the ground from rainfall, canal and pipe leakage, irrigated areas and the like which replenishes an aquifer

Virtual water — the amount of water consumed in the production of imported foodstuffs and goods

Water demand management

(i) *the implementation of policies or measures which serve to control or influence the amount of water used - UKWIR/ESA (1996)*
(ii) t*he use of price, quantitative restrictions and other devices to limit the demand for water - FAO/WB/UNDP (1995)*

Water allocation — a measure which determines the right of a group of consumers to a given amount of water

Water quota — a share that an individual or group of consumers is entitled to receive

Yield the supply that can be abstracted from an aquifer, river or reservoir without causing unacceptable depletion or damage to the resource.

Abbreviations and acronyms

ESA Environmental Services Association

IDRC The International Development Research Centre, Canada

OECD Economic Co-operation and Development

UKWIR United Kingdom Water Industry Research

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ANNEX C SUSTAINABLE LIVELIHOODS APPROACH

CONTENTS

PREFACE

This Document on the Sustainable Livelihoods Approach forms Annex C of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B - Water demand management
Annex C – Sustainable Livelihoods Approach
Annex D – Focus group discussions – Methodology & results
Annex E – Water Resources
Annex F – Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

Annex C that follows is presented in two parts. The first section covers a short literature review of the Sustainable Livelihoods Approach, and an appraisal of water-poverty links. The second section describes a methodology to assess levels of vulnerability in relation to water, and the relevance of such a methodology in deciding what water demand management measures are appropriate in different situations.

ANNEX C SUSTAINABLE LIVELIHOODS APPROACH

C1 GENERAL

C1.1 Literature Review

The Sustainable Livelihoods Approach (SLA) has its roots in the work of Conway and Chambers, 1991 (Ref 1), subsequently developed through the work of NGOs such as Oxfam and Care International, and prioritised by DFID (Ref 2) since 1997[1].

Over the past ten years, the SLA has experienced several interpretations and broadened its intellectual and practical applications over a number of sectors. In general, it is based on the following principles[2]:

- the priorities of the poor;
- a responsive and participatory approach in addressing the needs and concerns of the poor;
- adopting a holistic view towards poverty reduction;
- the need for multiple partnerships across sectoral divisions;
- sustainability of approaches;
- requiring flexibility to adjust to changing circumstances.

A "livelihoods approach" towards poverty and water use is also interpreted as a "people-centred approach" rather than a technical approach[3].

Numerous case studies have been sponsored by DFID, as well as several projects, to support and refine this approach based on experience and best practice. The SLA has proved helpful in several ways, including:

- improving integration of people-centred project planning and implementation;
- enhancing understanding of complex dimensions of poverty;
- encouraging flexibility during the course of project implementation, based on realities on the ground;
- supporting new development initiatives;
- encouraging inter-disciplinary working.

Simultaneously, the SLA has encountered obstacles which are no less significant in determining whether or not the concept has a viable application in the broader development context. Key limitations identified by development practitioners and listed by Allen & Sattaur include:

- missing links: the SLA fails to make sufficiently explicit the links between poverty, power relations, gender, environment and human rights;
- over-intellectualisation of SLA, and lack of practical and simple tools and methodologies to support implementation under existing project and budget cycles;
- holistic working in a sectoral environment is difficult at best and distinctly discouraged in some circumstances;
- monitoring and evaluation: it is difficult to attribute livelihood outcomes to specific project interventions;
- difficulty in translating the concepts;

[1] 1997 White Paper on International Development, DFID.
[2] An excellent review of the strengths and weaknesses of the SLA is by Catherine Allen & Omar Sattaur, (Ref 3) *Sustainable Livelihood Approaches: Engaging with SL or just best development practice?*, Paper presented at Bradford Workshop, 29-30 May 2002, quoted with permission of the authors. This section draws heavily on points made in this paper.
[3] Roger Calow, Alan Nicol, *Sustainable Livelihoods, Poverty Elimination and Water*, no date (Ref 4)

- oversimplification of complex realities;
- expectations raised beyond the competence of communities/institutions/projects to meet them.

The Case Studies in India and Jordan reflect conditions where both SLA strengths and weaknesses as listed above are reflected. Adopting a people- and poverty-centred approach for this section of Case Study analysis enabled identification of links between poverty, water and livelihoods impact. These links emerge from analysis of the fieldwork data described in Annex D.

Fieldwork investigations also confirmed the multiple and complex issues relating to water demand management as well as to poverty analysis in different rural and urban contexts.

Demand management is as much a social and political issue as a technical one. Developing, implementing and enforcing water demand management options that are people-centred is almost a contradiction in terms. Governments throughout the world are often reluctant to force people to curtail abstraction, foreseeing huge social and economic impacts on large sections of the population, or at the least, on small sections of the population with high levels of social and political influence.

While the SLA approach encourages and enables people's needs to be integrated into planning and management of water resources, it cannot substitute this for the current realities of water management and delivery responsibilities.

C1.2 Groundwater-Poverty Links

Water scarcity is caused by multiple factors which need various responses undertaken at multiple levels. These are more fully discussed in Annex D. Integrating differing water demand interests has always been a challenge that frequently leaves the poor worst off. Aquifer use spreads over a variety of responsible agencies and administrative and political boundaries. Moreover, different types of water users do not care much if other people's water needs are not met provided their own needs are met.

Water demand standards also shift according to how far they are met – once certain demands are met, standards change and new expectations are raised. The goalposts are constantly being shifted for water demand managers. An important factor for water demand management is to ensure that goalposts shift less arbitrarily and that those dependent on that source understand where they are placed.

A feature of water demand and its management is that different priorities are placed by different water managers and users on different aspects of demand management. This has tended to polarise attitudes in some cases, and in general to lead to lack of integration in determining rights, roles and responsibilities. Those least able to argue their case or bring their needs to the attention of decision-makers, are least well served. Characteristics of water-poverty links have been described by A. McIntosh (Ref 5) in a recent Asian Development Bank publication[4]:. Common characteristics of water poverty links in the survey areas from an asset-based perspective are outlined in Table C1.1.

[4] Arthur C. McIntosh, *Asian Water Supplies: Reaching the Urban Poor*, Asian Development Bank and International Water Association, ADB 2003

Table C1.1: Water-poverty links: the asset base

LIVELIHOOD ASSETS/CAPITAL				
HUMAN	**SOCIAL (POLITICAL)**	**NATURAL**	**ECONOMIC**	**PHYSICAL**
Insufficient human assets - lacking adults of working age	Insufficient socio-political assets - lack of relevant contacts	Water supply and quality location-dependent	Insufficient financial assets	Poor dwellings in more densely populated urban locations, lacking sanitation
Low awareness levels	Lack of power to regulate excessive extraction by other water users	Excessive extraction by some users	Limited earning power	No ownership of resource: heavily dependent on external suppliers
Women-headed households marginalised, less freedom of movement particularly at night	Greater power of other vote banks (e.g. farmers)	Multiple reasons for contamination of water limits areas where potable water can be extracted	Water treatment costs high	Supply timing variable and limited
		No ownership of water resource	No capital assets – livestock, property, land	
LIVELIHOOD/VULNERABILITY RELEVANCE				
Lost income while waiting for water deliveries	Vulnerable to extortion by local power brokers	Travelling distances to find sources of supply	Difficulty in paying bills	Poor service, inadequate maintenance and contamination of systems means higher incidence of disease
Unable to carry heavy loads long distances or up stairs	Dependent on goodwill of neighbours and community	Higher property values in locations with good quality/ quantity groundwater	Higher costs in purchasing water	Greater distance to find alternative functioning supplies: loss of time and wages
Women-headed HHs cannot seek alternative water supplies at night	Vulnerable to impact of over-extraction by other users	Higher incidence of water-related diseases	Neighbours bearing water costs for poor households	Sharing supply facility (standpipe) loses time in queuing
No understanding of the relation between water use practices and household vulnerability	Vulnerable to control of supplies and distribution by local elites	Prioritisation of water use based on quantity limitations	Cannot protect themselves against disease by consuming bottled water	Infrequent & unreliable supply - loss of wages waiting for water
Low consumer expectations	Locality more poorly served, lower levels of supply management responsiveness to complaints, lower rate of infrastructure maintenance	Limited ability to move to areas where water is more easily available	Cannot afford household connections	Poorer nutrition as food cut backs to pay for higher water-related costs
Higher labour input due to lack of storage			Cannot afford storage facilities, greater difficulty when supply interrupted	
Sleeplessness, anxiety, conflicts	High levels of inequity in accessing water		Cannot afford independent well	Last in line to receive piped water
			Cannot afford bottled water	

Poverty is also a highly complex issue with different levels, duration and capacities to deal with its reality. The degree of relationship between water and poverty is characterised by the nature of the links between water availability, the different reasons for water demand, and the ability of households to use their different types of assets most effectively. Water users with greater economic, social or political weight access water and influence demand management strategies more effectively than those without.

It is thus important for the water needs of the vulnerable to be adequately represented in strategic planning for water demand management. This can be assisted by identifying why some are more vulnerable than others, and in what way does this vulnerability manifest itself.

C1.3 Poverty Definitions – Sustainable Livelihood Approach (SLA)

The Sustainable Livelihood Approach (SLA) defines poverty in terms of an asset base. Five key assets are identified; those who are poorest have the east amount of these assets:

- Human assets
- Financial assets
- Socio-political assets
- Natural assets
- Physical assets

Those with a greater likelihood of experiencing harmful or negative impacts as a consequence of water shortage or increasing water shortage are the most vulnerable.

The poorest, as defined above, are more vulnerable to the impacts of water scarcity because their lack of assets result in, for example:

- too few adults available to wait for or collect water;
- insufficient household funds to pay for direct water connections, water storage facilities, independent borewells
- no power to influence water service providers
- heavy dependence on external water supplier
- no space or land to install a borewell.

C2 VULNERABILITY ASSESSMENT AND ITS RELEVANCE IN DECIDING WDM MEASURES

C2.1 Purpose of Vulnerability Assessment

There is no "one size fits all" approach to water demand management. There is also no "one-link is universal" in relating water to poverty. Some poor communities in some locations experience severe inequities in relation to water access. Others would experience difficulties, but vulnerability impacts are reduced due to supportive community or social networks. Still others are more vulnerable to water scarcity simply by virtue of where they dwell.

Any water demand management strategy needs to address the vulnerability of sections of society, and to make a commitment to ensure:

- reasonable compromises are made to accommodate the needs of different water users;
- pro-poor strategies are integrated into the wider planning process.

To achieve this, decision-makers need appropriate information about the scope and extent of vulnerability in relation to water, and appropriate ways of obtaining that information. An assessment of well-being in relation to water helps planners evaluate the conditions they confront. Armed with this knowledge, project planners can determine the most relevant priorities for an area or for a target group. This has numerous benefits:

- it makes subsequent planning of WDM measures more relevant to different communities;
- it can generate higher interest and ownership of actions and results with target groups;
- it is more cost-effective, channelling funds and resources most appropriately;
- it accommodates variations between localities, socio-economic groups, and gender;
- it enables qualitative and community-based comparisons to be made in a methodologically sound fashion.

From the Case Study fieldwork in both India and Jordan, common indicators of poverty in relation to water became apparent. The process by which these were converted into a vulnerability assessment methodology is described in the next section.

C2.2 Methodology

The **process of developing a methodology to assess vulnerability** highlighted several issues. These included the following:

- dimensions of poverty are highly complex;
- there are significant rural/urban differences, which planning processes need to account for;
- vulnerability in relation to water resources sometimes relate to socio-economic differences in a community, but sometimes they affect entire communities regardless of socio-economic differences;
- the higher the socio-economic status of water users, the higher the expectations for water supply;
- issues of resource management, demand management and supply management cannot be separated. Actions relating to one affect management of another. Integration of management systems are needed to develop a balanced system that can meet basic water needs;
- water/poverty links include:
    - political issues
    - social issues
    - economic issues
    - gender issues
    - technical issues
- the more complex the assessment methodology, the less likely it is to be adopted.

Different water users have different priorities and apply different indicators to determine levels of satisfaction. These can include technological and engineering indicators, health, livelihoods, quality standards, etc. Depending on which stakeholder the team spoke to, the focus shifted. The first priority for developing a methodology was therefore to integrate stakeholder priorities (community and institutional priorities) in a single framework. It proved a challenge to identify a range of indicators adequate to incorporate such different perspectives, and yet not to be so numerous as to be unwieldy.

It was also important that any vulnerability assessment methodology could be easily replicated by different sorts of stakeholder with indicators that mean something to them.

Because of the complex nature of poverty combined with competing water demand interests and multiple institutional involvement and priorities, multi-criteria analysis was used as the principal methodological guide.

Multi-criteria analysis is a decision-making tool developed for complex problems with multiple criteria that include qualitative and/or quantitative aspects of the problem in a decision-making process[5].

The procedure developed depends on simple rating and ranking systems and was arrived at after several stages. These stages included:

1. preliminary identification of vulnerability indicators and proxy indicators
2. ranking of key and proxy indicators
3. rating each indicator and proxy indicator
4. rating the intensity score for all indicators

Stage 1: The first step was to identify themes for investigation (see section D1.2.1), by pre-testing fieldwork tools, and then fine-tuning and finalising fieldwork methodologies in Chennai and Jordan.

Analysis of Case Study survey results pinpointed **ten key indicators** of vulnerability (Table C2.1) common to a wide variety of stakeholders.

Table C2.1: Vulnerability Indicators

Rank	Indicator
1	Access to water
2	Quality of water
3	Livelihood impact
4	Affordability
5	Asset base
6	Reliability of supply
7	Awareness
8	Empowerment
9	Health
10	Conflicts

Qualitative proxy indicators were next identified. These are shown in Table C2.2.

[5] *Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and Indicators*, The Criteria & Indicators Toolbox Series 9, Centre for International Forestry Research, 1999 (Ref 6)

Table C2.2: Qualitative proxy vulnerability indicators

Rank	Indicator	Rank	Proxy Indicator
1	Access to water	1a	Quantity of supply
		1b	Frequency of supply
		1c	Proximity of supply
2	Quality of water	2	
3	Livelihood impact	3a	Degree of water shortage impact on livelihoods (direct income loss)
		3b	Increased expenditure on water-related costs
		3c	% of household water expenditure in relation to monthly disposable income higher than other income groups
4	Affordability	4a	Ability to pay connection charges
		4b	Ability to pay bills
		4c	Ability to purchase and instal water saving devices
5	Asset base	5a	Proportion of households with zero or limited human assets
		5b	Proportion of households with zero or limited financial and capital assets
		5c	Levels of neighbourhood/ community co-operation & mutual support
6	Reliability of supply	6a	Degree of supply independence
		6b	Adequacy of supply system maintenance
		6c	Responsiveness of supply managers to community complaints
7	Awareness	7a	Knowledge how to use limited amounts of water to maximum advantage
		7b	Understanding of resource constraints
		7c	Knowledge how to safeguard water-related health
		7d	Knowledge of water source contamination
		7e	Knowledge of water usage by other water users
8	Empowerment	8a	Distribution equity
		8b	Presence of effective community representation
		8c	Ability to protect water source
9	Health	9a	Incidence of water-related health problems
		9b	Incidence of water-collection related health problems (eg. stress, miscarriage, anxiety, sleeplessness, etc.)
10	Conflicts	10a	Levels of inter-household conflict over water
		10b	Levels of conflict with water managers

Stage 2: Because indicators could only be finalised after fieldwork in both Case Study locations, the next step was undertaken by team members in Jordan at the end of April 2004 as a preliminary exercise to test the methodology.

Indicators were ranked by team members in order of perceived importance (Table C2.1). The most important was ranked 1, the least important ranked 10. After ranking each key indicator, proxy indicators were sub-ranked in order of perceived importance (Table C2.2).

Stage 3: Next, each indicator was "rated".

Relative weights were calculated and combined to arrive at an average rate. Tables C2.3 and C2.4 illustrate the procedure.

Table C2.3: Sum of votes for each criterion (example)

Indicator Rank	Participants Assigned Weight			Calculation	Combined weight
	Partic. 1	Partic. 2	Partic. 3		
1	15	10	20	15 + 10 + 20	45
2	20	15	10	20 + 15 + 10	45
3	15	13	15	15 + 13 + 15	43
4	14	15	10	14 + 15 + 10	39
5	10	13	11	10 + 13 + 11	34
6	7	15	9	7 + 15 + 9	31
7	7	9	10	7 + 9 + 10	26
8	6	8	7	8 + 8 + 7	23
9	7	7	8	7 + 7 + 8	22
10	5	6	7	5 + 6 + 7	18
Total					**326**

Table C2.4: Calculated relative weights for rating

Indicator	Relative Weight	
	Calculation	Rating
1	45 ÷ 326 x 100	14
2	45 ÷ 326 x 100	14
3	43 ÷ 326 x 100	13
4	39 ÷ 326 x 100	12
5	34 ÷ 326 x 100	10
6	31 ÷ 326 x 100	9
7	26 ÷ 326 x 100	8
8	23 ÷ 326 x 100	7
9	22 ÷ 326 x 100	7
10	18 ÷ 326 x 100	6
Total		**100**

Rating reflects the magnitude of importance between any two indicators. Hence the No. 1 ranked indicator was assigned the highest rate of 14, while the lowest ranked indicator No. 10, was assigned the lowest rate of 6.

Scores for all ten indicators being compared add up to 100 (Table C2.4)

Subsequently, scores were assigned to proxy indicators. Proxy indicator values assigned are not more than the total rate given to each indicator. For example, indicator No. 1, "Access to water", was assigned a total value of 14. This number was divided between three sub-ranked proxy indicators. Of these three, "quantity of supply" was ranked as the most important, "proximity of supply" as the least important.

Proxy indicators were assigned weights depending on their ranked importance: "quantity of supply" = 6; "frequency of supply" = 5; "proximity of supply" = 3, all adding up to a total of 14.

Where participants did not agree on weights, the same calculation as before was undertaken to arrive at average weights. Table C2.5 reflects the total rates and ranks of all indicators and proxy indicators.

Stage 4: The final step was to assess the degree of impact experienced by stakeholders in relation to each indicator and proxy indicator. This reflects the level of vulnerability of different stakeholders in relation to different indicators – the higher the impact, the greater the vulnerability.

Degrees of impact intensity were divided into low, medium and high (or for some indicators, poor, medium and good). The scoring system assigned the highest value to the greatest impact, which indicate the most vulnerable and unsustainable conditions. Lowest values were assigned to conditions of least impact.

For example, Indicator 1 ("Access to groundwater") was assigned a total value of 14 by comparison with other indicators. As described above, this was apportioned among the 3 proxy indicators as 6, 5, 3 (=14).

Each sub-indicator was then broken down into low/poor, medium, high/good. For example, stakeholders with a good quantity of water supply is assigned "1". One with a average supply quantity is assigned "2", and very poor quantity, "3". These total to "6", the assigned number for this proxy indicator.

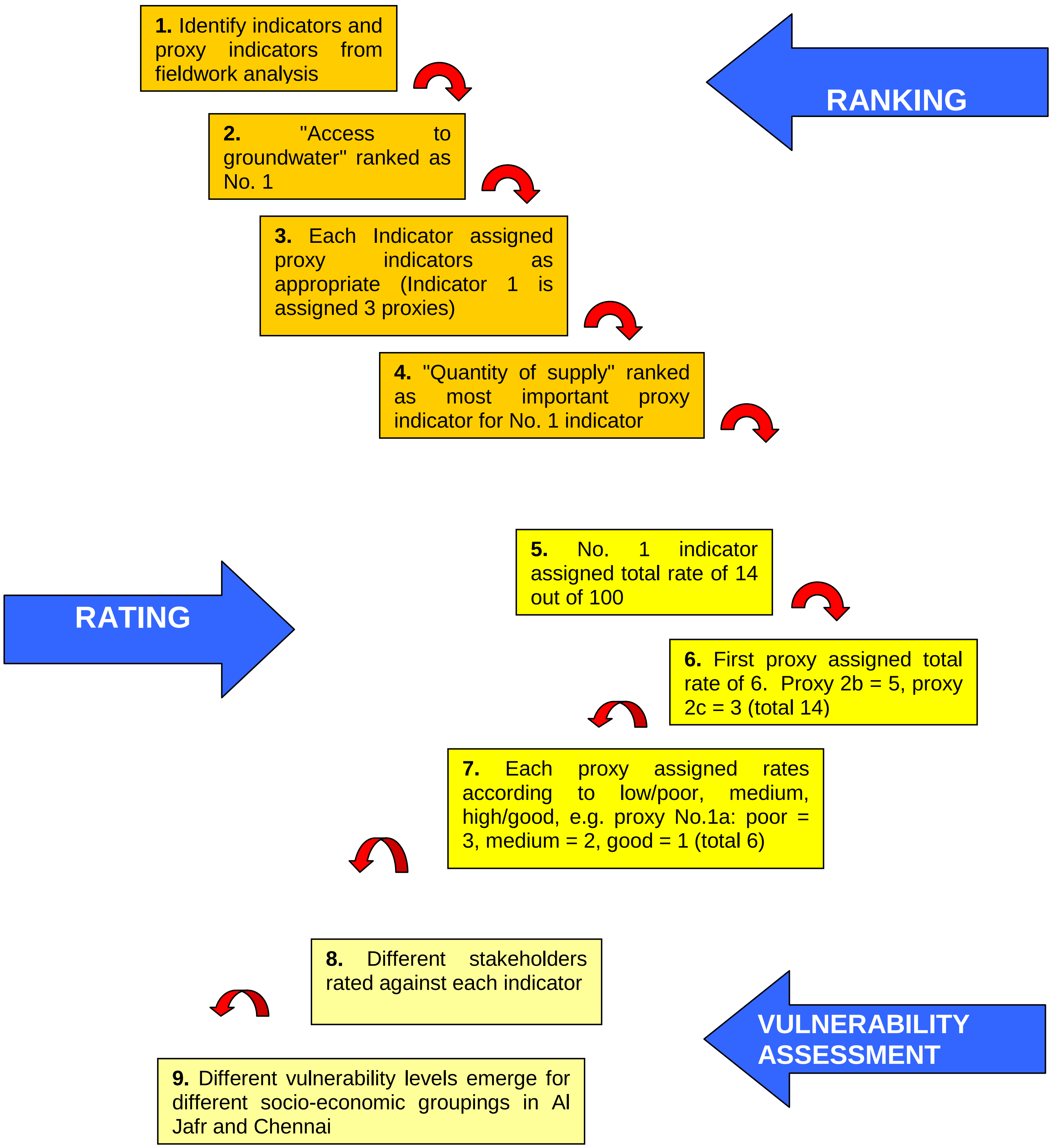
Steps are outlined in Figure C2.1.

Table C2.5: Overall rated and ranked vulnerability indicators (first draft)

Indicator Rank	Indicator Rating	Indicator	Proxy Rank	Proxy-Indicator	Proxy Rating	Relative weights & priorities: Rate (high impact)	Rate (medium impact)	Rate (low impact)
Joint 1	14	**Access to groundwater**						
			1	Quantity of supply	6	3	2	1
			2	Frequency of supply	5	2.5	1.5	1
			3	Proximity of supply	3	1.5	1	0.5
					Total = 14			
Joint 1	14	**Quality of groundwater**						
					14	8	4	2
					Total = 14			
2	13	**Livelihoods**						
			1	Degree of water shortage impact on livelihoods (direct income loss)	8	4	2.5	1.5
			2	Increased expenditure on water-related costs, eg. medicines, purchased vegetables instead of cultivated, etc.	3	1.5	1	0.5
			3	% of household water expenditure in relation to monthly disposable income	2	1.5	0.5	0
3	12	**Affordability**						
			1	Ability to pay connection charges	4.5	2.5	1.5	0.5
			2	Ability to pay bills	4.5	2.5	1.5	0.5
			3	Ability to purchase and instal water saving devices	3	2	1	0
4	10	**Assets**						
			1	Proportion of households with zero or limited human & financial assets	6	4	1.5	0.5
			2	Levels of neighbourhood/ community co-operation & mutual support	4	2	1.5	0.5
5	9	**Reliability of supply**						
			1	Degree of supply independence	5	3	1.5	0.5
			2	Adequacy of supply system maintenance	2	1.5	0.5	0
			3	Responsiveness of supply managers to community complaints	2	1.5	0.5	0

		Indicator		Proxy-Indicator		Relative weights & priorities		
Indicator Rank	Indicator Rating		Proxy Rank		Proxy Rating	Rate (high impact)	Rate (medium impact)	Rate (low impact)
6	8	Awareness						
			1	Knowledge how to use limited amounts of water to maximum advantage	2	1.5	0.5	0
			2	Understanding of resource constraints	2	1.5	0.5	0
			3	Knowledge how to safeguard water-related health	2	1.5	0.5	0
			4	Knowledge of sources of groundwater contamination	1	0.5	0.5	0
			5	Knowledge about groundwater usage by other water users	1	0.5	0.5	0
Joint 5	7	Empowerment						
			1	Distribution equity	3	1.5	1	0.5
			2	Presence of effective community representation	2	1.5	0.5	0
			3	Ability to protect groundwater source	2	1.5	0.5	0
Joint 5	7	Health						
			1	Incidence of water-related health problems	4	2	1.5	0.5
			2	Incidence of water-collection related health problems (eg. miscarriage, stress, anxiety, sleeplessness, etc.)	3	1.5	1	0.5
4	6	Conflicts						
			1	Levels of inter-household conflict over water	3	2	1	0
			2	Levels of conflict with water demand managers	3	2	1	0
Total 10	Total 100			Totals	100	58.5	31	10.5

Figure C2.1: Arriving at a Vulnerability Assessment: methodology steps



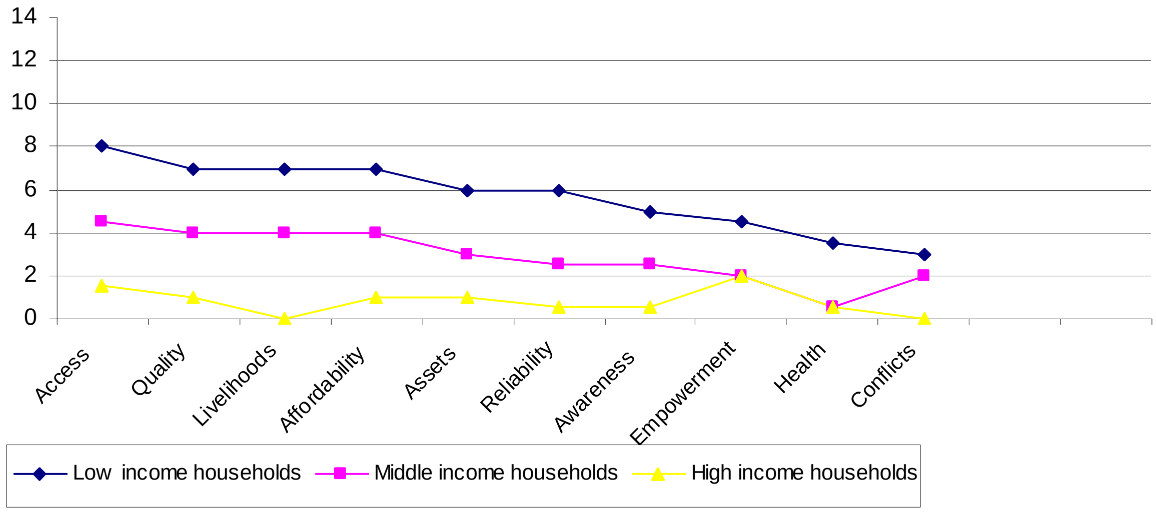
C2.3 Vulnerability assessment, fieldwork locations

Taking the above draft ranking and ratings, the Jordan team undertook the assessment as a practise exercise for Chennai and Al Jafr with different socio-economic categories of low, middle and high income households. It was not done for Al Shoubak where no low income households were interviewed.

Using fieldwork data content analysis as a guide, an assessment of how respondents in different fieldwork localities might have assigned values, was made. A certain amount of external judgement combined with community assessment is needed with this exercise in any case, as some sections of the community may project their situation as better or worse than it actually is.

This resulted in the following vulnerability appraisals (Figures C2.2 and C2.3).

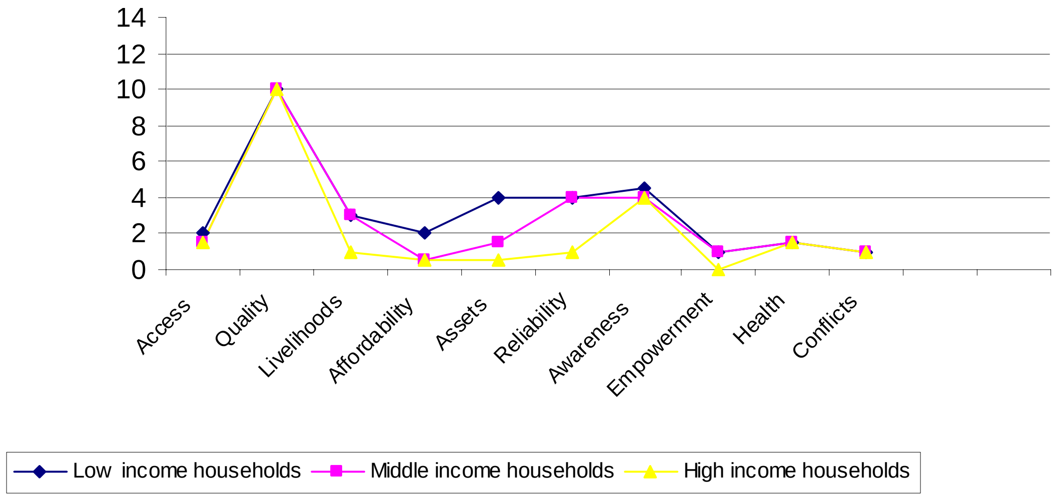
Figure C2.2: Vulnerability assessment, Chennai



This chart shows us that the highest impact for poor and middle income households is Access, followed by poor water quality, impact on livelihoods and affordability. For high income households, all these issues have some, but not much impact. The highest rated issue for rich households is empowerment, with low presence of effective community representation and inadequate ability to protect the water source.

Overall, we can see that low income households are severely affected at all levels in comparison with high income households. Middle income families are also affected, though to a lesser degree.

Figure C2.3: Vulnerability assessment, Al Jafr



In Al Jafr, the vulnerability assessment shows far fewer impact differences between socio-economic groups. There is a reasonable standard of access for all households, and the fact that primary sources of livelihood are not water-dependent indicates a relatively low livelihood impact, though there are some differences between rich households compared to middle and low-income families. The greatest impact differences are to be seen in levels of asset ownership (e.g. water storage tanks), where rich and middle-income households are less affected than low-income households, and supply reliability, where rich households are less affected than middle and low-income households.

Location-related vulnerability is also apparent, with all income groups being equally affected by poor water quality.

In evaluating these charts, differences between urban and rural contexts also become more apparent.

C2.4 Replicability

This Rating and Ranking exercise enables identification of vulnerability in relation to a variety of water demand management priorities. In complex water demand management situations, a vulnerability assessment could be incorporated into overall planning to manage a complex situation with multiple types of water users and multiple reasons for water scarcity.

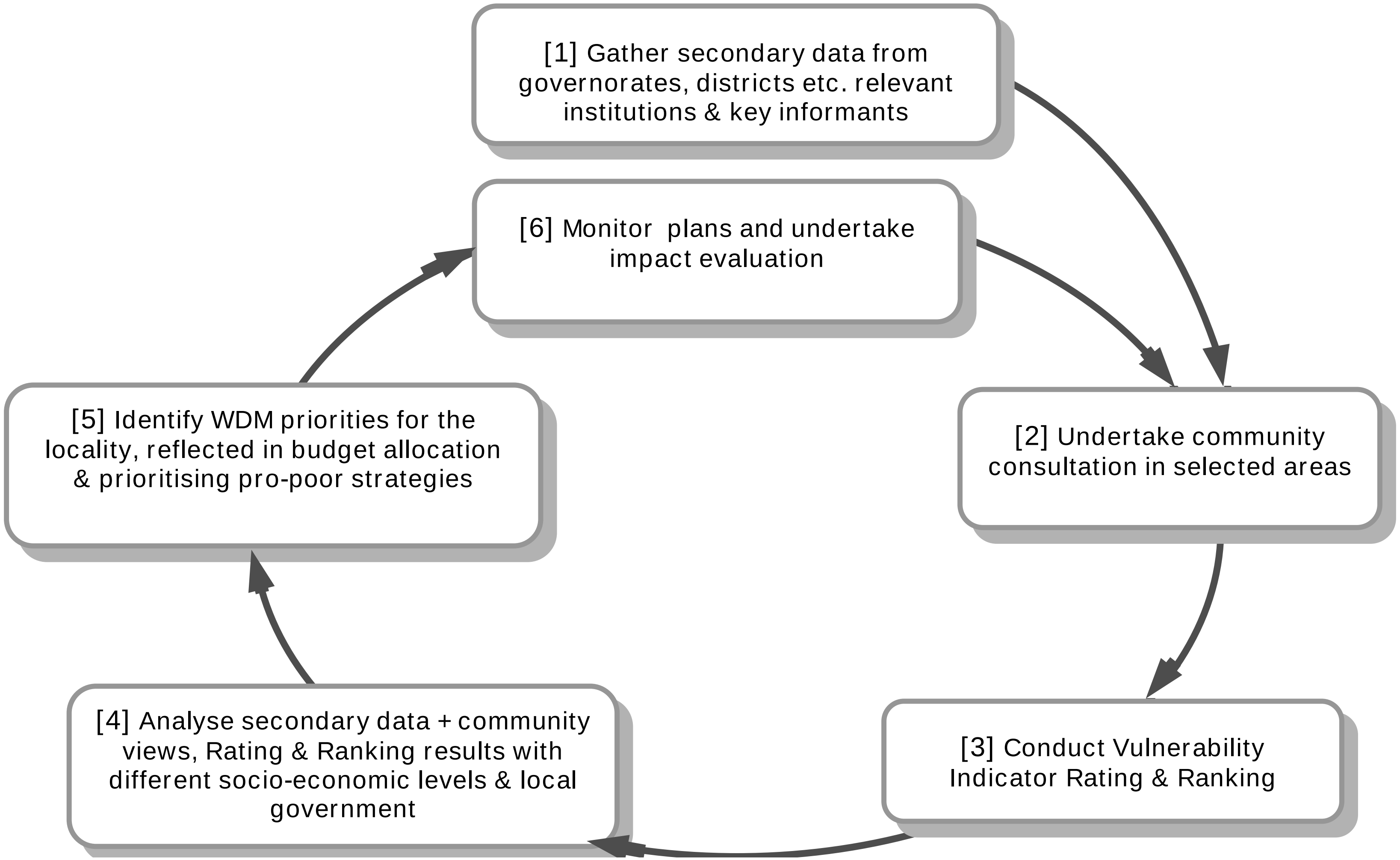
The methodology is simply a way of systematising and recording qualitative observations and judgements related to water and vulnerability. There is nothing fixed about the rank or rate of indicators. Indeed, it is expected that different stakeholders will assign ranks and weights in different ways. It is through comparison of these differences that planners can be alerted to critical differences, enabling them to adjust their planning accordingly.

The vulnerability assessments for Chennai and Al Jafr are simply first time examples of how different degrees of vulnerability can be determined for different income groups. It may equally be applied to compare men's perspective to that of women, or vulnerability of different occupational groups, or between different urban localities. It can be undertaken with communities or local government. Its purpose is to arrive at a trend indication of vulnerability at any level desired.

The greater the variety of exercises undertaken, the broader the scope of information available to assist decision-makers at different levels to prioritise actions and allocate budgets accordingly. For example, in Chennai, the highest assigned importance for poor households is lack of access.

It must be stressed, however, that this exercise would not be adequate to replace other qualitative and quantitative information gathering exercises. Indeed it can be more valuable when taken in conjunction with other tools, to enhance understanding of any given situation. The various steps are outlined in Figure C2.4.

Figure C2.4: Vulnerability Assessment Methodology in Six Steps



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ANNEX D: POVERTY AND LIVELIHOODS: SURVEY RESULTS

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PREFACE

This Document on Poverty and Livelihoods – Survey Results, is Annex D of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme – Water Demand Management in Areas of Groundwater Over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B – Water demand management
Annex C – Sustainable livelihoods approach
Annex D – Poverty and Livelihoods – Survey Results
Annex E – Water Resources
Annex F – Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken; one in Chennai, Tamil Nadu State, India, and the other in the Al Jafr-Shoubak regions, Hashemite Kingdom of Jordan.

Annex D that follows describes fieldwork outputs for the Poverty and Livelihoods component of the survey in relation to water use and demand in the India and Jordan Case Study Areas.

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India: Mr. V. Thangavelu, I.A.S, Managing Director of the Chennai Metropolitan Water Supply & Sewerage Board
Jordan: Dr. Kamal Khdier, Director, Water and Environment Department, Ministry of Planning, Mrs. Maha Ali Al-Zub'i, Water and Environment Department, Ministry of Planning

- National team members in India and Jordan, who sought out secondary data, made logistical arrangements, undertook fieldwork, and brainstormed on fieldwork findings. These include:

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Representatives of NGOs, community organisations, and local administrative offices, who helped us to arrange meetings, discuss water-related issues in the respective fieldwork areas, and guided us towards other studies and publications of relevance to this Survey. In particular:

India: CUPA, Mr. Sundar The Megha Foundation Social Service Society Kovur, Sr. Vimala Presentation Community Service Centre, Sr. Santhi Don Bosco Social Service Society, Virgil D. Samy, Arunodaya, L. Babu and Shanmugadasan, Arivoli, Sr. Jacintha, Arpanam, Gajalakshmi, Legal Education & Aid Society Tharamani, Exnora F Block Annanagar, Ms. Mallika Swaminathan, Harrington Road Residents Association.

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A special thanks to the communities and respondents of Chennai Metropolitan Area, and Kancheepuram districts (India), Al Shoubak and Al Jafr (Jordan), who gave their time to talk to us and discuss their water-related concerns.

ANNEX D

D1 INTRODUCTION

D1.1 Purpose of the Poverty & Livelihoods Component of the Study

As stated in the Scope of Work[1], the purpose of the Survey is to:

- *Identify the most appropriate demand management strategies to control groundwater abstraction in areas where aquifers are being over-exploited;*
- *Ensure such strategies safeguard the long-term livelihoods of the vulnerable and poor;*
- *Discuss and disseminate results and encourage uptake.*

The purpose of this Case Study component (Poverty & Livelihoods) is to approach water consumption characteristics from a community point of view, to understand the impact of existing water demand management approaches on the poor. The function of a poverty focus is twofold: first, while water scarcities affect all water users, the poor are usually most vulnerable to any changes in water quality and availability, leading to a correspondingly high impact on livelihoods, food security and health. The research intention is to understand who is most vulnerable, and what impact current and future water demand management strategies might have on them.

The second reason for a poverty focus is to ensure that any water demand management proposals do not increase negative impacts on the poor. Analysis of fieldwork data is intended to improve identification of who is most vulnerable, what their water demand priorities are, and how these can be integrated into a water demand plan which manages groundwater abstraction in the most effective way.

To achieve these objectives, the Survey was split into several parts, separated by several months. The programme followed to date is:

i) November/December 2003: undertake scoping exercises in India and Jordan, meeting representatives of Government and non-government agencies engaged in water-related activities. Gather secondary data, identify key information sources. During this period, potential aquifer locations for fieldwork were visited and fieldwork site selection was finalised;
ii) February 2004: develop fieldwork tools and methodology in preparation for checklist/ questionnaire translation and pre-test;
iii) March/April 2004: fieldwork in India and Jordan, pre-test tools and methodology, followed by fine-tuning and revision before final implementation. Data analysis and initial interpretation, team discussions on data findings, identification of information gaps and final collation of primary and secondary data;
iv) June 2004: Inception Report preparation and submission.

D1.1.1 Annex Layout

Following this introduction is a discussion of the methodology adopted. Thereafter, the principal sections of Annex D are:

- *Section 1:* **Fieldwork Findings**. This section presents fieldwork results in India and Jordan.

[1] Full Proposal, DFID Engineering Knowledge and Research Programme, Competitive Component – Bid Round 2003/4, *Water Demand Management in Areas of Groundwater Over-exploitation*, 11/11/02

- *Section 2:* **Observations**. This section discusses findings from the Survey and the fieldwork, and makes some observations concerning water and poverty. These observations are preliminary and open for discussion during dissemination of findings in November 2004.
- *Section 3:* **Pro-poor Water Demand Management Strategies**. This section reviews the need for special considerations when developing and implementing water demand strategies, to ensure that at the least, basic water needs of the poor are met.

D1.2 Methodology

D1.2.1 Approach and Study Design

The principal research instrument is through Case Studies using qualitative and quantitative tools to gather data. Case studies, if done correctly, are widely accepted as a valuable method to add qualitative perspectives to information gathered from quantitative data. This was applied at community level in both India and Jordan to complement and support statistically relevant data obtained from secondary sources and previous studies.

Study design and preparation commenced in November 2003, involving examination of secondary data sources, review of the survey and Case Study design, identification of a sampling frame, selection of survey sites, development of checklists-cum-questionnaires, meeting with national team members, and preliminary visiting of possible urban and rural survey locations in (i) Chennai, peri-urban and rural sites in Thiruvallur and Kancheepuram districts; (ii) villages in and around Al Shoubak and Al Jafr districts.

The methodology followed a five-stage process:
(i) Confirmation of the **purpose** of the Case Studies
(ii) Identification of **themes** for investigation
(iii) Identification of **units of assessment** and **sources of information**
(iv) Identification of **tools** to obtain data during the Case Studies
(v) Review of **site selection criteria**

The ***Purpose*** of the poverty and livelihoods component was confirmed with local project partners, both government and non-government, during initial scoping exercises and fieldwork.

Data on industrial and agricultural use, extraction rates and costs are analysed and included in Annex E: Economic Data. Data included in this Annex cover broader community analysis.

Units of assessment and **site selection criteria** are described in the respective country sections of this Annex.

Sources of Information:
- primary data from urban water consumers and agriculturally-dependent households
- NGOs and community-based organisations
- multilateral and bi-lateral agencies working on water issues
- Government agencies working directly and indirectly on water issues

Themes for investigation included:

Urban/Rural domestic water provision and livelihood impact	***Agricultural water profile***
1. Locality and community identification	1. Locality and community identification
2. Modes and diversification of water sources	2. Modes and diversification of irrigation sources
3. Levels of water security (quality, quantity, access)	3. Irrigation water security (quality, quantity, access)
4. Costs [see Annex E]	4. Costs (capital, recurring, crop calendar, land use, crop budgets) [see Annex E]
5. Conflicts	5. Conflicts
6. Coping strategies	6. Coping strategies
7. Satisfaction levels	7. Satisfaction levels
8. Dealing with change	8. Dealing with change

Key Tools :

Principal tools used in both countries included:

- Focus Group Discussions (FGDs) with semi-structured interviewing. Three separate checklists were developed for:
  (i) urban and rural domestic water users;
  (ii) rural agriculturally-dependent irrigation water users;
  (iii) industrial/commercial/small enterprise large volume water users
- Rating and Ranking exercises
- Seasonal Calendar
- Secondary Data (see References)

Domestic FGD: Chennai

Farmer FGD: Shoubak

D1.2.2 Study Tasks and Schedule of Activities

Details of key fieldwork tasks for the Community Development/Poverty Assessment component are given in Table D1.1.

Table D1.1: Key Fieldwork Tasks and Schedule of Activities

Main Tasks - Community development, Poverty assessment, Gender Issues	*2004*		*Month*			
	January	*February*	*March*	*April*	*May*	*June*
1 Drafting tools and methodologies		■				
2 Mobilisation and preparation, Jordan/India			■			
3 Survey design, pre-test and finalisation, India			■	■		
4 Data collection, analysis and initial interpretation, India			■	■		
5 Report preparation, India			■	■		
6 Pre-test and finalisation, Jordan				■		
7 Data collection, analysis and initial interpretation, Jordan				■		
8 Report preparation UK					■	
Submission of Reports	*January*	*February*	*March*	*April*	*May*	*June*
A First Progress Report	◆					
B Inception Report						◆

D1.2.3 Study Accuracy

The sampling frame used in the Study was designed to:
- (i) provide data that reliably represent overall conditions in communities dependent on over-exploited aquifers, and
- (ii) be replicable in more than one country in more than one circumstance.

Fieldwork was undertaken in early summer in India after an already unseasonally low rainfall the previous year, and during spring in Jordan. Checklists for Jordan were revised to reflect seasonal water demand with highs and lows of summer and winter.

In order to avoid bias in the type of respondents selected, and to prevent pre-selection of households, criteria for respondent selection included community-level wealth ranked criteria for different socio-economic levels. These criteria are set out in Tables D2.4 and D3.2. Respondents were selected from different income categories, the largest proportion in India being from lowest income households and in Jordan from middle income households. Despite its best efforts, the team was unable to arrange FGDs with low income households in Al Shoubak.

Data gathered from the FGDs are mainly qualitative. The FGDs relied on checklists to provide a guideline for discussions with focus groups.

Content analysis was used to review data drawn from FGDs, fieldwork observations and secondary sources. This was based on analysis of multiple criteria as reflected by chosen survey themes, which proved particularly helpful when addressing groundwater use and its impact on the livelihoods of the poor. All information was categorised as objectively as possible, grouped by themes and evaluated. Data obtained are therefore qualitatively and trend indicative but not statistically reliable.

D2 FINDINGS: INDIA

D2.1 Survey Areas

Units of Assessment, India:
1. Urban water users (domestic, industrial and commercial)
2. Rural agriculturally-dependent households (landowning and landless)
3. Low, medium and high income groups (male and female)

All categories:
- as equal as possible a proportion of male and female respondents (more female participants were included in Domestic Water FGDs, and more male in Agricultural FGDs)
- a minimum of 10 separately representative households per FGD

Industrial/commercial:
- large water users (e.g. polystyrene producer, agro-chemical producer, hotel)
- traditional water-dependent small enterprise (washermen)

Site Selection Criteria
Discussions were first held with Government and non-government agencies to determine key aquifers in Tamil Nadu which (i) are under significant stress due to over-extraction; (ii) serve as primary domestic and irrigated water sources for dependent communities and urban consumers.

Based on these discussions and preliminary field visits, the following sites were selected:
- The Araniyar/Koratailaiyar (AK) aquifer within the Chennai Basin
- Chennai Metropolitan Area (CMA)

Within these two areas, locations were selected for fieldwork. Criteria included a selection of both urban and rural locations. Survey areas represented five location types including:
- slum localities in CMA
- prosperous localities in CMA
- designated industrial zones of peri-urban areas of CMA in and Kancheepuram districts
- rural sites in AK aquifer
- rural site in the AK basin

Rural locations in Thiruvallur district were selected to reflect the following criteria:
- 4 sites district within the AK aquifer, at 10km staged distances from the sea
- 1 site in the AK basin between the Araniyar and Koratailaiyar Rivers

Maps D1 and D2 provide overviews of the survey areas and locations of sites surveyed. Table D2.1 names FGD locations, and indicates gender and total number of respondents. The total number of households represented in the FGDs was 153 (46 rural agriculturally-dependent, 107 urban domestic). Overall average household size is five persons. Three industries, one large business and one small enterprise were interviewed.

Table D2.1: FGD sites, Gender/Number of respondents

Type of FGD	District	Taluk/Urban Zone	Village/Locality	Gender of Participants		Number of Participants	
				Male	Female	Male	Female
Marginal farmer/landed farmer	Thiruvallur	Uttukottai	Pandeswaram	✓		17	
	Thiruvallur	Uttukottai	Vadamadurai	✓		16	
	Thiruvallur	Uttukottai	Orakkad	✓		20	
	Thiruvallur	Ponneri	Jothinagar	✓		6	
Marginal farmer/landed farmer/landless	Thiruvallur	Ponneri	Alanjivakkam	✓		10	
Landless labour	Kancheepuram	Sriperambadur	Kovur		✓		20
Sub-total	**6 FGDs**					**69**	**20**
Industry	Thiruvallur	Ambattur	Ambattur	✓		2	
	Thiruvallur	Ponneri	Manali	✓		2	
	Kancheepuram	Tambaran	Mettupakkam	✓		2	
Large business	Chennai 17	T.Nagar	GN Chetty Rd.	✓		2	
Small enterprise (washermen)	Chennai 31	VII, Nungambakkam	Dhobi Kanna, Chetpet	✓	✓	8	13
Sub-total	**5 FGDs**					**16**	**13**
Urban domestic low and middle income cons	Chennai 113	III, Pullianthope	Choolai, Natesannagar		✓		14
	Chennai 12	III, Pullianthope	Vysarpadi		✓		10
	Chennai 21	I, Tondiarpet	IOC Nagar		✓		14
	Chennai 13	II, Basin Bridge	Kasimedu	✓	✓		10
	Chennai 49	V, Kilpauk	SidcoNagar,Villivakkam		✓		13
	Chennai 14	VI, Ice House	Mishahibpet, Royapettah		✓		10
	Chennai 113	IX, Saidapet	T.V.Nagar, Taramani		✓		31
	Chennai 24	VIII, Kodambakkam	Rangarajapuram		✓		10
Sub-total	**8 FGDs**					**0**	**112**
Urban domestic high income consumer	Chennai 102	V, Kilpauk	F Block, Anna Nagar	✓	✓	8	2
	Chennai 1	V, Kilpauk	A Block, Anna Nagar		✓		11
	Chennai 31	VII, Nungambakkam	Harrington Rd., Chetpet	✓	✓	4	3
Sub-total	**3 FGD**					**12**	**16**
						Male	**Female**
Total FGDs	**22**			**Total persons participating**		**97**	**161**
						258	

D2.2 Demography of the Survey Areas

The population of Chennai Metropolitan Area (CMA) according to the 2001 national Census stands at 4,343,645.[2]. The overall urban growth in CMA and its two neighbouring districts has been 35% in the last decade (Table D2.2), reflecting CMA overspill and growth of a peri-urban area which supports industries and, increasingly, residential areas.

Farm land in peri-urban districts is now giving way to housing plots, boosted by the presence of the metropolitan area as a work location, the proximity of good communication and transport facilities, and better availability of water. The latter is a strong factor in house and land values[3].

Table D2.2: Urban growth rates, 1991-2001

District/ Metropolitan Area	Urban Growth Rate '91-'01	Total Population 2001	Total Urban Population 2001
Chennai Metropolitan Area	13.07%	4,343,645	4,343,645
Kancheepuram	55.77%	2,754,756	1,500,082
Thiruvallur	36.05%	2,877,468	1,534,966

Chennai has also become a popular venue for meetings and conferences, with corresponding growth in hotels catering to this demand.

[2] Final Population Totals: Tamil Nadu, Census of India 2001 (Ref 1)

[3] See forthcoming results, Can Markets Value Water Scarcity and Quality in India?, Dr. Haripriya Gondimeda & Dr. Vinish Kathuria, Madras School of Economics, June 2004 (Ref 2)

There is regular urban migration from peri-urban districts, on a weekly or daily basis, creating a weekly water demand bulge which may not be reflected in official figures. There are also scores of informal and uncounted squatter colonies of semi-permanent nature, termed as "slum dwellers", whose residential status has not been formalised.

The poor, classified as low-income or slum resident groups, officially totalled 1.4 million in 2001[4]. This is approximately one-third of the total 2001 Census population of the CMA.

Table D2.3: Demography of low income households, Chennai

Zone		No. of slums	No. of Households	Slum population	FGD Area	No. of HHs in FGD locality
Number	Name					
I	Tondiarpet (Royapuram)	124	21566	190,696	IOC Nagar, Korukepet	3,500
II	Basin Bridge	61	14230	168,405	Kasimedu	12,000
III	Pullianthope	183	38372	175,300	Vysarpadi	8,000
					Natesan Nagar, Choolai	500
IV	Ayanavaram	110	22060	98,715	NA	
V	Kilpauk (Anna Nagar)	151	32888	158,880	Sidco Nagar, Villivakkam	2,200
					Block A, Anna Nagar	no data
					Block F, Anna Nagar	no data
VI	Ice House (Triplicane)	94	13727	65,153	Royapettehe, Misarpet	3,300
VII	Nungambakkam	83	18364	72,694	Chetpet, Dhobikhana	1,500
					Harrington Road, Chetpet	750 high income
						2800 slum HHs
VIII	Kodambakkam	99	26264	106,977	Rangarajapuram, Kodambakkam	2,000
IX	Saidapet	103	23042	101,177	NA	
X	Adyar (Besant Nagar)	120	28208	114,273	Taramani	no data
	Total	1,128	238,721	1,252,270		36,550
Source: Continuing Education Department, Corporation of Chennai, 2004					**non-poor localities**	

D2.3 Poverty in the Survey Areas

Tamil Nadu prepared a Human Development Report (TNHDR) in 2002, in co-ordination with the Union Planning Commission, which prepared the first all-India Human Development Report in March 2002. In the foreword to the TNHDR, the Chief Minister points out that development objectives are defined not just in terms of increase in GDP or per capita income but more broadly in terms of enhancement of human well-being. The concept of human development focuses on the actual well-being of the people in terms of indicators like attainment of education, health, life expectancy, access to safe drinking water, sanitation facilities etc.

Development of a national and state perspective on human development, and by association, poverty alleviation, is a positive step taken. The next step is to link these perspectives to practical poverty alleviation targets and pro-poor actions to reach them. One important action was to establish the Tamil Nadu Slum Clearance Board in 1984, which continues to play an important role together with the Public Works Department in implementing various housing, slum improvement, rehabilitation and resettlement programmes to improve living conditions of urban slum families. It has also implemented, as a pilot project, rain water harvesting systems in select tenement schemes, in its Board and Division Offices, and in Community Centres in Chennai city.

However, the needs of the poor outstrip resources available to address those needs, and under circumstances of stress, such as the current water shortage, whether households can meet their daily water needs, highlights key poverty issues. These were identified first through wealth ranking exercises, which provided community criteria of socio-economic differences (Table D2.4).

[4] Sources: Tamil Nadu Slum Clearance Board 2001 and Continuing Education Department, Corporation of Chennai, 2004 (Ref 3)

Table D2.4: Wealth-rank criteria

Socio-economic level	Criteria
Poor	• primarily dependent on daily wage labour, or owning very small land (below 4 acres) • farmers using pumps below 5hp • non property owning (land or house), or if owning a house, of poor structure • low level knowledge and use of tools and technologies • absence of working adult males in proportion to number in household • very few assets • household income not more than Rs.4,000 per month
Middle Income	• more than one source of income • owning small amount of land • adults of working age, or ability to pay domestic labour • property owning or renting, but house of average quality structure • household income between Rs.4-15,000 per month, depending on number of household members
Upper Income	• salaried earners • property owning (large amounts of land/good quality house) • good level knowledge and use of tools and technologies • large number of assets • income above Rs.15,000

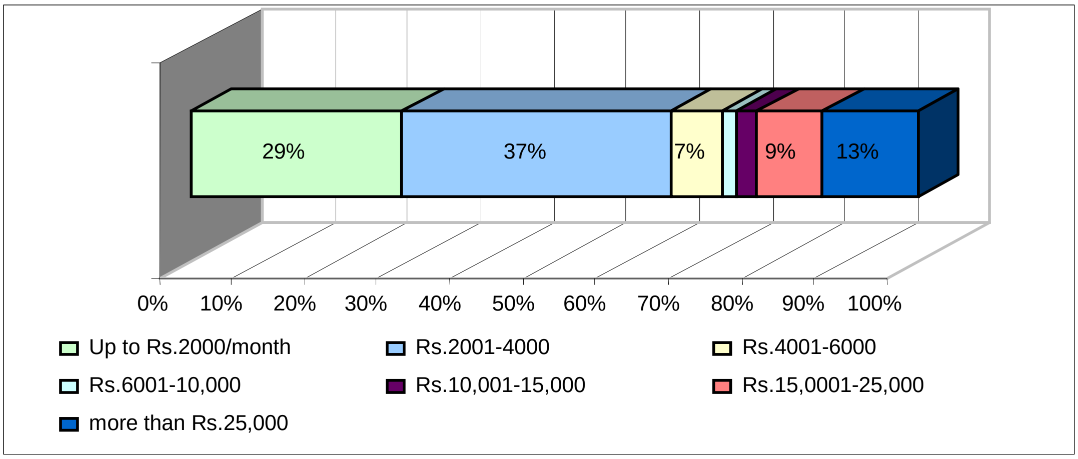
From such criteria it was possible to make the links where and how water stress is experienced by the poor as compared with other income groups. Community poverty criteria were compared with fieldwork results from selected themes. These clarified that in Chennai, key features relating water and poverty include:

- lack of human assets (too few adults mean no-one is available to wait for water deliveries)
- lack of financial assets (insufficient household funds to pay for direct water connections, water storage facilities, independent borewells, or bulk purchase of water)
- lack of socio-political assets (no power to influence service providers)
- lack of natural assets (dwellings are rented, small and in crowded areas. There is no space to install borewells and tankers cannot negotiate the narrow lanes)

Poor urban localities are characterised by crowded conditions and large number of families in small spaces. This means a higher dependence on external water providers, particularly via piped supplies to street tapstands and handpumps, as larger water transport (ie. tankers) cannot negotiate the narrow lanes, or where they squeeze in, cause serious traffic blockages. It also makes it impossible for those that could afford the capital investment of independent sources, to pursue these options, as there is no space to sink household wells.

Figure D1.1 shows income classification of the total number of FGD participating households. 66% belong to lowest income groups (up to Rs.4,000 per month). Middle income households averaged 12% of respondents (Rs.4-15,000), while higher income households represented 22% (above Rs.15,000).

Figure D1.1: Representative income categories, FGD respondent households



D2.4 Domestic Water Use, Chennai

D2.4.1 Diversification of Sources

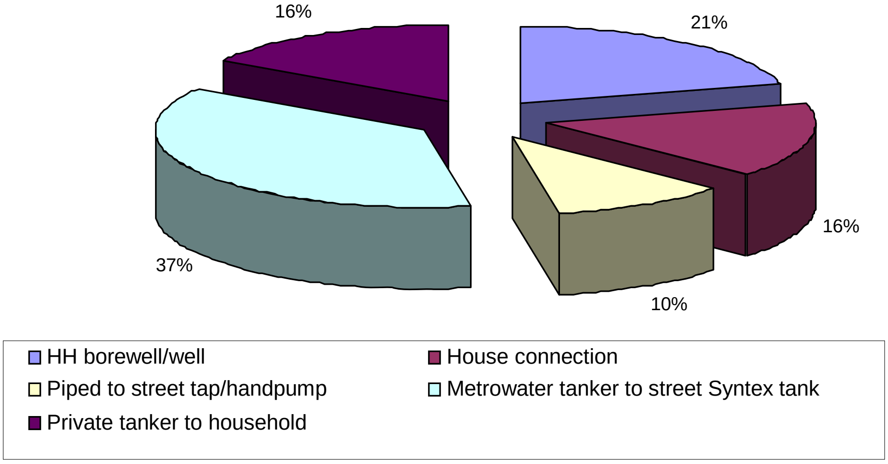
A survey conducted by Economic Perspectives[5] covering 4,500 users showed 85% of domestic consumers in Chennai have their own water source (borewell or open well) while 82% have a household Metrowater connection. However this survey's rapid appraisal indicates that while high income households have their own wells (100%), the majority of poor households are dependent on service providers (63%).

Thirteen separate domestic water supply sources were identified. Some sources are favoured by richer households, others have higher priority for low income groups (Figure D2.1). An average of five different water sources are daily used by each FGD locality to meet their household needs. The four most important, according to the proportion of Focus Groups dependent, are household borewell (21% of FGDs), piped water to street tap or handpump (10%), Metrowater tanker delivered to street PVC static tank (37%) and private tanker to household (16%).

Rainwater harvesting methods have been made compulsory by state government, though all respondents expressed frustration that since implementing recommended measures there has been very little rainfall. Among low-income households, 43% of respondents are implementing simple forms of rainwater harvesting, such as catching and storing rooftop runoff. 100% of high income households have installed improved guttering and well recharge equipment.

[5] The team was unable to obtain an original copy of this survey's findings. This figure is quoted from Joel Ruet, V. S. Saravanan, Marie-Helene Zerah, *The Water & Sanitation Scenario in Indian Metropolitan Cities: Resources and Management in Delhi, Calcutta, Chennai, Mumbai*, French Research Institutes in India, No. 6, 2002 (Ref 4)

Figure D2.1: Prioritised water sources (% FGDs identifying)



(Syntex tanks are high density polyethylene storage tanks, normally 4000 litre capacity)

D2.4.2 Water Security

Figure D2.2 illustrates differences in water security between households from different income groups, and the proportionately greater vulnerability of the poor. Boxed numbers show average household water consumption rates according to FGD respondents, though some localities in CMA are reported to receive only 10 litres per person per day. North Chennai is worst affected. Security of supply depends on location in the city, relative dependence on external supplier, purchasing power, sufficient financial assets to invest in independent borewells, and property size. Given the frequent failure of piped water supply to street taps and handpumps, large plastic 4000 litre storage tanks (PVC static tanks) have been installed at regular intervals along streets and lanes. These are sometimes filled daily (50% of FGD localities) in low-income areas, and sometimes on alternate days.

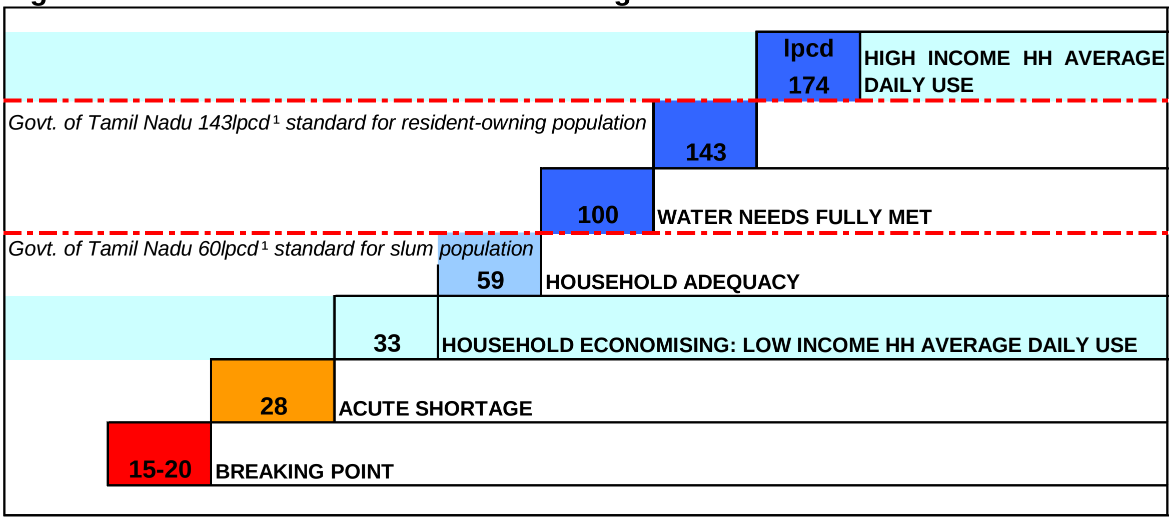
Water distribution, Chennai

Respondents were asked what constituted water security to them, and how much less could they manage with before their condition became acute. Poor households were easily able to identify stress levels. High income households could not identify these as easily and already considered their present situation one of acute shortage, despite average consumption being 31lpcd over Metrowater's standard for higher income households[6].

There is no shortage of water supply for those that can pay for it. Not only can higher income households afford the more expensive bottled water as well as regular tanker deliveries, they can achieve economy of scale with storage tanks which are filled regularly (on average every 3-4 days, depending on storage capacity). Prosperous localities are also better served by roads which can accommodate large private tankers.

Among high income households, participants in two of the three FGDs complained about water shortages but did not reflect the acuteness of the situation by changing their consumption habits.

Figure D2.2: Water Stress Thresholds among FGD Households



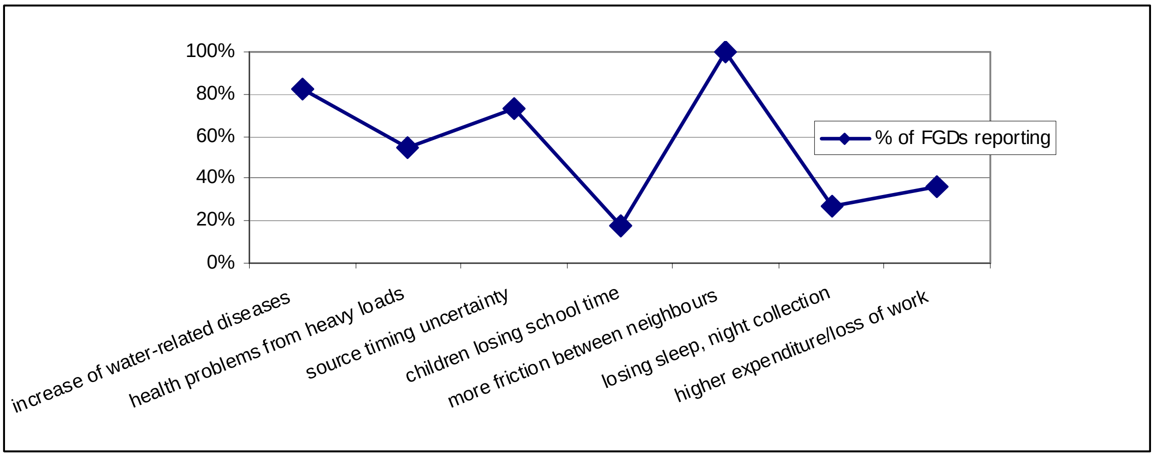
1: lpcd = average number of litres used per person per day

Many household wells in all parts of Chennai have been dry for some 2-3 years. For those with financial capital and land space, existing bores are deepened or new ones dug. The difference in well depth (depending on location) ranges between 25-40ft. five years ago, up to 80ft. at present. Household connections in all FGD locations have been cut off for the past 2 years, with the exception of one high income locality (Harrington Road). All FGD respondents said water supply from direct connections and wells decreased in the past three years, while dependence on tanker delivery and bottled water has increased by 81% and 54% respectively. Despite the survey occurring during a period of poor rainfall, this feedback is consistent with technical findings that in the past 4-5 years, the aquifer is not re-charging after rainfall as in previous years following rainfall scarcity.

All FGD respondents said they took 1-2 hours daily in fetching or waiting for water. One particularly poorly served area (Taramani) and some households in Pullianthope reported spending more than 4 hours a day in fetching water. Taramani is a location where squatters have been living for more than 15 years but have not had their residential status officially recognised by Government.

[6] Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) has established water demand ceilings for different types of water users. Water demand has been computed by taking 60 litres per person per day (lpcd) for the slum population, 143lpcd for the residential population, 133lpcd for the commercial population, and 18,000 litres per hectare per day for institutional and industrial demand. CMWSSB, *Chennai Metrowater: A Profile*, Government of Tamil Nadu, no date (Ref 5)

Figure D2.3: % FGDs reporting an increase in water problems in the past year



FGDs testified to an increase in other sorts of problems experienced in relation to water shortages, as reflected in Table D2.3. All respondents commented on an increase in neighbourhood disputes over water quantities taken by individual households.

D2.4.3 Costs

Costs are dealt with in more detail in Annex E: Economic Data. Basic costs of domestic water supply and water connections are set out in Tables D2.5 to D2.7. The price varies from location to location, and the sort of payment differs from area to area; prices given are averages from all used sources.

Table D2.5: Recurrent household domestic water costs

Type of water supply	Delivery Volume	Average cost of supply	Average price per litre
Private tanker	9,000 litres	Rs. 600	Rs. 0.06
Metrowater tanker load to shared street Sintex tank subsequently distributed to households by pots	15 litre pots	Rs. 0.37 per pot	Rs. 0.02
Tricycle trip to water loading station (including tricycle hire charge)	15 pots of 15 litres each	Rs. 20	Rs. 0.08
Bottled/Canned water	25 litre per can	Rs. 30	Rs.1.20
Domestic water tax	6 monthly	Rs. 300	na

All FGDs reported rising costs of water, though not necessarily less quantity available from supply sources. Private tanker owners have turned to delivering water as it is so profitable, rather than other sorts of products such as oil. Different tankers have different holding capacities, and domestic users purchase part loads. The largest tanker volume is 12,000 litres. In October 2003, the reported average cost of 6000 litres was Rs.275; the same amount now (April 2004) costs Rs.375-450, depending on the supplier. All high income households take water from private tanker suppliers. Metrowater tankers deliver water to street PVC static tanks free of charge, but without exception all respondents receiving municipal water stated they have to pay the drivers for the supply.

Table D2.6: Cost of Water Connections

Type of Housing[1]	Cost of water connection[1]	% of FGD HHs with connection	
Residential piped water			
Independent House – ground +1 storey up to 200m²	Rs. 1930	**Low income**	13%
Independent House – ground +1 up to 200m²	Rs. 1930	**Middle income**	80%
All other buildings/flats up to 200 m²	Rs. 2530	**High income**	100%
Residential borewell	**Cost of installation**	**% of FGD HHs with borewell**	
Average cost of installing borewell (90-150')	Rs. 50,000	**Low income**	37%
Average cost of deepening existing borewell	Rs. 16,000	**Middle income**	100%
		High income	100%
Non Residential			
Categories A-C	Rs. 2530	na	

[1]*Source: CMWSSB*

As Table D2.6 illustrates, the cost of a household water connection is well beyond the means of poor households, despite the fact that low-income households can make payments in three instalments. Household supplies have been turned off in all parts of the city, with the exception of FGD location 10 (see Map D2). Customers are obliged to pay six-monthly water tax as part of their property tax whether or not they receive any service in return. Despite this, customers continue to pay as fines are imposed on defaulters. Consequently poor households see no point in opting for a connection which might or might not function, as it represents too large a chunk of the household budget for no service.

Table D2.7: Water expenditure and consumption (figures rounded)

Income and expenditure	Low income	Middle income	High income
Average monthly HH income	Rs. 3,257	Rs.7875	Rs. 40,000
Average monthly HH expenditure on purchased water	Rs. 126	Rs.83	Rs. 346
Average cost per person per day	Rs. 0.84	Rs. 0.39	Rs. 2.31
Average consumption of purchased water per person per day	34 litres	26 litres	160 litres
Average HH consumption per month	5100 litres	5,540 litres	24,000 litres
% monthly disposable income spent on water costs	4%	1%	1%

Table D2.7 shows average monthly household water expenditure for respondents. As can be seen, in proportion to their total monthly disposable income, low income households pay more for their water in times of scarcity because they are fully dependent on external sources of supply. Middle income households have borewells to rely on, but tend not to purchase bottled water as do high income households.

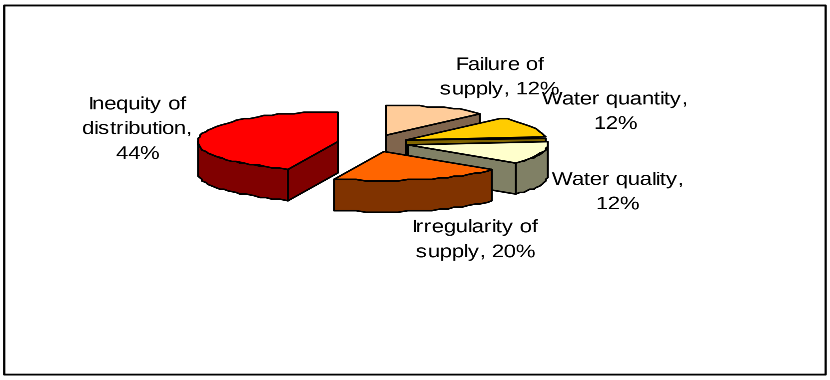
Costs shown here only include the minimum basic expenditure on water. They do not include all costs, such as waiting times, livelihood impact, electricity charges for pumping nor energy consumed in water treatment (e.g. boiling). Electricity charges are never calculated by households with their own borewells as the cost is simply integrated into the overall household electricity bill. However, among blocks of flats (increasingly more common among affluent parts of Chennai), energy costs can be calculated more easily, a typical tariff being Rs. 500 per household per month for pumping.

Costs of digging a borewell are also variable, but a minimum of Rs.20,000 is required for digging, and Rs. 10,000 for installing pipes and a minimum 1HP pump. For further deepening of a borewell which has dried out, a minimum of Rs.40 per foot is asked. The total amount is a big investment for middle income households, and a wasted investment when borewells run dry. However, the demand for water independence is so high, higher income households are willing to re-drill when this occurs.

D2.4.4 Conflicts

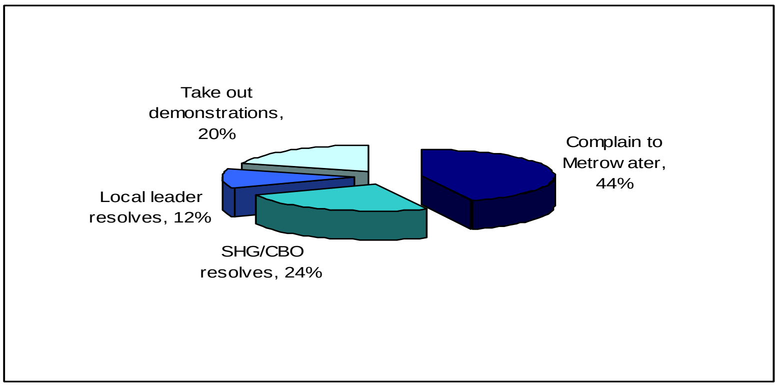
All households said they experience higher levels of conflict over water, sometimes between communities and water authorities or controllers of supply, but primarily between each other over distribution. Figure D2.4 shows the importance given by focus groups to types of problem, and methods adopted to attempt their resolution. Percentages indicate the importance of an issue given by focus groups.

Figure D2.4: Type of water problems important to Focus Groups



Most households attempt to resolve water shortage difficulties by complaining direct to Metrowater, either collectively or individually. However, many Focus Groups pointed out their dependence on intermediaries to address their needs and powerlessness to effect any change independently. Some of the poorest areas have resorted to direct action by blocking roads.

Figure D2.5: Preferred conflict resolution measures



D2.4.5 Coping Strategies and Livelihood Impacts

Higher income households respond to shortages from their normal supply sources by purchasing more bottled water and paying for private tanker delivery.

Low income households cannot afford to purchase more and cope by spending more time looking for alternative water sources. This involves longer distances to collect water from a wider number of supply sources. Many slum areas have been re-built as tenement blocks, where carrying buckets of water up flights of stairs is laborious. Intensive labour in accessing domestic water automatically represents a water management technique; if water is easily available from a tap, people tend to use this more freely and with less regard to amounts used.

Poor households are also the first to start making economies in their time, budgets and water use. 57% of poor FGD respondents said water shortages have had a negative impact on livelihoods. **Livelihood impacts** include:

- loss of wages due to non-attendance at work while waiting for water supplies
- loss of work opportunities due to irregularity of water delivery timing
- loss of work due to illness from water-related diseases
- reduced labour capacity due to poorer nutrition
- higher expenditure for medical treatment
- higher expenditure to purchase meals outside (no time to prepare food at home)
- higher expenditure for water purchases
- higher expenditure to local water distributors
- high levels of customer dissatisfaction with water supply managers

Typical economies for low income households include:

- reduce the nutritional intake by cutting out meat from the diet and reducing the number of vegetables eaten, or cutting a meal
- cut the cost of one household expenditure (e.g. electricity) to afford rising water costs
- reduce the number of baths taken and the number of times clothes are washed
- re-use grey water for sanitation
- take out bank loans to buy water
- keep children back from school while waiting for water delivery

D2.4.6 The Urban Vulnerable and Impacts of Water Shortage

Of those households already economising, women are the first in the family to do without. For example, women told us they would be the ones to cut out a meal or turn off the electricity while husband and children were out of the house. Some women said their men did not consider water shortages their problem and were unwilling to reduce their own spending accordingly. As one woman reported: "My husband tells me he earns the money so he can spend it as he wants. It is my responsibility to see water is in the household, so I have to find a solution as best as I can."

The most vulnerable are:

- the elderly who cannot afford to hire domestic help, particularly those living in blocks of flats
- women-headed households from low-income groups with no adults of working age (women earn less than men, they have responsibility for the children, they have responsibility for the domestic budget which includes water costs)
- women of child-bearing age (burden of carrying heavy loads)
- low income groups in particularly densely populated inner city localities relatively inaccessible to large vehicles
- those residing in poorly served areas
- non-formalised slum dwellers
- households dependent on daily wage earning

The most serious limitations of water shortages from the point of view of poor respondents are inequity of distribution of existing water supplies and timing uncertainty of deliveries, regardless of whether the supply is from Metrowater or from a private source. These two features have had the highest impact on livelihoods.

Inequity of distribution is experienced in several ways:

- Unequal distribution between low and high income households. Poor households are not provided with the basic minimum 60lpcd stipulated by the Government of Tamil Nadu[7], while the average high income household use exceeds the basic minimum of 143lpcd. Purchase power is key. Higher income households can afford to purchase as much water as they can pay for.
- Whatever amount of water is daily supplied to poor localities tends not to be equitably distributed among households, which leads to daily inter-household conflict. In some localities, local power brokers control water distribution and favour those who will pay most. Water intended for domestic consumption is diverted to small businesses (e.g. teashops) or favoured households (e.g. relatives of leaders).
- If households do not have someone at home all the time, they lose their share of water delivered to a street PVC static tank. They must spend more time looking for alternative sources. This involves night-time collection, or days/hours lost in work with corresponding wage cuts.

Some FGDs report local leaders organising distribution. Tokens are issued for a cost of Rs.10-20 per household per month. In exchange, people take turns for first place in the queue and are guaranteed 3-4 pots[8] supply. Although this enables local leaders to make substantial amounts of money[9], this is not necessarily resented by local people who at least feel the system is fair to everyone, they are guaranteed a minimum daily amount, do not have to additionally pay the tanker driver, nor have to stand in queues for indefinite periods of time, and need not resort to abuse and fighting to obtain their water.

[7] Government of Tamil Nadu, *Chennai Metrowater: A Profile*, Chennai Metropolitan Water Supply and Sewerage Board Information Brochure, no date (Ref 5)

[8] Each pot contains 15 litres

[9] For example, in one FGD location of 5,000 households, tokens must be purchased at Rs.20 a month, amounting to an monthly income of Rs.100,000 (£1300).

Timing uncertainty has a serious impact as people must wait for tanker deliveries not knowing when they will arrive. Many respondents reported loss of wages or jobs as a result of not turning up for work on time or missing a day while waiting for water.

The higher the income of households, the higher the levels of awareness reflected about water saving devices as a coping strategy. Some households reported installing double piping, one for drinking and another for sanitation, plus re-routing of drainage pipes to wastewater storage tanks for flushing.

D2.4.7 Satisfaction Levels

Overall satisfaction levels proved lower among high income households than middle and low income households. Expectations among the poor are very low and are related to their perceptions of empowerment. Poor respondents felt their only strength was in numbers and through direct action. Expectations concerning competence and representation of local leaders were correspondingly low.

However, satisfaction levels are not entirely related to socio-economic differences – or rather, to the different sources of social and financial capital that different income groups can draw upon. It is also related to widely differing variations even within quite small areas in close proximity to each others, depending on such factors as geological structure of the land and therefore the ability of some localities to depend on borewells better than others, as well as proximity to primary sources of contamination.

64% of total FGD respondents expressed high levels of dissatisfaction at current levels of water security and relative access to water sources. Water quality has also been a major source of discontent, another reason why households seek many different sources of water for their different needs. No-one uses borewell water for consumption any more, reserving it for washing and sanitation. There is slightly higher confidence in the quality of piped Metrowater supply, with all those with access to this source reporting its use for consumption. There is less confidence in the quality of Metrowater tanker supply, with respondents stating quality is very variable. 45% of FGDs reported using tanker supply for consumption purposes after boiling or treatment. Confidence in the quality of bottled water is high.

There are also differing states of awareness (again, linked to relative empowerment). Although awareness on water-related issues is greater among high income households in comparison to low income households, there are blind spots concerning multiple user access of groundwater; for example, it is not fully understood that sinking one's own household borewell will affect water levels of neighbours. Similarly, a common response to water scarcity is to recommend sinking another borewell, demonstrating weak understanding of why water levels are decreasing in the first place.

Questions were asked about overall satisfaction levels concerning water. Almost 65% of respondents from all income brackets indicated dissatisfaction, reflecting low confidence levels in service providers. Figures D2.6 and D2.7 reveal satisfaction levels for quality and quantity from different supply sources.

Figure D2.6: Satisfaction levels with water quality (%FGDs)

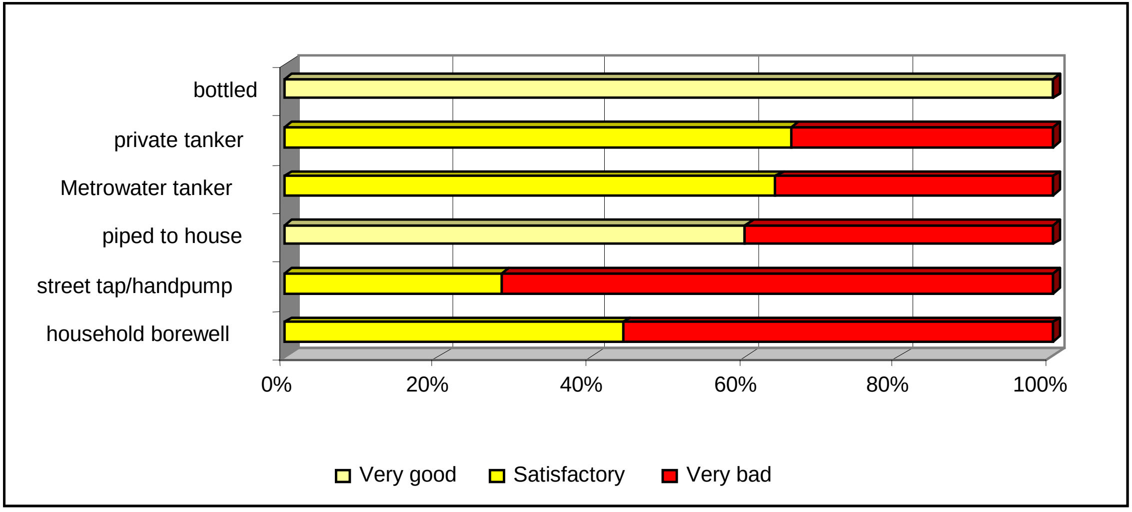
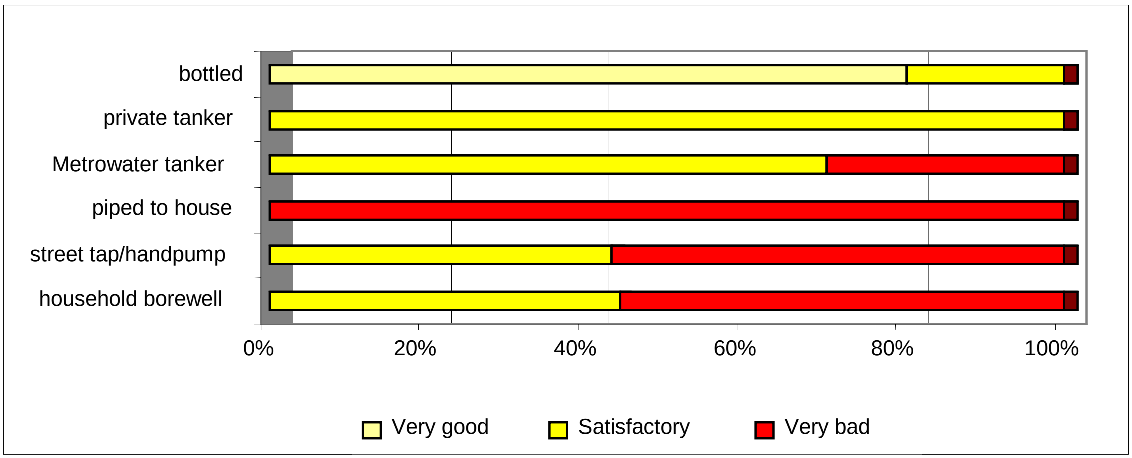


Figure D2.7: Satisfaction levels with water quantity (%FGDs)



D2.4.8 Dealing with Change

The water supply situation has become worse in Chennai over the past two years. Household economies and coping strategies thought to be temporary have now become established.

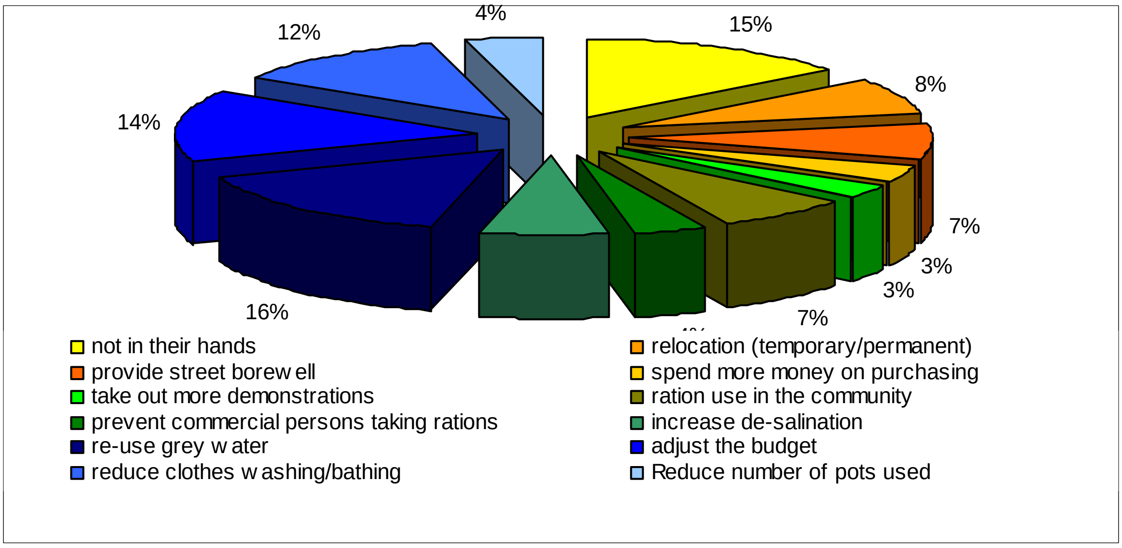
Respondents were asked the question: "If water supply stays the same or becomes even less, what methods will you adopt to cope with this?" Answers indicated practical coping strategies that would need to be adopted, as well as relatively low levels of awareness about the finite nature of groundwater. There is a general perception that one good rainy season solves all the problems.

Figure D2.8 reflects the relative popularity of different suggestions by respondents. Responses fell into roughly three categories:

- how to obtain more water, revealing low levels of awareness about causes of groundwater scarcity (yellow wedges)
- how to deal with current water access grievances, indicating dissatisfaction levels about the equity of existing water supplies and improving neighbourhood water demand management (green wedges)

- how to manage with less water, implying acceptance of a worsening situation and adopting household water demand management measures (blue wedges)

Figure D2.8: Respondent attitudes to dealing with water quantity changes (%FGD responses)



D2.5 Agricultural Water Use

More details are given on cropping patterns, crop budgets and related economic data in Annex E.

In the six FGD locations in the AK basin, approximately 92% of households own or rent land for agricultural purposes. Of the 46 agriculturally-dependent respondent households in the FGDs, landholdings averaged 14 acres per household. The smallest average landholding was in Pandeswaram (2 acres), the largest in Jothinagar (40 acres)[see Map D1].

The majority of land is cultivated (89%), and very little has been left fallow as a consequence of water shortage. The lowest rate of cultivation was in Orakkad, at 62% of landholdings.

The principal crops are all water-intensive. Paddy is the most important, with 86% of FGD locations cultivating. Sugar cane is also grown together with fruits (mangoes, guava, banana) and pulses. Increasingly, farmers are cultivating low water-intensive and high profit crops such as groundnut and green gram. 66% of farmers practised three cropping seasons, the remaining 34% two seasons.

D2.5.1 Diversification of Sources

The main source of irrigation water is farmer-owned borewells (66%) which feed crops via networks of open channels. 17% of FGDs identified some farmers sharing or purchasing water from another's well. Only 17% of FGDs reported dependence on traditional rainfed tank irrigation. Rainfed farming accounts for a small proportion of irrigation (10-20%) and only in one of the three cultivation seasons (*samba*).

Most farmers do not practise water-saving techniques, though a small number in two villages do water their fields via pipes to reduce evaporation. Two households use drip irrigation for fruit trees. No-one uses sprinkler irrigation, or mulching as a means to reduce water loss. Only one farmer pipes rainwater to recharge his well.

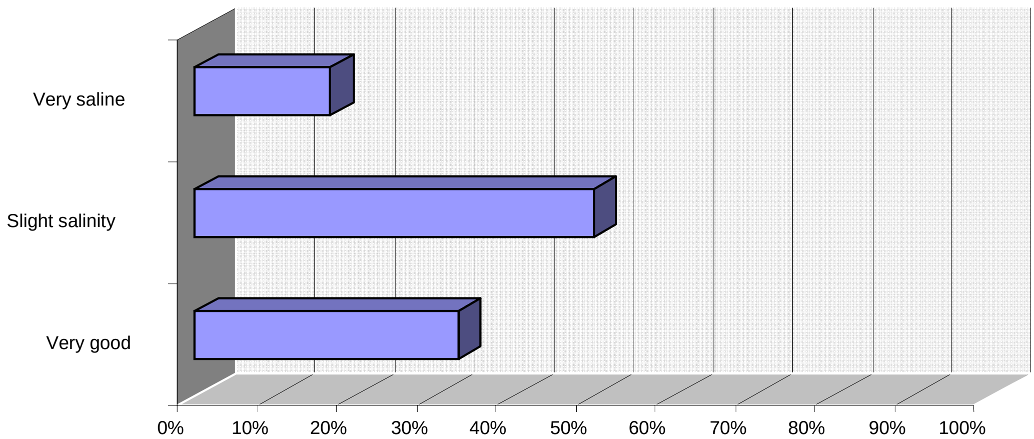
D2.5.2 Water Security

There were few complaints about water security. 67% of households said irrigation water was regularly available, and average pumping time per household was 17 hours a day.

However, there are some perceived changes in groundwater availability, with one FGD only reporting borewells dry up to six and nine months of the year. The remaining FGDs stated borewells are never dry, but all perceive a decrease in amount of water available. A third of FGDs complained about uncertainty of water supply. Figure D2.9 indicates FGD responses to questions about borewell water quality. Groundwater quality is variable, even within the same village.

Farmers have several borewells to meet irrigation needs. The average number of working borewells per household is 2, though in Jothinagar it is higher at 4 per household.

Figure D2.9: Farmer responses on water quality (% FGDs)



Most farmers have deepened their wells in the last five years by an average of 40 feet. Differences in depth according to location are set out in Table D2.8.

Table D2.8: Well depth changes in FGD locations

Location	Current well depth (2004) (in feet)	Borewell depth 5 years ago
Pandewsaram	80	40
Vadamadurai	80-120	40
Orakkad	80-90	100-105
Alinjivakkam	80-150	80-150 (but more water)
Jothinagar	140	100
Kovoor	35 (though now drying)	35

Two villages are involved in selling water to urban suppliers, both to Metrowater and private suppliers. In Alinjivakkam only one respondent sells water, pumping an estimated 300,000 litres 18 hours daily, for which he receives Rs.26 per hour. In Jothinagar village, half the respondents are selling water. They pump at an estimated rate of 42,000 litres per hour, 18 hours a day, for which they are paid Rs.25 per hour or Rs. 40 per 12,000 litre tanker load. Tankers either deliver to a distribution centre, or deliver straight to customers. Each tanker is estimated to make five or six trips a day.

D2.5.3 Conflicts

Respondents state there is very little conflict over water. The exception was in one village where there were disputes over the quantity of water taken by farmers sharing a borewell. All inter-farmer disputes are settled among themselves or with the assistance of village elders.

There is virtually no conflict between farmers and government, though there is much grumbling, particularly over the failure to maintain the tank system and to construct rainwater catchment checkdams. Farmers from all villages complain of the demise of tank irrigation due to lack of maintenance or alternative use by cultivators or sand extractors, both of which they regard as illegal. Excessive pumping from river beds by both Metrowater and private companies is also a grievance.

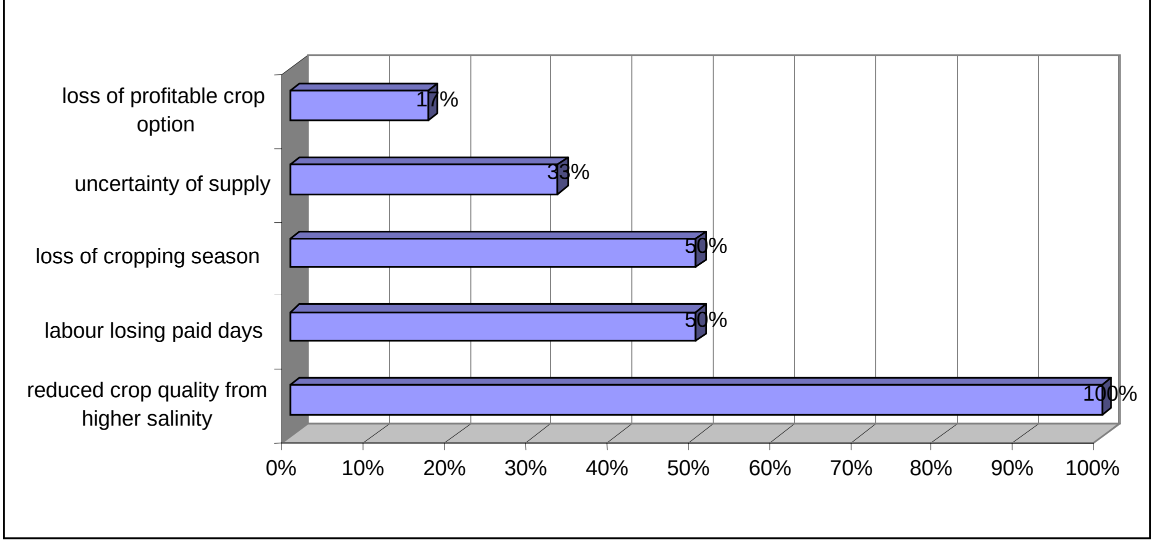
River bed pumping

There are other identified shortcomings relating to groundwater as illustrated in Figure D2.10.

Other limitations were acknowledged, though not all necessarily related to water. These points were of more concern to respondents than groundwater availability, including:

- dissatisfaction with fee rate for groundwater purchase
- lower price for lower quality produce
- labour shortages: landless labourers now have more occupational choice and increasingly choose to work in nearby factories
- lifting of inter-state tariffs making agricultural production less competitive

Figure D2.10: Key shortcomings with groundwater (% FGDs identifying)



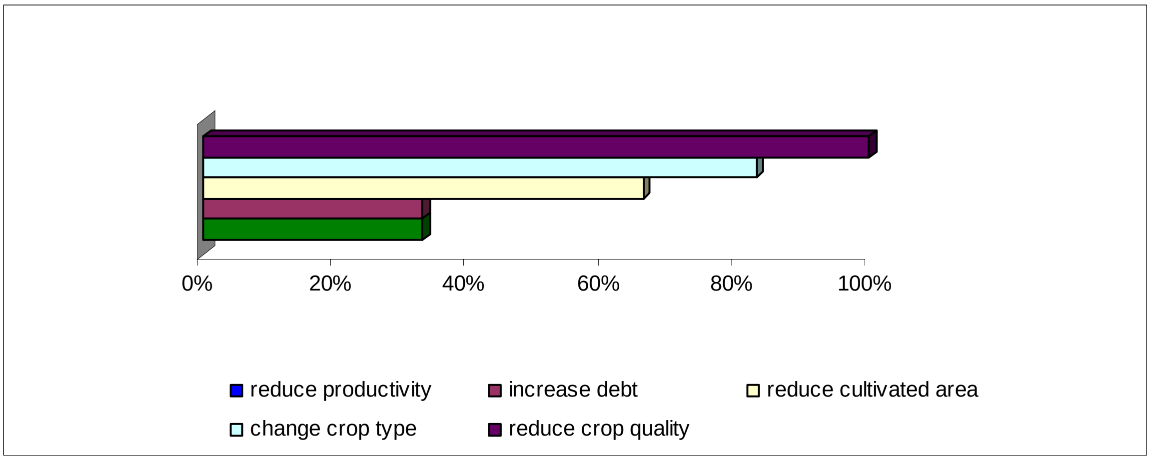
D2.5.4 Coping Strategies and Livelihood Impacts

Despite the stated availability of irrigation water, 66% of FGDs claim water problems have affected their livelihoods. However, they acknowledged that livelihood decline was set in train by other factors such as non-availability of agricultural labour, and water difficulties have simply accelerated the process. Key livelihood impacts are illustrated in Figure D2.10.

Livelihood impact in the rural context does not therefore appear to be as directly attributable to water problems, nor as severe as it does in the urban context. Even so, there are livelihood impacts and farmers have adopted corresponding coping strategies (Figure D2.11).

Although some farmers are willing to earn alternative income through sale of groundwater to urban suppliers, 66% of FGDs were adamant in refusing to sell. Current extraction rates are blamed for growing saline intrusion which has led to a current loss of crop productivity and quality. Farmers pointed out that the Minjur area in the eastern section of the AK aquifer has become useless for cultivation due to excessive groundwater pumping in the last ten years.

Figure D2.11: Preferred coping strategies for water-related livelihood loss (% of FGDs identifying)



D2.5.5 The rural vulnerable and impacts of water shortage

The impact has not really been felt so much by the poorest landless agricultural workers. Presented with alternatives, they have voted with their feet and are increasingly leaving the land. The impact is most felt by marginal farmers, with few financial and human assets to work the land, who find themselves increasingly indebted with no apparent way out. Water scarcity and decreasing quality is pushing them into a state of economic unviability, and landowners reported distress sale of cattle due to non-availability of fodder. This outcome is confirmed in a study recently undertaken by the Centre for Water Resources[10] which notes that "one alarming feature of inadequate and untimely supply [of water] experienced by marginal farmers is that it affects them, chronically at every stage, almost affecting one third of the population".

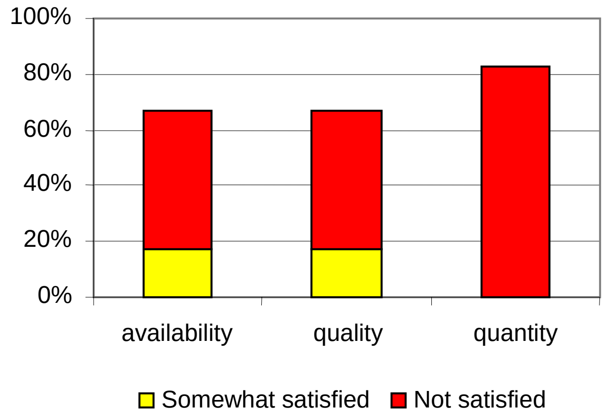
D2.5.6 Satisfaction levels

There are much higher levels of confidence among farmers as water-users than among urban dwellers. This is reflected in their knowledge that the agriculturally dependent are important vote banks and enjoy considerable political support, reflected by the lifting of electricity pumping charges over election periods.

Despite their relatively stronger sense of empowerment than urban dwellers, satisfaction levels over aspects of water are universally low. Those with higher dependence on tank irrigation are least satisfied with both availability, quality and quantity of tank water. However, most farmers no longer depend on tank irrigation and are independent with their own borewells. Satisfaction levels with borewell water are reflected in Figure D2.12.

[10] "Role of Women, Small and Marginal Farmers as Stakeholders in Lower Bhavani, Sathanur and Ponnaiyar Systems," Final Report, Centre For Water Resources. Anna University, Chennai 600025, March 2003 (Ref 6)

Figure D2.12: FGD Satisfaction levels with borewell water



D2.5.7 Dealing with Change

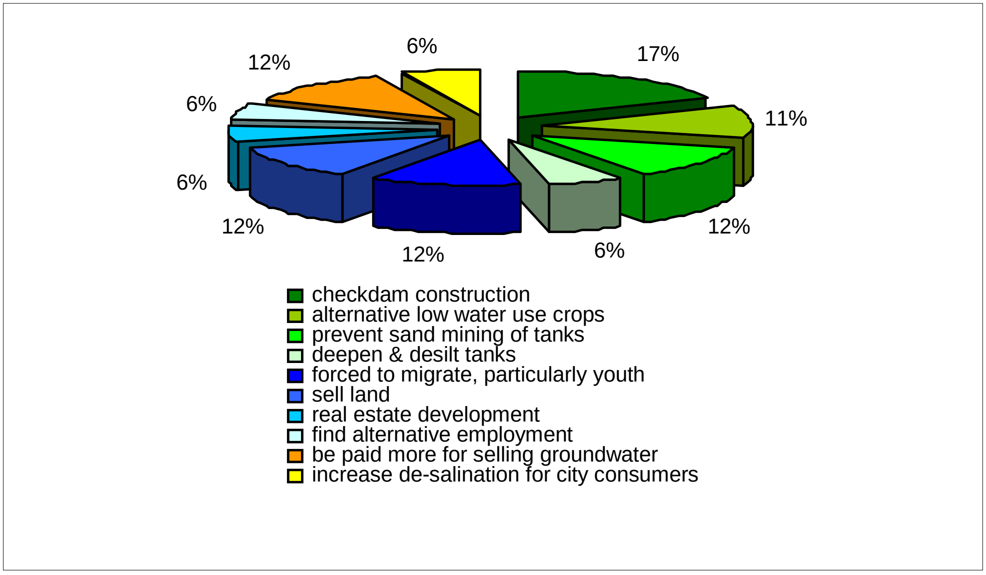
Change is taking place in rural Thiruvallur and Kancheepuram. Labour is leaving the land and turning to alternative employment opportunities, such as the construction industry, local factories sited in peri-urban districts of Kancheepuram and Thiruvallur, and weekly migration to Chennai Metropolitan Area. Abolition of inter-state tariffs has introduced a harsher level of competition, with cheaper and better quality agricultural products being transported from other Indian states. On top of this has come several years of low rainfall and an ever-increasing urban demand for water. The combination has proved an unhappy one for farmers in Thiruvallur and Kancheepuram, many of whom see the future, for their children if not for themselves, as an urban one.

During the period of fieldwork, Tamil Nadu state declared a moratorium on bank loans for six months, in an effort to support farmers until harvests were in. Despite these efforts, state agricultural production targets are maintained without compromise, reflecting a need to improve co-ordinated water demand management across sectors. Respondents also complained that the agricultural sector has been run down through lack of traditional irrigation infrastructure maintenance and failure to promote water saving land use methods, such as transfer to profitable drought resistant crops and promotion of water saving irrigation techniques. Some forward-thinking farmers have pursued these alternatives and report positive and profitable results. Most farmers have not made the adjustment to changing times. Farmers did say they were willing to pay to maintain tanks and construct checkdams, but were unable to obtain the necessary official approval to do so.

The importance of water in this equation was reflected in the recent 2004 state elections. "Cast your vote for water" was a rallying cry for those seeking votes. Farmers in some locations decided to exercise their mandate in favour of the candidate who provides water. Pumping water from rural areas to supply urban consumers has become a sore point in some *taluks*. Public service advertisements for the 2004 Lok Sabha elections showed a woman complaining because the tap is dry; the message was: "Vote today, don't curse tomorrow."

FGD respondents were fairly gloomy about the future of agriculture in their villages. When asked the same question as urban water users about water supply levels and standards remaining the same or becoming worse, replies reflected an approximate balance between those who want to stay on the land and improve agricultural opportunities (green wedges), and those who would choose to give up agriculture as a way of life (blue wedges). A small proportion responded on the relationship between rural groundwater supplies and urban demand (yellow wedges).

Figure D2.13: Respondent attitudes to dealing with groundwater situation (% of FGD responses)



D2.6 Industrial Water Use

More details are given on budgets and related economic data in Annex E.

Industry is an important water user in Chennai. Forty large industries account for CMWSSB's main sources of revenue. Some industries re-use wastewater and have installed on-site recycling plants for the purpose. Madras Fertiliser Ltd. and Chennai Petrochemical Corporation Ltd. are the best known, having set up their own tertiary treatment plants to reuse secondary treated water, resulting in a saving of 19MLD (million litres per day).

However, wastewater recycling is not pursued as actively as it might, and both large and small industries are responsible for major contamination of both ground and surface water sources. Hundreds of small industries discharge untreated effluent directly into waterways, such as the Cooum River and Buckingham Canal, and FGDs reported significant variability in borewell quality depending on proximity to contaminated sources.

Recommendations to improve Chennai's industrial wastewater management have been made in the past. Where implemented as seen above, they have contributed to lowering industrial water demand. Other recommendations remain to be applied.

D3 FINDINGS: JORDAN

D3.1 Survey Areas

Units of Assessment, Jordan
1. Rural domestic water users
2. Rural agriculturally-dependent households, both landowning and landless
3. Low, middle and high income groups, male and female

All categories:
- as equal as possible a proportion of male and female respondents (more female participants were included in Domestic Water FGDs, and more male in Agricultural FGDs)
- a minimum of 10 separately representative households per FGD

There was difficulty in obtaining a minimum of 10 representative households in each FGD. Communities were often reluctant to co-operate without some material benefit to themselves through a subsequent project. It proved impossible to interview poorest households in Al Shoubak, despite the best efforts of the team. However, an employment survey recently carried out by the Household Surveys Directorate[11] indicates that 10% of the population of Ma'an earns less than JD100 per month, while 68% earns between JD100-200 per month. Respondents from this income category were well represented in Shoubak FGDs. Respondents from all socio-economic levels were included in FGDs in Al Jafr.

Site Selection Criteria
Discussions were first held with Government and non-government agencies to determine key aquifers in Jordan which (i) are under significant stress due to over-extraction; (ii) serve as primary domestic and irrigated water sources for dependent communities.

Based on these discussions and preliminary field visits in November 2003, the following sites were selected by the Ministry of Water & Irrigation:

Jordan:
- Al Shoubak aquifer
- Al Jafr aquifer

Both locations are in Ma'an Governorate. Within these two aquifers, fieldwork sites were chosen. Selection criteria included areas where populations are dependent on groundwater for both domestic and agricultural use. All fieldwork sites were rural. In Al Shoubak, five locations were selected based on the following criteria:
- locations experiencing water stress;
- settled communities, with livelihoods depending partly or wholly on agriculture;
- domestic water users;
- a range of socio-economic levels, representing low, middle and high income households;
- formerly nomadic communities, now settled.

One FGD was sited in Udruh sub-district, also dependent on the Shoubak aquifer. In addition, separate interviews were conducted with large agricultural investors in Al Shoubak, owning substantial fruit farms. Results of these interviews are included in Annex E.

[11] *Employment and unemployment Survey 2003: Annual Report, Household Surveys Directorate, January 2004, Table 7.2, p. 121 (Ref 7)*

Maps D3 and D4 give an overview of the survey areas, including locations of sites surveyed. Table D3.1 gives numbers and types of FGDs conducted. Total number of represented households in the FGDs was 100 (63 domestic, 37 agricultural), overall average household size is 8 persons (7 in Al Shoubak, 9 in Al Jafr).

Table D3.1: Fieldwork sites: Gender and Number of Participants

Type of FGD	Governorate	District	Village	Gender of Participants: Male	Gender of Participants: Female	Number of Participants: Male	Number of Participants: Female
Agricultural: Low income	Ma'an	Al Jafr	Al Jafr	✓		7	
Middle income	Ma'an	Udruh	Al Jarba al Kabira	✓		8	
	Ma'an	Al Shoubak	Al Baq'a	✓		11	
High income	Ma'an	Al Shoubak	Al Zubayriya	✓		7	
	Ma'an	Al Jafr	Al Jafr	✓		6	
Sub-total	**5 FGDs**					**39**	
Domestic: low income	Ma'an	Al Jafr	Al Jafr		✓		19
Middle income	Ma'an	Al Shoubak	Al Zubayriya		✓		11
	Ma'an	Al Shoubak	Bir al Debagat		✓		7
	Ma'an	Al Shoubak	Juhaier		✓		13
	Ma'an	Al Jafr	Al Jafr	✓		7	
	Ma'an	Al Jafr	Al Jafr		✓		15
High income	Ma'an	Al Shoubak	Al Baq'a		✓		8
Sub-total	**7 FGDs**					**7**	**53**
						Male	**Female**
Total FGDs	**12**	**Total localities represented: 6**		**Total persons participating**		**77**	**128**
						205	

D3.2 Demography of the Survey Areas

In 1995, the Governorate of Ma'an was divided into four Districts. These included:

- Qasabet Ma'an
- Shoubak
- Petra
- Husseiniya

In addition, there are eight Municipalities, of which Al Jafr is one under Qasabet Ma'an District. In the year 2000, the total population of Shoubak District was estimated at 13,000[12] and Al Jafr at 11,230 (23% of Ma'an Governorate as a whole). The population of Ma'an Governorate is 103,915[13] which is 1.9% of the total population of Jordan. This reflects the unevenness of population distribution in Jordan, with high urban densities and particular concentration in the capital governorate of Amman and in Irbid, where 56% of the country's population lives.

Population density is very low in Ma'an governorate, estimated in 1997 as 2.7 persons per square kilometre[14]. This reflects the limitations of natural and economic resources in the area.

In the survey area, population distribution is characterised by division of clans belonging to tribes. The Hawettat tribe is dominant in Al Jafr, with its main clans of Al Tawaiha, Al Damanieh, Al Nawasra, Al Ftinah and Al Darawsheh. In survey locations in Al Shoubak, the Al Jazy clan (also from the Hawettat tribe and originally from Al Jafr area, but settled in Shoubak) was the only settled Bedouin community interviewed. Other communities included Al Zubariyah – Al Habahbieh; Al Juhaier – Al Tawara; Al Baq'a – Al Qunmieen; Bir al Dabagat – Al Amareen.

[12] Source: *Social and Economic Situation in Ma'an Governorate, March 2002*, General Statistical Department, Regional Planning Department, MOPIC (Ref 8)

[13] Source: *Statistical Yearbook 2002*, Department of Statistics (Ref 9)

[14] Source: *Jordan Human Development Report 2000*, Ministry of Planning, Hashemite Kingdom of Jordan, United Nations Development Programme, Amman (Ref 10)

D3.3 Poverty in the Survey Areas

Substantial work has been undertaken in Jordan on defining poverty and developing poverty alleviation strategies[15]. Jordan compares well with other countries over income levels and GDP per capita, despite having the highest population growth rate in the Middle East[16].

According to a Report published in 2000[17], poverty is not so much due to unemployment as to low income resulting from low participation in the labour force and low wage levels in the Kingdom. Poverty levels are taken from 1999 World Bank definition of JD313.50 per person per year. Based on this criterion, approximately 21% of the population of Ma'an is estimated to live below the poverty line. This compares with an overall estimation of 11% for the Kingdom of Jordan as a whole[18], making Ma'an the governorate with the second highest poverty concentration in Jordan and the lowest Human Development Index. However, regional poverty disparities are not well documented[19], and a 1994 World Bank study showed that poverty is deeper and more concentrated in rural areas.

Table D3.2: Wealth ranked criteria

Socio-economic level	Criteria
Poor Community estimations: Shoubak: 45% Al Jafr: 25%	• small farmers owning 1-10 *dunums* or having no land • dependent on National Aid Fund (NAF) • absence of family provider (no economically active members) • very few assets • income not more than JD120 per month • poor quality housing • farming not part of the household income • taking water from neighbours • female-headed households with small children • large number of family members compared to number of earners • no education
Middle Income Community estimations: Shoubak: 40% Al Jafr: 60%	• own house in good condition • not depending on (NAF) • income JD120-300 per month • home garden with house • owning 5-20 *dunums* of land • farming secondary income • receiving Government or retirement income • have some animals
Upper Income Community estimations: Shoubak: 15% Al Jafr: 15%	• income JD300-500 • receiving a salary plus income from other sources • owning more than 20 *dunums*, including home garden • owning a good quality house • owning animals

[15] *Poverty Alleviation for a Stronger Jordan: A Comprehensive National Strategy*, Jordan Poverty Alleviation Program, Ministry of Social Development, The Hashemite Kingdom of Jordan, May 2002 (Ref 11)
[16] Ibid
[17] USAID, *Poverty Levels in Jordan*
[18] Ibid
[19] *Jordan Human Development Report 2000,* Ministry of Planning, UNDP, Amman 2000 (Ref 10)

Local perceptions of poverty in Shoubak and Al Jafr were sought through a rapid wealth ranking exercise, which provided community criteria of socio-economic differences. (Table D3.2). The official national poverty line is taken as an income of JD156 or less per month for a family of five persons. Communities rated it as slightly lower at JD120 or less per month.

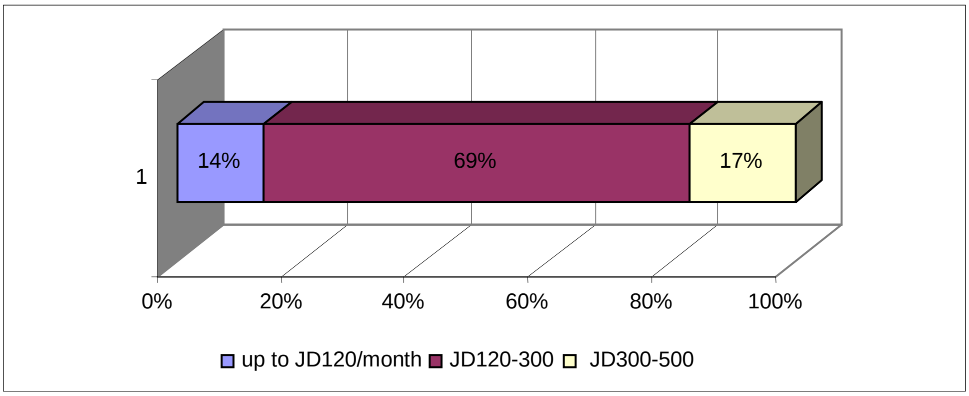
National and regional poverty alleviation strategies focus heavily on providing statutory services (education, domestic water supply, health facilities) as well as on targeting employment opportunities. Coupled with a recently begun process of administrative devolution from Central to Governorate level, the intention is to encourage people to remain living and working in the regions rather than migrate to Amman.

Poverty is characteristically higher among households in rural areas, among households with large numbers of children and among households with low educational levels. Female-headed households are particularly prone to low income and poverty, especially as there are strong cultural restrictions to obtaining paid work outside the home. In Al Jafr, poverty is also seen as caused by[20]:

- loss of pasture and decrease in animal resources
- high cost of fodder
- having many wives and large families
- refusal to accept certain types of work (e.g. agricultural labouring)
- comparative remoteness of the area, leading to high transportation costs

Figure D3.1 shows income classifications of FGD households. Of the 100 households interviewed, a total of 59 were willing to provide estimates of monthly household income. The remaining 37 households were not included in the calculations for Figure D3.1, but of these, 33% were estimated to be high income, the remaining middle income.

Figure D3.1: Representative income categories, FGD respondent households



D3.4 Domestic Water Use

D3.4.1 Diversification of Sources

All households in both Shoubak and Jafr rely on piped water to the house supplied from an artesian well belonging to the water authority. In Al Zubayriya, management of the well has been taken over by a society composed of village members. 10% of respondents in this village also purchase bottled water, particularly for young children or

[20] Participatory Rapid Appraisal, Al Jafr Department of Social Development, 2003

in times of illness. In Al Jafr, 40% of respondent households in the FGD representing low income households estimate they need to take water from neighbours during the summer. Approximately 17% of poor households in Shoubak take water from neighbours.

Domestic water is commonly used to irrigate home gardens. These are important features of women's livelihoods in which they cultivate vegetables, herbs, grapes, fruits (apples, grapes, apricots) and olives, as well as to raise small livestock such as chickens and a few goats.

On average, each household has 0.85 dunums of home garden, with rich households having an average of 1.39 dunums.

No-one uses rainwater harvesting methods, though households in Juhaier stated they use drip irrigation and mulching techniques for home gardens.

D3.4.2 Water Security

Access to and the quantity of water available depends considerably on aquifer variability. There are seasonal variations in sources of water; winter is considered to start in October and to run until April, with summer from May to September. Piped water is available in winter and summer in all villages in Shoubak, with the exception of Bir el Dabagat and Juhaier, when during summer it must be fetched in gallon storage containers from the main pumping station in Shoubak town. This is undertaken by male household members by vehicle.

All respondents in Al Jafr said there is no problem of water security either in winter or summer. Some poorer households have difficulties in summer when water is pumped alternate days. This is because they cannot afford storage facilities, and must take from neighbours. However, all agreed this posed no difficulty as neighbours were always willing to assist.

In Shoubak the seasonal picture is somewhat different. Even in winter, three of the four FGD locations receive water alternate days or 2-3 times a week. In summer the situation is more acute; Al Baq'a, which normally receives water daily in winter, receives it 2-3 times a week, while Juhaier receives it weekly, and Bir el Dabagat once every 2 weeks.

Adequate access to water for the poor appears to be guaranteed, even if it is in smaller amounts. Community co-operation is strong in both Shoubak and Al Jafr with neighbours willing to allow access to their supply.

There is some dissatisfaction in some locations with the distribution mechanism, with households at the end of the distribution network complaining of receiving less water.

Sixty-two of the 100 households interviewed own water storage facilities. No-one could tell how much water they used as everyone rushes to fill tanks and irrigate gardens as freely as possible when the water is flowing. Households estimated an average of 25% of their domestic water use goes to irrigate the garden.

All FGDs in Shoubak reported the quantity of water piped to the house has increased in the past 3 years. The opposite is the case in Al Jafr, where all FGDs reported the amount has decreased. All complained that the water is very hard, leading to higher purchases of soap, laundry detergent, etc.

D3.4.3 Costs

Costs are dealt with in more detail in Annex E: Economic Data. Basic costs of domestic water supply and water connections are set out in Tables D3.3 to D3.4.

Costs vary whether a water supply is managed by a village society or by the water authorities. Bills are issued every three months, though in Al Jafr respondents claimed bills are issued after nine months. Summer bills are some 59% higher than winter bills.

Not all respondents were able or willing to provide details of their water bills. 71% of respondent households provided details. 29% did not know the details; of these, just over half share the bill with extended family members.

Table D3.3: Domestic water costs

<table>
<tr><th colspan="2">Type of water supply</th><th colspan="2">Average cost of supply/HH</th></tr>
<tr><td colspan="2">Water authority</td><td colspan="2">JD27/3 months</td></tr>
<tr><th colspan="4">Cost per m³</th></tr>
<tr><td rowspan="4">Society-managed</td><td rowspan="4">Lowest bill JD2.50/month, highest JD70/month</td><td>0-100m³</td><td>0.07/m³</td></tr>
<tr><td>101-200 m³</td><td>0.15/ m³</td></tr>
<tr><td>201-300 m³</td><td>0.20/ m³</td></tr>
<tr><td>Above 301 m³</td><td>0.25/ m³</td></tr>
<tr><th colspan="2">Cost of connection – Water Authority</th><th colspan="2">Cost to install private well</th></tr>
<tr><td colspan="2">JD113</td><td colspan="2">JD50/ 1m³</td></tr>
<tr><th colspan="4">Cost of connection – Community Society</th></tr>
<tr><td colspan="2">Subscription fees</td><td colspan="2">JD10</td></tr>
<tr><td colspan="2">Water meter</td><td colspan="2">JD10</td></tr>
<tr><td colspan="2">Connection parts</td><td colspan="2">JD5</td></tr>
<tr><td colspan="2">Installation costs</td><td colspan="2">JD5</td></tr>
<tr><td colspan="2">Piping</td><td colspan="2">JD20</td></tr>
</table>

Table D3.4: Water expenditure (figures rounded)

Income and expenditure	Low income	Middle income	High income
Average monthly HH income	JD120	JD120-300	Over JD300
Average monthly HH expenditure on water	JD6	JD11	JD6
% monthly disposable income spent on water costs	5%	5%	JD2%

With the exception of one household, all FGD respondents said they could afford to pay connection charges. Almost all households could afford to pay their water bills. However, this does not mean that all actually pay them. In Al Jafr, all households said they did not pay, even when they could afford to do so. Reasons offered included:

- bills were not submitted regularly, causing accumulation of costs and higher amounts which households found difficult to meet in one chunk;
- people felt they should be paying for good quality water, which they feel they are not receiving.

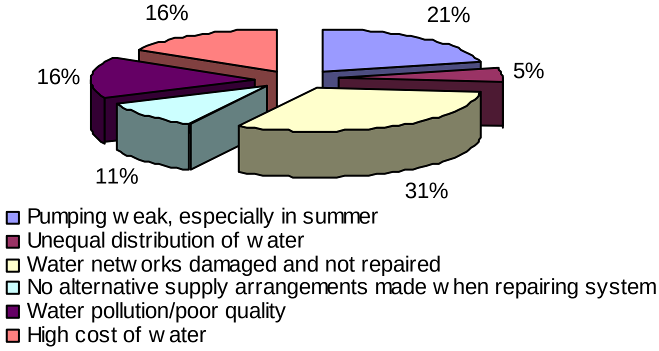
Where bills have been delayed in both Shoubak and Jafr, water authorities have worked out bill payment schedules with customers, enabling them to pay in affordable instalments. This has worked out well for the most part.

In Al Zubayriya where domestic supply is managed by a society, defaulters are warned three times before the supply is disconnected. To date there have been no disconnections. The advantage of a community-managed supply is that everyone knows who can and who cannot afford to pay bills. In Al Zubayriya, the water management society members know who is really poor, and have decided to cancel their bills. The society cannot raise enough money from bills to pay all the expenses of managing the water system, so subsidise it through income generation activities such as selling gas cylinders and agricultural inputs.

D3.4.4 Conflicts

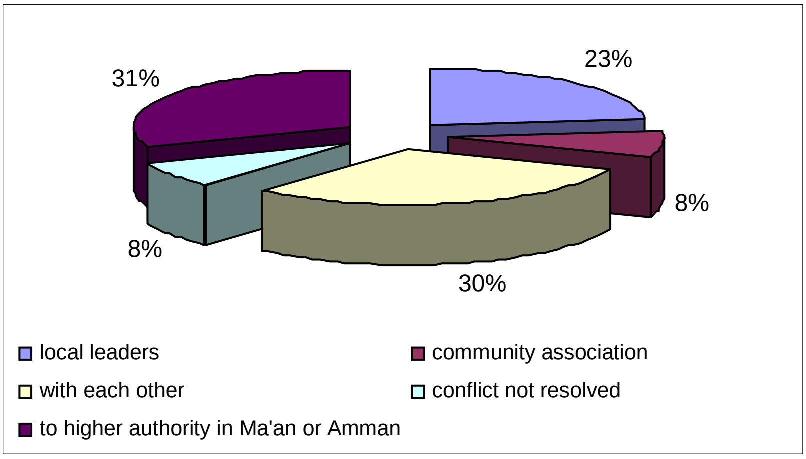
All FGDs confirmed there has been conflict over water. 57% of FGDs reported conflict between neighbours concerning distribution and equity of water, while 100% of FGDs reported conflict between communities and water authorities. One FGD mentioned problems between landlord and tenant in allocating water costs for shared facilities. Figures D3.2 and D3.3 show relative importance placed by focus groups to types of water-related problem and methods adopted to attempt their resolution.

Figure D3.2: Type of water problems important to FGDs



Most households attempt to resolve water difficulties by complaining through local leaders, or try and sort things out with each other. All FGDs pointed out their dependence on intermediaries to address their needs and willingness to bypass local water authorities go straight to higher authorities in Amman if need be. 57% of FGDs said they complained individually, 86% collectively. 28% have complained once only, 71% more than once.

Figure D3.3: Preferred conflict resolution measures



D3.4.5 Coping Strategies and Livelihood Impacts

85% of FGDs said that water difficulties have affected their livelihoods. For domestic water supplies, this has had a higher impact on women than on men, as the home garden is women's responsibility and one of the few ways in which they are able to earn some money. **Livelihood impacts** include:

- higher medication costs to treat water-related illness
- stop cultivating fruit and vegetables in the home garden
- higher cost in purchasing fruit and vegetables after ceasing home cultivation
- increased gas expenditure to boil water
- electrical appliances wear out more quickly
- higher cost in buying household items such as soap, shampoo, etc.

Typical economies include:

- reduction in nutritional intake by purchasing less foodstuffs
- reduction in other expenses such as children's clothes
- use of herbs instead of purchased medicines to fight diseases

There is fortunately a strong sense of corporate community responsibility which provides a valuable and welcome safety net for poorer households. Some of the richer families provide animals to poorer families to use their milk and return at the end of the season. This is particularly important in Al Jafr, where livestock is an important feature of the local economy. In Shoubak, subsidised animal fodder is available from government outlets. Local shops also extend monthly credit.

In Al Jafr, the Social Development and National Aid Fund calculate they provide cash and occupational rehabilitation for about 27% of households[21].

The poorest families look to government employment and the army to obtain regular income. They also use public services through their neighbours, such as extending an electric wire for a few hours in the evening, or taking some buckets of water in the morning.

[21] Department of Social Development PRA, Al Jafr, 2003

D3.4.6 The Vulnerable and Impacts of Water Shortage

The most vulnerable are:

- women-headed households with no working male adults and several small children
- women of child-bearing age in households with no water storage facilities (burden of carrying heavy loads)
- elderly people with no working adults
- families with little or no education and reduced work options

Vulnerability is also location-specific, with some areas such as Juhaier experiencing seasonal difficulties, while others such as Mansourah experience year-round problems.

D3.4.7 Satisfaction Levels

For Al Jafr and Al Shoubak combined, 45% of FGDs were not satisfied with summer access, although 100% of FGDs were satisfied with winter acces. 71% of FGDs were unsatisfied with the quality of water.

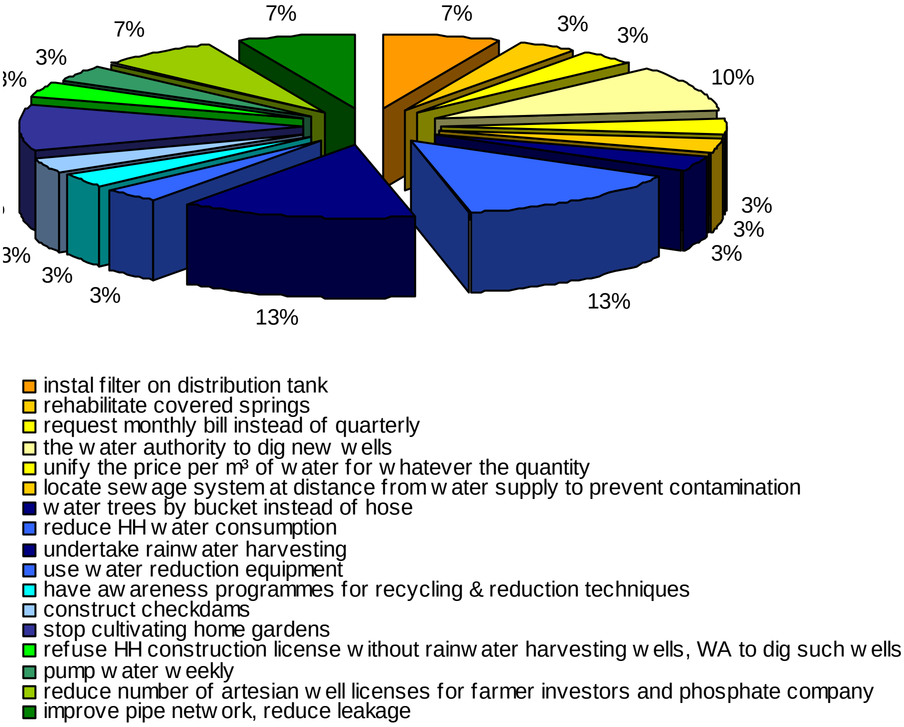
D3.4.8 Dealing with Change

According to respondents the domestic supply situation has improved over the past three years. Respondents were asked the question: "If water supply stays the same or becomes even less, what methods will you adopt to cope with this?" A very large number of answers were given, almost all of which reflected very low levels of awareness at all socio-economic levels concerning the finite nature of groundwater.

Figure D3.4 reflects the relative popularity of different suggestions by respondents. These fell into approximately three categories:

- actions reflecting low levels of awareness about causes of groundwater scarcity (yellow wedges)
- actions that could be undertaken by government (green wedges)
- actions that could be undertaken by the household (blue wedges)

Figure D3.4: Respondent attitudes to dealing with water quantity changes



D3.5 Agricultural Water Use

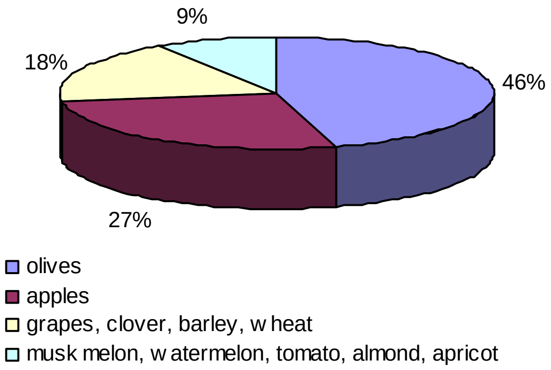
More details are given on large-scale farms with substantial external investment, in Annex E.

In the five FGD locations in Al Jafr and Al Shoubak, approximately 33% own land. Of the 37 cultivating respondent households in the FGDs, landholdings averaged 165 dunums (16.5ha) per household. However, sizes varied widely, with the smallest landholding being 5 dunums, the largest 1500 dunums. Landholdings among high income households in Al Jafr were particularly large.

The majority of land in Al Shoubak is rainfed. Only 26% of land is irrigated. In Al Jafr all cultivated crops are irrigated. Principal crops are drought-resistant, and include olives, grapes, almonds, clover, barley, wheat, melons, tomatoes and apples. There is only one cropping season in both Al Jafr and Shoubak, though tomatoes are cropped three times. Relative importance of different crops is shown in Figure D3.5.

Livestock is an important part of the domestic economy, particularly sheep. Sheep and goats are especially important for women's income, as are home gardens attached to the house.

Figure D3.5: Crop preferences (% FGDs)



D3.5.1 Diversification of Sources

The main sources of irrigation water are farmer-owned artesian wells, wells belonging to a society or co-operative, an artesian well belonging to the water authority in Al Shoubak, an artesian well belonging to the Ministry of Agriculture in Al Jafr, and natural springs in Al Shoubak. Farmers may use more than one water source.

Farmers in Al Jafr and Al Shoubak demonstrated different levels of familiarity and use of water saving techniques. In Al Jafr, most farmers are settled Bedouin and have less experience with water saving methods. 46% used some forms of water retention, including plastic mulching and drip irrigation. A few large farmers are using sprinklers on a large scale (see photograph).

In Al Shoubak, non-Bedouin farmers have been settled agriculturalists for generations, and are familiar with making the most of what little moisture they have. 76% practise drip irrigation, mulching, pot irrigation for fruit trees, rainwater harvesting in underground or surface reservoirs and rooftop harvesting.

D3.5.2 Water Security

There are few complaints about water security with all FGDs saying water is always available. Farmers in Shoubak noted, however, that some springs have dried up and water levels overall have decreased. The number of wells provided by the Water Authority has increased. All FGDs agreed the quality is very good.

Farmers in Jafr saw no change in quantity, but significant worsening of water quality with higher levels of salinity. There was no seasonal difference in quality in any of the fieldwork locations.

Most farmers depend on rainfed agriculture in the winter and on wells in the summer. Farmers will admit to one or two licensed wells on their land, but all acknowledged that a far higher number of unlicensed wells are used in reality.

All farmers are well aware of the impact that extensive and unregulated extraction by large fruit farms in Shoubak and by the phosphate company in Al Jafr, is having on their water sources. However, this does not necessarily stop farmers from continuing to pump water for their own purpose, quite extensively in some instances.

Small and large farms, Shoubak

Not everyone could specify differences in well depths, but all Shoubak FGDs confirmed deepening of wells in the last five years. Respondents in Al Jafr reported that there are 74 private working wells. One respondent showed his dried out well at 200 metres, but this was located at the very fringes of the aquifer. Table D3.5 sets out differences in depths.

Table D3.5: Well depth changes in FGD locations

Location	Current well depth (in metres)	Well depth 5 years ago
Al Jafr	50	50
Al Baq'a	210	(1970) 60
Al Jarba al Kabeera	75	50
Al Zubayriya	72	45

Conflicts

60% of FGDs reported conflicts over water. Of these, 40% were between farmers and water authorities and 60% between each other, principally over the amount of water taken by an individual, their turn in the water schedule, and farmers at the tail end of the distribution network suffering from low pressure (Al Zubayriya, Al Jarba).

Grievances with water authorities focused entirely on water pricing. However, at the time of fieldwork it was announced that the Council of Ministers amended the regulation governing the use of groundwater in the country, reducing the price of water extracted from licensed wells from JD0.25/m^3 to JD0.05/m^3.

All FGDs said they had complained about problems with water, 80% of them repeatedly, and 60% as a group. 60% of farmers said they complained directly to authorities in Ma'an and even to the Minister of Agriculture in Amman, reflecting where decisions are made.

Key shortcomings from the farmers' point of view are:

- shortage of irrigation water (40%)
- reservoir tank too small for all society member needs (20%)
- operational costs very high (80%)

D3.5.3 Coping Strategies and Livelihood Impact

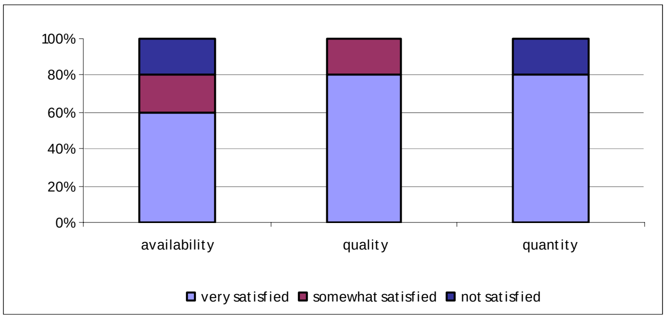
Both Al Shoubak and Al Jafr have always been arid and water-poor areas. Farmers are accustomed to adopting coping strategies, particularly in years of periodic drought. 60% acknowledged water problems have affected their livelihoods. Three principal coping strategies were identified, the most popular option being to reduce the cultivated area (50%), followed by decreasing the amount of water given to trees or to quit agricultural altogether and seek other forms of income generation (25% respectively).

Livelihood impact for farmers appears to be limited, though all farmers would like to cultivate more land than they are currently able to do. All respondents said agriculture is not the main or most important source of household income. Most households depend primarily on income from a salaried family member, or from government support.

D3.5.4 Satisfaction Levels

Satisfaction levels are fairly high for all categories. Those not satisfied with quantity are mainly those accessing water from co-operative and Ministry of Agriculture wells.

Figure D3.6: FGD satisfaction levels with well water

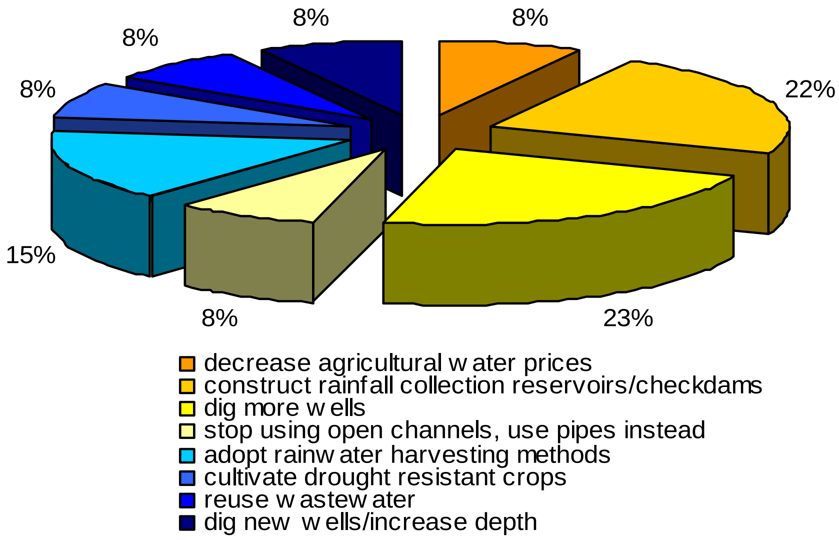


D3.5.5 Dealing with Change

There has been little change in Shoubak and Al Jafr, and most farmers feel it is the government's responsibility to sort out their water problems. Although there are high levels of awareness of the impact of large-scale water extractors from both aquifers, the main response appears to be a desire to do the same. Attitudes towards aquifer use reflect short-term thinking, and there are very low levels of awareness about aquifer capacities and how it will affect them in both the immediate future and long-term.

When asked the same as domestic water users about water supply levels and standards remaining the same or becoming worse, responses reflected actions which could be undertaken at community level (blue wedges) and at government level (yellow wedges). As can be seen, the scope of responsibility is proportionately considered more for government and less for farmers.

Figure D3.7: Respondent attitudes to dealing with groundwater situation (% of FGD responses)



D4 PRELIMINARY OBSERVATIONS – WATER DEMAND MANAGEMENT STRATEGIES AND LIVELIHOODS OF THE POOR

Water supply and demand management is defined as: "..*the implementation of policies or measures which serve to control or influence the amount of water used.*" UKWIR/ESA (1996)

D4.1 Water demand management measures

Water supply and demand management policies and measures implemented in the survey areas in India and Jordan which affect the poor are both statutory and voluntary, direct and indirect**.** **Statutory measures** are those where legislation, policies, government interventions and water management technical measures, are implemented. These presently include (not necessarily exclusive to any one area or region):

- *Demand forecasting*
- *Rainwater harvesting*
- *Targeted delivery to poor neighbourhoods*
- *Approval and/or implementation of legislation*
- *Formulation of water policy*
- *Pricing for water services*
- *Pricing for electricity*
- *De-salination*

Voluntary measures can be described as informal or voluntary actions by water users to regulate water amounts and its use. Examples in the survey areas include:
- *Internal demographic controls by not encouraging friends and relatives to stay*
- *Installing water-saving devices*
- *Domestic wastewater recycling*
- *Industrial wastewater recycling*
- *Excessive labour requirements (e.g. carrying distances) regulates the amount households are prepared to collect daily*
- *Water-saving agricultural techniques*
- *Indirect source protection (garbage recycling)*
- *Domestic supply community management*
- *Community support for poor families*

Despite these measures, water management tends to concentrate more on finding enough supplies of water, rather than on managing water demand. A supply-driven management structure means that ultimately volume of demand outstrips both the volume of supply and the capacity of groundwater to recharge. It also raises issues of how responsibilities are shared and where co-ordination can be achieved.

Water demand management (WDM), on the other hand, is a concept which requires recognition that a supply of water to serve the volume of any particular demand, may be limited, finite or economically unviable. Consequently instead of seeking more or new supplies to meet growing demand, both water providers and users have to manage what water they have more effectively.

Finding enough clean, potable water to meet a growing demand volume is a priority. But since groundwater is a finite source, just finding more is not the only answer. In the urban context, more water does not necessarily mean more water for the poor because of distribution inequities. Although the situation between urban and rural consumers is different, regardless of location or socio-economic status, unless constraints are imposed, people will use as much water as is available as and when they want it.

Water demand management cannot be separated from water resource management. In the case study locations, existing groundwater supplies fail to meet demand for a number of reasons including:

Resource:

- reduction of groundwater availability due to:
    - excessive groundwater pumping, leading to increased salination
    - failure to maintain traditional water harvesting systems, leading to higher dependence on wells and borewells
    - construction over former surface water supply sources (e.g. lakes, ponds) and groundwater recharge sites
- contamination of existing surface water sources, leading to higher demand for groundwater
- unregulated waste disposal methods, leading to contamination of some areas of groundwater

Distribution System:

- wastage through non-maintenance of infrastructure, high losses through seepage leading to low pressure and supply failure for households on affected networks
- contamination of piped system, leading to several hours of "flushing out" before potable water is flowing
- poor irrigation practices, leading to high levels of evaporation and unnecessary demand
- poor domestic water saving practices, resulting in unnecessary demand

Water Demand:

- urban population growth
- water thirsty crops and multiple cropping periods
- industrial use

Water shortages have had considerable negative impacts on people's livelihoods in Chennai, the greatest of which are felt by the poor, as described in previous sections. How these impacts can be addressed is discussed in the following section.

D5 PRO-POOR WATER DEMAND MANAGEMENT STRATEGIES

D5.1 Integrated Water Demand Management

If water demand management is one part of a linked system, WDM strategies require co-ordination between different sectors to address the impact of increased demand.

Water demand management responses should be multi-level and multi-agency. This is the principal challenge to any WDM strategy, as co-ordination at different administrative and water use levels is notoriously difficult.

An integrated vision is necessary because it is more cost effective. For example, technical and economic comparisons need to be made between the long term cost of recycling water and the long term cost of capital intensive projects, such as the Krishna river proposal in Tamil Nadu[22]

It is also important to cultivate an integrated approach so that stakeholders may perform complementary, rather than contradictory, tasks. This is necessary because:

- communities cannot undertake all WDM tasks, having neither the skills nor the wider vision necessary to integrate planning of multiple uses of a single source such as groundwater;
- devolution of rights and responsibilities outside traditional management structures can have benefits, but also carry risks. For example, more active participation of the profit-driven private sector needs to be negotiated with protection of the needs of the vulnerable;
- large-scale technical interventions are beyond the scope of most water users;
- community management is not a reason for government to abnegate its responsibilities;
- expectations of water users change in proportion to the amount of water available and their socio-economic standing. Expectations of different water users do not change synchronistically but erratically – water managers need to balance these expectations overall, raising them for some and reducing them for others.

D5.2 Pro-Poor Strategies

Where do the poor and vulnerable fit into this? At every level, which needs targeted action. For each action, the nature of vulnerability needs to be clarified. Those who fall into this classification should be identified, and pro-poor vulnerability reduction measures integrated. For example, not everyone who is poor is vulnerable: in Chennai, washermen who derive income from a traditionally low status occupation have their occupational water supply secured.

Analysis of fieldwork data has produced indicators linking water to poverty. From these, a methodology has been developed which allows a better definition of what vulnerability means and of who is vulnerable where water is concerned (Annex C). This can assist water planners and managers to know who needs special attention and what different kinds of mitigation measures could be adopted under differing circumstances.

Special attention is necessary because:

i. the poor also have rights to safe water, but lack the socio-political assets to make their voice heard;
ii. other stakeholder demands may outstrip those of the poor when accessing the same groundwater source;
iii. vulnerability can be specific to a location as well as to a socio-economic category;
iv. levels of vulnerability vary considerably in different environments, e.g. gender considerations, socio-cultural factors, rural/urban environments, different degrees of socio-political awareness, etc.

Steps which may absorb pro-poor WDM actions are:

First: involvement of non-government sectors;
Second: identification of achievable and measurable tasks which will interest and involve different types of stakeholder;

.[22] Joel Ruet, Marie-Helene Zerah, *Organisational Analysis of Water Boards/Municipalities: Lessons from Calcutta, Chennai, Delhi and Mumbai,* Paper presented at the Water Management Seminar organised by the Centre de Sciences Humaines, 17th December 2002, New Delhi (Ref 12)

Third: provision of support for tasks which do not normally receive budgetary consideration, particularly at community level;
Fourth: raise awareness on water saving and management tools and techniques, targeting schools, institutions, business and communities;
Fifth: review of costs and application of tariff structures which encourage water economy;

D5.2.1 Non-Government Sectors

There tends to be a debate as to who controls water, the people or the government, particularly where groundwater has been traditionally tapped for domestic and agricultural purposes. When supply exceeds demand, or where scarcity has always been a seasonal feature, the value of water as a negotiable asset increases. The issue then becomes, who has the right to negotiate the use of this asset? If there has been a tradition of unregulated local use, then negotiation is needed between those who seek to control the asset and those who use it. Where negotiation breaks down, violence or force may be viewed as the means to win the right to control the asset.

However, there are alternatives to force, provided that stakeholders acknowlege user rights, as well as responsibilities. In urban areas, this leads to a need for higher levels of people/government cooperation. In rural areas, higher levels of people involvement may be more practicable.

Co-ordination may be better achieved, in some cases, when there is a higher level of engagement of the informal and private sectors, particularly community-funded and **community-managed initiatives**, which can take greater responsibility and control of many direct and indirect aspects of supply management. This can leave water authorities free to concentrate on what they do best, namely provide engineering-centred response capability.

A community-managed initiative was seen in the domestic water supply of Al Zubayriya. Community level management brings the service deliverer in more direct contact with the service receiver, thereby increasing accountability. In Al Zubayriya, this was reflected in decisions concerning water payments, with community costs subsidised by income generating schemes and costs for the poorest households subsidised by community costs.

A good start for local NGOs engaged in water issues, or interested in becoming engaged in water issues, is to seek practical co-ordination of efforts to meet immediate community needs and to develop a vision for the future. Discussions should be targeted towards concrete results, with an action plan that has targets, a timetable, and clearly defined responsibilities, no matter how small scale in the first instance.

Factors for NGOs to consider include:
- the extent to which local people are willing and/or able to become involved in different sorts of water-demand management strategies;
- how far should the public be responsible for management and control of water-demand management;
- how much are communities willing to pay for capital costs of a water project and bear the risks of project development;
- what is the relevant experience and capabilities of intermediary organisations (public or private) willing and/or able to become involved in community-level water demand management;

- how will the poor benefit from such strategies.

Women can be encouraged to adopt a more direct involvement in operation and maintenance of domestic water supplies. Reasons include:

- women have primary responsibility for accessing and using domestic water;
- women are often left alone in the household with men migrating or out at work during the day, and have to cope with immediate water problems occurring;
- strengthening the practical capabilities of women improves rapid-response capabilities in a community concerning water difficulties;
- women-headed households are more frequently among the most vulnerable households.

Private sector participation is an increasing trend, particularly in the urban context. A popular suggestion from higher income households is to become more self-sufficient in water supply and management, contracting activities out to private business.

While this option has merits, it does not always work for the poor. Private companies look to make their business pay, which is difficult to achieve in low income areas which may be difficult to access and residents unable to meet costs. However, a feature of Chennai is that in most localities widely differing income groups live side by side in designated zones or urban wards. It is possible to develop tariffs and procedures which protect the basic needs of the poor, negotiate these with contracting agencies, and include in contracts specific measurable pro-poor indicators which can be monitored regularly by community groups. Here, integration and co-ordination with statutory requirements and legislation is necessary. Re-tendering of contracts to private agencies will depend on whether pro-poor measurements are implemented correctly.

In urban environments, localised **community level water management groups** can be established. With the advantage of localised knowledge, these could have multiple functions, including:

- equitable management of water distribution;
- contact point for awareness campaigns;
- working group to access resources for water-saving devices and practices;
- self-help group to support savings schemes to assist poor families obtain water-saving tools and techniques;
- organisational point for source protection activities.

Fixed daily quantities of delivered water can be calculated, and community water management groups made responsible for allocating this among households. This not only would help to ensure equity of distribution, it supports self-regulation demographically, as supply will not increase in proportion to more people.

With the spread of new housing, particularly in peri-urban areas, it is useful to ensure that new housing locations have community water source protection committees from the start.

Community-level implementation limitations include:

- budget management retained at government level
- water treatment and mains supply are retained by government
- heterogeneous urban populations with highly diverse income groups living side by side; cannot agree
- little or no technical knowhow

- local-level and small scale field of operations, whereas groundwater crosses these types of boundaries
- danger of community water resource control being captured by local power brokers

One main obstacle in both the rural and urban context has been enforcement difficulties in ensuring compliance with groundwater and pollution management legislation and policies. Experiments in some countries have devolved enforcement rights and responsibilities to **sectoral industry organisations**. This is based on the belief that farmers and industrial companies cooperate more with their own industry representatives than with government in ensuring compliance[23]. Such representatives work with members to develop collective action plans, oversee implementation of such plans, monitor effectiveness and sanction those breaking agreements. Evidence from pilot tests[24] shows that members are more willing to support sanctions from their own sectoral organisations than from government, but at least in the early stages of trial they remain reluctant to directly punish non-compliance through peer pressure or other informal mechanisms.

Involvement of the informal sector does not necessarily mean the source itself stops reducing when there are multiple and un-related extractors. Involvement of non-traditional water management is not a substitute for integrated WDM planning, it is simply a facet of it.

D5.2.2 Identify achievable tasks

Multiple WDM actions need the involvement of **multiple actors at different levels**. If different stakeholders are involved, they must have tasks appropriate to their level of involvement.

Water managers are often asked to review the way they **allocate and assign wate**r to different types of users. However, as is noted in Annex B, re-allocation of water is a "profoundly political act", and one which few water authorities are willing to address.

If water re-allocation between water users is a nettle no-one is willing to grasp, what WDM strategies are acceptable? For whatever strategies are considered, it is important to **monitor water levels and quality** to understand the groundwater situation and to anticipate pre-emptive measures. This requires regulation of wells and extraction rates. Where this is unregulated or where no accurate inventory of number of wells or extraction monitoring data exists, this will make the task more difficult.

In the meantime, other organisations can adopt different and complementary approaches more appropriate for community-level engagement. This could be **conservation-focused**. A conservation focus is not exclusive to community level. It is also appropriate to institutional and industrial levels. Improved conservation and recycling of existing water resources reduces volume of demand, hopefully enabling a slowing down of the groundwater extraction rate and improving recharge opportunities.

A conservation focus can include:

- improved community involvement in water source protection, both for groundwater and surface water sources[25] (see Appendix 1);

[23] Graham R. Marshall, *From words to deeds: enforcing farmers' conservation cost-sharing agreements*, Journal of Rural Studies, 2004, 20(2), pp. 157-167 (Ref 13)

[24] For example, farmers in New South Wales, Australia, faced with worsening problems of irrigation salinity, ibid

[25] Also see: *Water Systems for Small Communities: A Puzzle Guide for Local Officials*, Bulletin 910, Ohio Environmental Protection Agency, U.S. Environmental Protection Agency (Ref 14)

- rainwater harvesting and recharging;
- improved industrial awareness and anti-pollution practices (see below).

Positive benefits of **source protection** for the livelihoods of the poor can include:
- dependable potable water supply stimulates local economies, providing improved employment opportunities;
- good infrastructure leads to greater sense of ownership among local communities, thereby providing built-in demographic controls;
- overall quality of life is improved;
- property and land values increase;
- water-search time can be allocated to more economically productive activities;
- health related costs are reduced;
- leadership and confidence abilities are improved through involvement and direct action;
- success of source protection measures can enhance local leadership skills, enabling them to undertake other activities on behalf of the poor in different localities;
- costs of water treatment are reduced with increased efficiency of treatment; efficiency savings support the possibility of pro-poor water tariffs to be accommodated in pricing structures.

Further **community-level actions** could include:
- simple repairs to common resources outlets (street taps, handpumps), which could be undertaken by women;
- ensure distribution equity through community management of tanker arrival (timing of receiving water, timing of allocating it);
- fee collections;
- operation of local water distribution points;
- mediation with bulk suppliers;
- establish savings groups for community managed storage facilities;
- loan groups for installation of water-saving devices;
- local training in household level water-saving methodologies and technologies;
- combine old and new systems;
- undertake household leakage checks;
- stop building over recharge areas;
- advise where building controls are not being enforced;
- divert street drains into ground recharge.

Industrial options: some suggestions have been made that pollution tax be charged. This is only effective where regulation can be applied. More cost-effective than pollution tax is to demonstrate the financial benefits of cleaning up industrial acts. A means to do this is to establish a Centre[26] to promote and institutionalise clean production, recycling and wastewater management to undertake:

i) training of the human resource base in cleaner production methods

ii) demonstrate cleaner production in small, medium and large industry to practically illustrate the cost savings as well as environmental benefits, with in-plant demonstrations

iii) assist Government and decision makers to develop policies and practices for industry and legislation

[26] Vietnam Cleaner Production Centre, Ministry of Education & Training, Hanoi University, Institute for Science & Environmental Technology (Ref 15)

A similar Centre has been established in Vietnam (supported by UNDP). With the above strategy, it recorded 20% reduction of industrial wastewater and 20-30% reduction of total organic pollution in wastewater, as well as significant reductions in total consumption of water.

D5.2.3 Provide support for tasks

With any re-definition of WDM activities, it is important to provide support for tasks which do not normally receive budgetary consideration, particularly if NGO or community involvement is increased.

Any plan of action must evaluate:

(i) the scale of prioritised tasks– at what level is it necessary to start?
(ii) what permissions are necessary to do what, and are these insuperable blocks to activities, or can they be overcome, in stages if necessary;
(iii) what are the payment capacities of the target locality or population?
(iv) what alternative/additional funding options could be explored for non-recurrent costs?
(v) what agreements need to be made and between whom? Would the action plan include higher investment water management proposals for some high income localities and cheaper proposals for low income areas? Would schemes be community managed or contracted out to private companies
(vi) draw up financial incentives for agricultural and industrial users to implement water saving techniques, including recycling.

It is also essential to allow enough time to pursue different water demand management options, to develop an action plan starting with immediately achievable and visible actions and to include the long term perspective as well as the time-bound steps needed to achieve it. Success will breed support and confidence in the service provider.

Long term planning needs to forecast changes that may occur in the community. Changes bring about different levels of expectation concerning water use. e.g if there are difficulties in the agricultural sector not related to water (lack of labour), or other actions have an impact on agricultural production (e.g. removal of inter-state tariffs) this needs to be factored into plans. Review and re-negotiation of goals and objectives are therefore constant necessities.

The simplicity or complexity of community-level actions depend on local levels of awareness, tenacity and commitment. Support is necessary from NGOs, community groups or local government officers to assist community representatives negotiate with outside agencies. Organisations representing waste producers (e.g. industry, local domestic garbage collectors) could be formed to negotiate where, when and how waste can be disposed.

D5.2.4 Raise awareness

A feature of fieldwork analysis and of vulnerability rating has been the low levels of awareness among most water users on many features of water management. Awareness improvement can have the following benefits:

- cost savings of good water management;
- health benefits of improved water management;
- recycling benefits.

Public involvement at the start of conception and development of community action plans needs to be engaged to address water shortage response strategies, and throughout design and evaluation process. This requires coordinated public notification, outreach and public involvement strategies through local government in collaboration with NGOs, where appropriate.

Important water users for awareness raising on water saving and management tools and techniques include:

- schools;
- public institutions (e.g. hospitals, government offices, universities)
- hotels and conference venues;
- small enterprises;
- large industries;
- local communities;
- farmers.

WDM actions are related to monitoring of groundwater levels and quality. Accurate record keeping is important, providing early-warning systems over changing conditions. Linked to this is information dissemination to enable, for instance, farmers to avoid crop failure and financial losses.

Major urban water users can be identified for compulsory water conservation methods. Target dates can be negotiated for completion, with scheduled inspections and fines for non-completion.

The NGO sector and rural extension services are important facilitators of awareness raising. Possible themes could include recycling and wastewater management measures, as illustrated in Table D4.1.

Table D4.1: Recycling and Wastewater Management Options

Sanitation	• use bucket washes instead of showers and baths • keep taps closed when not in use. Brush teeth from a glass of water instead of under a running tap
Water-saving devices	• install low volume flush toilets • install flow control taps • re-route domestic water drainage system to holding tank for toilet flushing • install dual pipeline systems, one for drinking water and another for sanitation
Wastewater recycling	• retain washing and bathing water for toilet flushing, watering plants and recharging ground • demonstrate cost benefits to industrial wastewater recycling
Agricultural improvements	• improve use of water saving devices (e.g. drip irrigation) • improve mulching • reduce cultivation of heavy water-consuming crops • increase use of recycled wastewater for agricultural irrigation • improve support from extension services • maintain traditional tanks • create checkdams (with community involvement)

The private sector may assist in developing awareness programmes and better water use methods (e.g. flow control taps, limited flush toilets, etc.). Public and private sector policies and contracts need to incorporate pro-poor requirements with measurable indicators for poverty reduction. The trickle-down factor or welfare approach cannot be relied upon. Advantages of private sector contracts between commercial organisations and community organisations can include:

- reduced political interference;
- higher public confidence;

Contract compliance indicators are essential and can include pro-poor regulatory clauses which are to be implemented and monitored.

D5.2.5 Review costs

Charging more for water can be an effective method of managing domestic water demand. Willingness to pay is demonstrated by the proportion of water purchase in household budgets. If access is made more difficult or more expensive, domestic consumers tend to apply self-regulation much more stringently. High income households are more careless of water use than poor households because of its easy availability either through independent sources of supply (wells/borewells) or sufficient income to allow higher volumes to be purchased.

Water delivered through piped water connections costs less than purchased water in the Case Study areas. This leaves the poor at a disadvantage because (a) they cannot afford the connection; (b) capital cost of independent groundwater supply is too high; (c) they normally do not own the house they live in and are unwilling to invest money. Hence a larger proportion of the disposable income of the poor is spent on water purchase.

Costs can be reviewed and **tariff structures** applied which not only encourage water economy but could benefit vulnerable households. To ensure pro-poor features, costs could be rated by:

i) category of user (domestic, agricultural, industrial, commercial, etc);
ii) volume of use.

Pro-poor factors can be built into the tariff structure by:

i) sending water payment bills out on a monthly basis;
ii) allowing connection fees for low income groups to be incorporated into bills in manageable instalment amounts;
iii) allocating an initial fixed amount of litres per household per day free (of any income group), to account for basic human needs. This builds in household-level regulation on use.
iv) after the first initial fixed amount per household per day, introducing a steep cost increase per litre thereafter.

In addition, specific **poverty alleviation strategies** may include subsidies for installing water saving and recycling devices in poor households.

D5.3 Points of Negotiation Between Implementation Levels

Any WDM actions, whether community-based, private, or local government, need integration with national and regional government objectives. It is important to ensure that WDM actions are not isolated from state or regional planning.

It is important for an overall approach to be adopted, whereby legitimate different, but conflicting, water demands, can be reconciled. Moreover, government is responsible for policy instruments (legislation, economic, project investment). Where there is a will to do so, is able to develop formal water allocation policies, including contingency plans for emergency situation caused by non-compliance.

At the same time, institutional capacities invariably need strengthening to enable a shift from a supply-driven approach towards a water demand management approach. This may prove to be a long-change which meets with obstacles along the way. In the meantime, immediate practical measures are needed to encourage water users to adapt to conditions of scarcity and to greater degrees of self-regulation in exploiting the resource base.

Glossary

India:

Borewell	Vertical boring into the ground, producing a constant supply of water rising to the surface through pumping
Dhobi	Washermen
Panchayat	Elected local body at village level (it may include one or more villages)
Paisa	One hundred paise = one Indian Rupee
Samba	Winter crop of paddy (September/October to January)
Taluk	Administrative sub-division of a district
Water harvesting	Rainwater catchment techniques, used to store or recharge well water
Well	Shaft sunk in the ground and lined with stone or other protection to obtain groundwater

Jordan:

Artesian well	Vertical boring into the ground, producing a constant supply of water rising spontaneously to the surface. In Jordan, this term is sometimes used to describe a well where water is pumped to the surface
Dunum	1 dunum = 0.1 hectares
Water harvesting	Water conservation techniques, by construction of recharge dams

Abbreviations and Acronyms

General:

CBO	Community-based organisation
DFID	Department for International Development
ESA	Environmental Services Association, UK
FGD	Focus Group Discussion
NGO	Non-Government Organisation
UKWIR	United Kingdom Water Industry Research
WDM	Water Demand Management

India:

AK	Araniyaru Koratailaiyar (or in some examples, Arani Kottallaiyyar, or Araniar Kostastalayar) aquifer
CMA	Chennai Metropolitan Area
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board
GoI	Government of India
MBC	Most Backward Caste (GoI classification)
SHG	Self-Help Group

Jordan:

JPAP	Jordan Poverty Alleviation Programme
MOP	Ministry of Planning
MWI	Ministry of Water and Irrigation
NAF	National Aid Fund
WA	Water Authority

Selected Units

General:

ha	Hectare
HH	Household
kg	Kilogram
km	Kilometre
km^2	square kilometre
l	Litre
m	Metre
m^3	Cubic metre
MGD	Million gallons per day
MLD	Million litres per day
n.a	not applicable
n.d	no data

India:

lpcd	litres per capita per day
Rs.	Indian rupees

Jordan:

JD	Jordanian dinar

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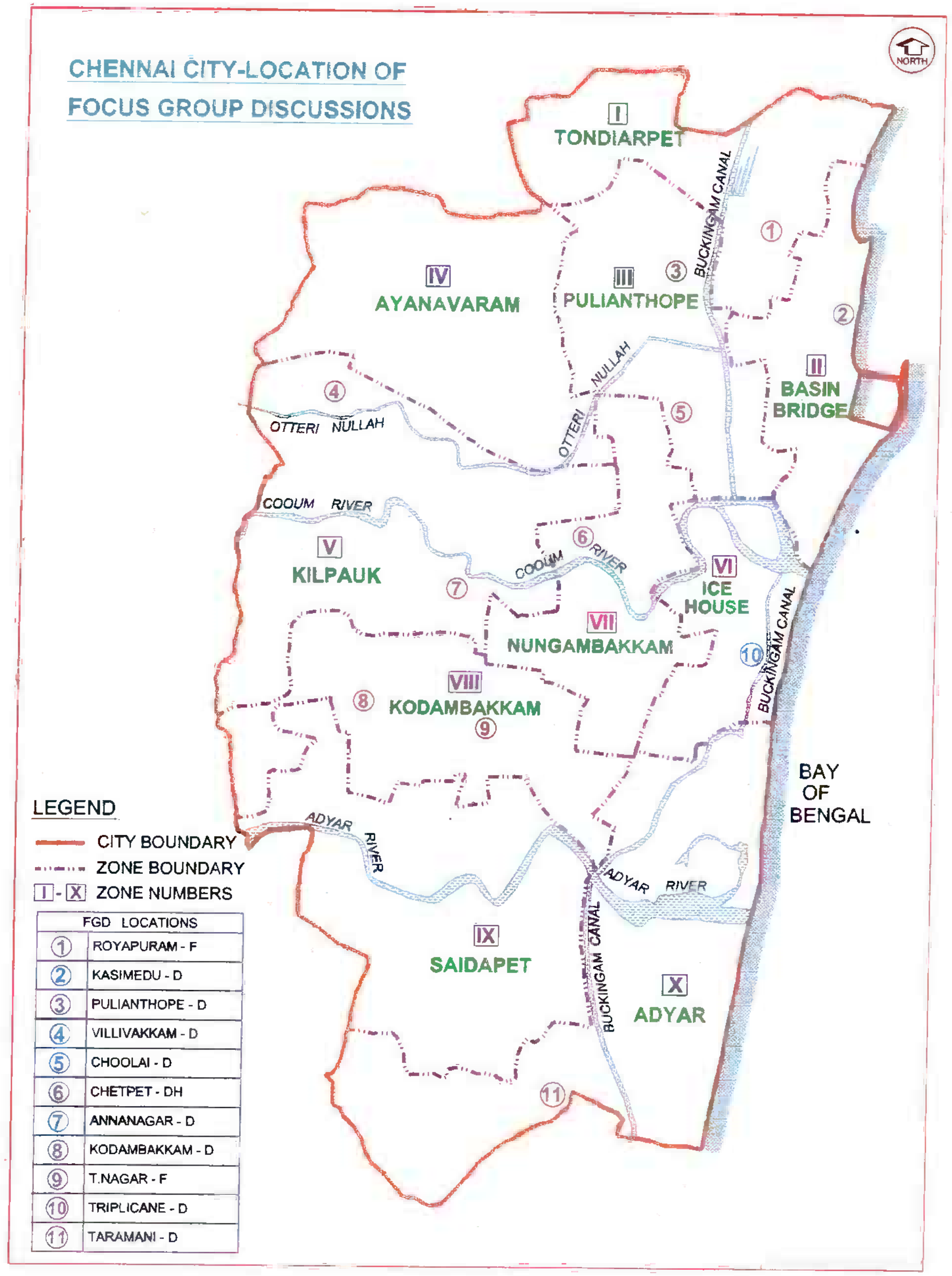
Appendix 1: Source Protection Measures

Key steps	Possible community actions
Identify the protection area	• Map groundwater and surface water areas • Map water courses (rivers, canals, streams, drainage channels, etc.) • Inventory activities that could threaten the water source, both direct and indirect • Delineate desired protection area • Identify where dumping (and what sort of dumping) could safely be carried out
Protection Strategies *Requires co-ordination with industrial waste/ landfill/garbage dumping agencies, planning, transportation and utility agencies, elected officials and property owners*	• Identify direct and indirect threats to water sources • Identify where dumping occurs • Identify who is responsible for it • Identify how often dumping occurs • Identify hazardous materials transportation routes in and around the community • Mark the location of each activity on the water source maps • Discuss with industry etc. representatives possible alternative dumping sites, routing and timing (e.g. underground petrol storage tanks can be excluded from a groundwater protection area) • Discuss with local resource agencies methods to develop protection strategies (e.g. on land use, mediation of community discussions, local health departments to provide information on household sewage systems and private wells in the protection area, etc.) • Draw up a timetable of cleanup activities of existing sources of contamination, identifying responsibilities and costs.
Combining new and traditional methods of source protection	• Identify tanks for cleanup and re-use • Construct checkdams • Construct check bunds in gullies and *wadis* • Construct diversion and infiltration systems to recharge sources
Home Protection Strategies	• Clean, cover and maintain your own well or borewell • Be involved – attend public meetings organised around water source protection • Organise a volunteer group to monitor locally agreed source protection methods • Help ensure local utilities that provide drinking water have adequate resources to do their job • Reduce paved areas in your area, allowing groundwater recharge more easily • Reduce the amount of garbage you produce: recycle more rubbish
	• Discuss with metropolitan decision-makers where locations that do not threaten groundwater

Encourage new partnerships	supplies could be excluded from a groundwater protection area • Purchase or lease undeveloped land in critical source protection areas • Develop zoning policies to control where activities which threaten the water supply could occur
Develop community-level water demand management plans	• Define goals • Identify water demand management priorities • Determine what the community needs to address these priorities • Define the timetable • Determine who will do what • Determine how tasks will be funded
Communicate with the public	• Work with local media • Messages to be delivered frequently and in a variety of ways • Highlight the cost and benefits of source water protection • Hold garbage & hazardous waste collection events and recycling fairs • Put up signs to identify the source protection area along with a telephone number to report violations • Ensure people fully understand the costs and benefits of water source protection, so as to limit negative response to politically unpopular decisions about limiting activities that threaten water supplies • Develop youth/school awareness programmes through neighbourhood activities, brochures,
Build up relevant expertise	• Identify where outside expertise is necessary to advise and mediate discussions • Strengthen the capacity of the human resource base to address issues through introduction of training programmes at universities and on-site demonstrations at factories, industrial production sites, etc.

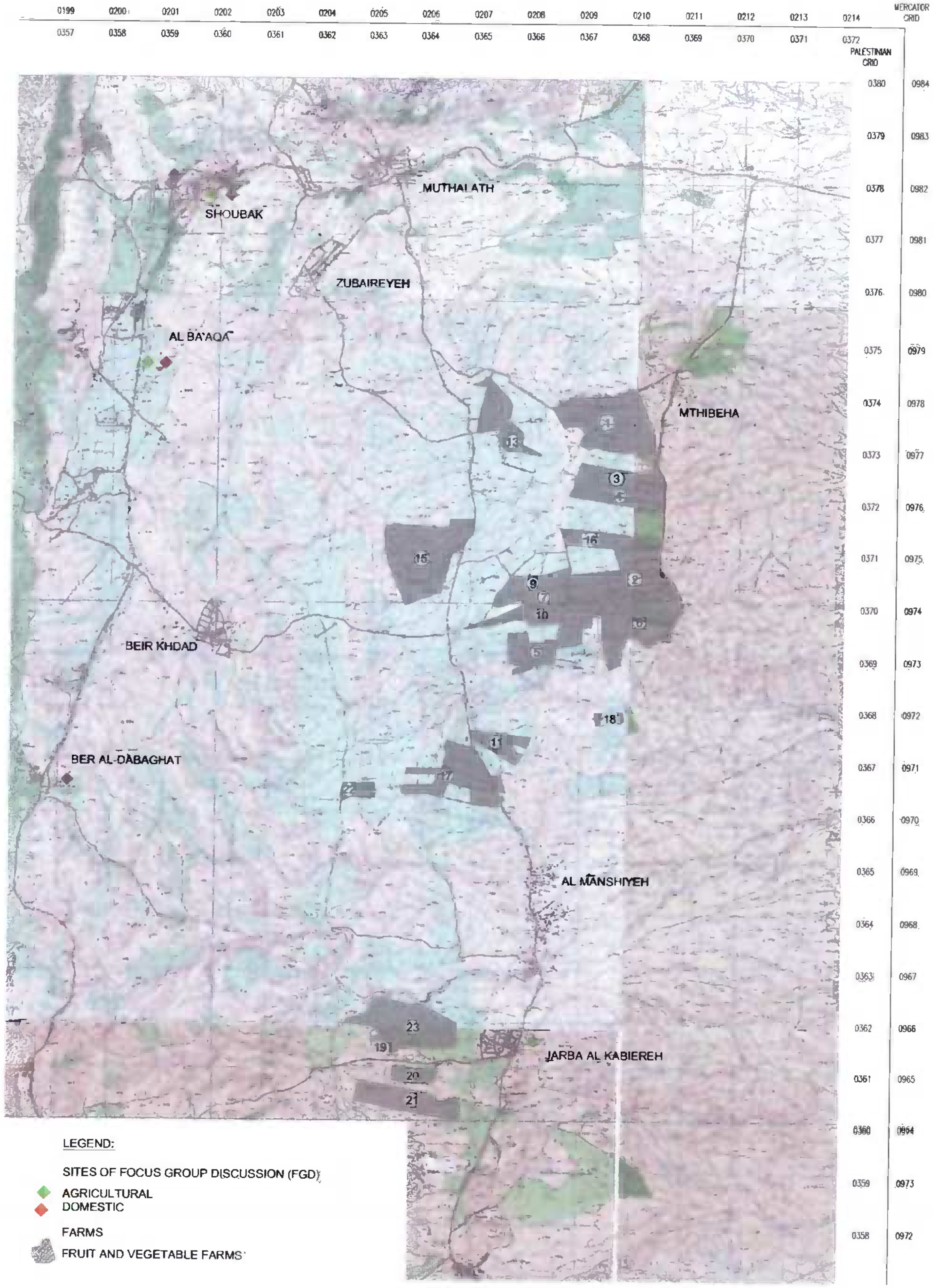
LOCATION OF FARMER S FGD AND INDUSTRY INTERVIEWS

MAP D1

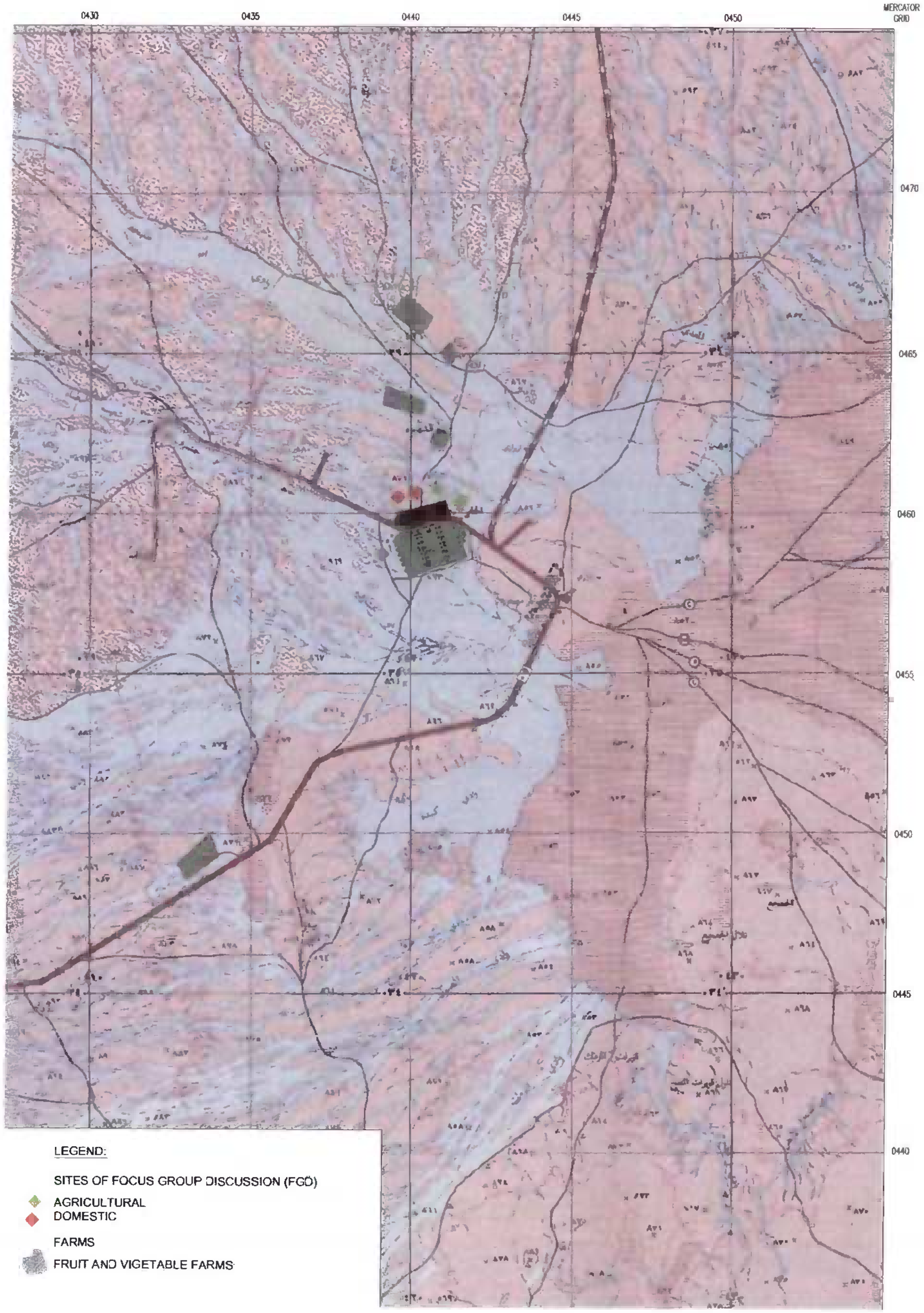


CHENNAI CITY-LOCATION OF
FOCUS GROUP DISCUSSIONS
NORTH
I
TONDIARPET
II
BASIN
BRIDGE
III
PULIANTHOPE
IV
AYANAVARAM
V
KILPAUK
VI
ICE
HOUSE
VII
NUNGAMBAKKAM
VIII
KODAMBAKKAM
IX
SAIDAPET
X
ADYAR
BUCKINGAM CANAL
OTTERI NULLAH
COOUM RIVER
ADYAR RIVER
BAY
OF
BENGAL
LEGEND
CITY BOUNDARY
ZONE BOUNDARY
I - X ZONE NUMBERS
FGD LOCATIONS
1 ROYAPURAM - F
2 KASIMEDU - D
3 PULIANTHOPE - D
4 VILLIVAKKAM - D
5 CHOOLAI - D
6 CHETPET - DH
7 ANNANAGAR - D
8 KODAMBAKKAM - D
9 T.NAGAR - F
10 TRIPLICANE - D
11 TARAMANI - D

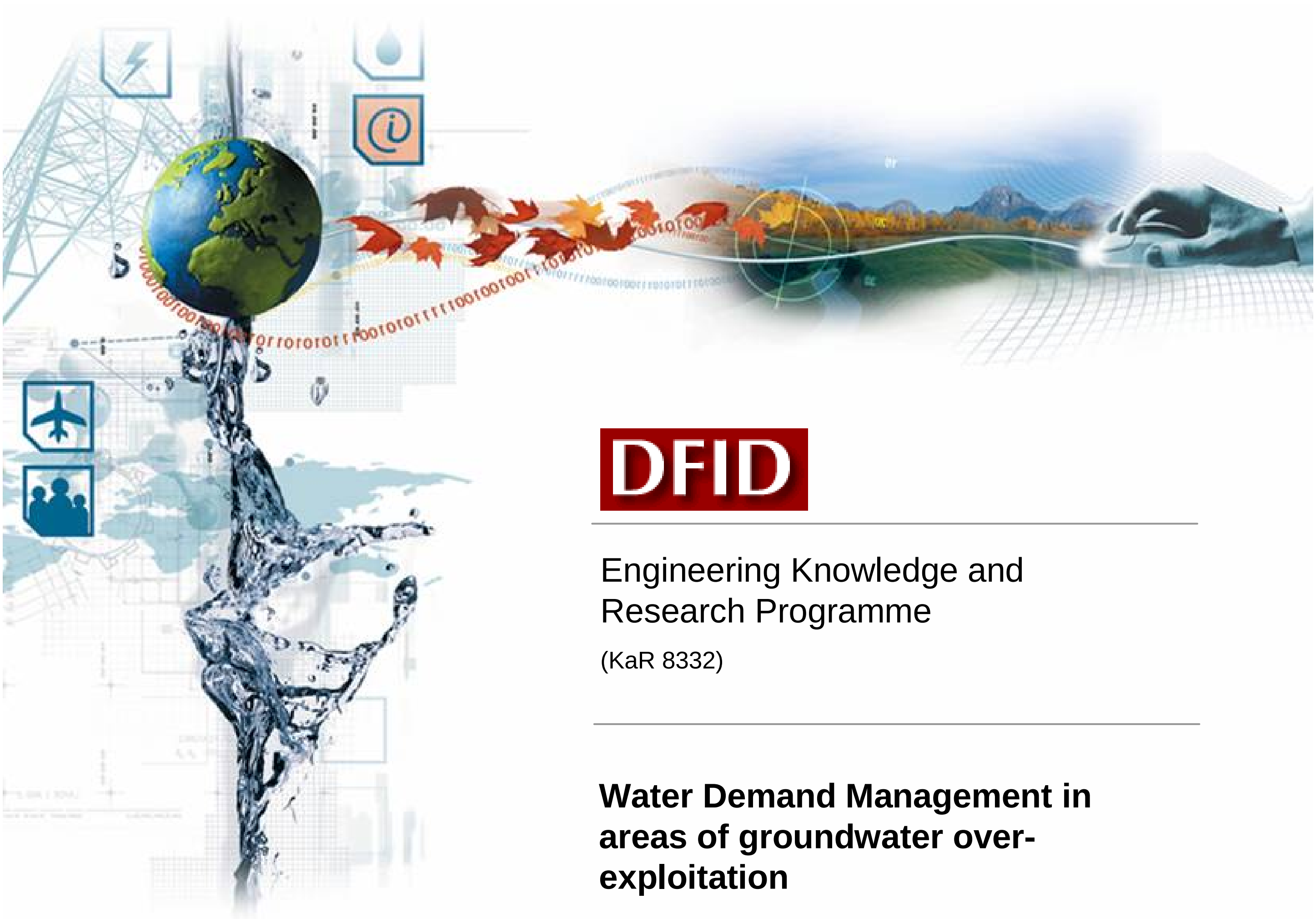
MAP D2



FGD Sites Shoubak
Map D3



FGD Sites Al Jafr
Map D4



DFID

Engineering Knowledge and Research Programme

(KaR 8332)

Water Demand Management in areas of groundwater over-exploitation

REPORT ON CASE STUDIES

ANNEXES E TO G

January 2005

BLACK & VEATCH

Black & Veatch Consulting

in association with

VRV Consultants (P) Ltd, Chennai, India

Jouzy & Partners, Amman, Jordan

REPORT ON CASE STUDIES – JANUARY 2005

ANNEXES E - G

This Document contains Annexes E to G of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

Annex E – Water Resources

Annex F – Economic data

Annex G – Water Policy, Institutions, Legislation and Regulation

The Annexes support the Main Report, which is bound separately, and are preceded by the following Annexes which are also bound separately

Annex A – Approach to the Study
Annex B - Water demand management
Annex C – Sustainable livelihoods approach
Annex D – Focus group discussions – Methodology & results

REPORT ON CASE STUDIES

ANNEX E WATER RESOURCES

CONTENTS

REPORT ON CASE STUDIES

PREFACE

This Document on Water Resources forms Annex E of the Report on Case Studies for the DFID funded project No. 8332 of the KaR Programme – Water Demand Management in Areas of Groundwater Over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B - Water demand management
Annex C - Sustainable livelihoods approach
Annex D - Focus group discussions – Methodology & results
Annex E - Water Resources
Annex F - Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two case studies have been undertaken one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

The Annex E that follows is presented in two parts.

The Groundwater Resources of the case study areas for Chennai, Tamil Nadu State, India are outlined in Part I and for Al Jafr-Shoubak, Hashemite Kingdom of Jordan in Part II.

Abbreviations and Acronyms

General:

DFID	Department for International Development, UK
ESA	Environmental Services Association
FAO	Food and Agriculture Organisation, Rome
FGD	Focus Group Discussion
ha	hectare (10,000 m^2)
ham	hectare metre
HP	Horse-power
JICA	Japanese International Cooperation Agency
lpcd	litres per capita per day
Mld	Million litres per day
Mcuft	Million cubic feet
m^3	cubic metres
Mm^3	Million cubic metres
MSL	Mean sea level
NGO	Non-governmental Organisation
RO	Reverse osmosis
TMC	Thousand million cubic feet
UKWIR	UK Water Industry Research
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WDM	Water Demand Management
WHO	World Health Organisation
yr	year

India:

A-K aquifer	Araniyar-Kortalaiyar aquifer
AED	Agricultural Engineering Department (Tamil Nadu)
AUA	Adjacent Urbanised Area
CGWB	Central Groundwater Board
CMA	Chennai Metropolitan Area
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board (also referred to as Metrowater)
DUA	Distant Urbanised Area
GSI	Geological Survey of India
IWS	Institute of Water Studies (Tamil Nadu)
PWD	Public Works Department
RWH	Rainwater Harvesting
TWAD	Tamil Nadu Water Supply and Drainage Board
WRCRC	Water Resources Control and Review Council (Tamil Nadu)
WRO	Water Resources Organisation, Public Works Department (Tamil Nadu)

Jordan:

DWL	drawdown water level
JD	Jordanian Dinar
JVA	Jordan Valley Authority
masl	metres above sea level
MIT	Municipal/Industrial/Touristic (sectoral water demand in Jordan)
MOA	Ministry of Agriculture
MWI	Ministry of Water and Irrigation (Jordan)
WAJ	Water Authority of Jordan
WIS	Water Information System
WL	water level

ANNEX E WATER RESOURCES

PART I TAMIL NADU CASE STUDY

EI.1. THE CASE STUDY AREA

EI.1.1 Description of the area

The water supply to Chennai city is derived from both surface water and groundwater sources.

EI.1.2 Surface Water

The main source of water supply to the city of Chennai is from a system of three reservoirs namely Poondi, Cholavaram and Red Hills, located between 20 and 50km to the northwest of the metropolitan area. These reservoirs receive surface water flows during monsoon rains, particularly during the North East monsoon. Another reservoir called Chembarambakkam, which is about 25km southwest of Chennai city, has also been into included in the Chennai water supply system since 2000. The locations of all these reservoirs are shown on Figure 1.

EI.1.3 Groundwater

The City gets its groundwater supply from two main sources:

- Well fields in the Araniyar-Koratalaiyar Basin
- Southern Coastal Aquifer.

Well Fields
There are six well fields in the Araniyar – Koratalaiyar Basin extracting groundwater. The locations of all these well fields are also shown on Figure 1.

The Tamaraipakkam, Panjetty and Minjur well fields were established during 1969 and the other well fields, namely Poondi, Flood Plains and Kannigaiper were established in 1987. There are 74 bore wells in the six well fields. The major part of the extraction from these well fields goes to the industrial area at Manali Town

Southern Coastal Aquifer
This aquifer is to the south of Chennai city and extends along the coast of the Bay of Bengal for about 20 km between Thiruvanmiyur and Muttukadu. The groundwater from this aquifer is pumped from 22 dug wells and supplied to the southern part of Chennai city. The location is also shown on Figure 1.

EI.2. HISTORY OF WATER RESOURCE STUDIES

EI.2.1 Introduction

There have been a number of studies carried out since the mid 1960s. These are summarised below in chronological order.

EI.2.2 Hydrogeological and Artificial Recharge Studies, Chennai, UNDP/CMWSSB Studies (1965-69, 1975-78, 1982-91)

This series of studies was the first to identify the Araniyar-Koratalaiyar (A-K) Basin as a source for groundwater supply. The study area is shown on Figure 1. The initial study of the groundwater resources of the area was carried out and reported on between 1965 and 1973. There then followed a second round studying water supply and sewage disposal and included the artificial recharge potential of the area. The third part looked at water resource development and management. Phase I of this project started in June 1982 and was completed in August 1985. During this period Satellite Image Analysis, Hydrology, Hydrogeology, Recharge studies, Sea Water Intrusion, Artificial Recharge, Socio-Economic studies and Water Quality studies were undertaken.

The hydrology study involved collection and evaluation of existing hydro-meteorological data, construction of gauging stations, topographic survey of reservoirs to determine siltation rates and land use and irrigation practices between Poondi lake and the coast of Bay of Bengal.

The following works were carried out as part of the hydrogeological study:

- satellite imagery survey to update the geological map of the project area,
- surface geophysical survey,
- exploratory borehole drilling comprising 16 test bore wells, 81 observation wells and 256 slim holes, to study the lithology,
- well inventory to determine ground water extraction,
- pumping tests,
- infiltration tests and artificial recharge experiments,
- sea water intrusion study, and
- mathematical modelling of the A-K basin.

The important findings of this study are:

1. In the A-K basin the alluvial deposits cover an area of 1000km^2. The thickest part of the aquifer (35m) occurs along the course of a buried channel. The approximate area of the buried channel is only 290 km^2 and is shown on Figure 1.
2. The aquifer is mostly unconfined in the west and confined by overlying clays in the east, towards the coast.
3. The general direction of ground water movement is eastward to the coast. However, due to over exploitation near the coast, the gradient is reversed. The seasonal water level fluctuation for the whole basin during the study period (1982 to 1985) is approximately 2 to 4.5m.
4. Transmissivities derived from pumping tests in the study area range from 140m^2/d to 6535m^2/day. In the production wells in all six well field areas they range from 1400m^2/d to 5980m^2/day.
5. The average annual groundwater recharge during a normal monsoon period in the A-K basin is about 450Mm^3. The average pumping from this

basin for domestic and irrigation purpose is about 350Mm^3. However, during below average rainfall periods, due to the poor storage of surface water runoff and reduced natural recharge, the additional extraction was met from groundwater storage.

6. The aquifer was modeled using the Pricket Lonnquist two-dimensional Finite Difference model with a rectangular grid network. The model results show that during a normal rainfall year 58Mm^3 (159Mld) could be pumped from the well fields, and in dry years it would be possible to pump 66Mm^3 (182Mld) from the well fields. The resultant average additional draw down in all the well field area would be approximately 5m.
7. During the study period the sea water and fresh water interface was around 8km from the coast. In addition to the sea water, the groundwater was also polluted by the percolation of concentrated saline water from the salt pans in the area. The average conductivity value of the brackish water in the Minjur well field was 4000 to 5000µS/cm. A Finite Element model was developed to predict the progress of saline intrusion. An injection experiment at Nadhiyambakkam village, which is about 3km east of Minjur where the groundwater salinity was 7000µS/cm, was carried out to test the feasibility of well recharge. During this study, water was injected for 19 days at the average rate of 200m^3/day and it was observed that the salinity fell from 7000µS/cm to 2500µS/cm in the observation well, which is 42m from the injection well. However, the salinity returned to the previous value 50 hours after the cessation of the test as the injected water was replaced by through flow due to the existing hydraulic gradient.
8. Infiltration testing using test pits was carried out in Tamaraipakkam, Poondi, Panjetty and Minjur. The infiltration rates in Tamaraipakkam and Poondi were high (3 to 17mm/d) and lower in Minjur (1.5 to 2.0mm/d). The study recommended that the areas of Poondi and Tamaraipakkam are suitable for artificial recharge. The Koratalaiyar river bed could also be used for artificial recharge by constructing five check dams.
9. The A-K Basin ground water was originally of the sodium bicarbonate type, but has now changed to sodium chloride type. This is most probably due to recycling of irrigation return flows. In Poondi and Tamaraipakkam the deeper aquifer quality is better than the shallow aquifer. However, in Minjur the shallow aquifer quality is better than the deeper aquifer and this is mainly due to saline intrusion at depth. In Panjetty the quality in the southern side is better than the northern side as the recharge from the Araniyar has to pass beneath agricultural land.

Phase II of the study was carried out between 1986 and 1991. Mathematical modeling was repeated using the data available during this period. This time a Finite Difference model based on the TALISMAN program was used. This model covers only the Koratalaiyar Basin, with an area of 1130km^2. On this basis it was calculated that the average abstraction by farmers in the period 1978-1989 was 400Mm^3/year and the reliable yield of all six of the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) well fields is likely to be between 10.95Mm^3/year (30Mld) and 25.5Mm^3/year (70Mld).

A mathematical model suggested that approximately 3Mm^3/year (8Mld) from the Minjur well field, if pumped into 15 injection wells would create a hydraulic barrier, to stop further intrusion. The construction of 15 injection wells was commenced in February 1991.

EI.2.3 Groundwater Resources and Development Potential of Chengai MGR District, Central Ground Water Board (1991)

This report dealt with hydrology and evaluation of groundwater resources of the Chengai MGR District (Chennai district renamed between 1984-85 after the former Chief Minister Mr. M G Ramachandran) which was divided into 10 blocks or administrative divisions. The report makes special mention of the groundwater situation of three well fields namely Minjur, Panjetty and Tamaraipakkam. From a water balance of recharge and abstraction it was suggested that 980Mm^3/year is available in the 10 blocks.

EI.2.4 Groundwater Resources and Development Prospects in Chennai District, Central Groundwater Board (1993)

Chennai district is part of a coastal plain with a gentle slope towards the east and the elevation of the ground varies from mean sea level to 10m above mean sea level. Adayar, Cooum and Otteri Nullah drain this district. The average annual flow in the Adayar is 89.43Mm^3 and in the Cooum is 40.2Mm^3. Cooum river is highly polluted with sewerage disposal from Chennai city. The annual rainfall is 1285mm and the NE monsoon contributes about 60 per cent of the total rainfall.

The major part of the district is covered by recent alluvium and only a small southern part is covered by crystalline rocks of Archaean age. Tertiary rocks and Gondwana shales are encountered at depth. The occurrence of ground water is limited to thin granular zones in the alluvium and in the weathered and jointed/fractured crystalline rocks. The Gondwana sandstones and shales are compact and fractured and in places contain an appreciable quantity of water.

The chemical quality of water is generally brackish and not suitable for drinking purposes. This may be due to a number of reasons including backwater effects in the main rivers and drains and clay mineralogy. In select pockets in Besant Nagar, Greenways road, Kilpauk and Nungambakkam area, the groundwater has less mineralisation but bacterial contamination due to pollution is common. The dynamic groundwater resources of the district, 170km^2, are of the order of 55.34Mm^3/year and almost 82 per cent of the dynamic resources are developed by a number of abstraction structures, such as domestic wells. The decline in water table is noted in some areas, which is an indication of more housing development, the fluctuation is widening with time and the static water level more or less recovers after rain.

EI.2.5 Hydrogeological and sea water Intrusion studies between Thiruvanmiyur and Muttukadu by RITES – CMWSSB (1995-96)

The study area (30km^2) extends from Thiruvanmiyur in the north to Muttukadu in the south. The Bay of Bengal is the eastern limit, while the Buckingham canal forms the western limit.

During this study period, the area was monitored for changes in water table and chemical quality of groundwater. Geophysical surveys were also carried out along 17 profiles, four times during the period of study. The area is represented by fluvial, marine and erosional landforms exposing sub-recent to recent beach deposits of Pleistocene to Recent age. The average normal rainfall is 1215mm.

The maximum thickness of the fresh water bearing sand occurs in the central part of the study area. The thickness ranges from 8m to 15m. The dynamic resource of groundwater is 9.4Mm^3/year and the optimum sustainable draft should be 6.58Mm^3/year. However, the actual annual abstraction from this area is 6.75Mm^3. Out of this, 64% is consumed in the northern part from Thiruvanmiyur to Neelangarai. In this area, the water table should not be allowed to fall below 6.0m below ground level in order to avoid sea water intrusion.

The saline water in the Buckingham canal seeps down and increases the salt concentration of the top layer of water in its vicinity. In Thiruvanmiyur, sea water intrusion has been observed above mean sea level, which is not a healthy sign as far as sea water intrusion towards land and may be the results of up coning of the saline water interface.

EI.2.6 State Frame Work Water Resources plan of Tamil Nadu, Public Works Department (1998).

This study was carried out by the Institute of Water Studies, which is the part of Public Works Department of Tamil Nadu. The objective of the report is to study and analyse the different findings relating to i) Surface Water potential, ii) Ground water potential, iii) Agricultural Water Demand, iv) Domestic water demand, v) Livestock water demand and vi) Industrial water demand.

These studies are based on river basins. There are 33 river basins in Tamil Nadu, including minor river basins.

Recommendations are given for each basin to increase the water potential. The recommendation given for the Chennai Basin, consisting of the Araniyar, Koratalaiyar, Adayar and Cooum rivers, is to develop Ramanjeri reservoir (33.42Mm^3) north of Poondi reservoir and Thirukandalam reservoir (28.32Mm^3) near the Kannigaiper well field to increase the surface storage in addition to the existing four reservoirs supplying surface water to Chennai.

EI.2.7 Groundwater Exploration in Tamil Nadu and Union Territory of Pondicherry Central Ground Water Board (1998)

This report provides general information on the hydrogeology and hydraulic properties of the alluvial aquifers of the A-K Basin. The report presents statistics of climate and agriculture and derives estimates of surface and groundwater potential with reference to the year 1994. Groundwater abstraction was estimated based on agricultural statistics of the early 1990s at 520Mm^3/year. The potential unused groundwater surplus in the A-K basin was estimated at 170Mm^3/year.

EI.2.8 A profile of Thiruvallur district, Tamil Nadu Water Resources Organisation (Public Works Department), 2000

This district has a distribution of Quaternary, Tertiary, Jurassic formations in the east and crystalline in the west. Free electricity for farmers encourages the utilisation of groundwater to the maximum extent. There are 12 meteorological stations in this district. Water levels are monitored every month in 42 shallow observations wells since 1971. Water quality data collected every 6 months is available from 1972 onwards. Block level groundwater recharge, extraction and the balance are given in this report. Hydrogeological particulars of all villages are available.

Administrative set up
Geographical extent of this district is 3424km^2, which is 2.25% of Tamil Nadu. Geographical position of this area lies between N latitude 12° 10'0" and 13° 15' 00" and E longitude between 79° 15'00" and 80° 20'00". This district consists of eight taluks, namely 1) Thiruvallur 2) Uttukottai 3) Poonamalle 4) Ambathur 5) Gummidipoondi 6) Ponneri 7) Thiruthani and 8) Pallipattu. These taluks are divided into a total of 14 blocks or administration districts and have 805 villages.

Physiography
The hilly western portion borders Andhra Pradesh. The rest of the district has a plain terrain with gentle slope towards the east and southeast. The major rivers are Araniyar and Koratalaiyar. The other rivers are Coovam or Cooum, Nagari and Nandhi. The rivers are flowing west to east into the Bay of Bengal. The three major surface water reservoirs are 1) Poondi 2) Cholavaram and 3) Red hills.

Name	Capacity in Mcuft	Catchment in km^2	Depth of water in metres (max.)
Poondi	3231	32.634	6.25
Cholavaram	881	14.556	5.45
Red hills	3300	19.684	6.46

The drainage of the rivers Koratalaiyar, Nandhi and Nagari is the catchment area of Poondi reservoir. The Koratalaiyar enters Poondi in the southwest and drains from the northeast. The Araniyar river originates in Andhra Pradesh and flows in the northern portion of the district. The Cooum originates in Kancheepuram district and flows in the southern part. All the rivers are seasonal and depend on monsoon rain.

Climate and Rainfall
The climate is subtropical and the normal average rainfall is 1082.2 mm, based on 16 rain gauge stations in this district.

Season	Period	Rainfall in mm	Percentage
Winter	January and February	45.8	4.23
Hot period	March to May	72.8	6.73
SW Monsoon	June to September	418.2	38.64
NE Monsoon	October to December	545.4	50.40

Irrigation by surface water
The main surface water features of Thiruvallur district are as follows:

Araniyar river catchment
The river originates near Karvet Nagar in Andhra Pradesh. The average number of days that run-off is discharged into the Bay of Bengal is 10 days/year. This river runs 65.2km in Andhra Pradesh to Surutapalli and a further 66.4km in Tamil Nadu. The total catchment area is 1470km^2, out of which 763km^2 lies in Tamil Nadu. There are two anicuts in Tamil Nadu, namely Annappa Naickam Kuppam and Lakshmipuram anicuts. The surplus flow over the weir and down the river in Lakshmipuram Anicut is as follows (in Mm^3).

Year	Surplus flow (Mm^3)
1987	166.0
1988	110.01
1989	46.69
1990	46.67
1991	383.26
1992	1.56
1993	118.43

Koratalaiyar river catchment
This river originates from Panapakkam reserve forest of Andhra Pradesh and flows through Thirutani, Tiruvallur and Pooneri taluks. The total length of the river is 155km. The Nageri and Nandhi rivers are the main tributaries. The total catchment area is 4273km^2, of this 3242km^2 lies in Tamil Nadu. The Poondi reservoir was built across Koratalaiyar in 1945. Downstream of the reservoir are two anicuts one at Thamaraipakkam (1879) and the other at Vallur (1872).

The Cholavaram lake, which was an irrigation source, was converted to a drinking water source in 1969. It is also supplied by the Tamaraipakkam anicut. The Red Hills lake also an irrigation tank has been improved in various stages since 1870. The surplus flow over the weir and down the river at the Vallur anicut is as follows (in Mm^3).

Year	Surplus flow (Mm^3)
1989	Nil
1990	23.33
1991	294.16
1992	Nil
1993	31.07

Cooum river catchment
This river originates in Kacheepuram district from the surplus flows of the Cooum Tank of Cooum village. It joins with the old Bangaru channel that takes surplus flows over the Kesavaram anicut and forms the river proper. The total length of the river is 66.5km. The catchment area is 682km^2. There are five anicuts along this river, namely 1) Aranvoyal, 2) Korattur, 3) Ayalacheri, 4) Paruthipattu, and 5) Ayananbakkam. The surplus flow over the weir down the river at the Korattur Anaicut is as follows (in Mm^3).

Year	Surplus flow (Mm^3)
1990	23.32
1991	293.95
1993	31.05

This river also serves as a surface drainage carrier of Chennai city.

In the Thiruvallur district there are 1986 tanks and 17 canals which serve as main sources for irrigation.

Irrigation by Groundwater
Groundwater sources play a major role in the irrigated area. The groundwater sources are used roughly for more than 820km^2 and surface water sources are used roughly for less than 427km^2.

Geology
This district can be classified into hard rock and sedimentary formations. This district is principally made up of Achaean, Upper Gondwana and Tertiary formations. These are overlain by laterites and alluvium. The hard rocks constitute 15% of the total area. Groundwater potential is limited in this area and the assessment of groundwater potential in hard rock areas is a relatively complex task. Blocks of the district are categorised as Dark, Grey and White, depending upon the level of extraction as a percentage of recharge.

- Dark block - extraction between 85% and 100% of recharge R.K. Pet, Thiruvalangadu, Minjur, Poondi, Thiruvallur, Puzalal and Cholavaram
- Grey block - 65% to 85% Thiruttani, Villivakkam and Poonamallee
- White block - <65% Ellapuram, Gummidipoondi and Pathipattu.

In order to obtain a continuous and adequate supply of groundwater, without much disturbance to normal storage within the aquifer, artificial recharge methods such as percolation ponds, construction of check dams, conjunctive use of groundwater and surface water have to be used and implemented wherever possible.

Groundwater potential (1992) (in Ham) *Mm*^{3}

Groundwater recharge	89417
Utilisable Groundwater	76006
Net Groundwater draft (estimated from cropping pattern and water requirements)	62119
Balance	13887

Water quality
Samples are collected in shallow wells. Good quality water with electrical conductivity (EC) up to 750micromhos/cm occurs in parts of Uthankottai, Gummadipoondi, Tiruvallur, Puzhal, and Minjur. Poor quality water with EC from 2250 to 3000micromhos/cm occurs around Ambattur.

Pattern of water use as of January 1992
Total dynamic groundwater resources available – 89 Mm^3
Quality reserved (15%) for domestic and industrial use - 13.4 Mm^3
Drinking water needs - 1.3 Mm^3

EI.2.9 Second Chennai Water Supply Project, Scott Wilson Piesold (UK), for CMWSSB (2002)

The consultancy services to reassess the groundwater potential and transferable water rights in the A-K basin was awarded to Scott Wilson Piesold with a study period of 18 months comprising of two phases. The study area is shown on Figure 1. In Phase I, the firm has to carry out a hydrogeological investigation to establish a sustainable yield of 100 Mm^3 per year or 270Mld. The period for Phase I is 10 months. On establishing the sustainable yield of 70 Mm^3, Phase II study has been taken up, which includes presentation of proposals for introducing transferable water rights in the A-K basin (the period of study is 8 months).

So far an Inception Report and First Interim Report have been submitted. In January 2004 the second interim report was submitted and is under review by a committee of Metrowater officials. The final report on Phase I was submitted in March 2004.

EI.3. DEVELOPMENT AND CURRENT USE OF WATER RESOURCES IN THE A-K BASIN

EI.3.1 Introduction

The A-K Basin and its surroundings have provided water from both surface sources and groundwater to Chennai city since its earliest foundation. A map showing the various sources within the basin is enclosed. (Figure 1)

EI.3.2 Surface Water Development

The first organised Public Water Supply Works was executed in the year 1772 and it was designed to supply 0.635 million litres per day from a cluster of 10 shallow wells. The water supply of Chennai city was for many years obtained solely from shallow wells and it was not until 1866 that it was decided to adopt a Public Water Supply Scheme. The scheme designed by Mr. Frazier, which combined the Chennai City Water Supply with irrigation of 3500Ha of wasteland, was commenced in 1872. The surface water flow from the Koratalaiyar river was diverted to Cholavaram and then to Red Hills lakes. Further development, which took place after 1907, resulted in the construction of an outlet tower and roughing filters at Red Hills, an underground conduit to convey water to the city and slow sand filters at Kilpauk Water Works. The new works resulted in a designed supply of 160lpcd.

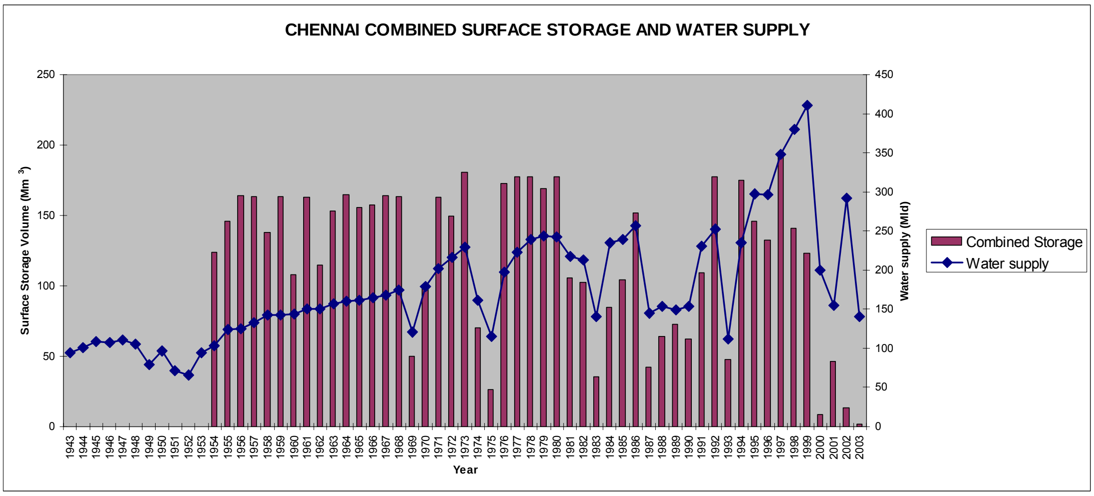
To meet the increasing demand for water in the city, the irrigation supply from the lakes was discontinued sometime during the 1940s or 50s. The treatment capacity of Kilpauk Water Works was increased by the provision of rapid gravity filters with a capacity of 45Mld, which was later increased to 135Mld and then to 190Mld. One more conduit to convey the raw water to Kilpauk was also laid and this was strengthened by the third conduit in the 1980s. To increase the available yield from the catchment, the Sathyamurthy Dam was constructed between 1940 and 1944 across the Koratalaiyur river to form a reservoir at Poondi.

The current storage capacity of these reservoirs are as follows Mm^3 (Tamilnadu Water Supply and Drainage (TWAD) Board Handbook, 2002)

Poondi	97.98
Cholavaram	25.3
Red Hills	93.46

The average rainfall in the catchment is 1300mm, based on the records of rain gauges at each of the reservoirs. In the year 2000, water from another reservoir, namely Chembarambakkam, which is to the southwest of Chennai city, with a storage capacity of $103.21Mm^3$ was also utilised for city water supply. At present due to insufficient rainfall only water from dead storage is available in all the lakes. Only 10 to 15Mld from the dead storage in the Red Hills reservoir is being diverted to the city, treated at Kilpauk Water works and put into the distribution system. A graph showing the combined storage available in the reservoirs is shown in Figure 2.

Figure 2



EI.3.3 Groundwater Development

The main source of groundwater is from the Araniyar-Koratalaiyar Basin aquifer. The A-K Basin aquifer comprises alluvial deposits of an old buried channel of the Palar river. This aquifer extends from the vicinity of Poondi reservoir to the north east of Chennai to the Minjur area to the north. This aquifer covers an area of roughly 750km^2, which includes the course of Koratalaiyar river and the lower reaches of the Araniyar river. The groundwater occurs under unconfined or confined conditions in the A-K Basin. In its lower part, roughly downstream of Tamaraipakkam, the aquifer is layered and further downstream it is confined in nature. An impervious base of Gondwana formation comprising shale, clay, underlies the alluvium. Recharge into these alluvial aquifers is mainly from precipitation, flow through the river beds, water bodies, return flow from the irrigated fields. The quality of water is generally good.

In the 1950s the groundwater was drawn from shallow wells within the city boundaries, particularly in the suburbs. Further groundwater development occurred after 1968 based on a UNDP/PWD study, which recommended development of well fields in the Araniyar-Koratalaiyar aquifer. Based on this recommendation, three well fields namely Tamaraipakkam, Panjetty and Minjur were developed in 1969, with a designed total capacity of 125Mld (Tamaraipakkam 50Mld; Panjetty 42.5Mld and Minjur 32.5Mld). The groundwater from these three well fields mainly supplied water to the Industrial area at Manali, which is in the northern side of Chennai city, contributing only a little to the city supply.

To meet the additional demand, Metrowater took up the task of reassessing the groundwater potential in A-K Basin and looking for new sources once again in the early eighties with the assistance of UNDP. This resulted in the commissioning of three new well fields during 1987, namely Poondi (28Mld), Flood Plains (13.5Mld) and Kannigaiper (13.5Mld) with a designed total capacity of 55Mld.

Hence the total designed capacity from the six well fields is 180Mld. However, against this designed withdrawal capacity, the maximum withdrawal to date from these six well fields has been 120Mld in the year 1987, when the additional three well fields were made operative. Details of the well fields are given below and their locations shown on Figure 3.

EI.3.4 Poondi Well Field

Poondi Well Field is located south of Poondi reservoir. The aquifer in this part consists of alluvium, deposited by the Koratalaiyar river. Sand of medium to coarse grain size intercalated with clay lenses forms the aquifer and is of semi-confined character. In some parts a two layered aquifer is encountered. These aquifers are hydraulically connected and underlain by the relatively impervious Gondwana formation.

The total depth of the aquifer in this well field ranges from 24 to 35m, the average aquifer thickness is 30.76m. The average water level during 1988 was 19.33m below ground level. The water level started to decline yearly to a low of 22.55m by 1993. There was gradual recovery from 1996 onwards. This was mainly due to the conservation measures taken by the CMWSS Board, to reduce the extraction of groundwater, when an additional source of surface water from the Krishna Water Scheme was put online. Then due to insufficient rainfall from 1999 onwards, the water level in the well field started to decline again and the average water level in March 2004 was 24.33m below ground level. The ground elevation of this well field area ranges from 42.24 to 48.75m above mean sea level (above MSL). A total number of 18 bore wells have been constructed in this well field since 1987. At present only 13 wells are used for extraction. Five wells have been abandoned due to poor yield. The maximum average extraction from this well field was 16.38Mld in the year 1994. The present average extraction from this well field is 10Mld. The normal average yield in each well is 2000lpm, but at present the average yield is only 1000lpm. The map showing location of wells and graphs showing extraction and water level is enclosed (Figures 4 and 5).

EI.3.5 Tamaraipakkam Well Field

Tamaraipakkam well field encompasses a section of Koratalaiyar river with its southern flanks covering 46km^2. This part of the aquifer is an alluvial plain that is gently sloping in an easterly direction. The average width of alluvium in this region is about 6.5km. The well field is located about 15km downstream of the Poondi well field. The lithology of this well field indicates the existence of a partially confined upper zone and a confined lower zone. A total number of about 40 wells have been constructed in this well field since 1969 and only 30 are operational. The remaining 10 wells have been abandoned due to poor yield. Of the 30 operational wells, only five wells are working at present. Due to insufficient rainfall since 1999, the water level in most of the production wells has fallen below the minimum required pumping level. The average water level during 1969 was 12.80m below ground level and since then it fell until 1993 but improved again to 1999, due to optimum pumping operation, as there was sufficient storage in the reservoirs from water received from the Krishna Project. The average water level during 1999 was 2.00m above the 1969 level. This is because of the proximity of the production wells to the Koratalaiyar river, the Velliyur check dam and the Tamaraipakkam Anicut. During the normal monsoon period the production wells are recharged from the above three sources. However, due to insufficient rainfall since 1999, the water level in the aquifer shows an increasing decline and the average water level for the month of March 2004 was 30.88m, which is the lowest recorded level in the past three decades. The total depth of the production wells ranges from 28 to 38m, with an average aquifer thickness of 35m. The ground elevation of this well field area ranges from 22.19 to 30.50m above MSL. The maximum extraction achieved from this well field was during the year 1969 (34.27Mld) and second to this was during the year 2000 (32.26Mld). The average yield of a production well is 1800lpm during normal monsoon period, but at present, it is only 900lpm. The present extraction is only 5Mld. The map showing location of wells and graphs showing extraction and water level is enclosed (Figures 6 and 7).

EI.3.6 Flood Plains Well Field

Flood plains well field is a portion of the aquifer that exists between Tamaraipakkam and Kannigaiper well fields, mainly along the northern bank of the Kortalaiyar river. The lithology and other hydrogeological conditions are more or less similar to that of the Tamaraipakkam well field. The source of recharge is mainly from the Koratalaiyar river, rainfall infiltration and irrigation return flow. The total depth of the production wells range from 29 to 36m and the average aquifer thickness is 34.86m. The average water level during 1988 was 21.48m below ground level and then the water level was generally stable until 1995 when, like other well fields, it started showing an improvement until 1999. Due to conservation measures, the water level during 1999 was nearly 8.00m above the 1988 level. However, due to insufficient rainfall since 1999, the water level has fallen and the water level in March 2004 was 32.18m. Six production wells were constructed during 1987, out of which only five wells are operational. The average water level in the year 1988 (21.48m) was more or less maintained and it had not fallen below the 1988 level until 2000. However, after that, the depletion rate has become very high due to insufficient rainfall and absence of flow in the Koratalaiyar river. The average water level in March 2004 is 32.18m below ground level. Since the average depth of the aquifer in this area is 34.86m, the water column available for pumping is not sufficient and hence no production wells in this well field have been working since September 2002. The average discharge of a production well during normal period is 1000lpm. The maximum pumped quantity was achieved in the year 1988 (9.12Mld), after that it has gradually come down and finally during 2002, it was only 0.69Mld. The map showing location of wells and graphs showing extraction and water level is attached (Figures 8 and 9).

EI.3.7 Kannigaiper Well Field

This well field is a portion of alluvium located in between Tamaraipakkam and Panjetty well fields, on the northern side of the Koratalaiyar river. It consists of medium to coarse sand with intercalation of clay lenses overlying Gondwana formations. The aquifer is of unconfined to semiconfined character. The source of recharge is mainly from the Koratalaiyar river. This portion of the aquifer gets sufficient recharge only when there is run-off followed by standing water in the river bed. Since such occurrences have not happened in the recent past, the water level in the production wells has depleted rapidly. The average water level during 1988 is 22.05m and this level was maintained until 1999. Since 2000, the depletion rate is high and the water level in March 2004 was 31.78m. The elevation of this well field area ranges from 24.70 to 32.50m above MSL. A total of nine wells have been constructed in this well field and five are operational. The average thickness of aquifer in this area is 33.00m. Since there was not sufficient water column for pumping all five wells have not been working from December

2002 onwards. The maximum pumping from this wellfield was during the year 1988 (9.42Mld). After this year, this quantity was never achieved again, it was gradually reduced year by year, and finally during 2002 the average extraction was only 0.72Mld. The map showing location of wells and graphs showing extraction and water level is enclosed (Figures 10 and 11).

EI.3.8 Panjetty Well Field

The Panjetty well field is a portion of alluvial deposits, located between the Araniyar river in the north and the Koratalaiyar river in the south. The well field has been developed along the National Highway (N.H. 5). This well field is about 5km from the Kannigaiper well field. There are two aquifers in this area, the upper unconfined and the lower semiconfined. The average thickness of the unconfined aquifer depth is 10.00m. 20 wells had been constructed since 1969 and now only 13 wells are operational. The average water level during 1969 was 12.95m and it is gradually depleting with some small improvements now and then. The water level in March 2004 is 39.39m below ground level and the average thickness of the aquifer is 41.15m. The elevation of this well field area ranges from 11.60 to 17.78m above MSL. Since the available water column for pumping is insufficient, all 13 production wells have not been operated since December 2002. The maximum extraction achieved was 35.36Mld during 1987 and the lowest extraction was 1.99Mld during 2002. The map showing location of wells and graphs showing extraction and water level is enclosed (Figures 12 and 13).

EI.3.9 Minjur Well Field

Minjur Well Field is a portion of alluvial deposits and exists at the eastern side of the A-K Basin, adjacent to the coast of Bay of Bengal. This aquifer consists of fine to medium sand intercalated with clay lenses of a rather continuous character and therefore occurs as a two layered aquifer, especially in the eastern part. The alluvial deposits overlie Gondwana formations. The Kortalaiyar river flows over this part of the aquifer. The Minjur aquifer is a channel type having a semipermeable clay barrier both in the north and south and a recharge boundary of saline water in the east namely the Buckingham Canal. From 1969 onwards, about 22 wells have been constructed in the Minjur area. At present only eight wells are operational and all the other wells have been abandoned due to salinity. Even though this part of the aquifer has a highest potential of groundwater than the rest of the well fields with longest water column available, due to the threat of seawater intrusion, only a minimum quantity is being pumped from this well field. The average water level during 1969 was 11.86 below ground level and during that time the water level was below Mean Sea Level. The height of this well field area ranges from 2.90 to 12.24m above MSL. The average water level has fallen to 23.86m during 1993. Due to the continuous depletion of water level and progressing sea water intrusion, the extraction rate has been gradually reduced. Because of this measure, the water level rose again to 16.23m during 1999 (ie. 7m rise). However, due to the present drought condition, the extraction has been now slightly increased. The maximum withdrawal from this well field during 1978 was 28.42Mld, but at present the withdrawal is limited to 10Mld. The average water level during March 2004 is 30.25m below ground level. The map showing location of wells and graphs showing extraction and water level is enclosed (Figures 14 and 15).

EI.3.10 Current use of Groundwater

The list of total wells and operation wells (March 2004) in the well fields is given below.

Well Field	Total Wells	Operational Wells
Poondi	13	10
Tamaraipakkam	30	5
Flood Plains	5	-
Kannigaiper	5	-
Panjetty	13	-
Minjur	8	6
Total	74	21

The average extraction from the 21 operational production wells is 20Mld.

Due to the limited source of surface water and ground water, agricultural wells are hired from farmers to extract groundwater to manage the current severe drought situation. The farmer's borewells are commonly constructed with 150mm diameter PVC pipe and fitted with 12.5HP submersible pump.

The groundwater from the hired agricultural wells is collected in a sump constructed for this purpose and pumped into the existing distribution system. The location of the collection sump is based on the availability of a cluster of 15 to 20 borewells within a radius of 1.5km. According to the agreement with the farmers each borewell has to supply 0.4Mld for 18 hrs of pumping. The payment for the water is made on an hourly basis at Rs.22 for one hour. At present, there are 15 such collection sumps in the A-K basin and there is a proposal to have more. Each collection sump supplies about 5 to 8Mld. This system of hiring agricultural wells was started in April 2001 and at present about 60Mld is being extracted from these wells. A map showing the locations of these sumps is enclosed (Figure 3).

In some villages, within the radius of 100km of Chennai city, where it is not possible to get a cluster of 15 to 20 borewells, groundwater from two or three wells is collected and transported to the city by tankers/lorries. At present around 50Mld is supplied to the city in this way.

EI.4. DEVELOPMENT AND CURRENT USE OF WATER RESOURCES WITHIN CHENNAI CITY

EI.4.1 Introduction

Chennai city forms part of the Tamil Nadu coastal plains. A major part of the city has a flat topography with a gentle slope towards the east. The surface elevation varies from 10.00m above MSL in the west to sea level in the east. Fluvial, marine and erosional land forms are main geomorphic features of the area.

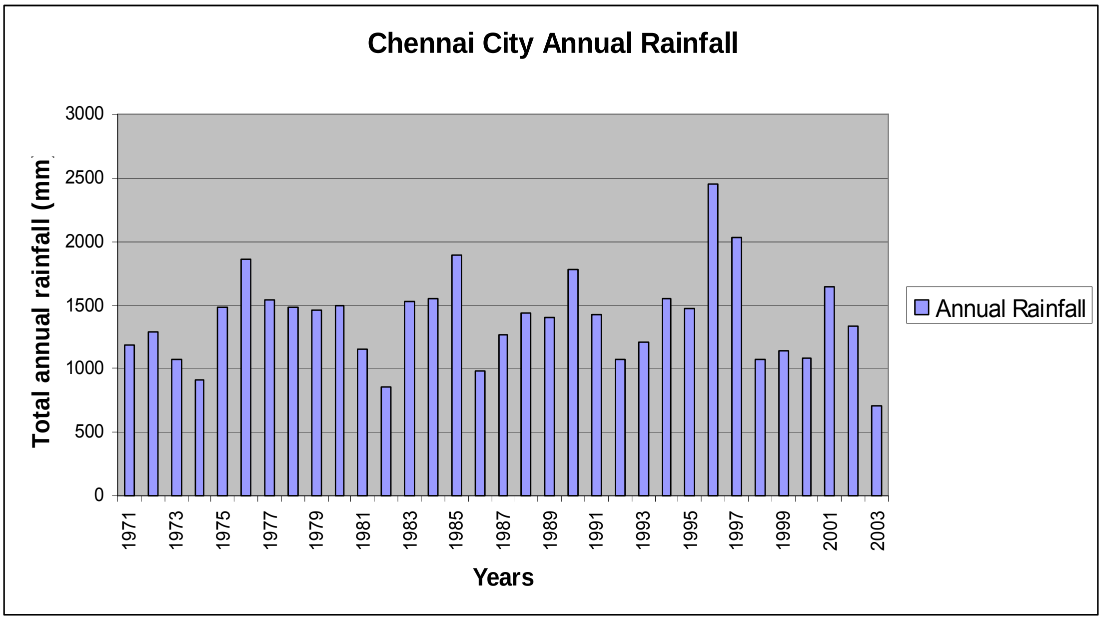
Adayar and Cooum are the two main river courses flowing across the southern and central parts of the city respectively. Otteri Nalla is another small stream flowing in the northern part of the city. Buckingham canal is a man-made channel flowing north to south in the city, along the eastern part parallel to the sea coast. Nowadays, all these water courses have become sewage carriers. During the high tides, the water in these back up from the Bay of Bengal inland up to 3 to 4km distance.

EI.4.2 Climate and Rainfall

Chennai enjoys a tropical climate with mean annual temperature of 24.3°C (min) to 32.9°C (max). However, the period April to May is the hottest and driest part of the year when the temperature exceeds 40°C.

The City gets its rainfall during the South West monsoon as well as the North East Monsoon. However, the North East monsoon (October, November & December) contributes the maximum rainfall, about 65% of total rain. Most of the rainfall occurs from one or two cyclones caused by depressions forming in the atmosphere over the Bay of Bengal. The South West monsoon rainfall is highly erratic and summer rains are negligible. The average annual rainfall of the city is in the range of 1200mm to 1300mm, which is higher than the state average. The annual rainfall measured at the rainfall station at Nungambakkam from 1971 to 2003 is given in the graph (Figure 16).

Figure 16



EI.4.3 Geology

Geologically the city is underlain by various formations from ancient Archaean to Recent Alluvium. The major geological formations are grouped into three units namely, (i) Archaean Crystalline Rocks, (ii) Consolidated Gondwana and Tertiary sediments and (iii) the Recent Alluvium.

The lithological data encountered in major parts of the city shows that sand deposits (alluvial), intercalation of sand and clay formations and crystalline rocks are the predominant formations that are encountered in different sequences. The general lithological formations found in different parts of the city have been grouped into seven categories given as below:

Group I	Alluvial Sandy Formation
Group II	Sand-Clay-hard clay formations
Group III	Clay-sand-hard rock formations
Group IV	Clay-sand-shale formations
Group V	Clay-hard rock formations
Group VI	Clay Formations
Group VII	Hard crystalline rock formations

A map showing the distribution of the different geological formations in the city is enclosed (Figure 17).

EI.4.4 Hydrogeology

Groundwater occurs in all the geological formations, the Archaean Crystallines, Gondwanas, Tertiaries and Alluvial deposits, and is developed by means of dug wells, filter point wells, bore wells and dug-cum-bore wells. Groundwater conditions of the various important geological formations are described below:

Groundwater in Alluvium
Groundwater occurs as the water table and semi-confined to confined conditions in the porous alluvial formations. Gravels, coarse to fine sands, clay and silty clay constitute the alluvial materials and among these, gravel and sand form potential aquifers. The alluvium deposited by the Cooum and Adayar rivers is limited in thickness and it is highly variable. The beach sands of Besant Nagar-Thiruvanmiyur have better yields. The tube wells constructed in the alluvium vary from 10 to 30m in depth and the depth of dug wells vary from 8 to 10m.

Groundwater in Gondwanas and Tertiaries
Groundwater occurs under water table conditions and confined conditions in the Gondwana formations. The shale and clay are highly consolidated and fractured and act like weathered crystalline rocks. The fractures and bedding joints within sandstones and shales contribute to a moderate quantity of water. The quality of water from the wells tapping granular zones of the top alluvium and the weathered Gondwana sediments is generally brackish to potable in nature.

The presence of Tertiary sandstones and shales are not clearly demarcated in Chennai city. Groundwater in these formations occurs under semi-confined to confined conditions.

Groundwater in Archaean Crystallines
The crystalline rocks underlie the southern part of the city and the occurrence of ground water is essentially limited to the weathered mantle and the fracture zones in the rock. These hard rock aquifers are heterogeneous in nature and their water bearing characteristics like weathering and fracturing vary widely both laterally and vertically. Groundwater occurs under phreatic conditions in weathered rocks and under semi-confined conditions in the fractured and fissured zones of the rocks. The thickness of the weathered mantle is 5.0 to 10.0m in general. The thickness of soil cover varies from place to place.

Monitoring of groundwater levels
The Hydrogeology wing of CMWSSB is carrying out monitoring water table in Chennai city periodically. A network of 71 observation wells (shallow open wells) has been set up throughout the city monitoring various lithological formations. Water levels in these wells are being observed every month from 1987 onwards and water samples are being collected quarterly from 22 wells for quality analysis. The locations of observation wells are given in the enclosed map (Figure 17).

Apart from CMWSSB, the Central Groundwater Board (CGWB) and the Groundwater Department of State P.W.D. are also monitoring the groundwater table in the city. The CGWB has 14 observation wells with the data collected on quarterly basis and the Groundwater Wing of P.W.D. has 18 observation wells with the data collected monthly.

The average water level data collected over the period from 1987 to 2003 covering all the 71 observation wells is given in the graph (Figure 18).

Study of Groundwater Fluctuation
The water table generally follows the topography with gentle slopes towards the rivers as well as the sea. In general, the average depth of water level in the city ranges between 3.00m to 6.75m during the pre-monsoon/summer and 1.35m to 3.50m during the post-monsoon period. This varies according to different lithological formations. The depth to water level (pre-monsoon and post-monsoon) for each group of formations from I to VII is given in the table.

	Depth to Water Level in metres						
Groups	I	II	III	IV	V	VI	VII
Pre-monsoon	8.50	8.00	9.00	10.50	7.00	7.00	9.00
Post-monsoon	1.50	0.50	2.55	1.10	G.L.	2.00	1.00

There are many factors that influence the fluctuation in water table including:
- Amount of rainfall
- Quantum of exploitation by the residents
- Rate of supply by Metrowater Board
- Increasing population every year

It has been observed that in all the formations the minimum water level (highest level) has been observed during the period December to January and maximum water level (lowest) observed during the period April to May. In general, the water table depleted during the summer is replenished during the subsequent North-West monsoon rainfall. However, the rate of depletion and recharge vary for different lithological formations.

During the period of low rainfall and drought years the water table goes down sharply and most of the dug wells become dry. Naturally, during this period the groundwater extraction for domestic purpose increases manifold and the situation becomes worse.

In recent years, due to the development of multi-storied apartments in the city, it has become necessary to construct deep bore wells as the shallow open wells could not sustain the effect of over withdrawal to meet the domestic water requirements in such complexes. The increase in number of apartments results in heavy withdrawal of groundwater locally. The rate at which the water level declines indicates the rate of groundwater abstraction.

The water table was depleted highly during the years 1993, 1997, 1999–2000 mainly due to low rainfall. The nature of fluctuation follows the same pattern in all the areas except in Velachery, Guindy and Villivakkam. Velachery and Guindy comprise hard rock formations and Villivakkam is comprised of clayey formations. The rate of recharge and aquifer storage characteristics are limited in these formations.

Even though the quantum of water level depleted during the summer is replenished during the subsequent North-East monsoon rainfall, there is a decreasing trend in the water table noted from 1996 onwards until 2001. Insufficient rainfall and much reduction in the rate of Metrowater supply results in the heavy withdrawal of groundwater. The rapid rate of urbanisation during the recent years has contributed mainly to the depletion of the groundwater table. However, the water table improved considerably during 2002 due to the South-West monsoon. A graph showing the relationship between rainfall and water level is enclosed (Figure 18).

As the rate of depletion of groundwater table has increased during the last 3 to 4 years it has become important that certain remedial measures have to be taken to conserve the groundwater resources. In this context, Rain Water Harvesting plays a vital role in sustaining the water table and conserving the groundwater.

EI.5. DEVELOPMENT AND CURRENT USE OF WATER RESOURCES IN THE SOUTHERN AQUIFER

EI.5.1 Introduction

This aquifer is bound in the east by the Bay of Bengal, in the west by Buckingham Canal, in the north by Thiruvanmiyur and in the south by Muttukadu and covers an area about 36km^2 with a gentle slope towards the sea. The ground elevation ranges from sea level to 8.00 m. The average rainfall is 1200mm and 60% of the rainfall is from the North East monsoon. The nearest rainfall station is at Kovalam and annual rainfall totals from 1971 to 2003 (Oct) is given in the graph (Figure 19).

EI.5.2 Geology and hydrogeology

The alluvial deposits consist of sand, silt and clay, and the thickness ranges between 16 and 22m. The alluvium is underlain by charnockite of Archaean age. To the east of the Buckingham canal the alluvial thickness ranges from 14 to 23m and in the west the alluvial thickness varies from 10 to 14m. The alluvial aquifer is unconfined in nature and recharge is mainly from direct infiltration of rainfall.

In 1975, Tamil Nadu Water Supply and Drainage (TWAD) Board developed an emergency water supply scheme to meet the prevailing drought situation. Due to this, the city had a 4.5Mld supply from a 5km stretch of this aquifer. Subsequently the Geological Survey of India (GSI) conducted a detailed hydrogeological survey during 1975 – 77 in this coastal belt from Thiruvanmiyur to Kovalam for a distance of 20km. The observations made by this study are,

- Potable groundwater occurs under water table conditions.
- The main recharge is by infiltration of rainfall, and
- There is no surface run-off except during stormy rains.

Engineering Science Inc. (USA) 1976-1978 studied the coastal aquifer between Thiruvanmiyur and Kovalam for a distance of 20km, with the help of information compiled and assembled by the GSI, and made the following observations.

Fresh water exists in the coastal zone between Thiruvanmiyur and Kovalam, where the Buckingham canal meets the Bay of Bengal.

It is possible to extract 25Mld of groundwater from the 20km stretch of coastal zone over a width of about 750m without causing adverse effects.

To reassess the groundwater potential and to study the possibility of seawater intrusion a project, “Hydrogeologial and Seawater Intrusion Studies between Thiruvanmiyur and Muttukadu”, was awarded to M/s. Rites during 1996 by CMWSSB. Rites reported that, since the seawater – fresh water interface lies 6m below ground level, it is advisable to maintain the extraction such that it should not go beyond the level of 6.0m. However, due to the continuous poor monsoon since 1999, the water level in this aquifer has gone down below this safe limit from March 2003 onwards, in the thickly populated Thiruvanmiyur, Kottivakkam, Palavakkam and Neelankarai area. In Akkarai area the average water level is 5.5m below ground level. In Sholinganallur, Panayur, Uthandi, Kanathur, Karikattur and Muttukadu the water level is less than 5m. The water level in this aquifer has since been monitored from 28 shallow wells. The details are given in the table and graph (Figure 19).

EI.5.3 Groundwater use

Groundwater from this aquifer is being extracted by 19 shallow open/dug wells with a total depth ranging from 7.75 to 11.60 m. The locations are shown in Figure 20. There are eight wells in the Neelangarai area and eleven wells in the Akkarai area. Extraction from individual wells ranges between 0.06 to 0.50Mld. The wells are located along the coastal area between the East Coast Road and the Bay of Bengal. In the Neelangarai area the wells are located from Neelangarai to Injambakkam and in the Akkarai area the wells are located from Akkarai and Nainarkuppam. Groundwater extracted from these wells is pumped to the Thiruvanmiyur head works for further distribution. Presently about 3.5Mld is being extracted from these wells. Apart from these 19 wells, two more wells have been constructed in Panaiyurkuppam village of Akkarai area by Metrowater Board, to supply water exclusively to Aavin Dairy at Sholinganallur. The details of production wells at Neelankarai and Akkarai area are given below.

Details of wells in Neelankarai Area

Well No.	Location	Total Depth (m)	Water level in metres as on 17-2-2004		HP of pump	Hours of pumping per day	Expected yield (Mld)
			Static	Pumping			
1	Neelankarai (burial ground)	9.60	6.90	--	7.5	12	0.25
2	Neelankarai (Buhari)	9.35	6.10	--	7.5	7	015
3	Chinnandi Kuppam (GEM)	8.70	5.50	--	7.5	13	0.27
4	Near VGP	11.60	5.00	6.10	7.5	8	0.17
5	Head works	8.20	7.00	--	7.5	3	0.06
6	Neelankarai (near office)	8.20	6.20	--	7.5	5	0.10
7	Injambakkam (Lions' Club)	10.50	--	5.80	7.5	6	0.12
8	Injambakkam EB Office	9.95	--	7.90	7.5	6	0.12

Details of wells in Akkarai Area

Well No.	Location	Total Depth (m)	Water level in metres as on 17-2-2004		HP of pump	Hours of pumping per day	Expected yield (Mld)
			Static	Pumping			
4	Akkarai	9.00	--	6.10	7.5	24	0.50
5	Akkarai	8.10	--	3.15	7.5	24	0.50
6	VGP Layout	8.80	3.30	--	7.5	12	0.25
7	VGP Layout	8.80	4.60	5.80	7.5	12	0.25
8	Rajiv Gandhi Nagar	7.75	3.75	5.55	7.5	24	0.50
9	Kudumiyandi Thouppu	9.35	5.65	--	7.5	15	0.31
10	Nainarkuppam	8.55	3.15	--	7.5	15	0.31
11	Allikulam	--	--	--	7.5	3	0.06
12	Head works	10.75	5.75	--	7.5	3	0.06
13	Panaiyur	--	--	--	7.5	24	0.50
14	Panaiyur	--	-	--	7.5	24	0.50

EI.6. DISTRIBUTION AND TREATMENT OF RAW WATER FOR SUPPLY

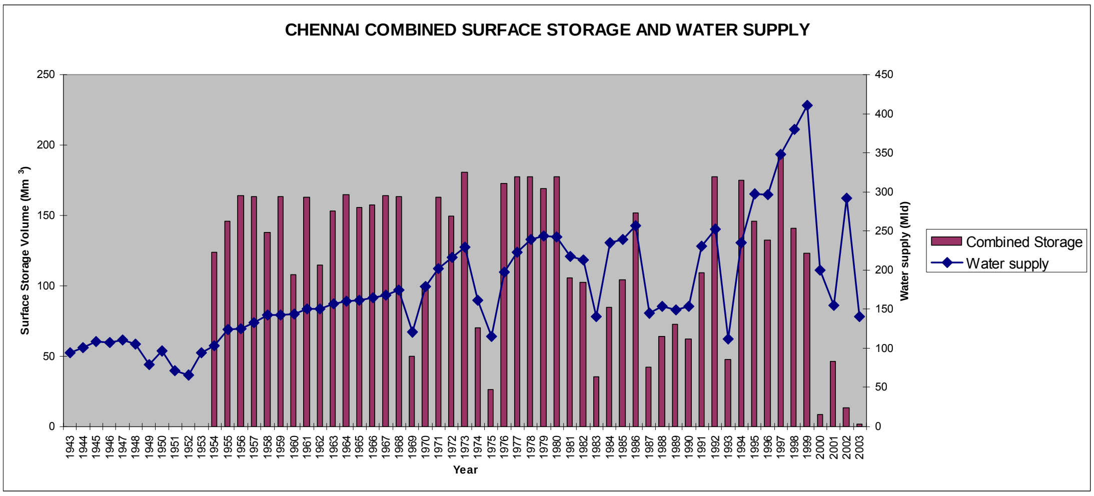
EI.6.1 Introduction

The distribution of the raw water from the surface reservoirs, treatment works and transmission mains to the water distribution stations within the city is shown on the attached map (Figure 21).

EI.6.2 Domestic Water Supply

The predominant water supply to Chennai is from the surface water i.e. run off during monsoon periods, stored in three surface reservoirs (Poondi, Cholavaram, Red Hills). Since 2000, storage in the Chembarambakkam reservoir is also being diverted to Chennai City. The water supply to the city from these reservoirs depends upon the storage available. The appreciable increase in water supply during 1996 to 2002 is attributed to the additional storage available in the reservoirs due to contributions from Krishna Water Scheme. Graph showing the relationship between combined storage and water supply is given below (Figure 22).

Figure 22



EI.6.3 Domestic Water Supply outside the metropolitan area

In the rest of the study area, the TWAD (Tamil Nadu Water and Drainage Board) is responsible for carrying out the selection of well site, drilling of bore well, well development and construction of overhead tanks. After the completion of the work, the well is handed over to the local authorities for maintenance and utilisation. There is no record available regarding the extraction from these sources. However, M/s. Scott Wilson Piesold (UK), who are reassessing the groundwater potential in A-K Basin, has arrived at a tentative quantity for domestic use in the study area, based on the population statistics. For this calculation, the water consumption in the rural area was assumed as 40lpcd and for the urban areas it has been taken as 70lpcd. The estimated quantity is 20Mm^3.

EI.6.4 Industrial Water Supply

Groundwater from the six well fields in the A-K Basin supplies the industrial area at Manali, north of Chennai city. The average quantity supplied to the industry is 14.6Mm^3/year (40Mld). Groundwater acts as a supplement to surface water for city requirements only during drought years.

EI.6.5 Water Treatment Plants

There are two water treatment plants at present treating the raw water from the three reservoirs Poondi, Cholavaram and Red Hills.

- Kilpauk water works
- 300 Mld Treatment plant at Red Hills

Kilpauk Water Works
This treatment plant was established in the year 1914 and the present capacity is 270Mld. The raw water from the Red Hills reservoir comes to this treatment plant by gravity through pipelines. The treatment methods are by chlorination and addition of chemicals such as alum, lime followed by flocculation, clarification and filtration through rapid gravity filtration. Apart from treatment of water, this location is also used as water distribution station.

Due to insufficient rainfall only dead storage is available in all the three reservoirs. The dead storage in the Red Hills reservoir is being diverted to city by digging a canal to the discharge point. Now the plant receives only 10 to 15Mld raw water to treat.

300 Mld Treatment Plant
This treatment plant is located beside the Red Hills reservoir. Construction was completed in 1996, mainly to treat the additional water arriving from the Krishna Water project. The method of treatment is the same as in the Kilpauk Water Works. The filter house has programmable logic control operation. The treated water from this plant can be supplied by three raw water trunk mains to the North, Central and South zones of Chennai city. However, at present this plant is not functioning due to very low levels of storage in the reservoirs.

530 Mld Treatment Plant
This plant is under construction and situated beside the Chembarambakkam reservoir. This plant was also constructed to treat water transferred from the Krishna water canal and stored in Chembarambakkam reservoir and to supply Chennai city. This reservoir is connected to Poondi reservoir by a link canal to transmit the surplus Krishna water from Poondi reservoir. This treatment plant is going to use pulsator technology.

EI.6.6 Distribution

In view of the water demand of the projected population of Chennai city for the year 2021; removing the existing systemic deficiencies and to ensure equitable distribution of water throughout the city, CMWSSB is in the process of executing a Water Supply and Sewerage Master Plan. Apart from four existing water distribution stations, namely Kilpauk, K.K. Nagar, Southern Head Works and Anna Poonga a further 12 additional water distribution stations were planned as part of the master plan for utilisation of additional supply from Krishna river. Out of the 12 stations, five stations, namely Valluvarkottam, Triplicane, Choolaimedu, Kannaparthidal and Ekkattuthangal, were taken up under HUDCO funding and are now completed. The balance of seven stations, namely Koluthur, Vyasarpady, Patel Nagar, Pallipattu, Mylapore, Nandanam and Velachery were taken up under World Bank assistance as part of the Second Chennai Water Supply Project.

Sl.No.	Name of the Water Distribution Station	Improvement made	Capacity in Mld
1	Kannappar Thidal	Under HUDCO Funds	18
2	Triplicane		17
3	Choolaimedu		6 / 45
4	Valluvarkottam		18
5	Ekkattuthangal		4
6	Patel Nagar	Under World Bank Funds – Second Chennai Project	12
7	Vyasarpadi		6
8	Kolathur		4
9	Mylapore		5
10	Nandanam		5
11	Pallipattu		10
12	Velachery		5
13	Anna Poonga	Existing Water Distribution stations	3
14	Kilpauk		270
15	Southern Head works		
16	K.K. Nagar		14

At present, the water from the treatment works is delivered to the Water Distribution Stations by the transmission mains and is then being supplied to the surrounding areas only by tanker lorries, due to shortage of water.

EI.6.7 Water supply to Adjacent Urbanised Areas and Distant Urbanised Areas

Metrowater decided to expand its area of operation around the city into the Adjacent Urbanised Area (165km^2) and in the Distant Urbanised Area (142km^2) expecting the receipt of Krishna water. The work has been proposed to be undertaken in two phases.

In the Phase I the work has been taken up in three AUA's and the details are as follows.

Beneficiary AUA	Scheme	Estimated cost Rs. Crores ($x10^7$)	Population benefited	Present stage of work
Korattur (Ambattur Municipality)	Water supply	1.20	15,000	Commissioned in August 1998
Pukhraj Nagar (Madhavaram Municipality)	Water supply	0.94	28,000	Partly Commissioned in March 1999
Padi Pudu Nagar (Ambattur Municipality)	Water supply and Sewerage facilities	1.90	20,000	Completed in March 1999 Commissioned in July 1999

In the Phase II, action to augment the water supply in another set of urbanised areas has been initiated. Brief details of this Phase of the Project are as follows:

Name of the Local Body	Quantity of additional water to be supplied in Mld	Population benefited	Estimated Cost of the Project Rs. Crores ($x10^7$)
Alandur St. Thomas Mount (AUA)	12.8 1.6	150,000 18,000	6.65
Pammal (DUA) Anagapthur (DUA) Meenambakkam (Panchayat)	3.0 1.5 0.5	50,000 26,000 12,000	3.90
Pozhichalur (Panchayat) Gowl Bazaar (Panchayat)	1.0 0.5	26,000 12,000	2.86
Puzhuthivakkam (AUA)	0.8	18,000	2.83
Porur (AUA)	3.2	35,000	4.26
Valasaravakkam (AUA)	2.6	31,000	1.85
Maduravayal (AUA)	1.9	32,000	2.90
Ramapuram (AUA)	2.0	31,000	1.29
TOTAL	**31.4**	**441,000**	**26.54**

However, due to the prevailing drought condition, there is not sufficient water even to meet Chennai city's requirements. Therefore, the water supply to the AUA and DUA will be undertaken when there will be enhanced water storage in the four surface water reservoirs from rainfall and Krishna water transfers.

EI.7. AUGMENTATION OF GROUNDWATER RESOURCE

EI.7.1 Rainwater harvesting

Considering the importance of Rain Water Harvesting (RWH) in conserving the precious ground water resource, the Metrowater Board has taken the initiative to constitute a fully dedicated "Rainwater Harvesting Cell". The main objective of the cell is to create awareness and to offer technical assistance, free of cost to the residents, to select and implement suitable cost effective methods of RWH in their premises voluntarily.

An information centre on RWH was opened at the CMWSS Board Headquarters and wide publicity has been given through press, radio and TV media including various private TV channels informing the public on its use and to encourage its services. Regular training programmes were being conducted at the Metrowater Resources Centre for the benefit of public, private engineers and construction workers. A list of resources persons has been prepared and made available to the public. Various information on Rainwater Harvesting including design of various structures, guidelines, list of resource persons, are also made available on Metrowater's website http:/www.chennaimetrowater.com.

In order to ensure proper reach throughout various sections of the public CMWSSB has established RWH live demonstration structures in Raj Bhavan, High Court, Lady Willingdon school, Presidency College, Children's Park, Museum etc.

A Rain Water Harvesting centre has been set up in Anna Nagar office, where simple and cost effective working models are exhibited. An Information Centre at the High Court complex has been erected for providing information and guidance to the public.

The provision for Rain Water Harvesting structures has been made compulsory for the building (irrespective of size and areas) for new water and sewer service connections. Amendments have been made in the existing Tamil Nadu Municipal Buildings Rules and in the Chennai Metropolitain Area Groundwater (Regulation) Act to make Rainwater Harvesting mandatory for all the buildings.

Advertisements / Public notices are issued in all leading newspapers. Special booklets / brochures are issued along with the newspaper / weekly magazines giving information on the various methods of Rainwater Harvesting. Programmes on Rainwater Harvesting have been arranged in the electronic media also.

Due to the intensive campaign and due to the ordinance issued a large number of people are installing Rainwater Harvesting structures in their houses. Rainwater Harvesting structures have been installed in 319,297 houses / buildings.

To monitor the effect of RWH, 730 domestic wells have been selected in Chennai city where the quality and water level are monitored periodically. Since there was not sufficient rainfall during the year, no significant effect has been noted. Methods of Rain Water Harvesting are explained in Figure 23.

EI.7.2 Macroscale (artificial recharge – check dams)

In order to improve the availability of ground water in future years, certain long term measures such as (i) construction of check dams to recharge the aquifer and (ii) construction of injection wells in Minjur aquifer to arrest sea water intrusion were initiated as a result of the UNDP studies.

There are already two anicuts across the Araniar, namely A.N.Kuppam and Lakshimipuram and two across the Korattaliyar river, namely Tamaraipakkam and Vallur. Based on the recommendation of the UNDP studies, five further locations for check dams were proposed. These would harness the flood waters in Korattaliyar river during high flow periods in order to increase recharge of the aquifer. Of the five locations recommended by the study, check dams were constructed at three locations along the Korattaliyar river, at Melsembedu, Velliyur and Jaganathapuram, during 1991-93 by the CMWSSB. Due to the construction of these check dams some of the production wells in the well fields closest to them have benefited from appreciable recharge. Water level measured before and after the construction of the check dam indicates the increase in water level. In general the water level increases during the rainy seasons but whenever there is water storage behind the check dam the water level in the nearby production wells is measurably recharged. The radius of recharge effect is seen to be around 2km. The average rise of water level around the check dam is 2m. This may vary depending upon the quantity and the duration of storage of water behind the check dam. It is expected that an additional quantity of 9Mld can be pumped due to the recharge effect of the check dams.

EI.7.3 Injection wells

In the Minjur area to arrest the sea water intrusion, the UNDP study recommended the construction of recharge wells between the coast and Minjur to arrest sea water intrusion. The proposal was to use part of Minjur well field water for recharge purpose. This experiment to assess the intake capacity of recharge well was conducted in an area north of Nanthiampakkam village, where the aquifer has already been affected by seawater intrusion. Based on the positive results obtained from the test a proposal was formulated to create an artificial barrier by providing a battery of 15 injection wells parallel to the coast to the east of the Minjur well field with an injection rate of around 6.8Mld of fresh water from the well field.

EI.8. AUGMENTATION OF SUPPLY

EI.8.1 Managing and Developing Existing Resources/facilities

In view of the expected gap between demand and supply in the future, CMWSSB has initiated various conservation measures as a part of its comprehensive water management strategy. Leak detection and rectification work, installation of small reverse osmosis (RO) plants and the hiring of agricultural bore wells in the A-K Basin are some of the important measures being systematically undertaken by CMWSSB.

EI.8.2 Leak Detection and Rectification work

Due to growing demand, conservation measures such as unaccounted for water programmes and leakage control measures are drawing increased attention among water utilities as alternative means to extend the available sources. In an effort to address comprehensively and successfully the issue, CMWSSB has embarked upon a massive leak detection and rectification work throughout the city. Under this programme, all house service lines are proposed to be replaced with non-corrosive Medium Density Poly – Ethylene (MDPE) pipes along with the renewal of all damaged distribution mains and PVC/AC distribution mains with cast iron pipes. Due to this effort, the leakage level is hoped to be reduced from 30% to 5%, compared with an internationally acceptable leakage level of 10%. The overall saving is projected to be about 30Mm^3/year (80Mld) of water.

EI.8.3 Reverse Osmosis Plants

CMWSSB has taken a conscious decision to focus on Fisherman's colonies and economically disadvantaged sections of the public, to supply them with good quality water for drinking and cooking purposes. Since most of them are located close to the sea and at the end of the city water supply distribution system, they suffer from lack of potable water, resulting in major health related problems. CMWSSB has proposed to locate a number of RO plants to help these groups by supplying potable water by treating locally available brackish groundwater through the reverse osmosis process.

The RO plant consists of shallow dug wells and borewells to provide the required brackish water for treatment. The raw water drawn from the wells is stored in storage tanks and pumped to the dual media filters, consisting of quartz sand and anthracite, wherein suspended particles are removed. The filtered water is then pumped to a micron filter to remove the micron size particles and then fed into the Reverse Osmosis Process Unit by means of high pressure pumps. The Reverse Osmosis Process Module consists of a thin film composite of polyamide membrane. When brackish water is passed through this membrane, the dissolved solids are removed and the output water is of potable quality with a dissolved solids content below 500ppm. The rejects from the RO module with high salt content is put into the nearby server system for disposal, since the quality is within the permissible limit for disposal through the server system.

In Chennai city the small scale RO plants were installed at four locations, namely Velachery (1998), Nachikuppam (1998), Royapuram (2001) and Ayothikuppam

(2003) to treat brackish water of up to 5000TDS. The average production is 100,000litres per day in each plant.

EI.8.4 Hiring of Private Agricultural Wells

Due to the limited source of surface water and ground water, agricultural wells are hired from farmers to extract groundwater in order to manage the severe drought situation.

The groundwater from the hired agricultural wells are collected in a sump and pumped into the existing distribution system. The location of the collection sump is based on the availability of a cluster of 15 to 20 borewells within a radius of 1.5km. The agreement with the farmers is that each borewell has to supply 0.4Mld for 18 hrs. of pumping. At present there are 15 such collection sumps in the A-K basin and there is a proposal to have more. Each collection sump supplies about 5 to 8Mld. This system of hiring agricultural wells was started in April 2001 and at present about 22Mm^3/year (60Mld) is being extracted from these wells.

In villages where it is not possible to get a cluster of 15 to 20 borewells, the groundwater from even two or three wells in villages within the radius of 100km of the city is being transported to city by tankers/lorries. At present around 18Mm^3/year (50Mld) is supplied to the city in this way.

EI.8.5 Reuse of waste water

To conserve the fresh water, an attempt was made to supply secondary treated sewage to industries, which will in turn treat and use it for industrial purpose. Two major water intensive industries (an oil refinery and a fertiliser plant) were advised to use the secondary sewage effluent after appropriate further treatment. They have set up a tertiary treatment unit and about 18Mm^3/year (50Mld) of secondary sewage effluent is being supplied by CMWSSB. This practice of reuse of water has been taken up further by a power plant, which has started using about 10Mld of raw sewage after further treatment at their premises. Recently both petro-chemical plants in Manali plan to expand the re-use of treated sewage effluent from the city.

EI.9. DEVELOPING NEW SOURCES

EI.9.1 Telugu Ganga Project (Krishna Water)

An agreement was made in February 1976 between three states namely, Andhra Pradesh, Karnataka and Maharastra each to spare 5TMC (141.6Mm^3) of water every year to meet the drinking water needs of Chennai City. During October 1977, the above states agreed to spare the above said 15TMC (425Mm^3) of water from Sri Sailam Dam in Andhra Pradesh. Then an agreement was made with Andhra Pradesh during April 1983 for supplying 12TMC (340Mm^3) of water at the Zero Point of the Kandaler-Poondi canal near the Tamil Nadu border according to the following Schedule:

- July to October 8 TMC(Thousand Million Cubic Feet)
- January to April 4 TMC

Total 12 TMC (340Mm^3)

The project provides for the drawing off from the reservoir and conveying by canal 15TMC of water to Chennai (12TMC, excluding losses) besides irrigating about 275,000 acres in the Royalaseema region of Andhra Pradesh. The various components of the scheme are shown on Figure 24. The capital cost of all the components is Rs. 2191x10^7, out of which Government Tamil Nadu's share was Rs. 522x10^7. So far the Government of Tamil Nadu has paid Rs. 512x10^7. The quantity of water received from this scheme is shown below.

Year	Quantity in TMC
1996	0.076
1997	2.292
1998	2.812
1999	1.83
2000	3.591
2001	3.437
2002	3.342

There has been no water received from scheme since 2003, due to the prevailing drought in Andhra Pradesh.

EI.9.2 New Veeranam Project

The Chennai Water Supply Augmentation Project (New Veeranam Project) is to draw 69Mm^3/year (190Mld) of raw water from Veeranam Lake, which is at a distance of about 230 km south of Chennai City. The various components of the scheme are shown on Figure 25. 65Mm^3/year (180Mld) of water is to be treated, conveyed and distributed to Chennai City. The project is estimated to cost Rs. 120x10^7 and is being implemented to meet the part of Chennai City Water Supply requirements. The work was commenced in November 2002 with a completion period of 18 months. The project is due for completion by March 2004. The testing and commissioning of the system will commence in April 2004 and the entire system will be ready by the end of May 2004. In this project, the major components involved are (i) raw water withdrawal and pumping arrangement (ii) conveyance and treatment (iii) treated water pumping (iv) conveyance and distribution to Chennai City. The total length of the mild steel pipeline is about 230km and the pipe size ranges from 1500mm to 1875mm diameter.

The storage in Veeranam Lake is dependant on the flows in Coleroon river, which itself carries the surplus flows from Cauvery river. Even though the pipeline under this project may be ready by May 2004, due to failure to monsoon, this source may not be counted upon to bring relief to Chennai City in the current year.

EI.9.3 Drilling of Borewells in Panruti Vadalur Aquifer

A feasibility study to extract groundwater along the route of the pipeline laid for the Veeranam project identified that it is possible to extract 22Mm^3/year (60Mld) from the Panruti-Vadalur aquifer, which is 200km south of Chennai City. Based on the recommendation of this study it was proposed to drill 40 deep borewells (250 m) in this aquifer and then convey the water to Chennai City through the pipe line laid for the Veeranam project. This work commenced in March 2004 and will be due for completion during May 2004.

EI.9.4 Construction of Collector wells in Coleroon river bed

In addition, another feasibility study is considering tapping 36Mm^3/year (100Mld) from the Coleroon river bed, which is 230km south of Chennai City, by constructing a series of collector wells. The water from this scheme will also be conveyed to the Chennai City through the pipelines laid for the Veeranam project.

PART II AL JAFR – SHOUBAK CASE STUDY

EII.1. THE CASE STUDY AREA

EII.1.1 Description of the area

The two case study areas, Al Jafr and Shoubak, are in the Al Jafr basin. The basin is located in the southern part of the Hashemite Kingdom of Jordan. The basin is situated between latitudes 19°30'N and 20°30'N and longitudes 35°30'E and 37°00'E. The location of the project area is shown on Figure 1.

The Al Jafr basin is located to the west of the Wadi Araba and Southern Ghors rift valley system and is part of the Central Jordanian Plateau. The basin shows a centripetal drainage pattern with all wadis draining from the surrounding highlands to the central desert playa at Al Jafr. The ground elevations vary from 1400m above sea level in the western highlands around Shoubak to 860m above sea level at Al Jafr.

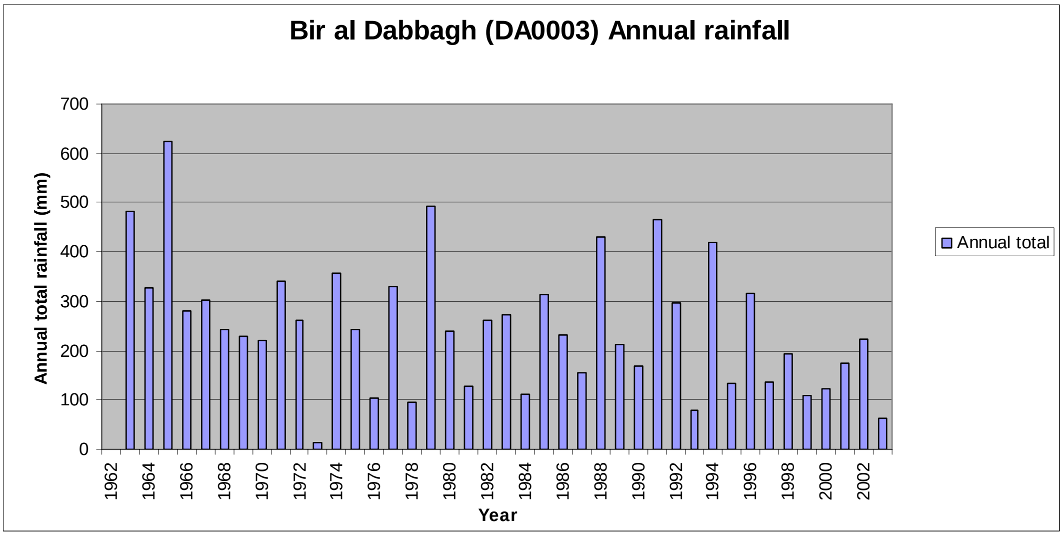
The central part of the basin is a peneplain with occasional hills and weakly incised wadis with intermittent flows resulting from local precipitation that is usually intense and caused by scattered storms.

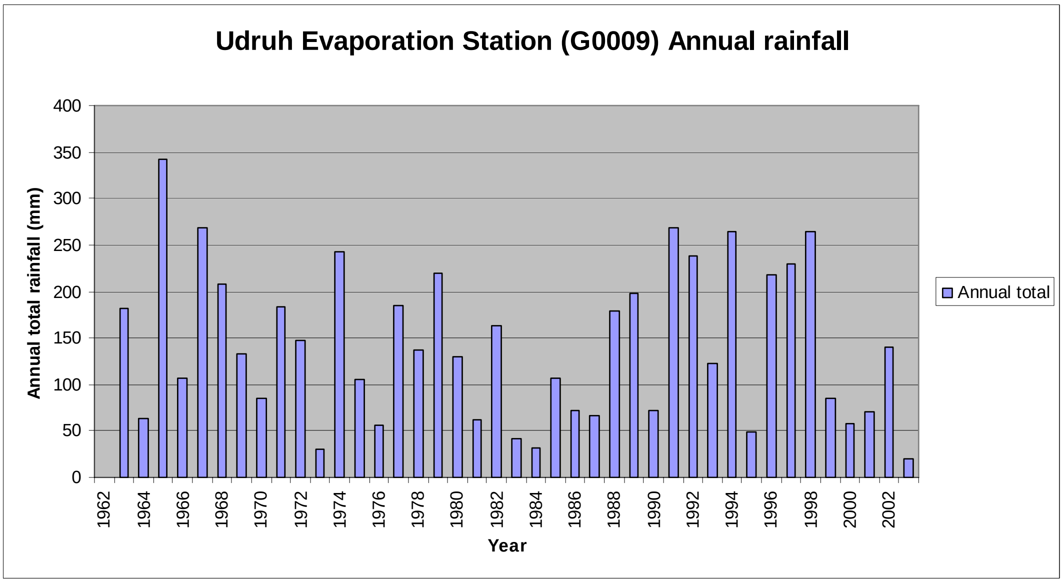
The climate varies between arid and semi-arid desert for most of the basin with a Mediterranean type climate in the highlands in the west. The basin plateau of the eastern desert is hot in summer and cold in winter. The temperature may reach more than 40°C during summer days and drop to a few degrees below zero in winter, especially during the night. The humidity is also low, in winter around 50-60% and in summer it may fall to 15%. In the highlands, the climate is more temperate, cold and wet in the winter with temperatures reaching a few degrees below zero during the night and hot dry summers with temperatures reaching 35°C at midday but with a relative humidity of 15-30%, temperatures at night drop to below 20°C and cause dew to form.

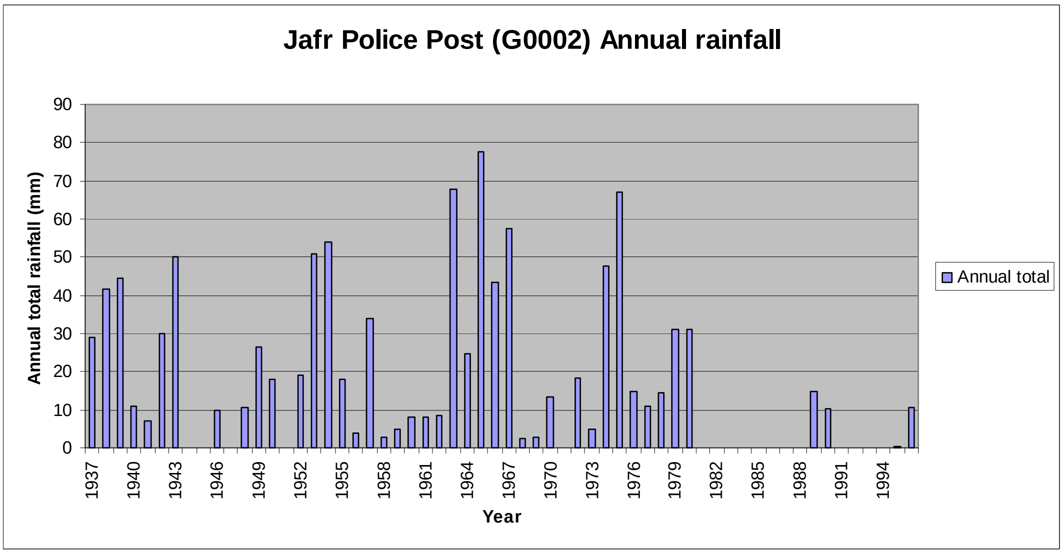
The average total rainfall varies between 300mm/annum in the west and less than 40mm/annum in the east. The area is provided by winter rainfall from October to May with the majority falling in January and February. Snowfall does occur once or twice a year in the highlands with up to 75 days of frost. The mean annual potential evaporation rate varies from 1150mm/year in Shoubak to 2500mm/year in Al Jafr. The annual rainfall varies significantly about the mean value and in a cycle between 1 and 5 years, with drought periods that continue for 3 to 5 years. Plots of annual rainfall totals for three rainfall stations across the study area are included as Figure 2. Bir al Dabbagh is in the western highlands, Udruh is further east and the third is a record for the Al Jafr area.

The water supply to the Al Jafr – Shoubak areas is derived from both surface water from a limited number of spring sources in the western highlands and groundwater sources.

Figure 2


Bir al Dabbagh (DA0003) Annual rainfall
Annual total rainfall (mm)
Year
Annual total

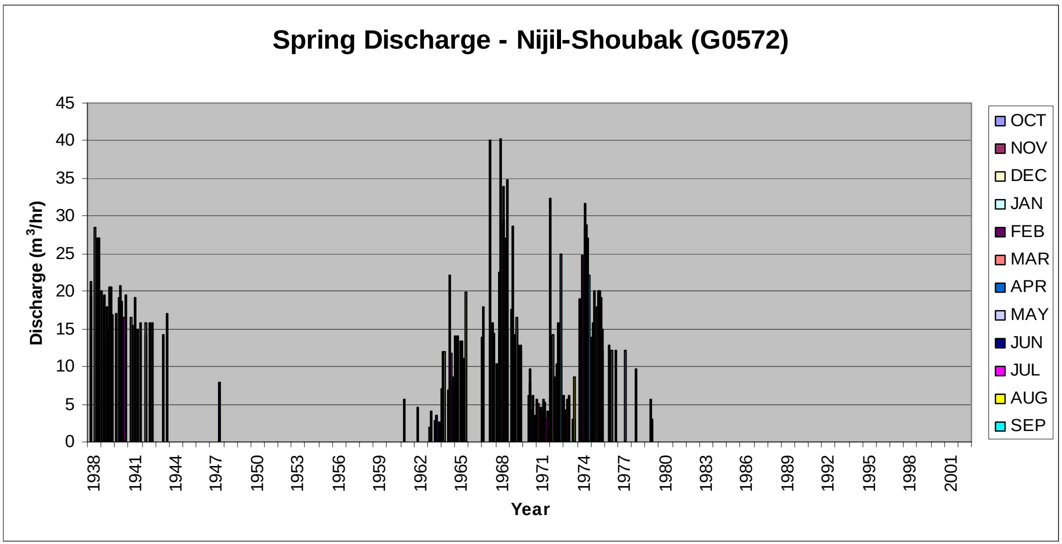

Udruh Evaporation Station (G0009) Annual rainfall
Annual total rainfall (mm)
Year
Annual total

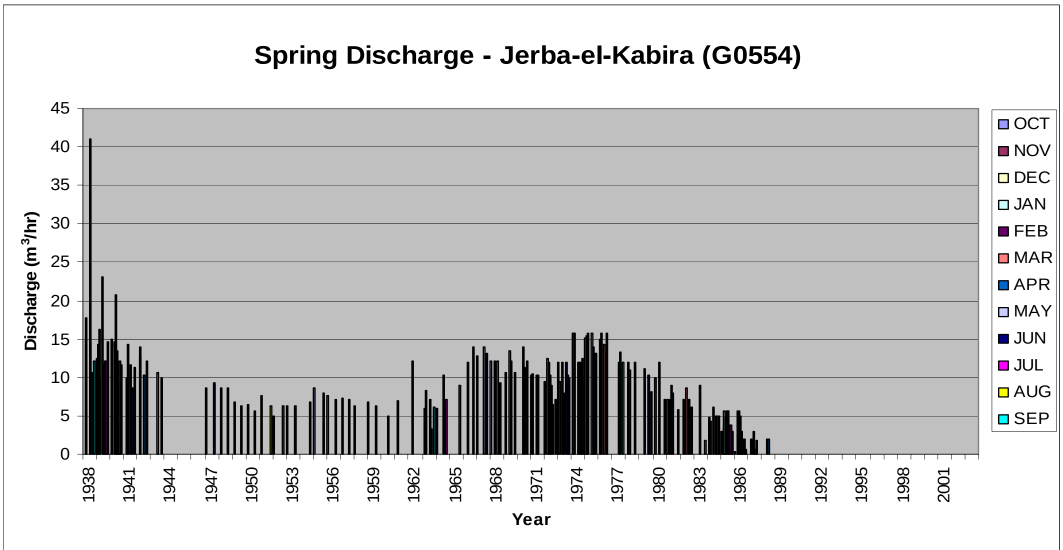

Jafr Police Post (G0002) Annual rainfall
Annual total rainfall (mm)
Year
Annual total

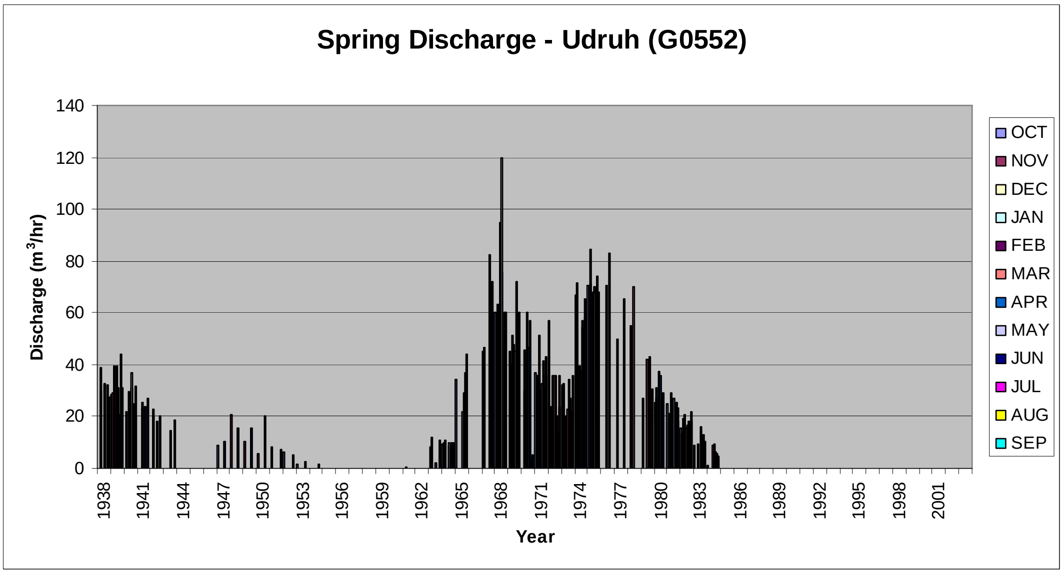
EII.1.2 Surface water

The Al Jafr basin is a completely contained depression with a catchment area of around 13,500km^2. The total surface water runoff of the catchment is reported to be between 22Mm^3/year (JICA) and 15Mm^3/year of which 10Mm^3/year flows as floods into the Al Jafr depression where they either evaporate or infiltrate into the ground (Kdhier). There are no perennial stream flows. There are proposals to augment recharge to the aquifer by the construction of recharge dams at six locations across the wadis in the Western Highlands (JICA, 1990). One earth-type dam to harvest the annual runoff in Wadi Jurdaneh for watering of livestock has been constructed.

Base flow in the form of spring discharge in the western highland is used for irrigation. The Ministry of Water and Irrigation (MWI) Data Bank has provided discharge data for the main springs in the area. The mean annual spring discharge is reported as between 0.75Mm^3 (JICA) and 1.3Mm^3 (Kdhier). The long term records show that there has been a general reduction in spring flow in recent decades with a number drying up completely. These include Nijil-Shoubak (G0572), Jerba el Kabira (G0554) and Udruh (G0552) that have all dried up since 1989. The plots of monthly discharge (m^3/hour) measurements are included in Figure 3.







EII.1.3 Groundwater

Groundwater is the major source of water in Jordan. The aquifers of Jordan are divided into three main systems or complexes:

- Deep sandstone aquifer complex
- Upper Cretaceous carbonate aquifer complex, and
- Shallow aquifer complex

The Upper Cretaceous carbonate aquifer system forms the major regional aquifer system of Jordan and this is so in the Al Jafr basin. It is essentially continuous and contains productive aquifers throughout the country.

Four aquifers have been recognised within the Upper Cretaceous sequence. The main one is the Amman - Wadi Sir (B2/A7) which extends throughout most of the country. The others are the Na'ur (A1/2), the Hummar (A4) and the Rijam (B4) and are of importance locally throughout Jordan. In the Al Jafr basin the Hummar is not well developed.

The B2/A7 and the underlying older Kurnub (Lower Cretaceous) and Disi sandstones (Cambrian to Ordovician) form the deeper aquifers in the Al Jafr basin and are separated from each other by thick aquitards. A hydrogeological profile across the Al Jafr basin, taken from Khdier (1997), is included as Figure 4. In the central part of the basin, the overlying thick impervious argillaceous unit of the Muwaqqar (B3) Formation confines the B2/A7, while in the surrounding higher areas to the west it is unconfined. The different aquifers within this unit are considered to be in hydraulic continuity. The aquifer has an average thickness of 100m, 40m of Amman (B2) and 60m of Wadi Sir (A7). In general, the aquifer thins to the south and thickens to the north.

The main groundwater aquifer in the centre of the basin area is the B4 Formation of the Belqa group, consisting of thin beds of chert, limestones, clays and marls with a total thickness of 20-25 metres. In the central part of the basin the B4 is saturated under water table conditions, whilst in the surrounding areas it is unsaturated.

Recharge to the B4 aquifer takes place from surface runoff from the highland of Shoubak. Direct recharge to the saturated part of the aquifer in the centre of the basin is negligible because the surface area of the playa where the flood water collects is covered by very fine sediments which do not allow rapid infiltration and groundwater recharge.

The groundwater flow in the B4 and B2/A7 aquifers is generally from west to east. In the deeper aquifers, the groundwater flows in a generally northerly direction with components towards the northeast and northwest.

EII.2. WATER RESOURCE STUDIES

EII.2.1 Introduction

Groundwater investigations in Jordan began in the early part of the 20th century. There have been several regional studies that included water resource evaluation for the Al Jafr Basin.

- Muhammad M Abu-ajamieh (1967). A quantitative assessment of the groundwater potential of the Rijam Formation aquifer in the Jafr Basin, Natural Resources Authority.
- Bender and Duerbaum (1969) reported on the exploration and exploitation of groundwater in the Arja Uweina area for an irrigation project. This work was carried out in cooperation with the Natural Resources Authority of Jordan and the UN Special Fund Sandstone Aquifer Project.
- The UNDP study (1970) Sandstone Aquifer Project defined the general outlines of the hydrogeology of the region.
- Agrar-und-Hydroteknik (1977) compiled all the available data on geology, hydrology and groundwater for compilation of the National Water Master Plan of Jordan (WMP).
- Howard Humpreys Ltd. (1986) studied hydrogeology and hydrochemistry of the Mesozioc-Cainozoic aquifer of the Ma'an-Shidiya-El Jafr region.
- Japanese International Co-operation Agency (JICA) with the cooperation of WAJ (1990) conducted a study of the Wadi Hasa and Jafr basin. The study included drilling new observation boreholes and groundwater mathematical modelling.
- Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) (1991) and WAJ cooperated on a technical study of the groundwater resources of Southern Jordan.
- Kamel M. Khdier's doctoral thesis (1997) was an assessment of regional hydrogeological framework of the Mesozoic aquifer system of Jordan.

The bodies responsible in the past for monitoring/reporting on water resources in the Al Jafr basin include the Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ) and the Ministry of Agriculture (MoA). The MWI Data Bank provided water resource data for this project. In 2002 there were 190 wells in the Al Jafr basin as a whole extracting 25Mm^3. Of these, there were 32 for domestic supply, 20 industrial, 122 irrigation and 5 for domestic private use.

EII.2.2 Shoubak area and the Amman - Wadi Sir (A7/B2) aquifer

Within the outcrop area of the A7/B2 aquifer system in the Western Highlands a recharge mound has developed which is divided by tectonic and morphological features in to three flow systems (BfB). The largest part of the recharge area drains eastward towards the Al Jafr basin. The flow system of Nijil – Shoubak area drains north and that of the Wadi Musa area to the west of the surface catchment divide drains to the west to discharge as springs and seepages along the base of the A7 aquifer on the escarpment above Wadi Araba.

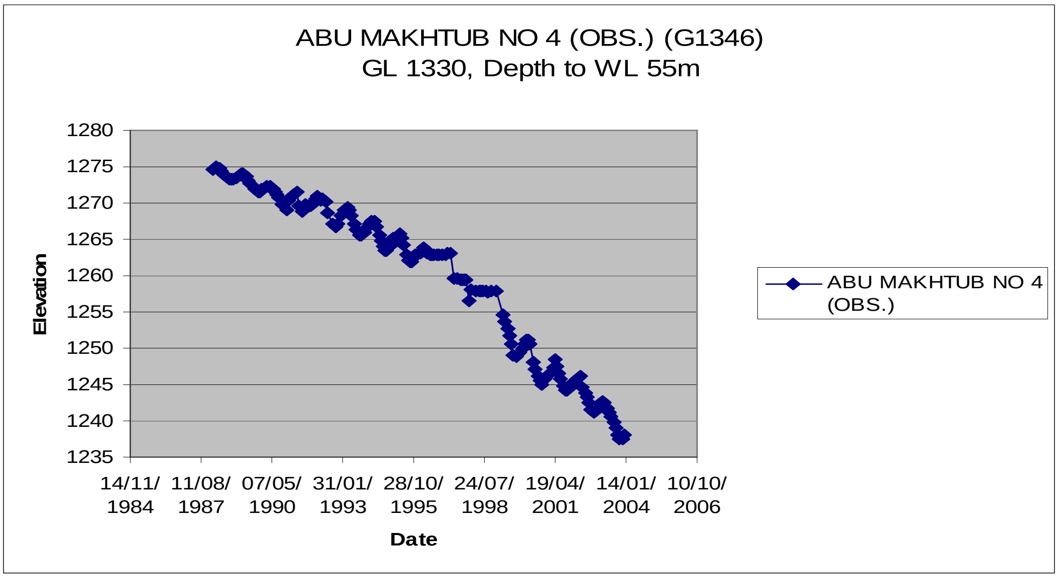
Several tectonic structures such as the Arja-Uweina flexure act as flow barriers to the eastward direction of ground water flow. The presence of the hydraulic barriers is indicated by the marked head drop across the structures. The JICA study records piezometric levels in the Western highlands of 1200 to 1500m, while they are as low as 800 to 900m immediately east of the Arja-Uweina flexure. In the central part of the Jafr basin the piezometric elevations are reported to be between 750 and 800m with a nearly flat hydraulic gradient.

Eastward of the flexure the groundwater of the A7/B2 aquifer is confined by the impervious marl of the Muwaqqar (B3) horizon.

The agricultural farms 5 to 10kms to the east of the villages of the Shoubak area are the main abstractors of groundwater from the aquifer. The locations of the agricultural areas and the wells are shown on Figure 5.

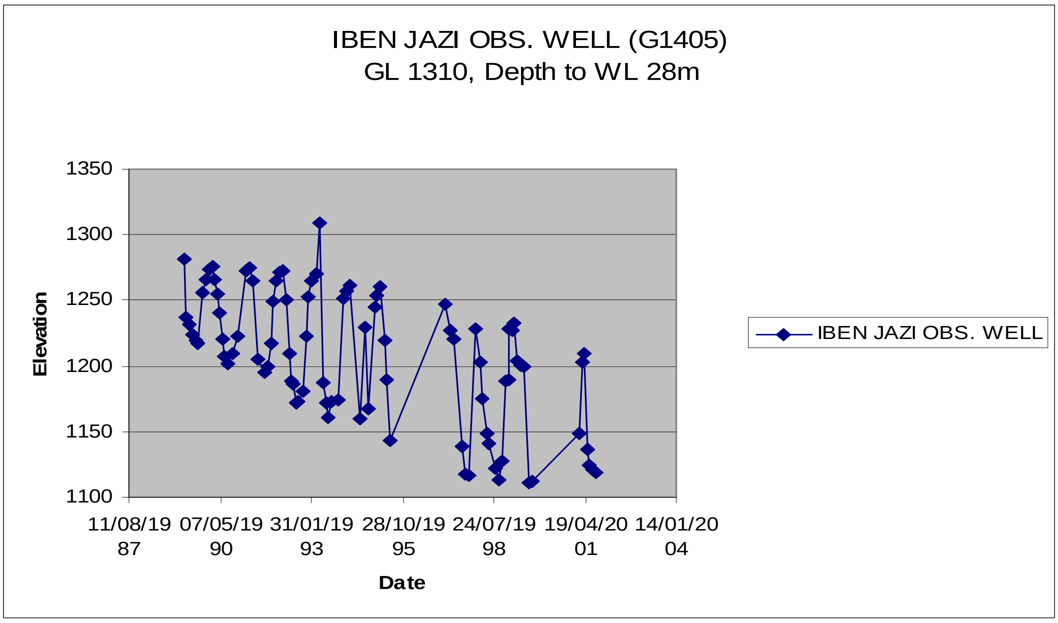
The observation well Abu Makhtub No. 4 (G1346), some 7kms to the southeast of Shoubak, has provided a record of the water table in the area of agriculture from 1988 to 2003 (Figure 6). Over that period the water level has fallen 40 metres. The annual seasonal fluctuations vary from 0.5m to 2m. Over the period 1988 to 1996, the average annual decrease in water level was 1.5m/year. Since 1994, the average annual decrease has doubled to 3m/year.

Figure 6



Two kilometres further east, the Iben Jazi observation well (G1405) shows the seasonal influence of abstraction (Figure 7). The seasonal fluctuations vary from 65m in 1989 to 120m in 1998-99. Over the period 1989 to 2001 the average annual decrease in water level was 6m/year.

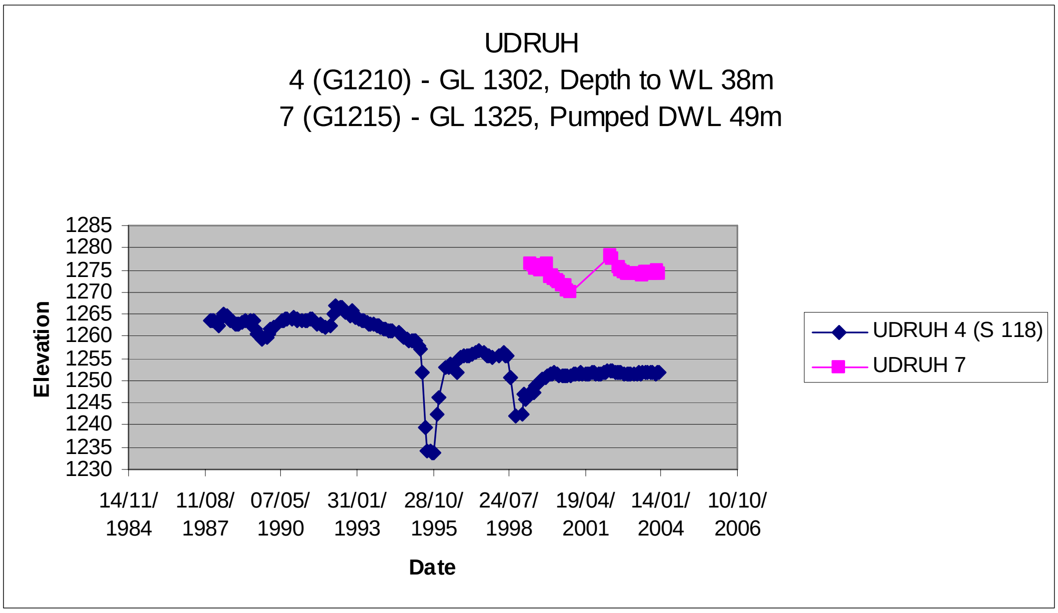
Figure 7



The observation well Jarba 1 - S65 (G1344) located some 7kms to the south shows a 0.5m variation in water level in 1.5 months. So seasonal variations in the order of 5m may be considered possible. Even greater changes of the groundwater table may be expected over a longer period as a result of the extremely variable annual recharge amounts. In 1967 when the well was drilled the water level was 82 metres below ground level; on 31st March 2002 the level was 127metres below ground.

The results of groundwater level monitoring at Udruh 4 (G1210) indicate that from 1987 to 1994 the water level was reasonably stable (Figure 8). There then followed a period of large drawdown (28 metres) between 1995 and 1996 in response to local abstraction which recovered to a slightly lower level by 1997. The water level was stable until 1999 when there was a second large drawdown of 15 metres. The water level recovered once again to a slightly lower level by 2000. Since then the water levels have remained stable. Over the period of record the water level has fallen 12 metres.

Figure 8



Direct recharge in the infiltration area of the Shoubak-Ras en Naqb recharge mound calculated by the UNDP Sandstone Aquifer Project and reported by BfB for the period 1953 to 1967 shows a wide variation over several years, even consecutive years going from 0 to very high 43 and 94Mm^3. The average value over this period is 10Mm^3. A mean total annual ground water flow of about 14Mm^3 is expected east of barriers at Hamam-Udruh and Basta-Qurein (BfB).

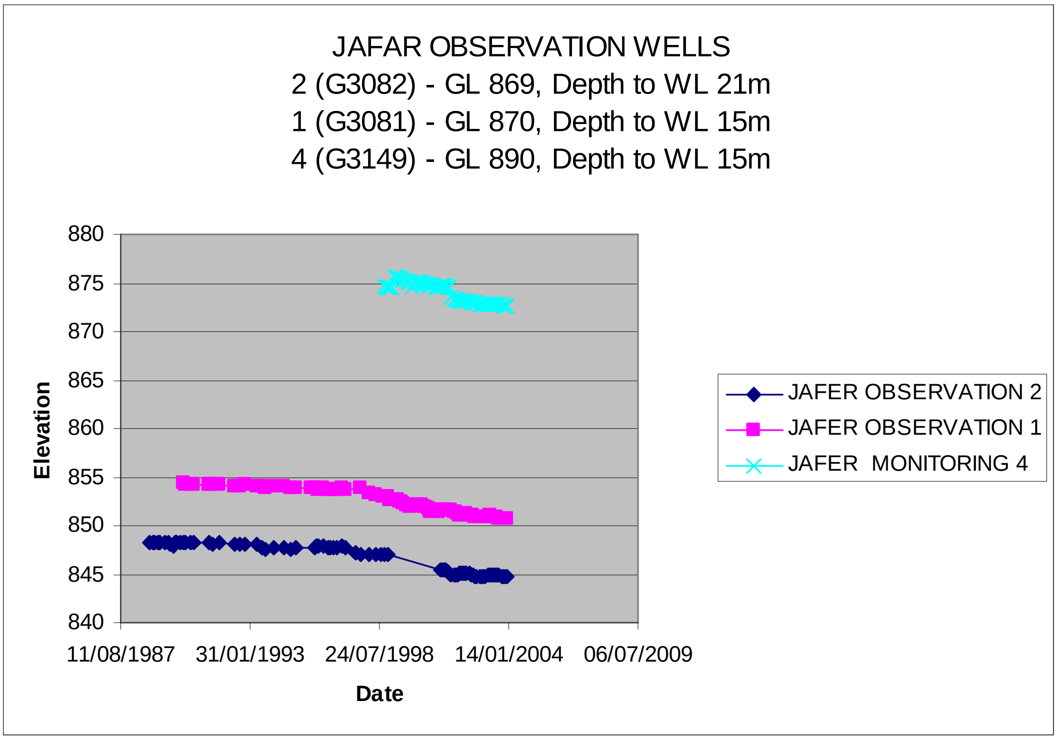
EII.2.3 Al Jafr area – Rijam (B4) aquifer

In the early sixties (late 1964) groundwater was developed in the Al Jafr area to provide water for both domestic and agricultural uses. Here the shallow Rijam (B4) aquifer was exploited using shallow 50m deep wells. Since 1971 the salinity of the water abstracted increased and its yield became unsuitable for irrigation use (JICA).

Prior to 1967, abstractions were just over 1Mm^3/year. In 1990 five boreholes were used to withdraw 2Mm^3/year. Each borehole abstracted between 864 and 3629m^3/d with an average 2400m^3/d. Water levels monitored since 1964 show water level decline 0.1m/yr to 0.36m/yr in those 16 to 22 years, corresponding to a fall of water level in the 10 to 20 years of 2 to 7 metres.

Based on the record supplied from MWI for Jafer Observation well 2 (G3082) for the period 1988 to 2003 the decline between 1988 to 1997 was 0.5 metre and then until 2003 was a further 3 metres (Figure 9). This response indicates that the average annual abstraction exceeds the natural recharge.

Figure 9



Sustained yield of Rijam aquifer is evaluated as varying between 7Mm^3/year (Parker 1979) and less than 2Mm^3/year due to the limited groundwater recharge through the wadi beds during the occasional floods (JICA).

EII.3. DEVELOPMENT AND CURRENT USE OF WATER RESOURCES

EII.3.1 Introduction

The Jafr basin is a desert area that has no surface water resources. Present groundwater use for all purposes in the basin is 8Mm^3/year for domestic, 10Mm^3/year for agriculture and 7 Mm^3/year for industry (WAJ, 2002). As the safe yield of renewable groundwater is estimated to be around 9Mm^3/year, the overdraft is 16Mm^3/year.

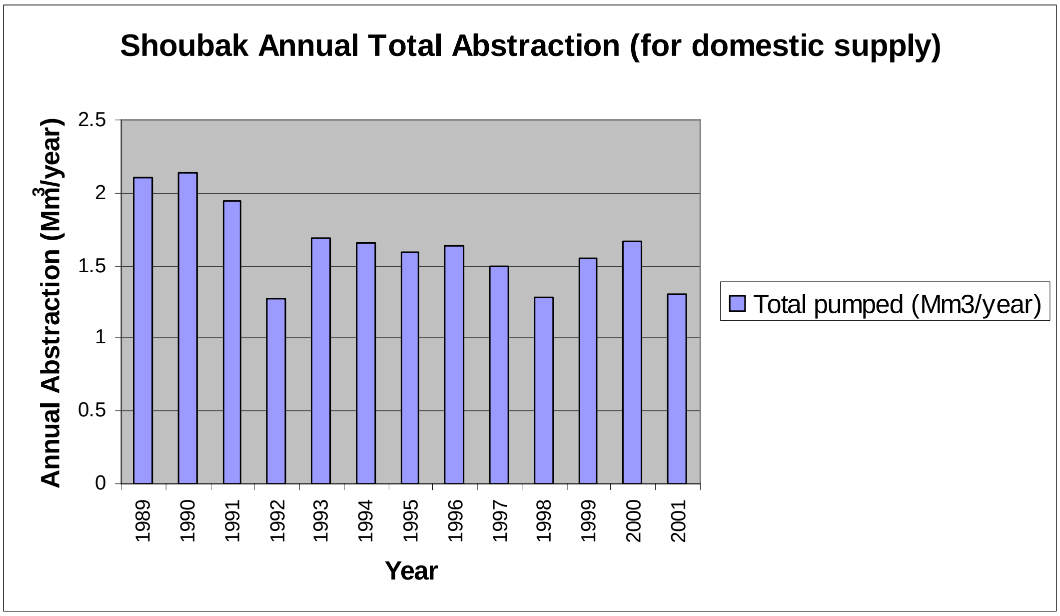
EII.3.2 Shoubak area

The domestic supply for the Shoubak area is supplied by six wells belonging to WAJ. The records for the totals of water pumped for each well for the period 1989 to 2001 held by MWI are given in the table and the annual total plotted in the graph (Figure 10). A 68kms long pipeline from Shoubak supplied Tafila until May 2003, when the replacement wellfield at Wadi Hasa came online.

Table showing annual abstraction from WAJ wells in the Shoubak area

Year	Well 1 (G1235)	Well 1B (G3157)	Well 3 (G1407)	Well 3A (G3162)	Well 4 (G3003)	Well 6 (G3008)	Well 6A (G3173)	Well 8 (G3174)	Total annual abstraction
1989	1054960		1054960						2109920
1990	1067223		1067223						2134446
1991	973925		973925						1947850
1992	425084		425084		425084				1275252
1993	563404		563404		563404				1690212
1994	552927		552927		552927				1658781
1995	532197		532197		532197				1596591
1996			544694		544694	544694			1634082
1997		374307	374307		374307	374307			1497228
1998		255348	255348	255348	255348	255348			1276740
1999		257964		257964	257964	257964	257964	257964	1547784
2000		277775		277775	277775	277775	277775	277775	1666650
2001		260741		260741	260741		260741	260741	1303705

Figure 10



The water is pumped directly into supply. Each village is divided into zones to ensure delivery at the end of the pipelines. The wells are pumped for 10 hours per day during the winter and 24 hours per day in the summer. The summer supply is reported to be given every third day for about 5 hours.

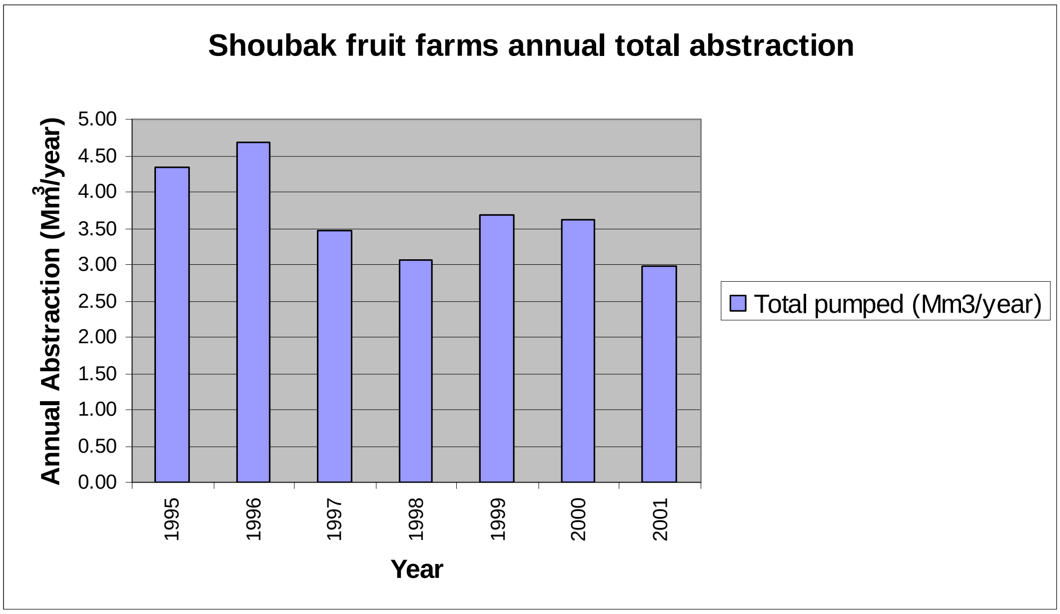
A pipeline from the Ail pumping station (WAJ) supplies the Udruh, Jarba and Menshiye area at a rate of 1200m^3/day during the summer and 500m^3/day from November to the end of March.

JICA estimated the B2/A7 abstraction in western highlands to be 9.36Mm^3/year. No significant regional drawdowns have been recorded except in the Shoubak wells. The Western Highlands are the major recharge area for the aquifer.

East of the desert highway the groundwater in the confined aquifer is untapped until the well field for Shadiya industrial area.

The JICA study (1990) reported that an estimated 3.3Mm^3/year was being used for irrigation in the Shoubak area. Based on the abstraction records held in the MWI Data Bank, the total annual agricultural abstractions from the fruit farms in a 25km^2 area located 8kms to the south east of Shoubak varied from 4.6Mm^3/year to 2.9Mm^3/year between 1996 and 2001 (Figure 11).

Figure 11



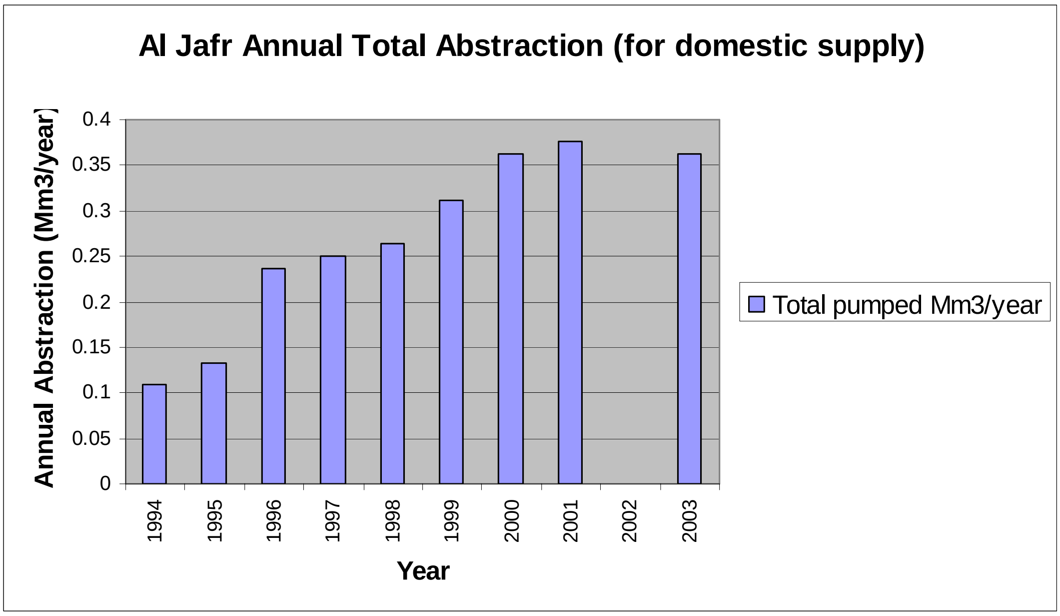
The JICA study (1990) reported that an estimated 3.3Mm^3/year was being used for irrigation in the Shoubak area.

EII.3.3 Al Jafr area

Two wells, Jafr 29 (G3020), 50metres deep and pumping from the B4 aquifer, and Jafr 30 (G3175), 60 metres deep and pumping from the B2/A7 aquifer, supply domestic water to the town of Al Jafr.

The recorded abstraction, based on the MWI Data Bank, for the Jafr 29 well is shown on Figure 12.

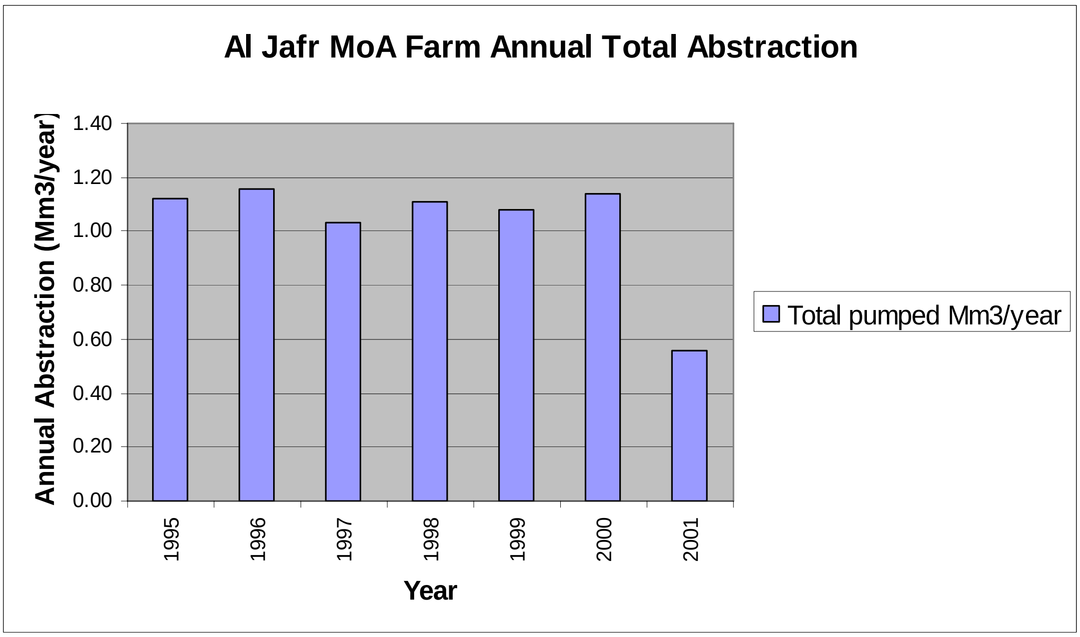
Figure 12



We understand that the pumps run for 17 hours per day in winter and 22 hours per day in the summer. The water is pumped to an overhead storage tank (capacity of $55m^3$) and delivered to 400 connections that are fitted with water meters. The average demand is reported to be $1200m^3$/day.

Five boreholes (Jafr 17, 18, 19, 20 and 23) supply the Government Ministry of Agriculture (MoA) farm of 250 hectares. Jafr 18 is reported now to be used by the ostrich farm within the farm area. The recorded abstraction for the period 1994 to 2001, based on the MWI Data Bank, is shown on Figure 13.

Figure 13



Within a 5km radius of the farm there are forty-six wells abstracting groundwater either from the B4 or B2/A7 aquifer. The net effect of this abstraction is a lowering of the water level.

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Annexure 1

REPORT ON AL JAFER AQUIFER

By Professor Elias Salameh

GEOLOGIC UNITS, STRUCTURES AND AQUIFERS

Seismic studies (Bender 1968) show that the bottom of Jafr basin consists of an elongated NW-SE striking depression in the Precambrian Basement Complex underlying the area.

Sarmuj Conglomerates

The oldest known formation overlying the basement consists of the Sarmuj Conglomerates, which crop out along the western slopes to Wadi Araba. No wells within the basin were drilled deep enough to reach these conglomerates but geologic and seismic evidence indicate their presence overlying the basement complex.

Palaeozoic Sandstones (D)

Overlying the Sarmuj Conglomerates and in places the basement complex itself series of sandstones including a dolomite – shale formation were deposited.

These sequences of sandstones (Ram sandstones, Salib arcosic sandstone, Burj dolomite-shale, Um Ishrin Disi an the overlying Kurnub sandstones) build in the area one composite aquifer (sandstone aquifer complex) with a total thickness of around 750 m.

The water in this sequence originates from recharge in areas lying further southwest in Aqaba – Disi area and further west, as a result of infiltration along the escarpment foothills.

The groundwater at a depth of around 1000 m below ground level is believed, due to its origin in Disi and Ras en-Naqb escarpment areas, to be fresh.

Wells drilled in the Lajjon area further north, in the down gradient area of Jafr and those drilled in Disi – Mudawwers, up gradient of it encountered fresh water in the sandstone aquifer complex. Therefore, it can be deduced, that the deep aquifer underlying Jafr contains also fresh water.

Lower Cretaceous Sandstone (Kurnub Sandstone (K)

The Kurnub Sandstones directly overlie the Disi Sandstones in the area.

At the base of the Kurnub sandstone a gravel bed of a few meters in thickness is found. It is in most areas in Jordan overlain by a few meters of marls and shales functioning locally as aquicludes. On a regional scale, (Jafr Basin scale), these marls and shales act as aquitards allowing water to flow through via joints and faults.

Hence, the sequence of rocks overlying the Basement Complex through the Lower Cretaceous is considered as one aquifer complex.

The thickness of the lower Cretaceous Sandstone in the area is around 160 m (Bender 1968).

The groundwater in the Lower Cretaceous Sandstones is fresh with a salinity of 600-800 mg/l (well $ 15) (Khudeir 1968).

Upper Cretaceous

Nodular Limestone (A1-A4)

The Upper Cretaceous sediments consist of a series of predominantly carbonate rocks with marls, shales and sandy limestones, designated by Bender as Nodular Limestone series.

The lowest part consists mainly of marls and marly limestones gradually going into limestones, dolomitic limestones and marly limestones in the upper part.

The formation is considered as an aquiclude. The upper portions of the formation form a poorly developed aquifer.

The middle part, which consists of marls, siltstones and nodular limestones contains gypsum beds and forms an aquiclude in the area.

The upper part of the series consists of thin-bedded sandy, dolomitic limestones, in places separated by beds of marls.

The total thickness of Nodular Limestone series in Jafr area is around 60 m forming as a whole an aquiclude, but some parts of the series form badly developed aquifers.

Echinoidal Limestone (A5,6)

Overlying the Nodular Limestone series a sequence of Echinoidal Limestones is found. It consists mainly of marly limestones, with gypsum beds.

The thickness in the area is around 50 m forming an aquiclude.

Sandy Limestone (A7)

Overlying the Echinoidal Limestone is a sequence of Sandy Limestones. It consists of sandy limestones with intercalations of dolomites, marls and chert beds. In the central part of Jafr marls, dolomites and clays are encountered within this sequence (well no S1 and S15).

The thickness of the sequence in Jafr is around 110 m, thinning out in southerly and westerly directions (Bender 1968).

Silicified Phosphatic Limestone (B2)

Overlying the Sandy Limestone sequence is a sequence of Silicified-Phosphatic Limestones. The sequence consists of silicified limestones, phosphorites, chert and thin marl beds with a total thickness of 100 m in Jafr basin. The sequence forms a good aquifer in the area.

Chalk Marl (B3)

Overlying the Silicified–Phosphatic Limestone sequence is the Chalk Marl sequence consisting of chalky marls, bituminous marls with concretions and chert beds. The sequence is around 450 m in thickness and is considered as an aquiclude.

Nummulitic Limestone – Chert (B4)

Overlying the Chalk – Marl sequence is a sequence of Nummulitic Limestone – Chert. The sequence consists of nummulitic limestone, chert and phosphatic beds with a total thickness of 35 m. The sequence forms an aquifer in the area.

Recent sediment

Overlying the Nummulitic Limestone – Chert sequence is a series of Conglomerates and fluviatile sediments with lacustrine limestones. This sequence of a few hundred meters of conglomerates and fluviatile sediments is mainly found in the area lying to the west of Jafr basin. In Jafr itself the sequence consists of fluviatle sediments of around 100 m in thickness overlain by lacustrine limestones of 20 m in thickness. These are, in central Jafr overlain by recent mudflat sediments of a few tens of meters in thickness, which weg out in all direction.

Structures

In the west, the study area is borderd by the Jordan Rift Valley and is separated from it by several step faults with downthrown western blocks (Figure 1).

The study area is uplifted to reach heights of more than 1500 masl. The slopes towards Wadi Araba in the west are formed by the Upper Cretaceous Sandy Limestone and Sandstone Unit (A7), which dips gently to the east towards the Jafr depression. The Silicified–Phosphatic unit (B2) overlies the A7 and dips also towards east. Further east the Chalk Marls, the Nummulitic Limestones and the Recent sediments build the area.

A number of N-S striking faults affect the area. Generally, these faults have downthrown eastern blocks of a few tens of meters, which are covered by recent sediments.

Due to their tensional type, these faults form conduits for the groundwater movement, discharge and interaquifer flows.

According to the BGR 1991 the base of the B2/A7 in the area extending from Shoubak to Jafr forms a trough with a width (NNE-SSW extension) of 10-20 km and a WNW-ESE extension of around 80 km. The base of the B2/A7, at the bottom of the trough, 10 km to the east of Shoubak lies at an elevation of 350 masl and increases in all directions. At a distance of 20 km south of the trough, the base of the B2/A7 lies at 650 masl, and in Jafr, the base lies at 550 masl. To the north the trough terminates at the ± E-W trending Salwan Fault with its up-thrown southern block (Figure 2).

The top of the B2/A7 shows also the Jafr trough with migration of its center towards ESE, Jafr. This migration continues throughout the deposition of the B3, B4 and B5 when the trough becomes filled with sediments.

From the groundwater contour lines (Figure 3) it can derived that along this trough the flow of water diverges to the ENE and ESW indicating a low permeability zone compared to areas lying further north along Salwan Fault or to the south along Wadi Jurdhan.

GENERAL GROUNDWATER RESOURCES SITUATION

Two relevant aquifers are found in the study area:

* The Upper Cretaceous composite aquifer (B2/A7), which is formed by the Sandy Limestone (A7) and the Silicified Phosphatic Limestone (B2).

* The Lower Cretaceous and older sandstones (K + D).

The local shallow surface aquifer composed of recent sediments, or a combination of recent sediments and the Chert-Nummulitic Limestone unit is only of local importance and it does not form a continuous aquifer in the study area. Where it exists in the western parts of the study area, this shallow aquifer contains small amounts of fresh water, with only minor importance as a water supply. In the eastern part, the shallow aquifer is recharged by infiltrating rainfall and flood water in an arid area resulting in local groundwater bodies with relatively high salinities.

Within the Echinoidal and Nodular Limestone units A_1 to A_6, (which separate the B2/A7 from the deep K + D), there are several sequences with adequate potential for groundwater. These sub-aquifers have not yet been studied or evaluated. Their water, together with the underlying K+D aquifer complex seem to build the basis for the B_2/A_7. Given the recharge area further west and south, the fresh water in the overlying and underlying aquifers (B_2/A_7 and K + D) it seems appropriate to suggest that fresh water is filling the A_1 – A_6 aquifer portions, especially in areas lying west of lattitude 230 PG.

The B_2/A_7 aquifer is recharged in the western and southern parts of the study area at the Jordan Rift and Ras en Naqb escarpments. The groundwater flow is directed from the west and south (escarpments) towards east and north east (Jafr Basin).

The different faults in the area are not found to form barriers to the groundwater flow because of their small down-throws and their tensional nature (Figure 4). Across the faults the water levels may differ by tens of meters.

The fault zones, moreover, form high flow, permeability and productivity areas for groundwater. The aquifer transmissivity as calculated from wells drilled in this aquifer ranges from 8.4×10^{-2} m^2/s to 10^{-3} m^2/s.

The groundwater body in the B_2/A_7 is confined along almost the entire area of the aquifer extent, by the thick B3 aquiclude. In low topographic areas the aquifer produced artisian water. The ground- -water in this equifer is originally of low salinity and can be used for all purposes without restrictions. In the eastern parts of the aquifer the salinity of the water shows some increases either as a result of water rock interactions or leakages from the overlying aquifers.

The recharge to the B2/A7 aquifer was calculated by Bender and Dürhaum (1969) to amount to 18 MCM/yr. including around 1.5 to 2 MCM/yr. flowing from the escarpment area of Shoubak towards north and 1 MCM/yr. towards Wadi Araba. This figure is still used as the amount of aquifer recharge (JICA 2001).

The Sandstones of K + D form in the area one composite aquifer at a depth of 600 to 750 m below groundlevel. The groundwater flow in this aquifer is directed towards the north-northeast. The aquifer is recharged along the Jordan Rift and Ras en Naqb escarpments and further south in Disi – Aqaba mountainous areas.

With the exceptions of the Ras en Naqb and Jordan Rift escarpment immediate surroundings, the groundwater body in the K + D aquifer is confined.

Due to its thickness of more than 750 m the K + D aquifer does not seem to be affected by the faults of a few tens of meters down-or upthrows.

PRESENT SITUATION OF THE GROUNDWATER IN THE STUDY AREA

As can be shown on the examples of wells G1346, G1210, G3081 and G1342 (Figures 5, 6, 7, 8 and 9) the water levels in the area have, since the early nineties been dropping. In the shallow aquifer the drop in the level between 1990 and 1998 was about 12 cm/yr, whereas form 1998 to early 2004 it averaged 50 cm/yr. Since this aquifer is a free-water table aquifer a drop of 0.5 m/yr. in the groundwater level should give a clear warning about the sustainability of this aquifer.

In the recharge area of the B2/A7 aquifer, the water level in observation well G1210 showed, in the years 1987 to 1994 normal fluctuations. In 1995 and 1996 a fast drop of about 28 m was followed by a recovery of 23 m. The same level persisted until early 1999, when a fast drop of about 15 m within a few months and a recovery of 10 m in the following year took place. From 2000 to 2004, the water level stabilized at a depth of 50 m below ground level. The total drop from 1995 to 2004 was 12 m or 1.30 m/yr.

The behaviour of the water level can be attributed to the free water table conditions of the aquifer in the surroundings of the recharge area. The fact is, that the water levels of the aquifer are dropping as a result, of water extractions in the area.

In observation well G1346, the water level has, since 1988 been dropping. From 1988 to 1996 the average drop was 1.5 m/yr, after that the rate increased to reach an average of 3 m/yr. This is a very high rate of dropping groundwater level even when dealing with confined aquifer, and it should be considered as a warning about the sustainability of that aquifer.

Observation well G 1342 showed a similar behavior like G1346 and G1210, the water level has been continuously dropping since 1991, with a strong drop and recovery in 1993.

The average drop, in this well from 1991 to 2004 was 18.4 cm/yr, which shows the vulnerability of this confined aquifer to the present exploitation of its water.

The extracted water amounts in the study area averaged in recent years 23 MCM/yr (JICA, 2001 and WAJ information), whereas the safe yield of the exploited aquifer, B2/A7 is only 14 to 15 MCM/yr, (BGR 1991) which means an overdraft of 8 to 9 MCM/yr. During the last 14 years the total over draft amounted to around 115 MCM.

<u>Hydrochemistry</u>

The Jafr basin, which started to be developed in the sixties of the last century, was the first major groundwater basin in Jordan to suffer from overexploitation manifested in water resources depletion (drop in water levels) and water quality deterioration (increasing salinity).

The B2/A7 aquifer has been exploited at a rate of 23 MCM/yr in the years 1996 to 2002. After that extractions declined slightly as a result of abandoning of wells and savings in irrigation water.

Water uses for drinking purposes amout presently to 7.6 MCM/yr. Industries use an amount of 6 MCM/yr and irrigation in the year 2000, 10.4 MCM/yr. declining after that to 8.1 MCM/yr.

Generally, the original salinity of the groundwater in the area showed increases from the recharge areas in the west to the Jafr Basin Center in the east.

Wells G1205, 1210, 1215, 1220 and 1315 lying in the western part of the Jafr Basin have a Salinity range of 500-750 µS/cm, whereas those in the intermediate area between the recharge area and Jafr Basin center (wells, G1004, 1225, and 1260) have salinities ranging from 700 to 1200 µS/cm.

In the surroundings of Jafr Basin Center, the salinities reached values of 800 to > 2000 µS/cm (wells G1002, 1006, 1034 and 1038).

Pumping from the different aquifer parts led, in addition to the drop in the water level as mentioned above, also to increasing salinities in the eastern parts of the aquifer. As examples, the salinity of well G1002 increased from around 900 µS in the sixties to more than 3000 µS/cm in the eighties, in well G1034 from 900 to 5000 µS/cm and in well G 1006 from 2000 to more than 6000 µS/cm.

In the central area of Jafr Basin salty water of the deposits of mudflats gradually infiltrates to reach the B2/A7 aquifer, especially along joints or faulted zones.

Pumping of water in this area seems to have mobilized these saltwater leachates into the water body in the B2/A7. As a function of well distances from jointed or faulted zones, the salinity increased to varying degrees; in some wells slightly in others very strongly.

In the intermediate part of the aquifer, between the recharge area in the west and the Central Jafr in the east the salinity increases were slight, because of the missing sources of saline water, e.g. wells G1004, 1225 and 1260.

In the recharge area, no major changes in salinity were observed; the variations registered in the different wells were non-monotonous and reversible, e.g. wells G1205, 1210, 1215, 1220 and 1315.

Further drawdown in the aquifer water level as a result of overdraft are expected to result in:

- Slight, tolerable increases in salinity in the western third part of the aquifer (the recharge area).
- Intermediate increases in salinity in the central part of the aquifer, with salinities not expected to go beyond 1500 µS/cm.
- Strong increases in salinity the eastern third of the aquifer (Central Jafr Basin), resulting from saltwater mobilization, resulting in a total damage of the aquifer there.

Water Types

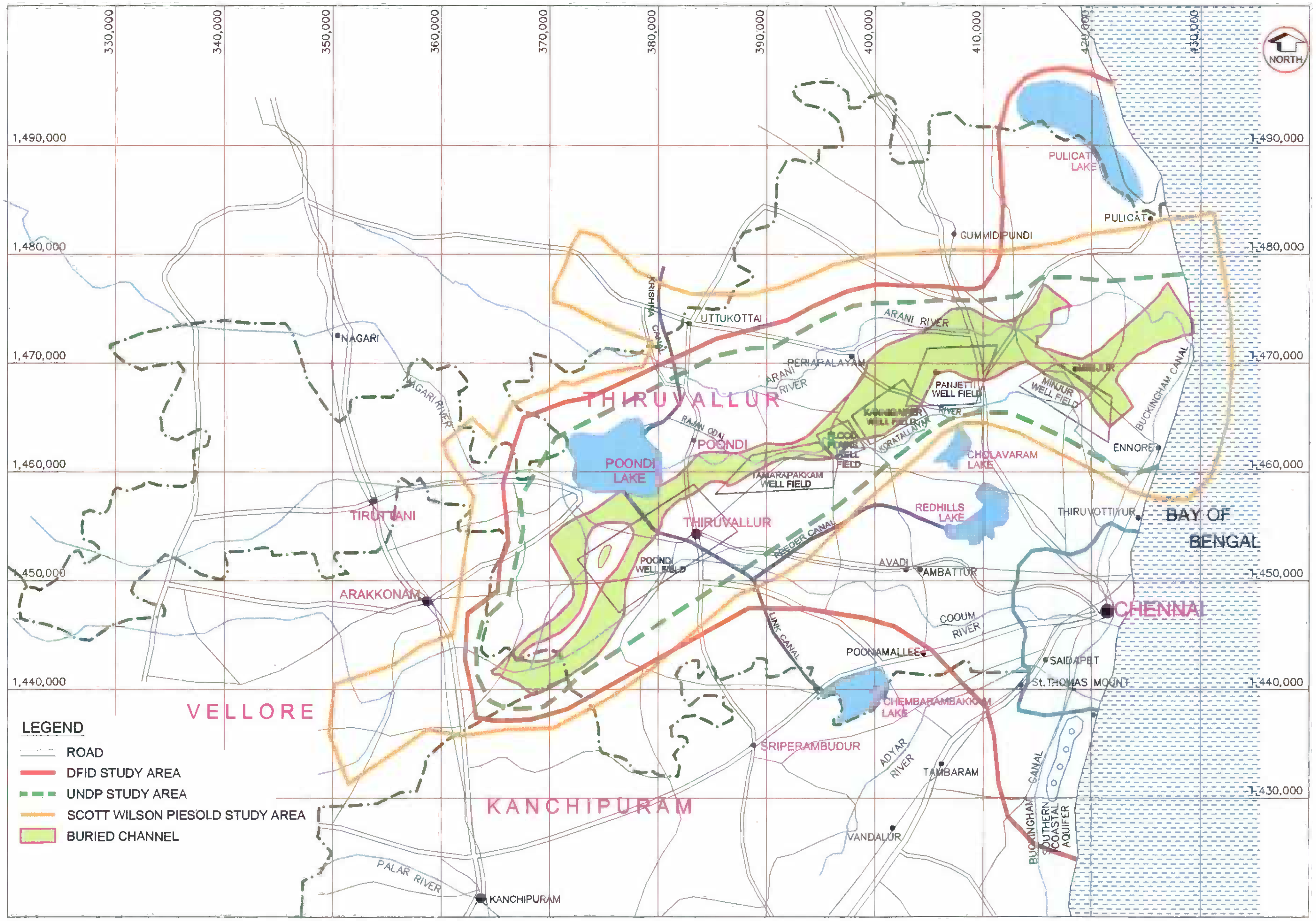
The original water of the aquifer during the sixties of the last century was of earth alkaline type with increasing portions of bicarbonates, resembling precipitation water reacting with carbonate aquifers. Even those areas in the eastern parts of the aquifer (Central Jafr Basin) produced, at that time this type of water, with a slight shift towards a sulfate component resulting from gypsum dissolution (Figure 10). Because gypsum is found in the rock matrix there, and in the salty gypsiferous playa water, which infiltrates down into the B2/A7 aquifer.

Historic and recent groundwater analyses show the following facts:

- In the western (recharge) area, the water type is still the same, as it used to be in the sixties and seventies of the last century; namely earth alkaline type with prevailing bicarbonate.

- In the intermediate area (between the recharge and the Jafr Central Basin), the groundwater has gradually been changing to earth alkaline type with prevailing bicarbonate and sulfate, resulting from the dissolution of gypsum from the rock matrix.

- In the eastern parts of the aquifer, Jafr Central Basin the groundwater has gradually changed to earth alkaline type with prevailing sulfates, resulting from gypsum dissolution from the rock matrix and from the infiltration of gypsiferous playa water into the B2/A7 aquifer.



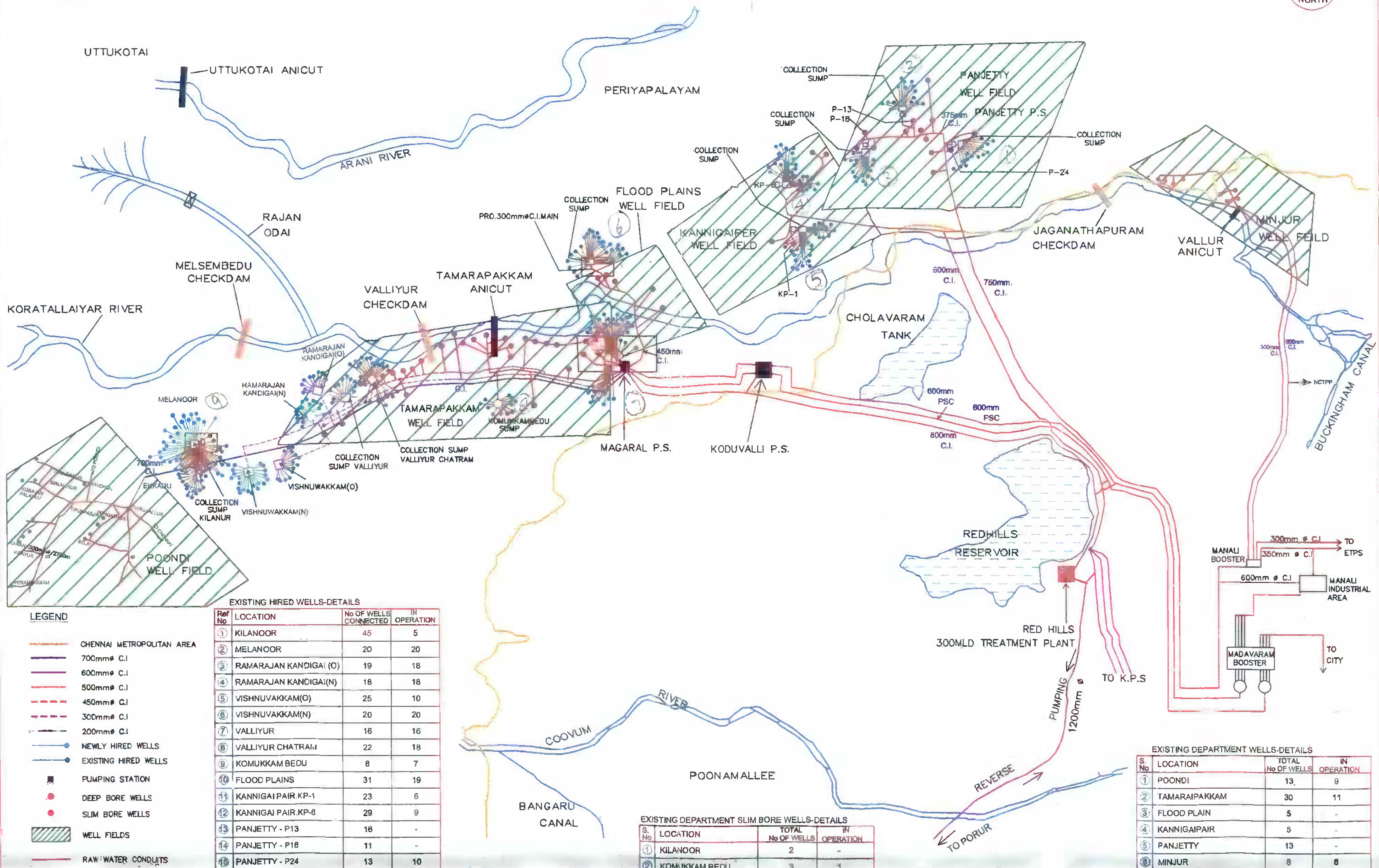
SOURCE-CMWSSB

STUDY AREA

FIGURE 1

CMWSSB

SOURCE MAP



EXISTING HIRED WELLS-DETAILS

Ref No	LOCATION	No OF WELLS CONNECTED	IN OPERATION
1	KILANOOR	45	5
2	MELANOOR	20	20
3	RAMARAJAN KANDIGAI (O)	19	18
4	RAMARAJAN KANDIGAI(N)	18	18
5	VISHNUVAKKAM(O)	25	10
6	VISHNUVAKKAM(N)	20	20
7	VALLIYUR	16	16
8	VALLIYUR CHATRAM	22	18
9	KOMUKKAM BEDU	8	7
10	FLOOD PLAINS	31	19
11	KANNIGAI PAIR KP-1	23	6
12	KANNIGAI PAIR KP-6	29	9
13	PANJETTY - P13	16	-
14	PANJETTY - P18	11	-
15	PANJETTY - P24	13	10
16	MAGARAL	35	19
	TOTAL	351	195

EXISTING DEPARTMENT SLIM BORE WELLS-DETAILS

S. No	LOCATION	TOTAL No OF WELLS	IN OPERATION
1	KILANOOR	2	-
2	KOMUKKAM BEDU	3	1
3	MAGARAL	1	1
	TOTAL	6	2

EXISTING DEPARTMENT WELLS-DETAILS

S. No	LOCATION	TOTAL No OF WELLS	IN OPERATION
1	POONDI	13	9
2	TAMARAIPAKKAM	30	11
3	FLOOD PLAIN	5	-
4	KANNIGAIPAIR	5	-
5	PANJETTY	13	-
6	MINJUR	8	6
	TOTAL	74	26

SOURCE-CMWSSB

FIGURE 3

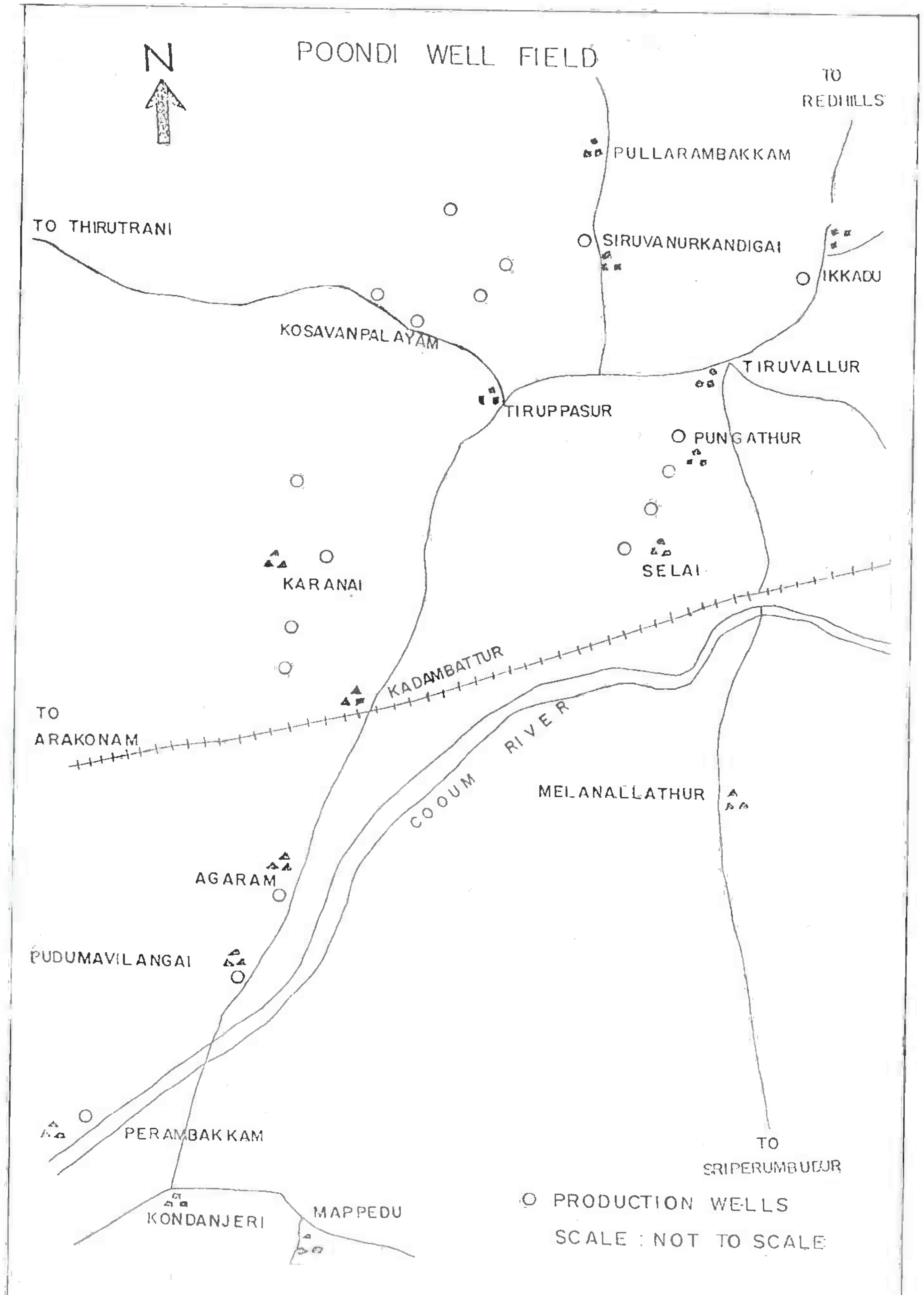

N
POONDI WELL FIELD
TO
REDHILLS
PULLARAMBAKKAM
TO THIRUTRANI
SIRUVANURKANDIGAI
IKKADU
KOSAVANPALAYAM
TIRUVALLUR
TIRUPPASUR
PUNGATHUR
KARANAI
SELAI
KADAMBATTUR
TO
ARAKONAM
COOUM RIVER
MELANALLATHUR
AGARAM
PUDUMAVILANGAI
PERAMBAKKAM
TO
SRIPERUMBUDUR
KONDANJERI
MAPPEDU
PRODUCTION WELLS
SCALE : NOT TO SCALE

FIGURE 4

POONDI WELL FIELD
Water level and extraction from 1988 - 2003

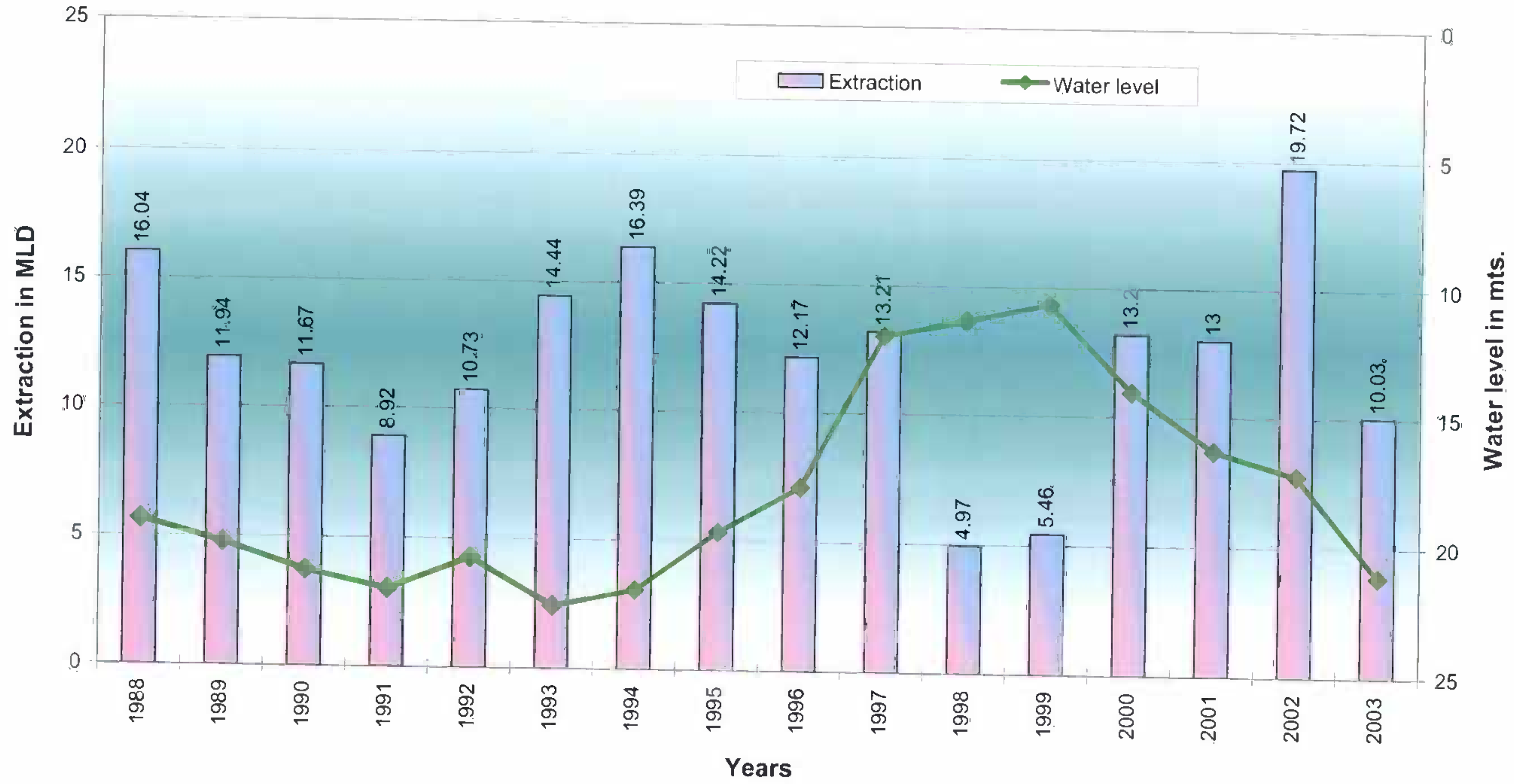


FIGURE 5

TAMARAIPAKKAM WELL FIELD

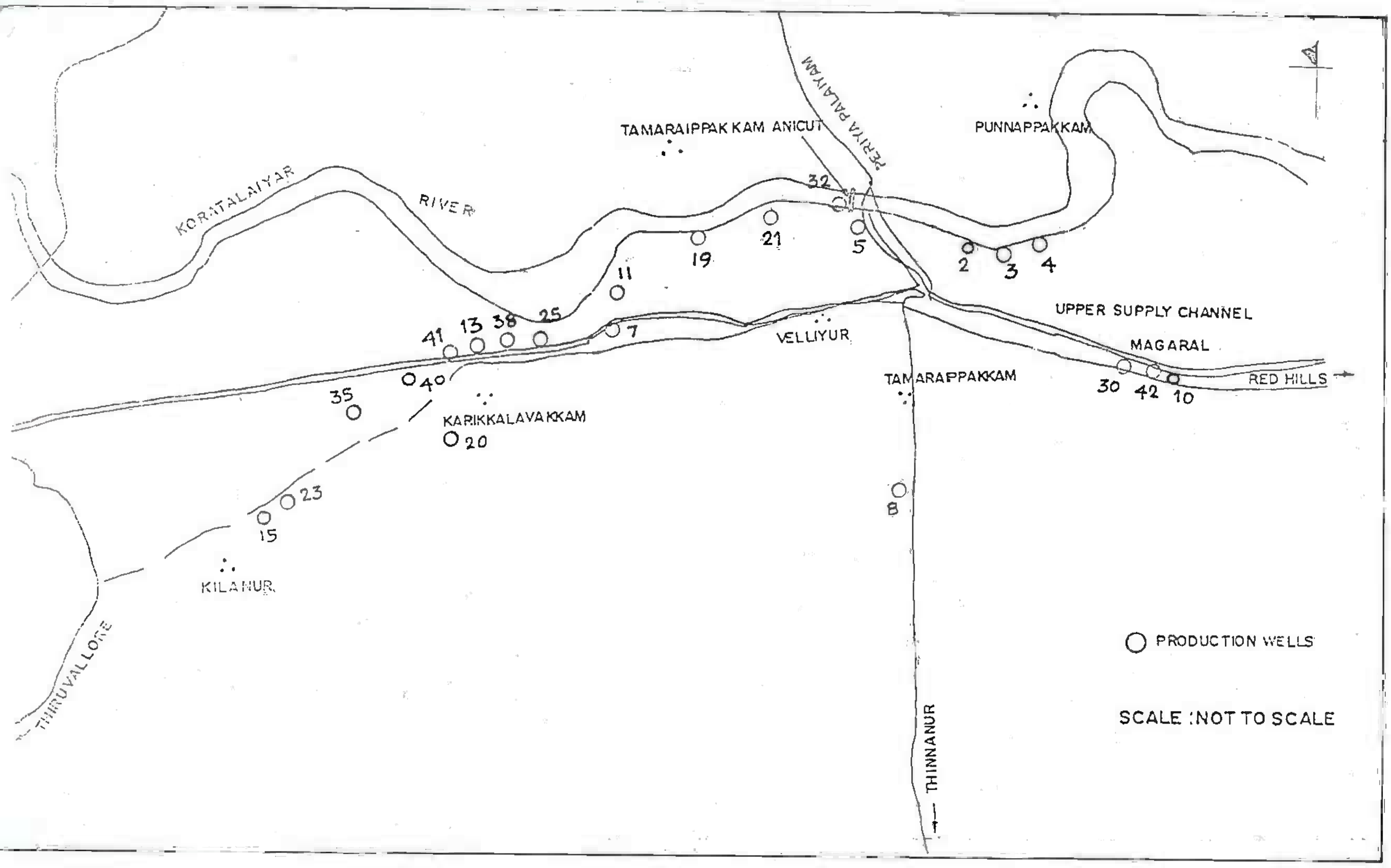
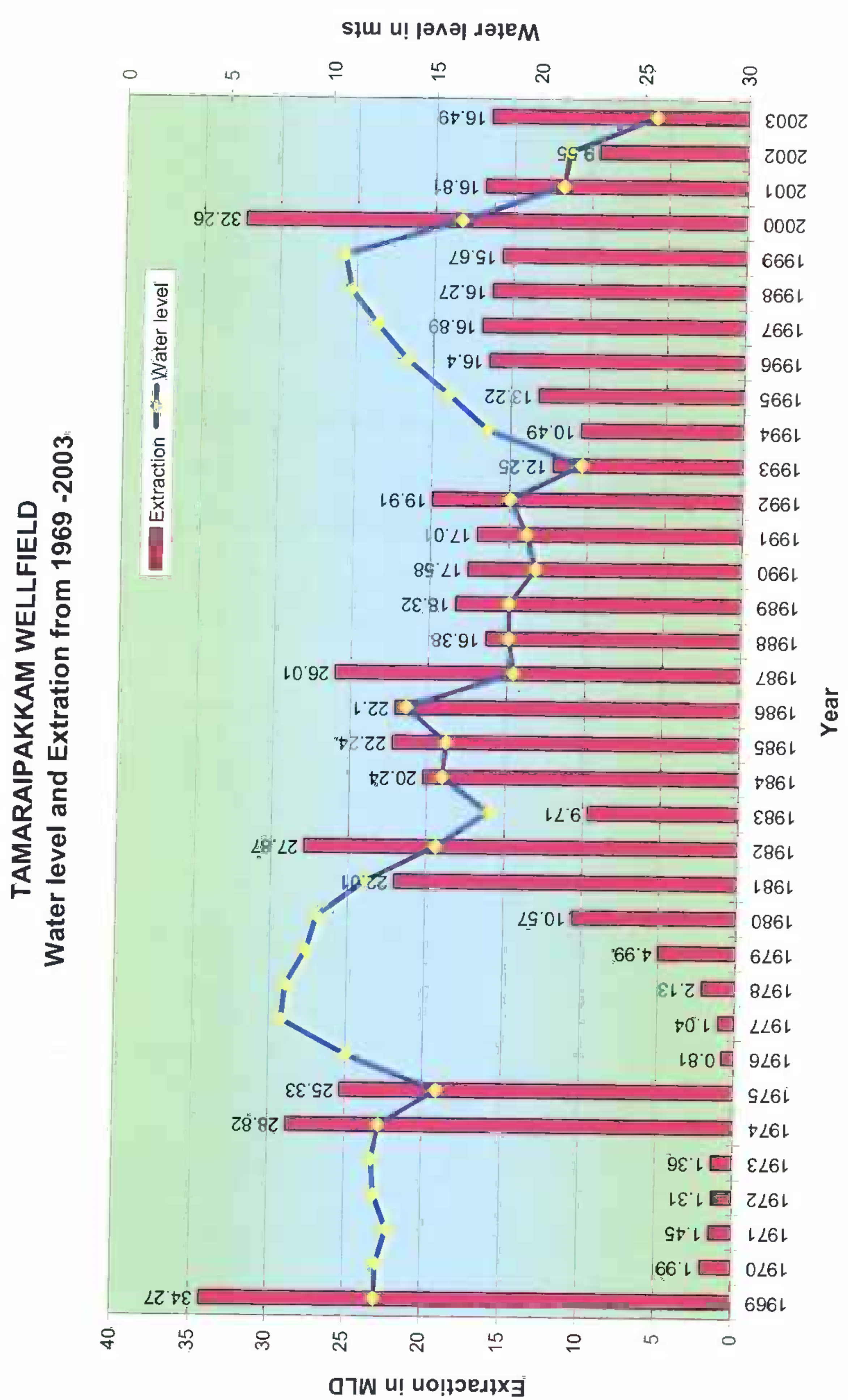


FIGURE 6



TAMARAIPAKKAM WELLFIELD
Water level and Extration from 1969 -2003
Extraction
Water level
Water level in mts
Extraction in MLD
Year
0
5
10
15
20
25
30
35
40
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1969
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
34.27
1.99
1.45
1.31
1.36
28.82
25.33
0.81
1.04
2.13
4.99
10.57
22.01
27.87
9.71
20.24
22.24
22.1
26.01
16.38
18.32
17.58
17.01
19.91
12.25
10.49
13.22
16.4
16.89
16.27
15.67
32.26
16.81
9.55
16.49

FIGURE 7

FLOOD PLAIN WELL FIELD

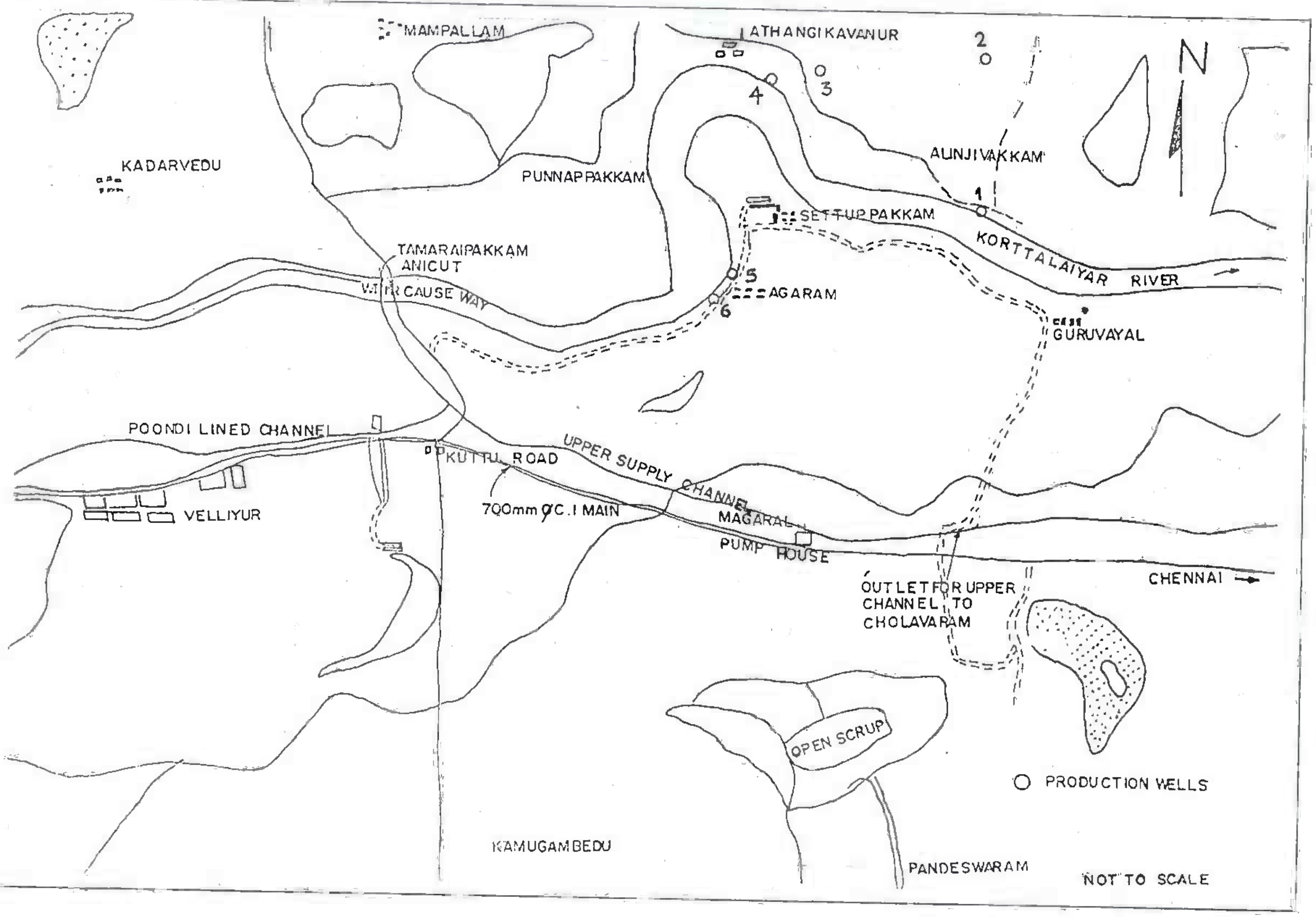


FIGURE 8

FLOOD PLAIN WELL FIELD
Water level and Extraction from 1988 -2003

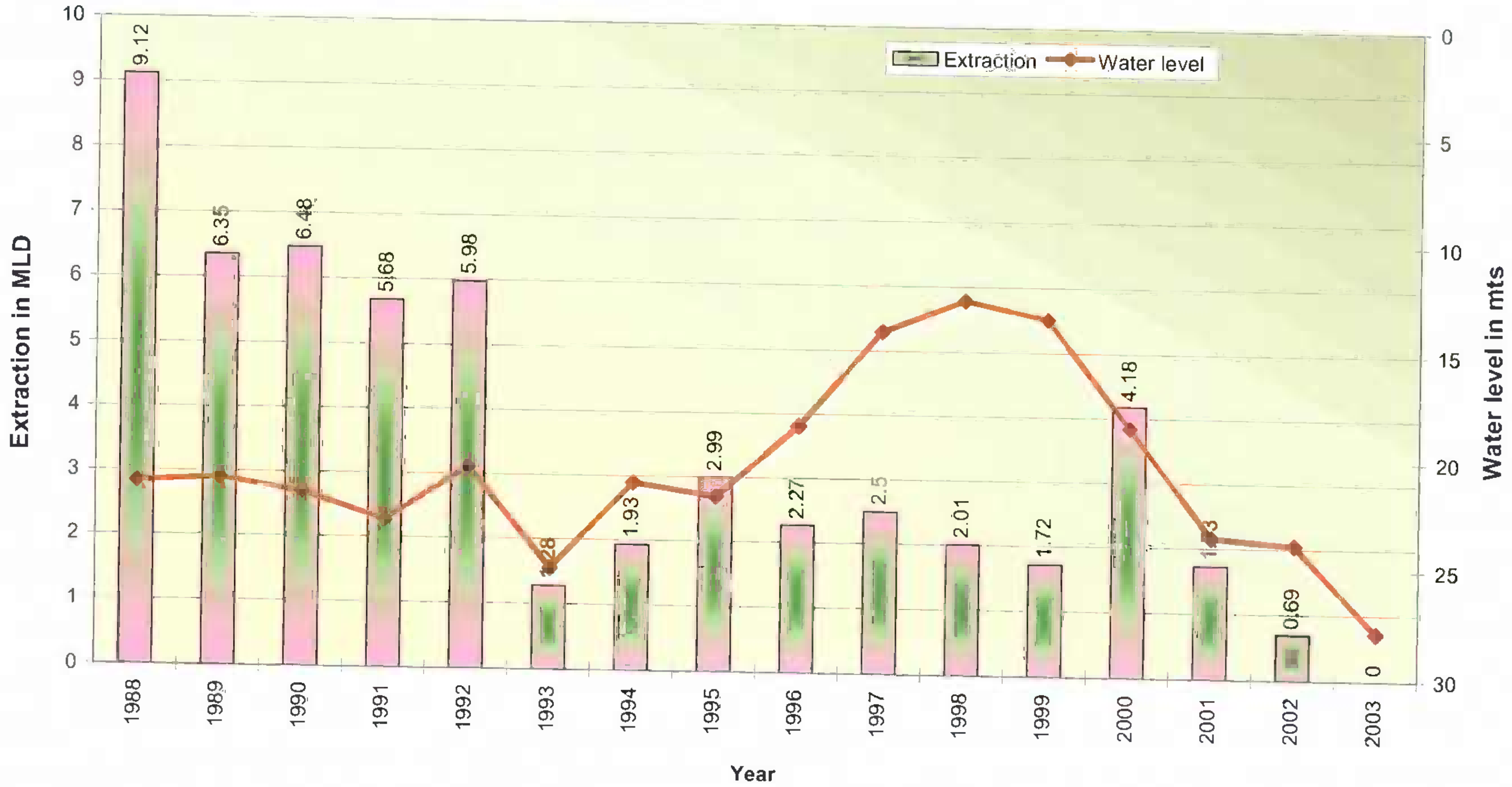


FIGURE 9

KANNIGAIPPER WELL FIELD

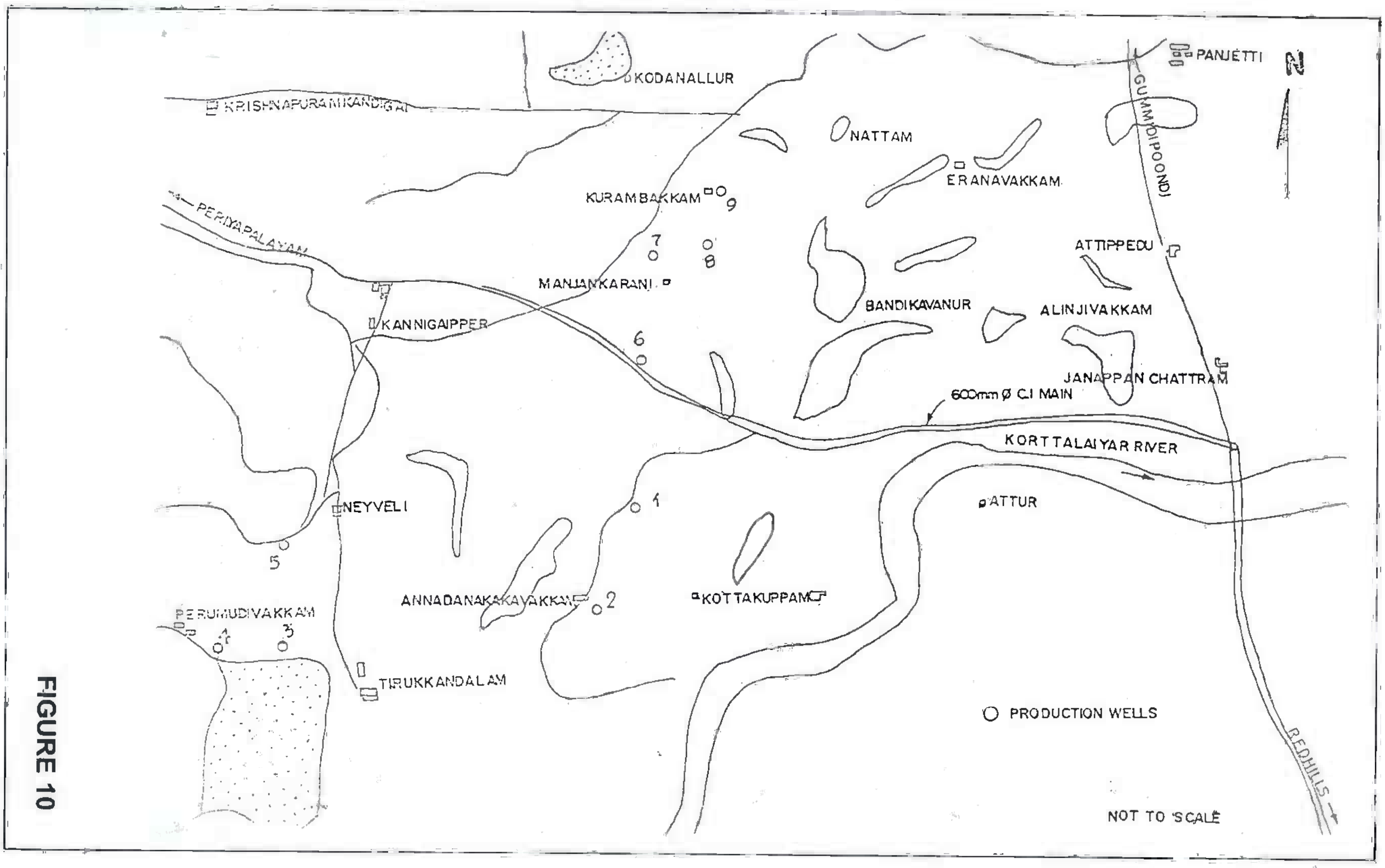


FIGURE 10

KANNIGAIPER WELL FIELD
Water level and Extraction from 1988 - 2003

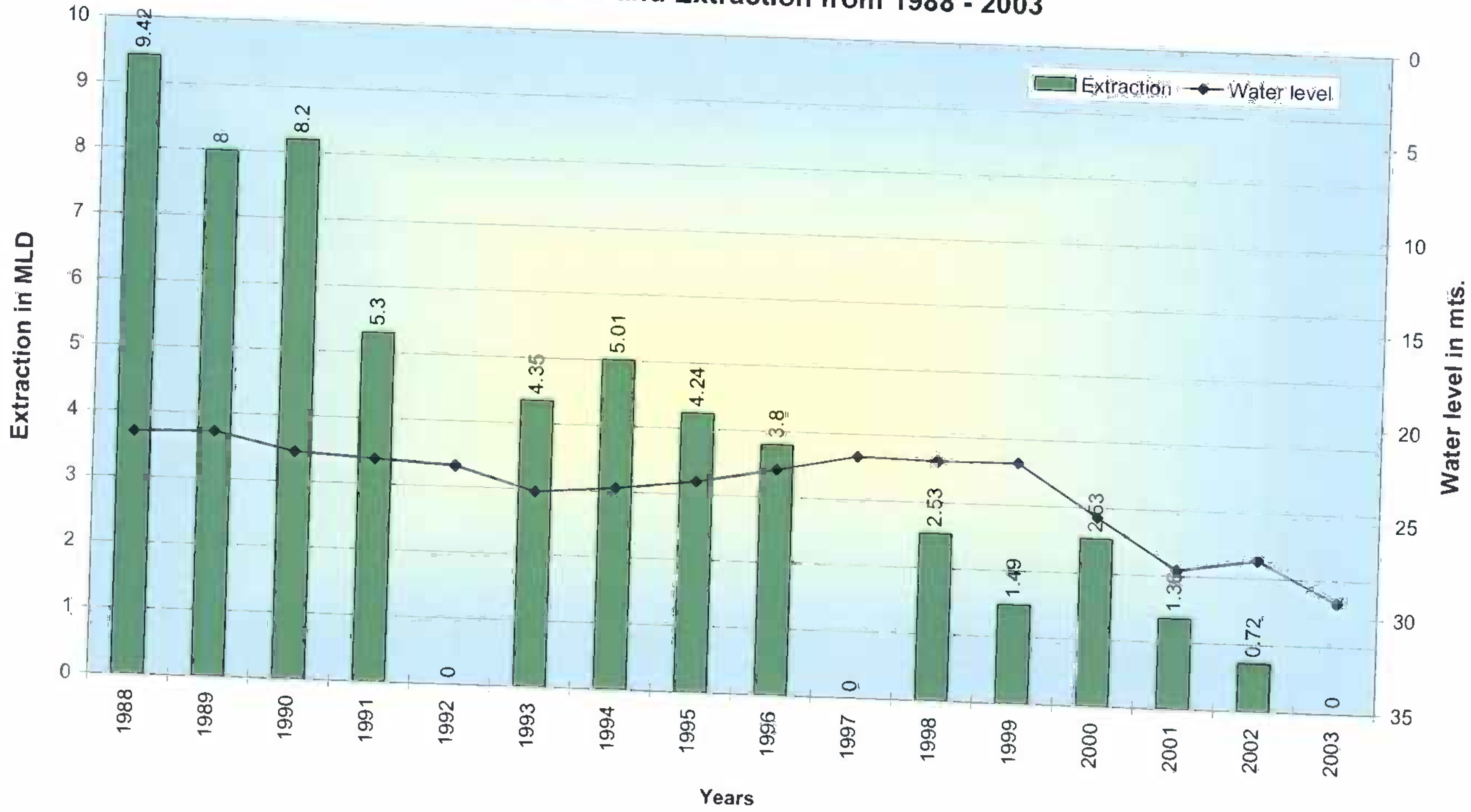


FIGURE 11

PANJETTY WELL FIELD

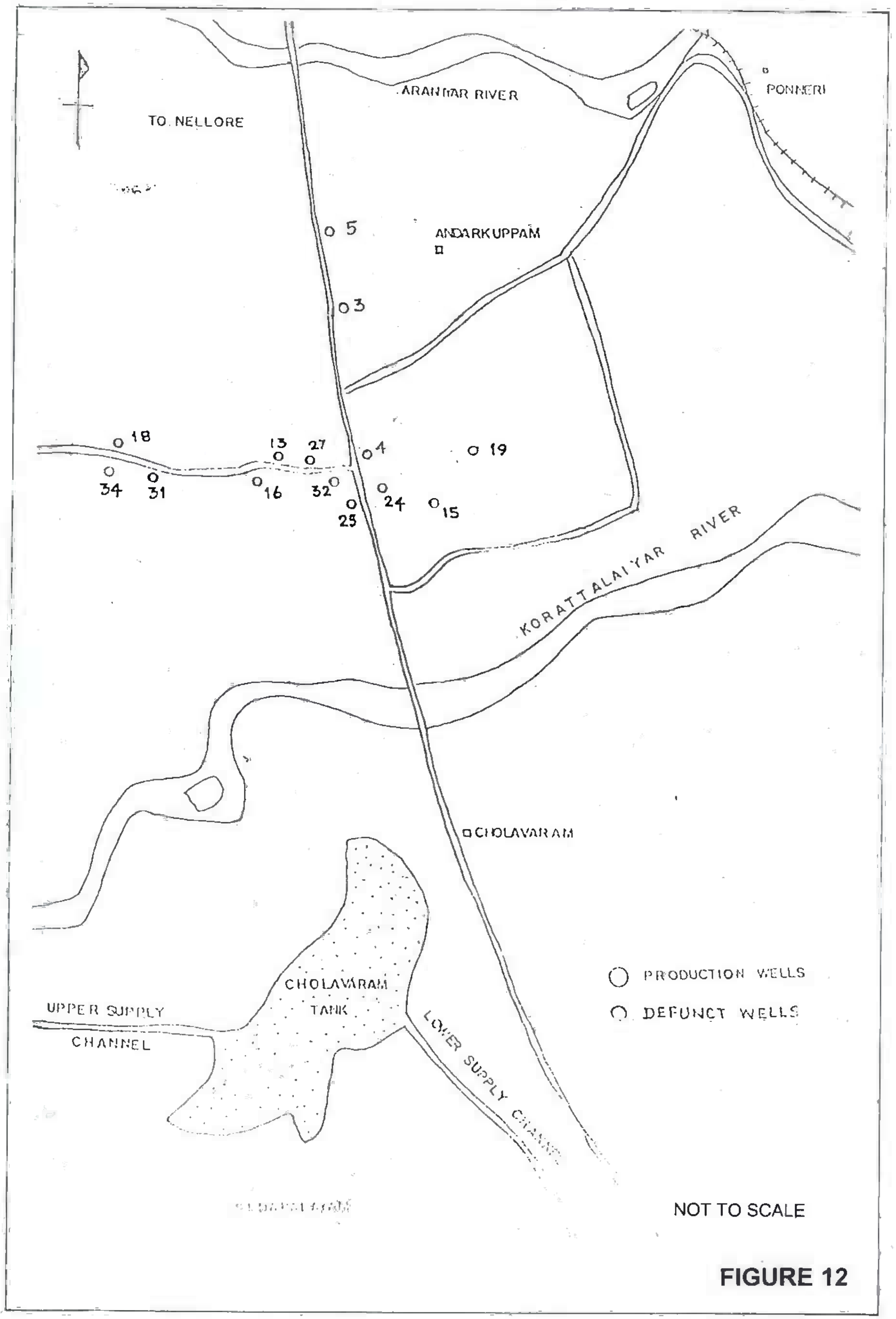


FIGURE 12

PANJETTY WELL FIELD
Water level and Extraction from 1969 -2003

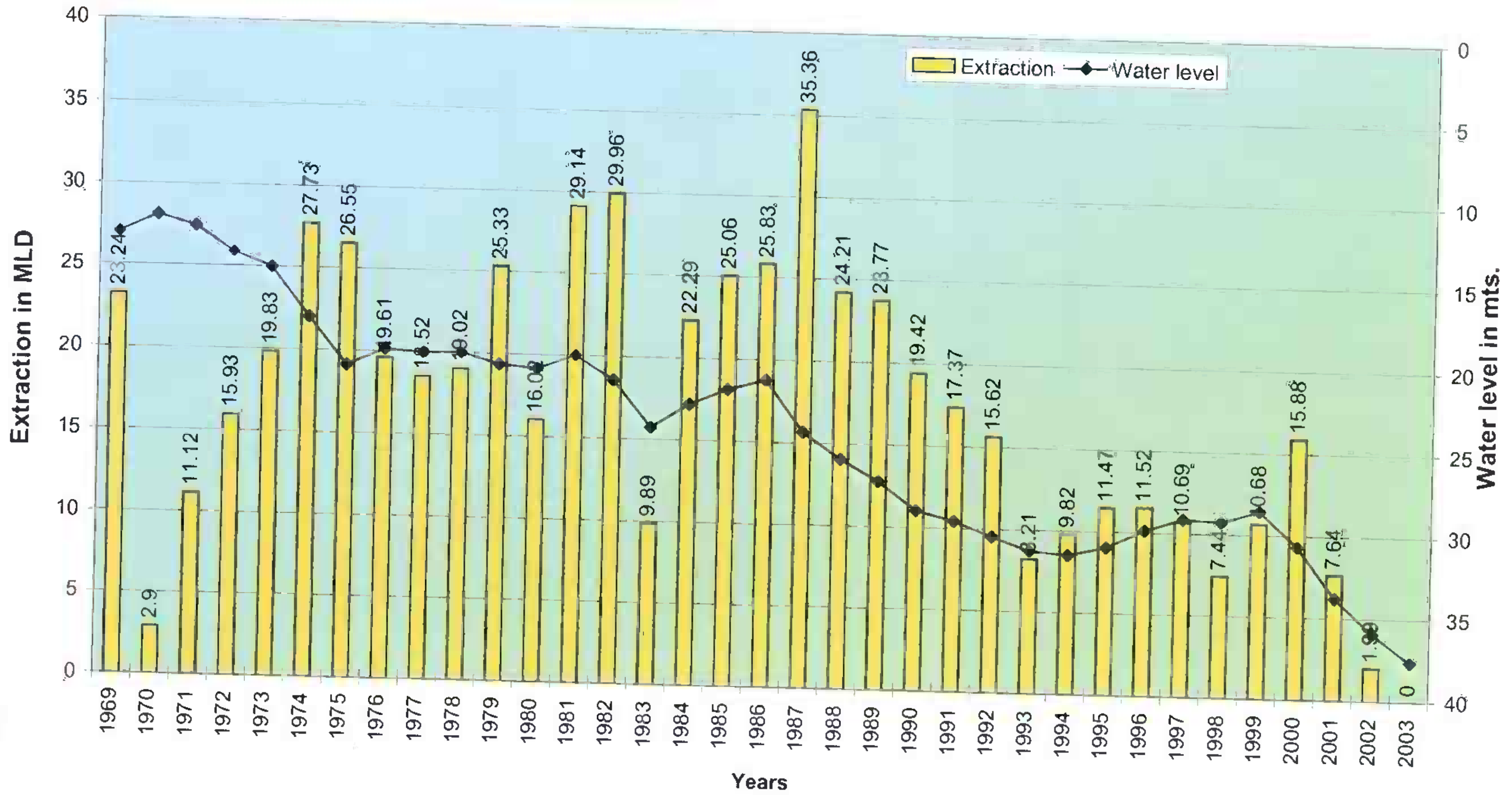


FIGURE 13

MINJUR WELL FIELD

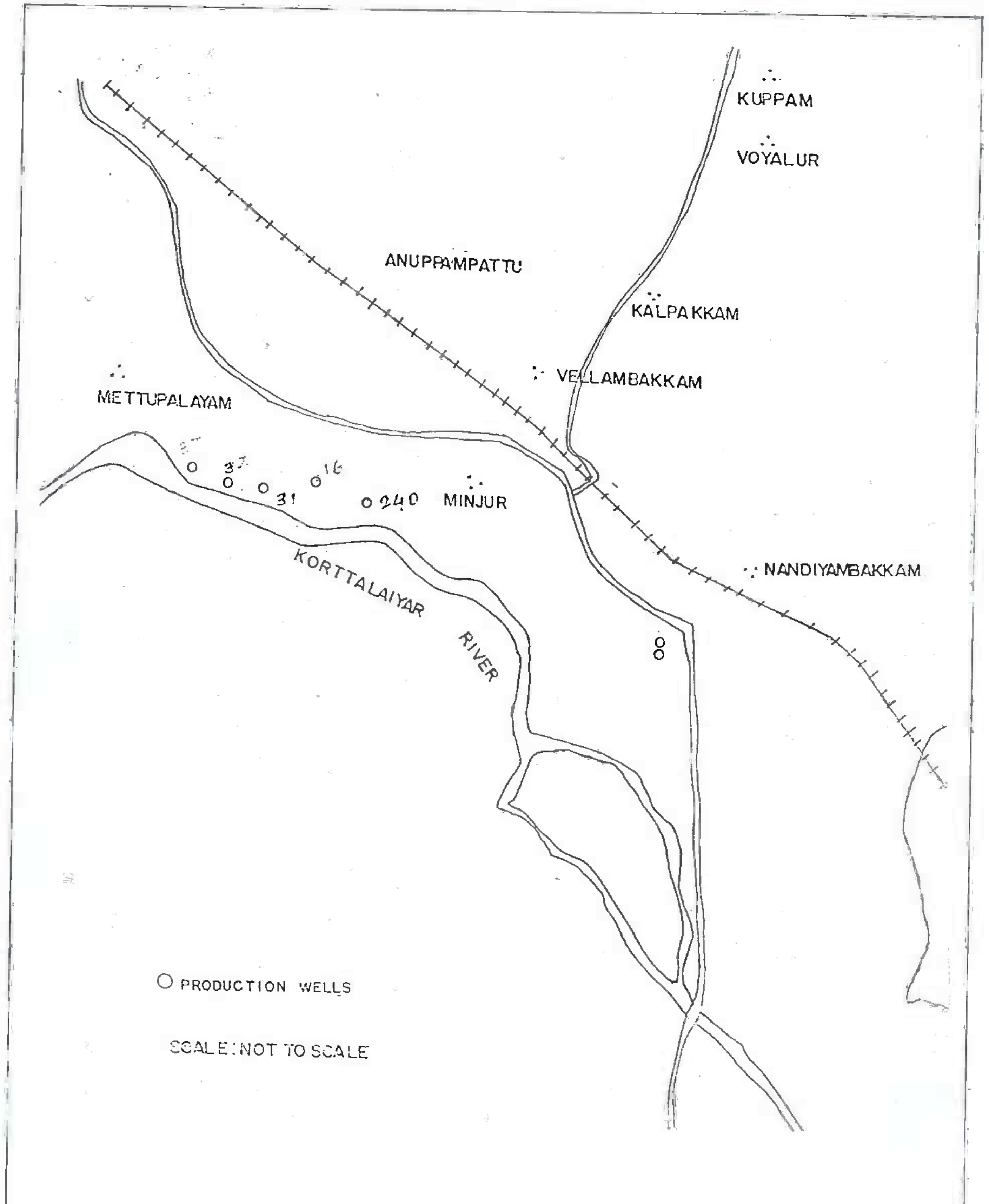


FIGURE 14

MINJUR WELL FIELD
Water level and Extraction from 1969 - 2003

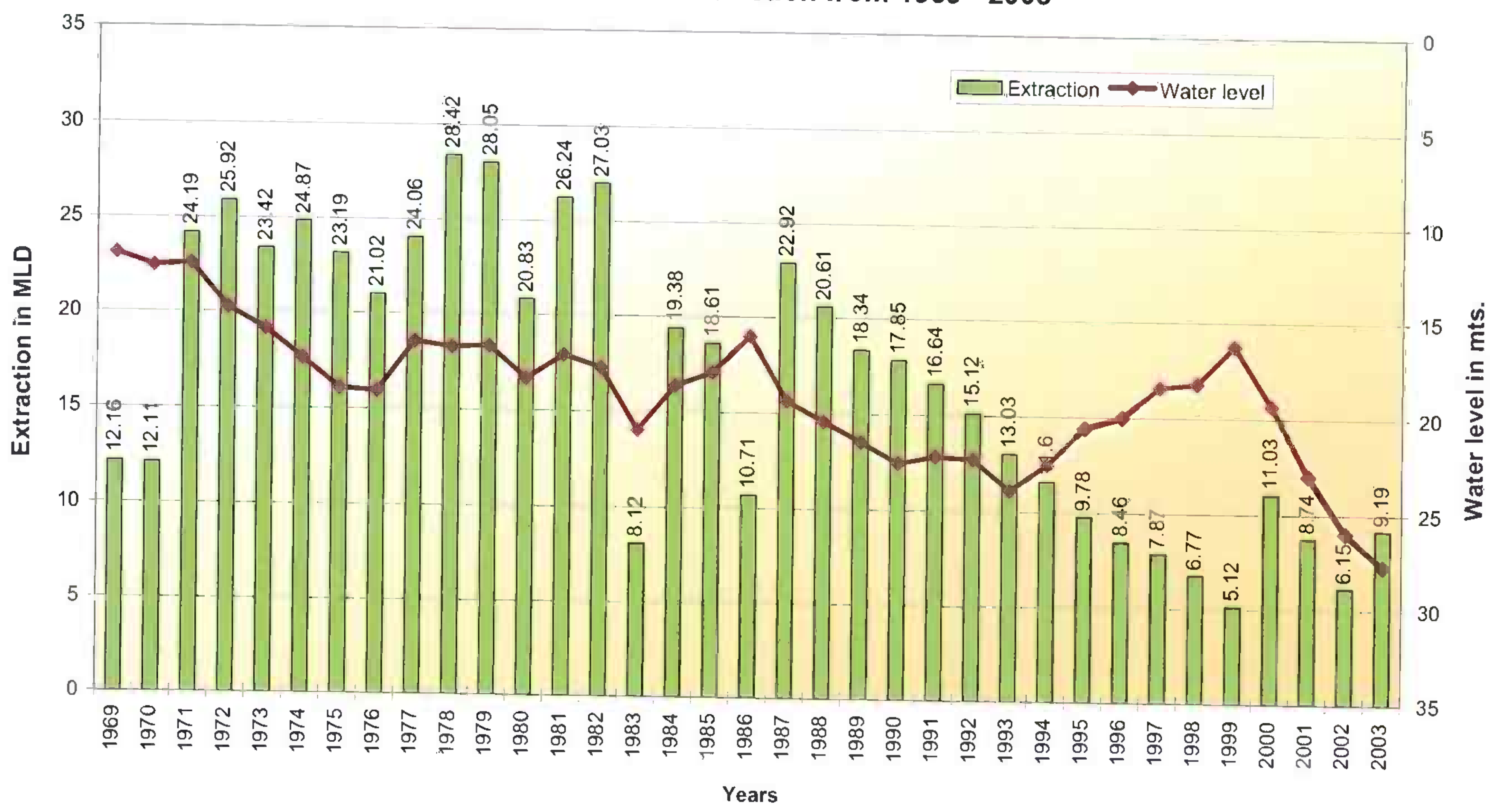
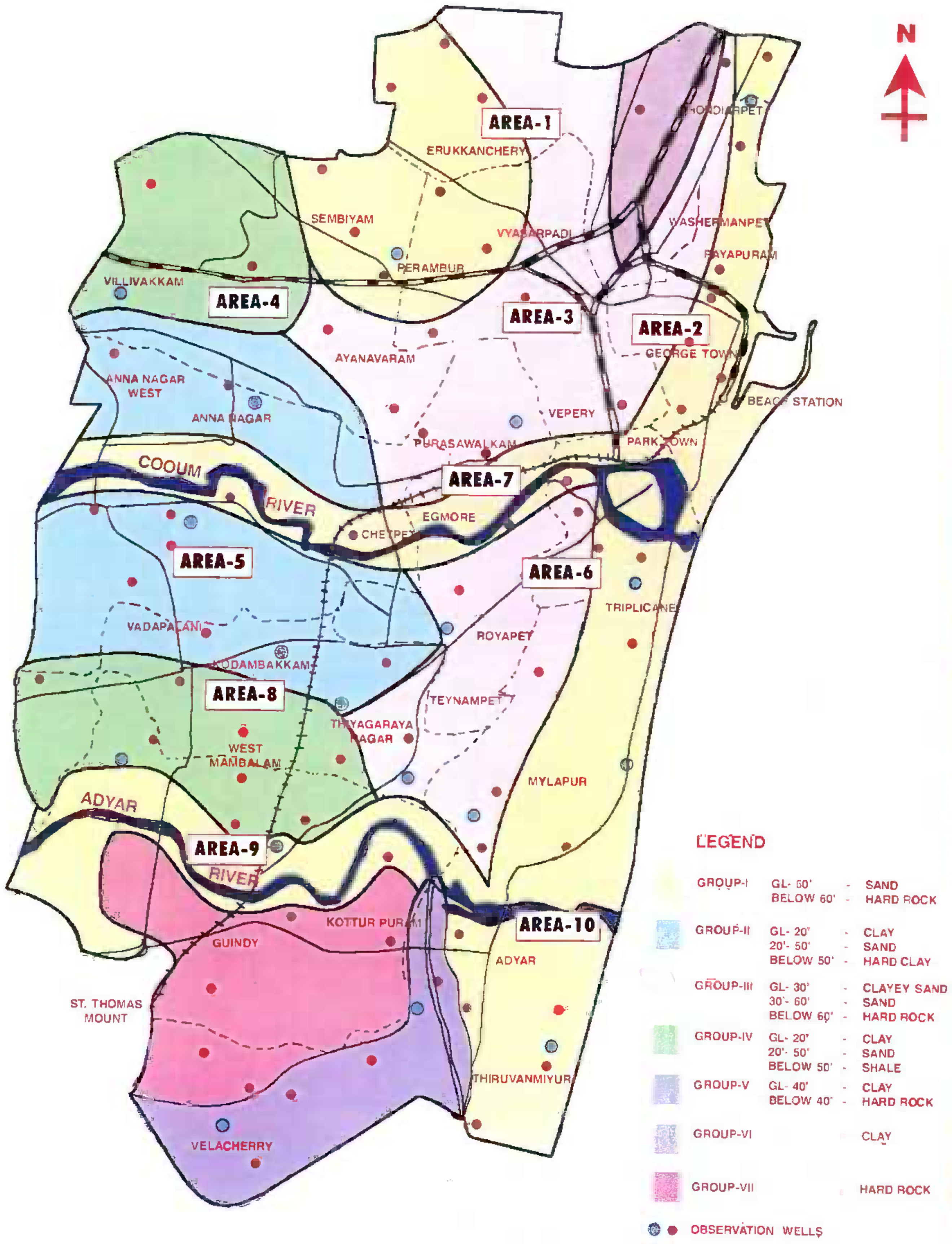


FIGURE 15

CHENNAI CITY - GEOLOGIGAL MAP



NOT TO SCALE

FIGURE 17

CHENNAI CITY
Annual Rainfall and Water level from 1987-2003

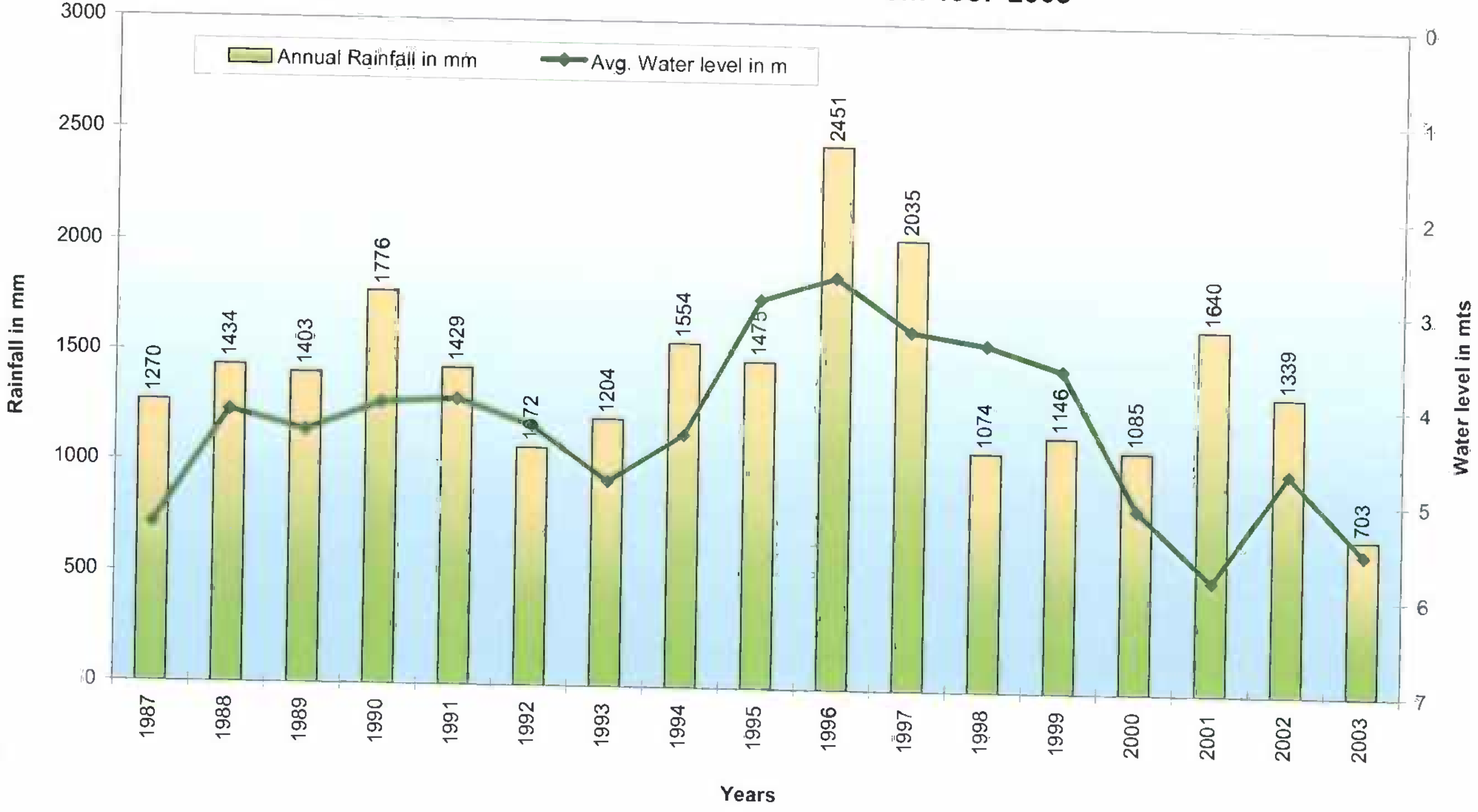


FIGURE 18

Sourthern Coastal Aquifer
Rainfall and water level from 1988 -2002

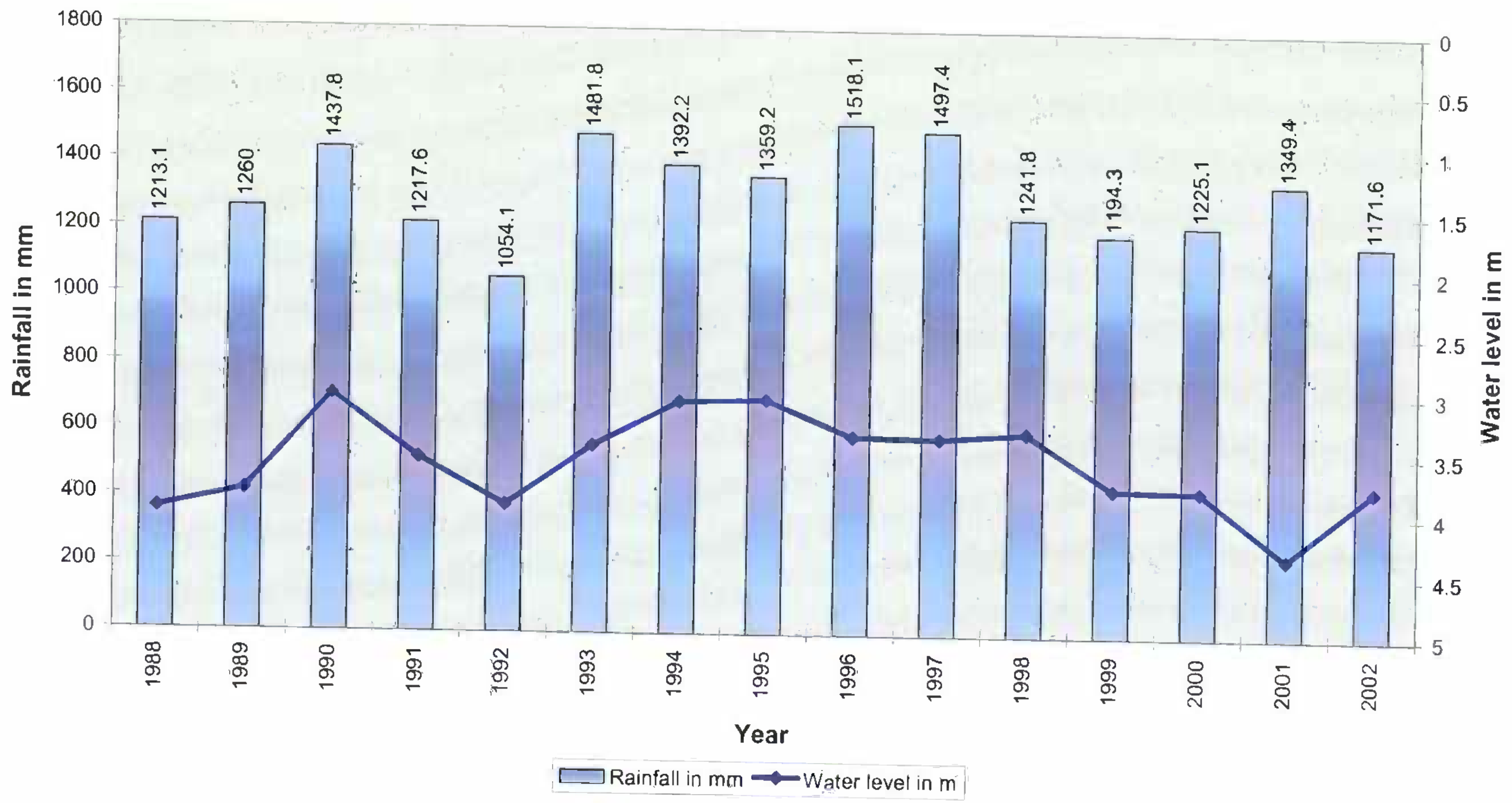


FIGURE 19

SOUTHERN COASTAL AQUIFER

LOCATION OF PUMPING WELLS

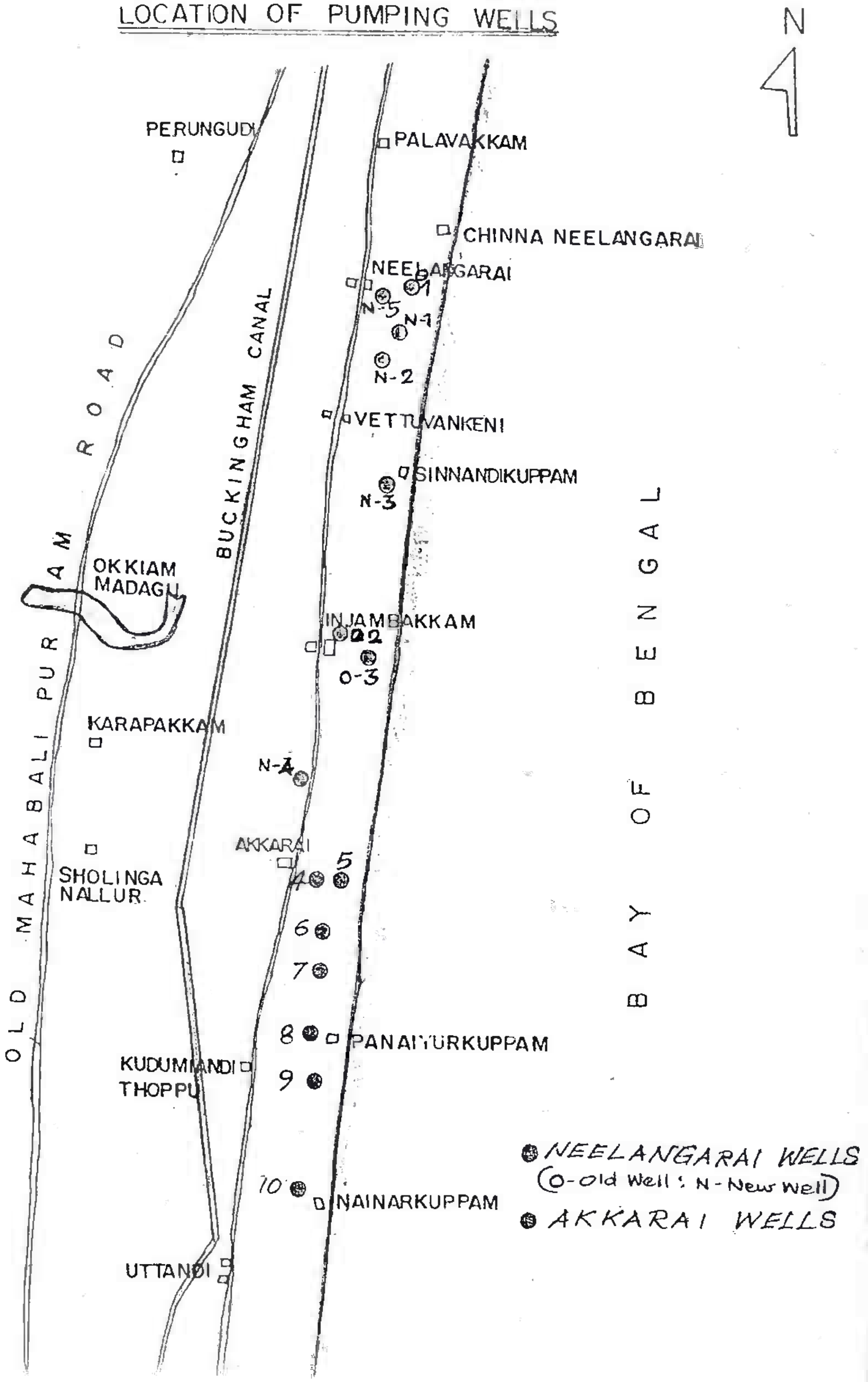
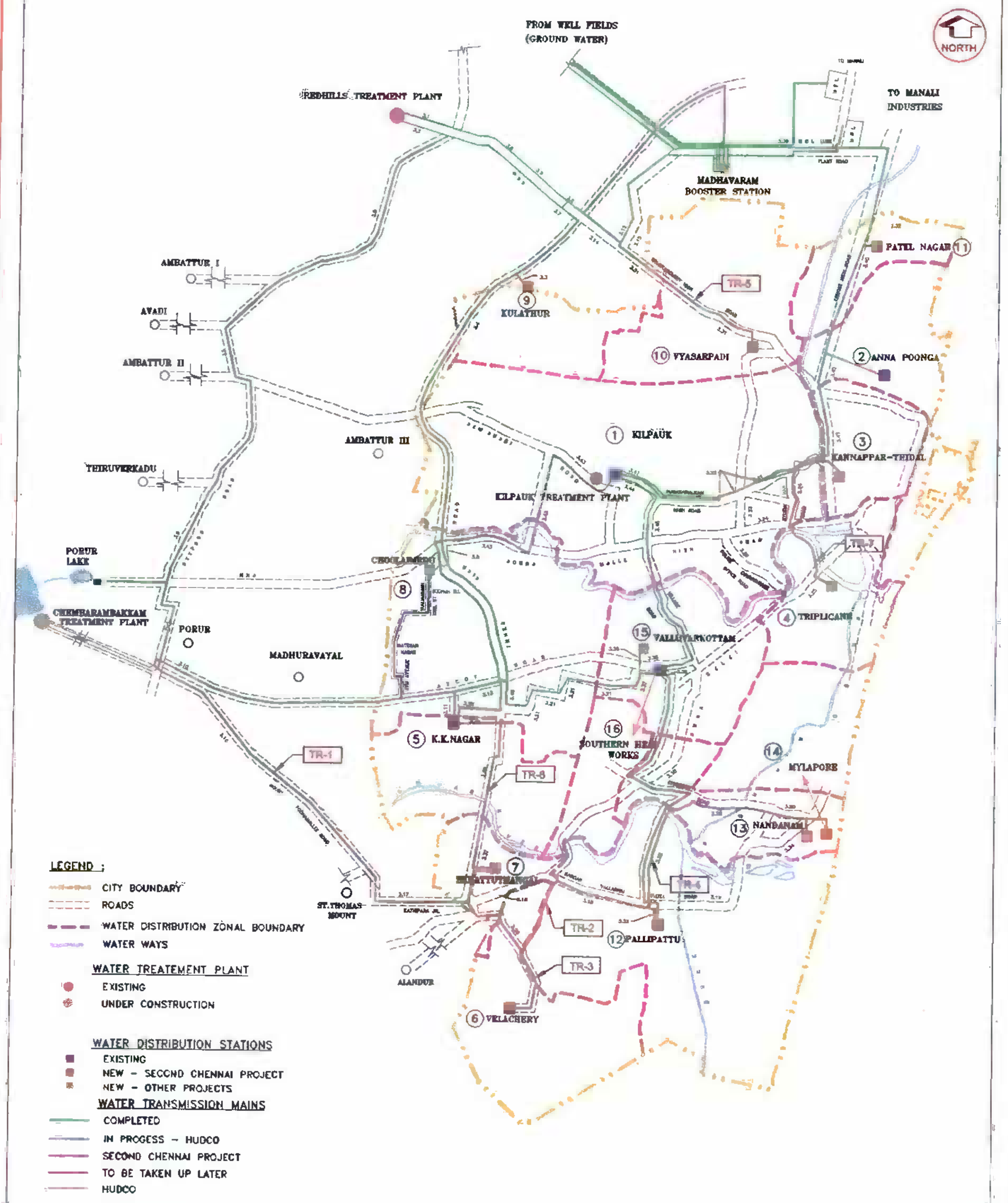


FIGURE 20

CHENNAI CITY-WATER TREATMENT PLANTS AND DISTRIBUTION STATIONS

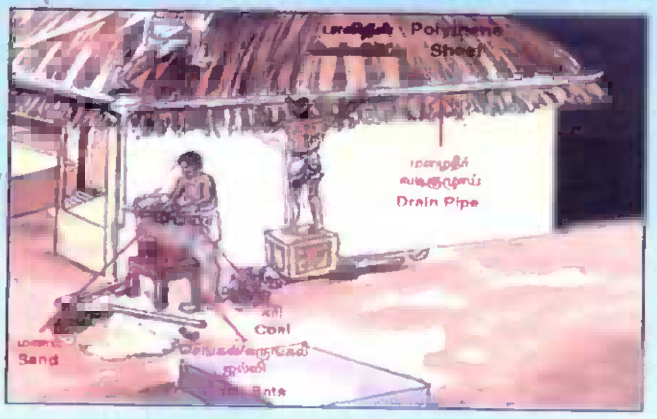


SOURCE-CMWSSB

SCALE=1 : 149000

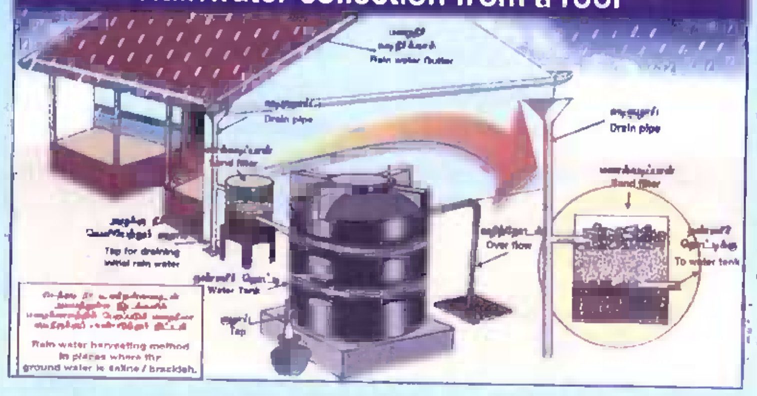
FIGURE 21

Rainwater collection from thatched & tiled roof



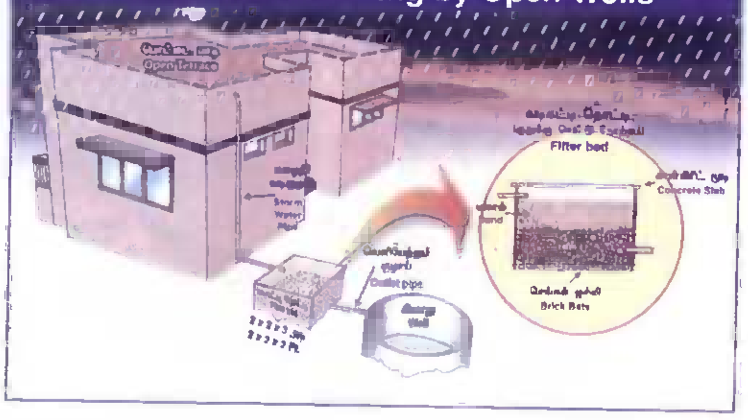
- In the thatched house, polythene sheets can be used for collecting the rainwater.
- Rainwater from the roof is collected through the gutters in the roof.
- The collected water is filtered through a filter.
- The filtered water is collected either in a storage tank or existing sump.
- Approximate cost : Rs. 800/- - 1,000/- (excluding storage tank).

Rainwater collection from a roof



- Rainwater from the roof is collected through the gutters in the roof.
- The collected water is filtered through a filter.
- The filtered water is collected either in a storage tank or existing sump.
- If it is a thatched house, polythene sheets can be used for collecting the rainwater.
- Approximate cost : Rs. 800 - 1,000/- (excluding storage tank).

Rainwater Harvesting by Open Wells

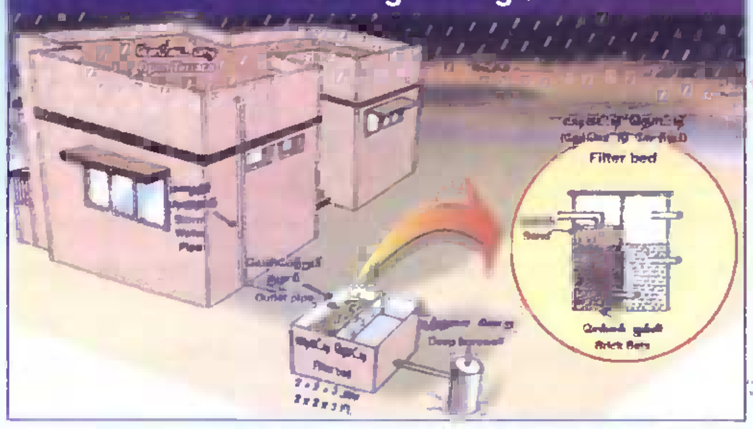


- Rainwater collected from the terrace is diverted to the existing open well using PVC pipes through a filter chamber/sump.

FIGURE 23a

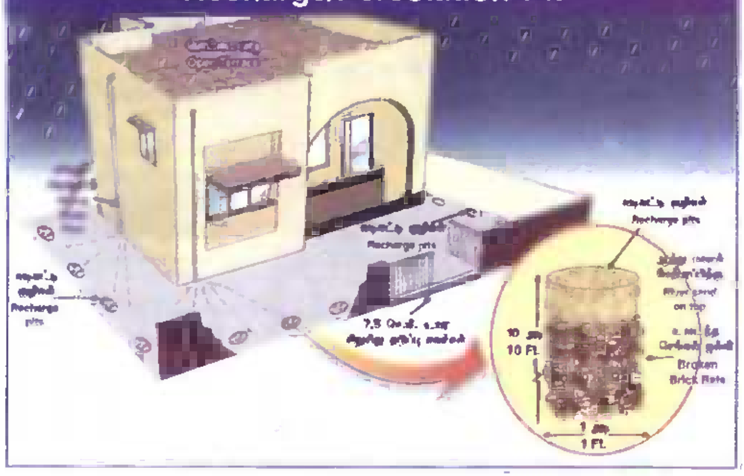
- The size of the filter chamber may be 2' x 2' x 3' filled by brick bats/pebbles in the bottom and coarse sand on the top.
- The chamber may be covered with RCC slab.
- Approx. cost : Rs. 1,350/- (for chamber only).

Rainwater Harvesting through Borewell



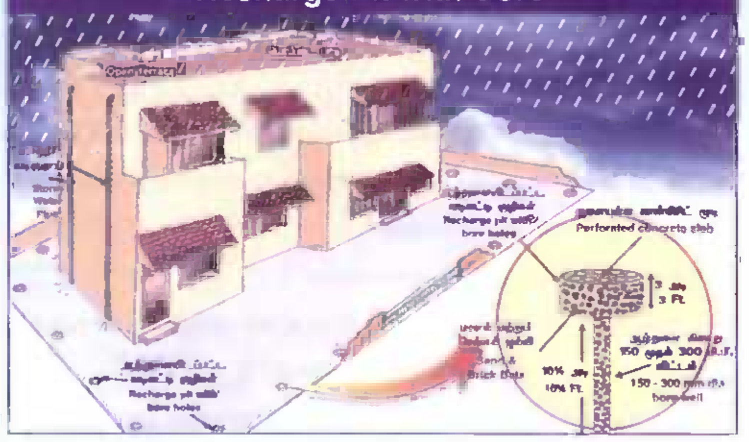
- Roof top rainwater may also be diverted to an existing borewell also.
- A settlement / filter tank of required size has to be provided.
- Overflow water may be diverted to a percolation pit nearby.
- Approximate cost : Rs. 1,000 - 1,200/-

Recharge/Percolation Pit



- Recharge pits are constructed in the open space at required intervals around the building.
- Size : 3' x 3' x 4.5' (depth).
- They may be square/rectangular/circular in shape.
- Filled with brickbats/pebbles.
- Suitable for sandy sub-soil area.
- One unit for 250 sq. ft. area (approx.).
- Approx. cost : Rs. 650/- per unit.

Recharge Pit with Bore



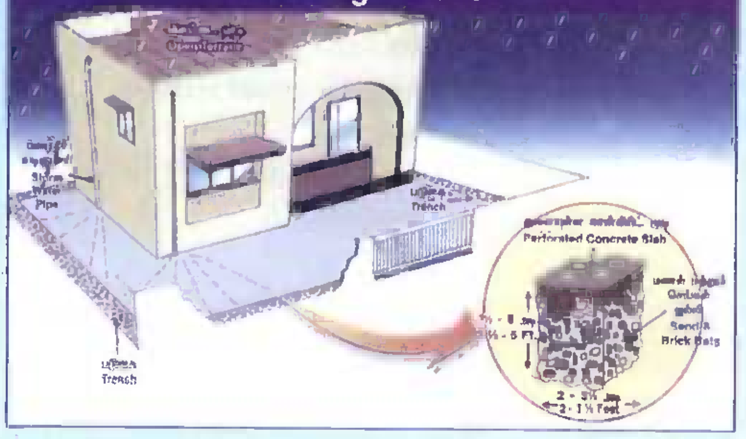
- In addition to recharge pit, a borehole is to be drilled at the centre.
- Suitable for clay sub-soil area where deep percolation is needed.
- Bore hole size : 150-300 mm. dia with 10-15 ft. depth (approx.).
- Filled with brickbats/pebbles.
- 1 unit for 250 sq. ft. area (approx.).
- Approx. cost : Rs. 1,200/- per unit.

Note :

1. Above structures are meant for area with small catchment like individual houses.
2. RCC slab cover is optional.
3. Top (1') portion may be filled with coarse sand.

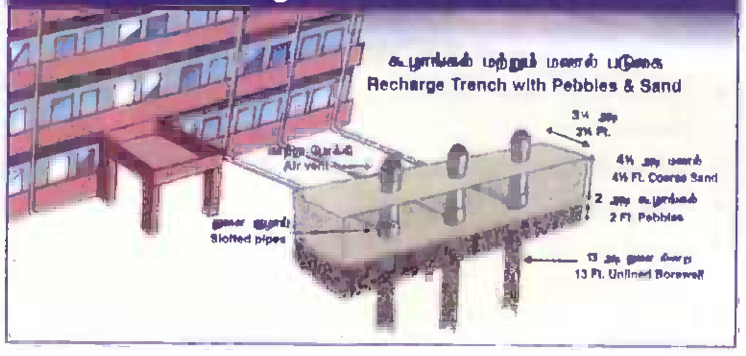
FIGURE 23b

Recharge Trench



- Similar to Recharge Pit but constructed longitudinal in shape.
- Size : 1' - 3' wide/3' - 4.5' depth, length may vary from 3'-15'.
- Filled with brickbats/pebbles.
- Suitable for sandy sub-soil area.
- One or two units required based on the catchment / run-off.
- Approx. cost : Rs. 650/- per unit with 3' x 3' x 4.5'.

Recharge Trench with Bore

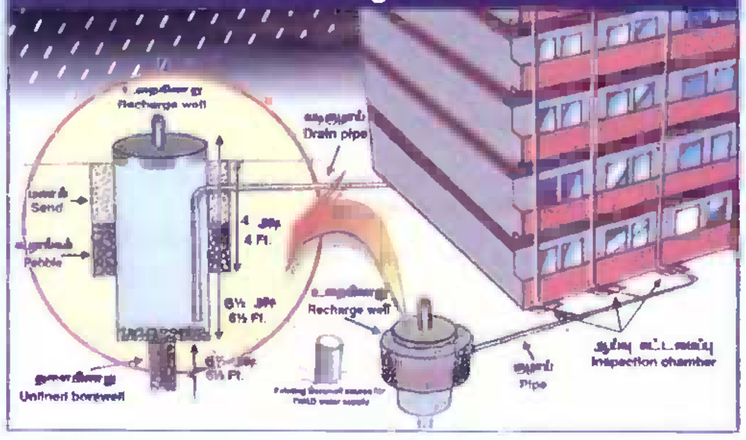


- Along the recharge trench, boreholes has to be drilled.
- Bore hole size : 150-300 mm. dia with 10'-15' depth.
- Filled with brickbats/pebbles.
- Borehole interval : 10'-15'.
- Suitable for clay sub-soil area.
- Approx. cost : Rs. 900/- per metre.

Note :

1. Above structures are meant for area with large catchment like apartments / big complexes.
2. RCC slab cover is optional.
3. Top (1') portion may be filled with coarse sand.

Recharge Well



- Small diameter wells.
- Size : 3' dia with 5' - 10' depth.
- Constructed with brick/concrete rings.
- Side walls must be perforated.
- Bottom (1') is filled with brickbats.
- Covered with RCC slab/manhole.
- Suitable for sandy sub-soil area.
- Approx. cost : Rs. 4,100/- per unit.

Note :

1. Above structures are meant for large areas with heavy run-off.
2. Run-off water diverted through a filter media preferably.
3. One well is sufficient for areas with more than one ground extent.
4. Rainwater may be diverted through small trenches (if necessary).

FIGURE 23c

Rainwater Harvesting Structures :

Sandy Sub-soil areas :

1. Percolation Pit.
2. Recharge Trench.
3. Recharge Well (Small Diameter/Shallow).

Clay Sub-soil areas :

1. Percolation Pit with Bore.
2. Recharge Trench with Bore.
3. Recharge Well (Large Diameter/Deep).

Hard Rock areas (Weathered) :

Recharge Well (Large Diameter / Deep).

Note : Open Well (existing), Bore Well and Defunct / Bore Well methods are common for all areas.

Things to be remembered

1. The nature of Rain Water Harvesting (RWH) structures and their design parameters remain the same for any building except the physical scale (size) and No. of structures which may increase corresponding to the size of the catchment.
2. For harvesting rainwater in open space around the building, a dwarf wall of required height (approx. 7.5 cm.) should be constructed at the entrance (gate) to avoid surface run-off and to make rainwater available to recharge.
3. If manholes (waste water line) are present in the open space, the height of which have to be raised a little to avoid draining of rainwater along with waste water.
4. The cost of RWH structures may vary depending on the availability of existing structures like wells/tanks which may be modified to be used, thereby reduce the cost.
5. Grill/mesh has to be fixed at the entrance / mouth of the rainwater pipe in the terrace to filter large particles such as leaves etc.
6. Avoid pavements since unpaved surfaces have more percolation rate. If paving of open space is unavoidable, use perforated pavement blocks to allow percolation of rainwater.
7. For effective recharge of rainwater, combination of different structures may be used as per the site requirement viz. area of the building and soil conditions.
8. All recharge structures must be properly maintained for effective recharge throughout the year. Maintenance is very easy and simple.

FIGURE 23d

Should Rainwater be stored directly or recharged ?

The decision to store or recharge rainwater depends on the rainfall pattern of a particular region. For example, in places where rain falls throughout the year, one can depend on a small domestic sized water tank for storing rainwater, since the period between two spells of rain is short.

On the other hand, in areas where the total annual rainfall occurs only during 2 to 3 months, the water collected during the monsoon has to be stored throughout the year which require huge volumes of storage containers and as well as some treatment processes. Therefore, considering the other benefits of ground water recharge, it is more feasible to use rainwater to recharge ground water aquifers rather than for storage.

How much water can be harvested ?

Amount of rainwater harvesting depends on the annual rainfall, total area of collection and the amount of recharge into the ground.

Average annual rainfall of Chennai	1200 mm. (1.2 m.)
Amount of rainwater collected in one ground plot (223 sq.m.) per year	223 x 1.2 = 267 cu.m./ 2,67,000 litres / year (approx.)
Volume of water recharged into the ground (considering of 60% effective recharge)	1,60,000 litres / year (approx.)

This means that 1,60,000 litres / ground / year is replenished out of the total quantity of water extracting from the ground.

Methods of Rainwater Harvesting

- Rainwater can be harvested from roof tops and also from open spaces.
- Wherever open wells / bore wells are available, roof top water can be used for direct recharging of these wells.
- Rainwater available in the open spaces can be recharged into the ground using other recharge structures.

Rainwater may be collected and recharged into the ground water aquifers through the following simple and cost-effective methods :

1. **Roof-top Harvesting**

a) Open well method.

b) Bore well method.

2. **Roof-top / Open space Harvesting**

a) Percolation / Recharge pit.

b) Percolation / Recharge pit with bore.

c) Recharge Trench.

d) Recharge Trench with bore.

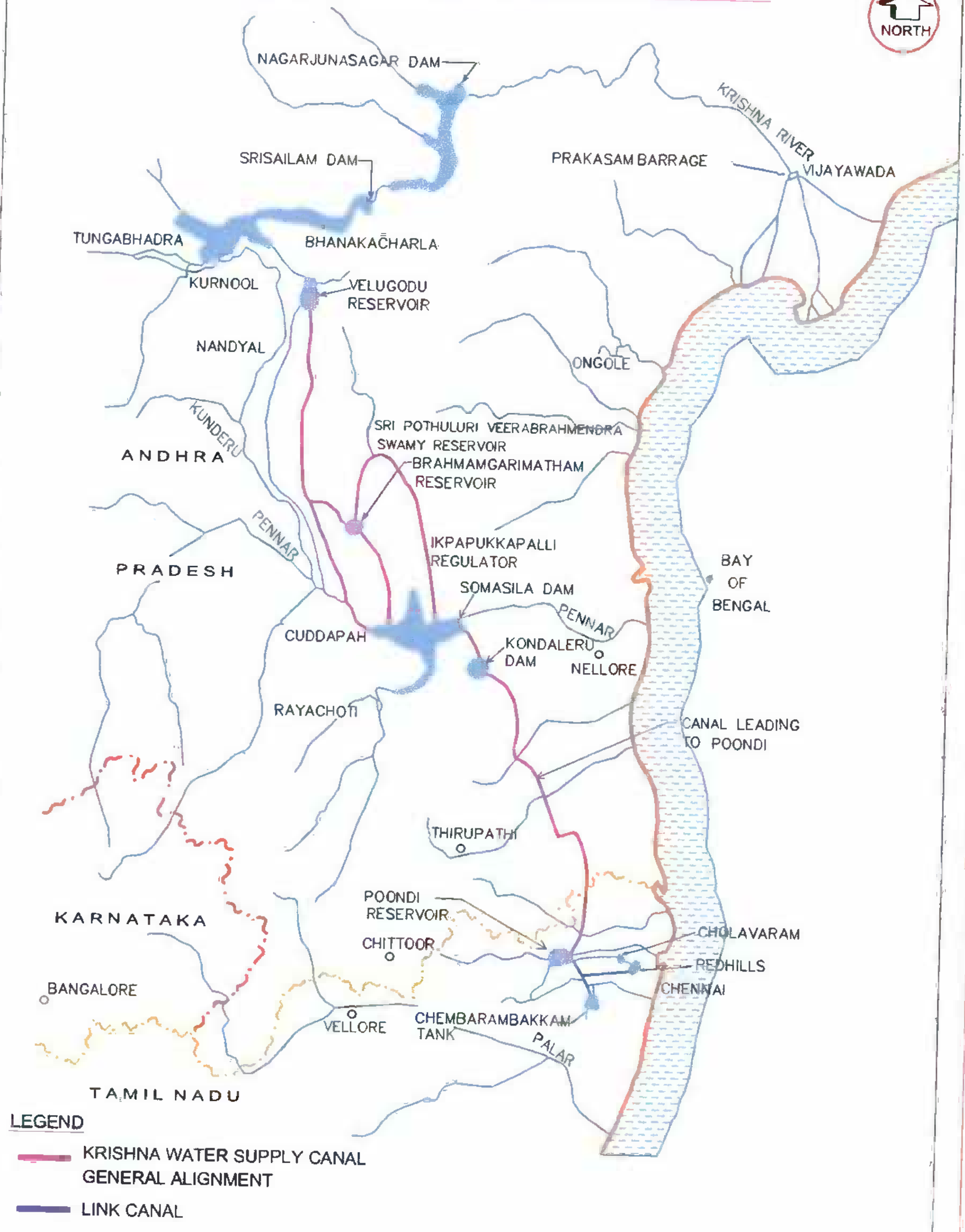
e) Recharge well (Small diameter).

f) Recharge well (Large diameter).

Note : Basically, these are simple and common methods from which any combinations can be selected based on the site conditions such as the extent of the building and sub-soil conditions. For example, in large apartments / commercial complexes, No. of units of RWH structures may be increased since the volume of the rainwater collected is more.

FIGURE 23e

KRISHNA WATER SUPPLY FOR CHENNAI



SOURCE-CMWSSB

FIGURE 24

CHENNAI METROPOLITAN WATER SUPPLY AND SEWERAGE BOARD
CHENNAI WATER SUPPLY AUGUMENTATION PROJECT - I

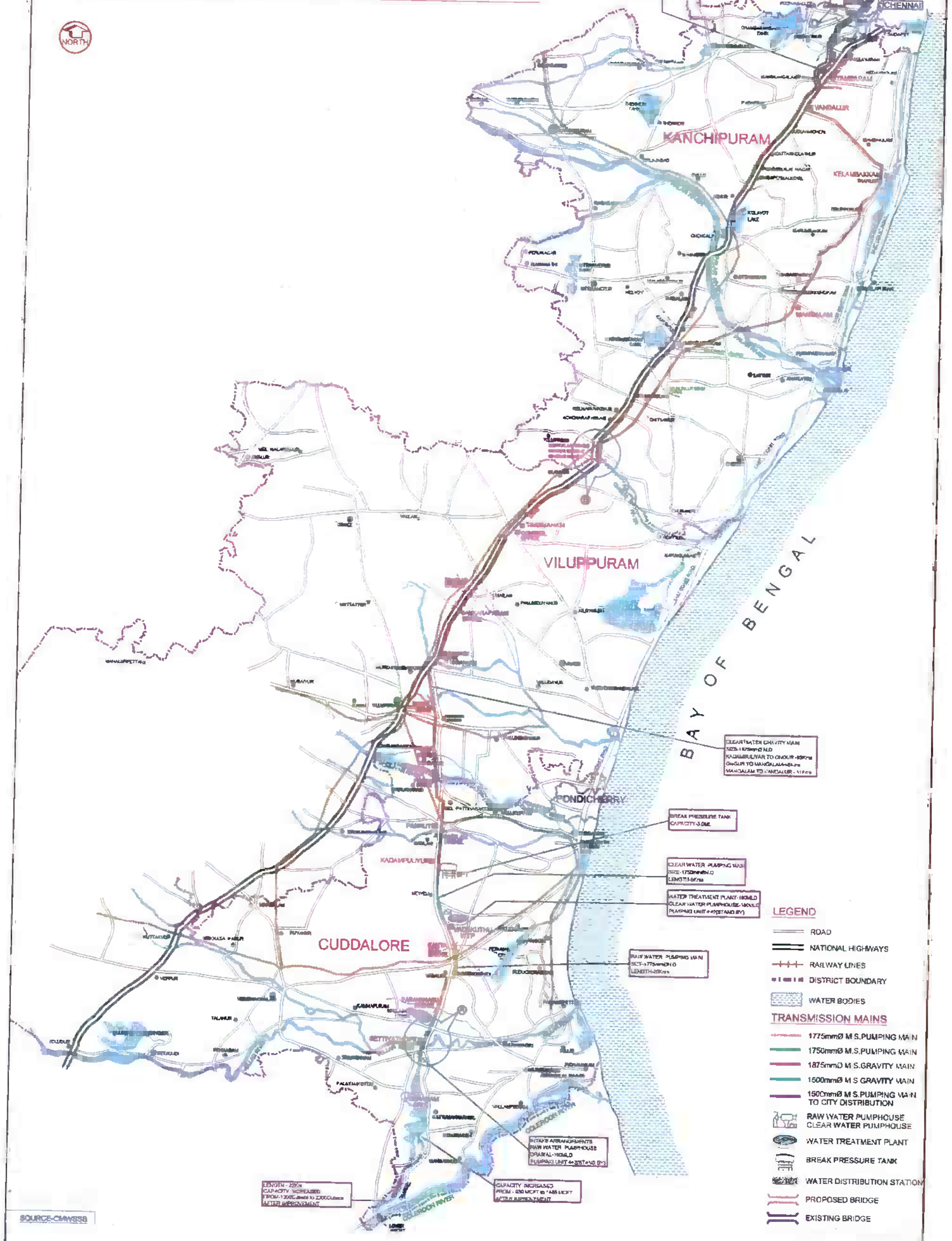
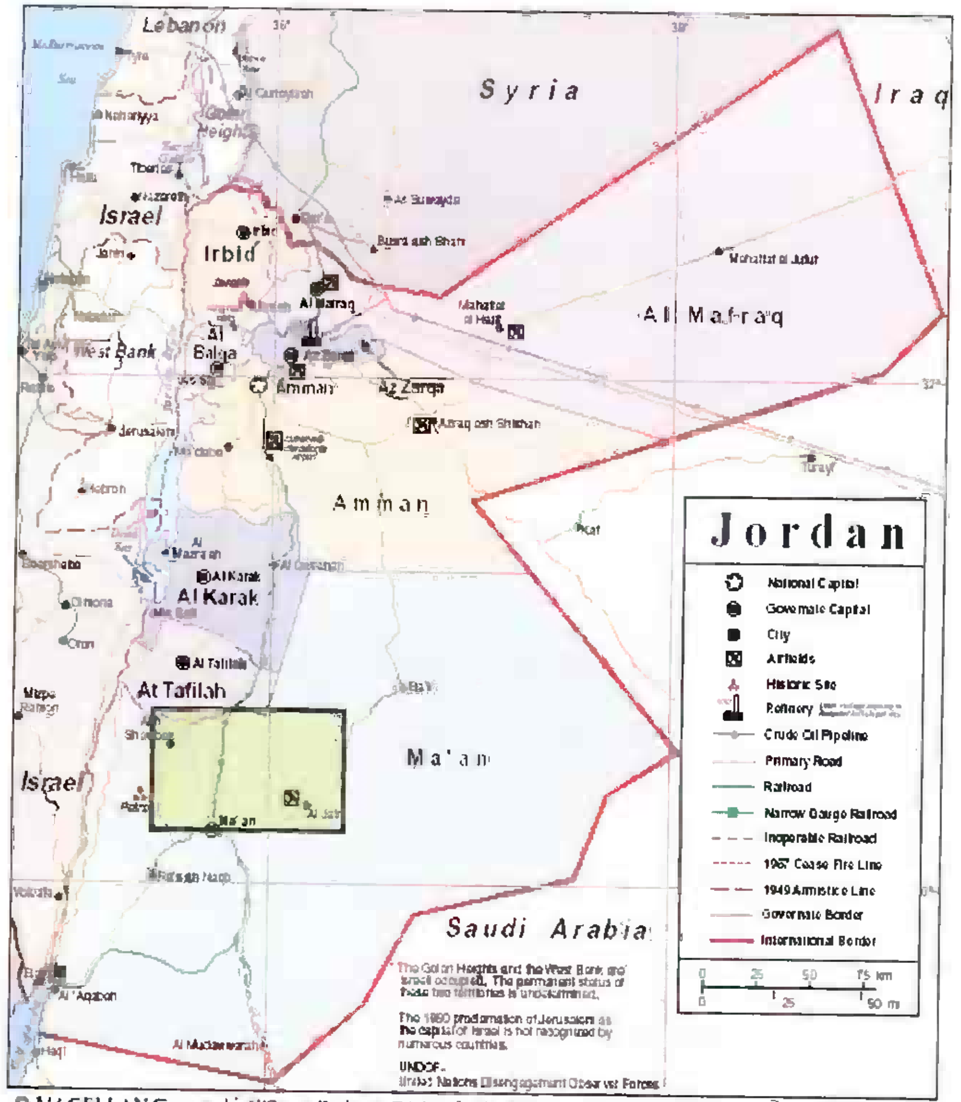


FIGURE 25



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Case Study Area Shoubak – Al Jafr

Location of Case Study Area
Figure 1

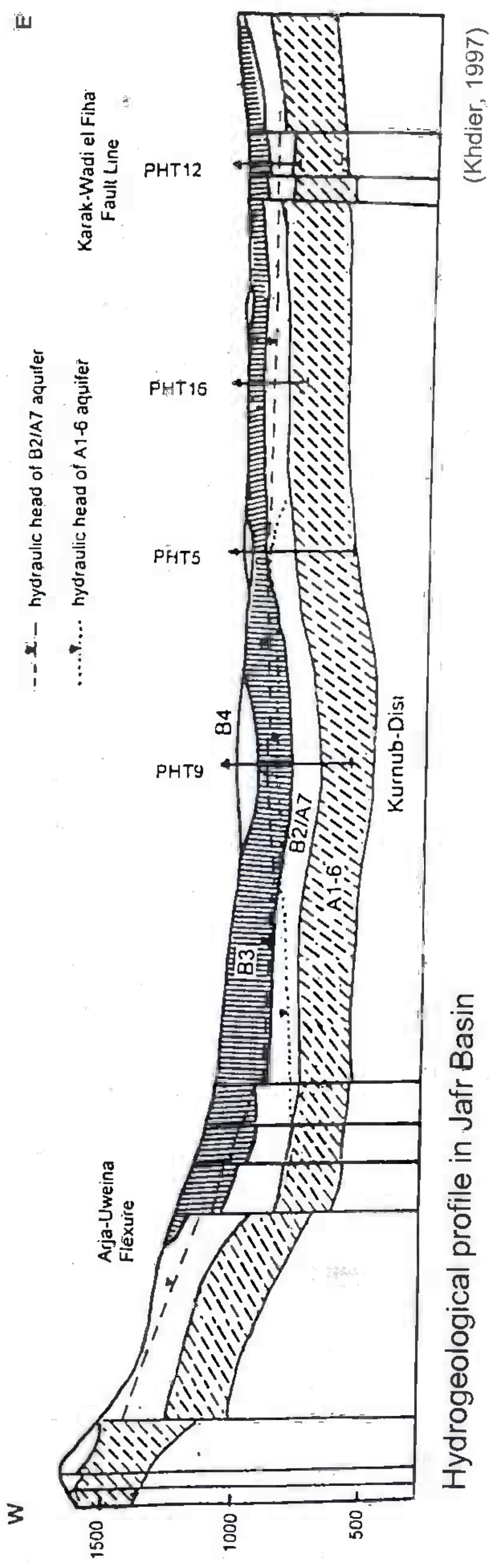
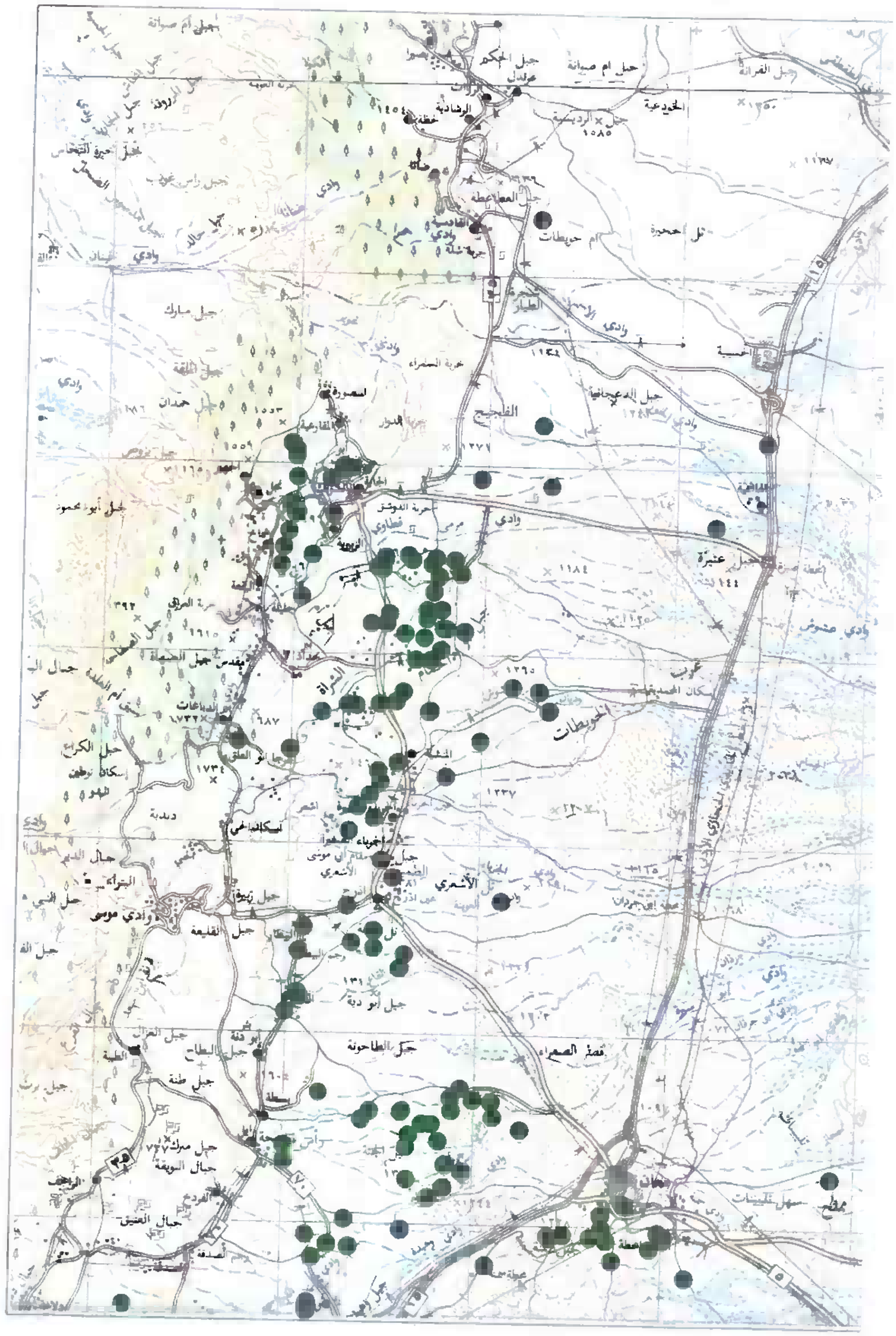

W
E
1500
1000
500
hydraulic head of B2/A7 aquifer
hydraulic head of A1-6 aquifer
Karak-Wadi el Fiha Fault Line
PHT12
PHT16
PHT5
PHT9
B4
B3
B2/A7
A1-6
Kurnub-Disi
Arja-Uweina Flexure
Hydrogeological profile in Jafr Basin
(Khdier, 1997)

FIGURE 4



Location of wells
FIGURE 5

REPORT ON CASE STUDIES

ANNEX F ECONOMIC DATA AND AGRICULTURE

CONTENTS

PART II JORDAN CASE STUDY (AL-JAFR SHOUBAK)

Abbreviations and acronyms

References

Appendices

REPORT ON CASE STUDIES

PREFACE

This Document on Economic Data and Agriculture is Annex F of the Report on Case Studies for the DFID funded project No 8332 of KaR Program - Water Demand Management in Areas of Groundwater over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A - Approach to the Study
Annex B - Water demand management
Annex C - Sustainable livelihoods approach
Annex D - Focus group discussion - Methodology & results
Annex E - Water resources
Annex F - Economic data and agriculture
Annex G - Water policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

Annex F describes the agricultural activities and economic data in the areas studied including (i) economic value of water used in agriculture in different prevailing cropping patterns; (ii) cost of additional water provided through augmentation of supply or by water savings through demand management.

PART I TAMIL NADU CASE STUDY

FI.1. The Case Study Area

The Case Study area is south of the Tamil Nadu – Andhra Pradesh boundary, the District of Tiruvallur covering the A-K aquifer and the Chennai Metropolitan Area. The sections that follow make use of data related to Tamil Nadu as a whole and also to studies that have been carried out in Chennai city, the Chennai Basin and the A-K basin.

FI.2. overall economy

FI.2.1 Economy of Tamil Nadu

Tamil Nadu consists of 30 districts covering a geographical area of 130,000 km^2 with a total population of 62.41 million (2002). The surface area of Tamil Nadu is only 4% of India but population comprises 6% of the country.

The GDP of Tamil Nadu in 2001-2002 was Rs 1,309.2 billion at current prices (or Rs 814.9 billion at 1993-1994 prices). The annual growth rate of the state GDP was 5.9% in the period 1993-2002. The State’s contributions to the GDP in 2002 were 18%, 32% and 51% respectively from the Primary, Secondary and Tertiary sectors.

The Primary sector (agriculture, forestry and fishery) plays an important role in the State's economy but its contribution to the economy has reduced from 26% in 1993 to 18% in 2002 due to the growth rate of the Tertiary sector (business and services) in the structure of the economy. During a period of 1993-2002, annual growth rates were 0.8%, 5.7% and 8.5% per annum for the Primary, Secondary (Industry and Construction) and Tertiary sectors respectively.

GDP per capita in 2002 was Rs 13,055 at 1993 fixed prices equivalent to about US$ 650. See Table F2-1.

Industries in 2000-2001 comprised 32,658 registered units providing 240,332 employment to generate a production of Rs 72.7 billion. Beside these industries, Khadi and Village industries including cotton, woollens, silk and muslin produced an additional value of Rs 5.5 billion.

Tamil Nadu's Tenth Five Year Plan (2002 - 2007) proposes to give a big push to agriculture at a growth rate of 4% in agricultural sector. The overall growth rate is targeted at 8% in GDP during the Tenth Plan with a reduction of poverty level from 21% in 1999-2000 to 10% in 2007.

The net area[1] sown in Tamil Nadu (2002) was about 5.3 million ha of which about 2.9 million ha (55%) of principally paddy and sugarcane crops is irrigated from canals, tanks, wells and other sources. Main agricultural production outputs were paddy (7.37 million tons), total cereals (8.55 million tons), groundnut (1.36 million tons) and others such as cumbu, rag and cholam with about 300-400 thousand tons each crop.

Export values by sea and by air through Tamil Nadu were Rs 269.8 billion in 1999-2000 (17% of the export value of all India) and Rs 117.4 billion in 2000-2001 6% of the export value of all India).

[1] The Statistic Hand Book of Tamil Nadu, 2002

Table F2-1: Selected Economic Indicators Tamil Nadu State

(Rs billion - Fixed prices 93-94)

	Sectors	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
I	PRIMARY	135.50	151.21	131.07	129.70	141.22	153.52	146.82	150.42	144.50
1	Agri-forest-fish	132.43	147.90	127.97	126.77	138.11	150.67	143.77	146.88	140.93
	Agriculture	123.54	138.53	118.77	117.19	129.07	140.78	133.66	136.74	130.71
	Forestry	3.94	4.03	3.94	3.96	4.12	4.23	4.51	4.55	4.55
	Fishing	4.96	5.35	5.26	5.62	4.93	5.66	5.60	5.59	5.67
2	Mining & quarrying	3.07	3.31	3.10	2.93	3.10	2.85	3.05	3.54	3.58
II	SECONDARY	166.01	189.37	209.23	207.62	212.53	210.76	239.38	247.65	258.21
III	TERTIARY	214.25	239.27	260.04	286.87	324.42	354.44	371.69	393.14	412.14
IV	GDP	515.76	579.85	600.35	624.19	678.17	718.71	757.90	791.21	814.86
V	POPULATION (1000)	57,670	58,340	58,992	59,624	60,235	60,821	61,381	61,913	62,416
VI	GDP/capita (Rs)	8,943	9,939	10,177	10,469	11,259	11,817	12,348	12,779	13,055
VII	GDP growth (%/year)	-	12%	4%	4%	9%	6%	5%	4%	3%
	GDP Structure (%)									
	Primary	26%	26%	22%	21%	21%	21%	19%	19%	18%
	Secondary	32%	33%	35%	33%	31%	29%	32%	31%	32%
	Tertiary	42%	41%	43%	46%	48%	49%	49%	50%	51%
	GDP	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Statistic hand book, Tamil Nadu 2002

FI.2.2 Economy of the Area Studied

Most of the activities in the Case Study area are centered on the city of Chennai. Most of the farming communities comprise marginal farmers who depend on jobs in the city for their livelihood. There has been a trend during the last ten years of sending young people to the city for work and of investing in better education for children to derive better income and better social position. This has resulted in a shortage of labour for agricultural activities especially at peak season demand.

There are about 18,000 small scale industries, and 124 large and medium industries of various types. These provide ample employment opportunities for the basin population as well as for the migrants from other parts of the Tamil Nadu.

Fishing is also a major source of livelihood for a section of the population. Manufacture of bricks, stone, metals, granite slabs and similar items also provides considerable employment.

The area has great potential to attract tourists. The area is well connected by roads and rail. The Chennai harbour and Meenambakam airport provide major facilities for tourists and other economic activities.

FI.3. PRICES

FI.3.1 Agricultural inputs and outputs

The agricultural survey carried out through Focus Group Discussions (FGD) during 25-31 March, 2004 by the study team showed that the cost of inputs and outputs in the A-K Basin are as shown in Table F3-1 below.

Table F3-1: Cost of main inputs and outputs, 2003

	Kg per bag	Rs per Bag	US$/Bag	US$/kg
DAP	40	480	10.7	0.27
Urea	50	250	5.6	0.11
Complex 17-17-17	50	460	10.2	0.20
16-20 mix	40	380	8.4	0.21
Potash	50	250	5.6	0.11
Ammonium Chloride	50	250	5.6	0.11
Paddy	75	450	10.0	0.13
Groundnut	40	650	14.4	0.36

FI.3.2 Power and fuels

Electricity tariff

- High Tension (HT) class I: Rs 3.60 per kWh;
- HT class II: Rs 4.50 per kWh;
- For railways: Rs 4.50 per kWh;
- Low Tension (LT) II commercial : Rs 5.0 per kWh (for 0-50 units); Rs 6.60 per kWh (for over 50 units);
- LT-III: Rs 3.85 per kWh

Electricity is provided free for crop irrigation.

The market price (2003) of fuels at gas stations in Chennai

- Super Rs 36.0 per litre (US $ 0.79)
- Unleaded petrol Rs 34.6 per litre (US$ 0.76)
- Diesel Rs 22.0 per litre (US$ 0.48)

FI.3.3 Un-skilled labour

The Second Chennai Water Supply Project study report by Scott Wilson Piesold, March 2003 indicated that unskilled labour in crop cultivation was Rs 30/day for weeding.

Discussion with farmers, when the research team visited in November 2003, indicated that wage rates were Rs 80-100 per man-day and Rs 60 per woman-day. The opportunity for work is about 100 days a year.

FI.3.4 Domestic water supply

Compared to other developing countries in Asia, the domestic water tariff in India is low. This has implications for Government. Financial subsidies provide a high dead weight loss (i.e. the tariff is much lower than the selling price) in economic terms.

According to the Costing Department of the CMWSSB, the cost of domestic water supply during the period from April 2002 to February 2003 was Rs 19.16/m^3.

Meanwhile, domestic consumers with connections are charged at a flat rate of Rs 50 per month for 10 m^3 (assuming 5 members of a family consume 70 liters per head per day over 30 days). With a production cost of 10 m^3 at Rs 192 and domestic consumer paying

Rs 50, the subsidy to the consumer is effectively Rs 142 per month. Where the supply is in the category of 40 liters per person, the effective subsidy is Rs 65 per month per domestic consumer.

The water tariff and sewerage charges are presented in Table F3-2 and F3-3.

Table F3-2: Current water tariff per household connection

No	Groups	Rs per 6months	Rs per month	US$ per month
1	Domestic	300	50	1.11
2	Partly commercial	900	150	3.33
3	Commercial/Private Hospital	4800	800	17.78
4	All others	3900	650	14.44
5	Commercial (non-water intensive)	2400	400	8.89
6	Institution/Private education	2400	400	8.89
7	Institution/Government Hospital	1200	200	4.44
8	Institution/ all others	1800	300	6.67

Source: Chennai Metrowater

Table F3-3: Sewerage Service Charges (only for sewer connection)

No	Groups	Rs per 6months	Rs per month	US$ per month
1	Domestic	150	25	0.56
2	Non domestic others	900	150	3.33
3	Non domestic (water intensive)	3900	650	14.44

Source: Chennai Metrowater

FI.3.5 Opportunity cost of capital

This section gives the main assumptions used in the economic analysis. The analysis of water supply and water demand management measures has been undertaken to identify the economic cost of water produced and/or saved. The analysis has been based on the following assumptions:

1. The opportunity cost of capital (social discounted rate) has been taken as 12%. This is one of the suggested criteria for improving investment efficiency for future development in the "State Framework Water Resources Plan of Tamil Nadu" prepared by the Institute of Water Studies (IWS) No:1/99;
2. For discounting purposes, the project life has been taken as 30 years;
3. The discounted life value, for land which might be recovered by the Government when used for alternative purposes (e.g. purchase of agricultural land to reduce water demand) has been taken as 50 years.

FI.4. AGRICULTURE

FI.4.1 Key notes from field visits to A-K Basin

Somandha Village, Western part of Chennai
(November 16, 2003)

1. Groundwater is insufficient for cultivation;
2. Average farm size is 3 acres (Min: 0.5 acres and Max: 10 acres);
3. 3 crops per year: 2 paddy and groundnut. Only 2 crops of paddy in wet land;
4. Almost all family labour, no hired labour;
5. Average family size is 4-5 persons (Maximum 7-8 persons);
6. Electricity for pumping water for irrigation is free;
7. No control on abstraction and number of well;
8. Drinking water for village comes from deep well to pipe to public taps;
9. Perception of local people of reason for lack of water (i) less rainfall; (ii) more demand for water; and (iii) high cropping intensity;
10. No payment for water from tank irrigation system;
11. Agricultural taxes Rs 100-150 per acre;
12. Net return of paddy is about Rs 3,000 per acre (i) Revenue: Rs 8,000/acre (20 bags/acre @Rs 400 per bag); (ii) production costs: Rs 5,000/acre;
13. Net return of groundnut is about Rs 5,000 per acre (i) Revenue: Rs 12,000 (20 bags/acre @ Rs 600); (ii) production cost: Rs 7,000 per acre;
14. Wage rate of semi-skilled labor (non-agricultural activities): (i) man Rs 80-100/day; (ii) women Rs 60/day; (iii) opportunity of work 100/365days;
15. Cost of land (i) wet land no access Rs 100,000 per acre; (ii) wet land with some access Rs 150,000 per acre; (iii) Rs 1 million per acre for land located next to road.

Jagannapuram Village, Thiruvallur District, Northern part of Chennai City
(November 16, 2003)

1. Farm size average is about 5 acres. Maximum size is 60 acres;
2. Well depths of 100-130 ft and 300 mm diameter. Some wells were dry;
3. This area grows 3 paddy per year (i) November-March; March-June; July-October;
4. No electricity charge for pumping irrigation but, since 2003 a cost of Rs 250 per half-year for licensing pumps more than 5 HP has been applied:;
5. Some years ago a regulation was introduced on ground water abstraction but no implementation took place;
6. Net return from paddy is about Rs 5,000 per acre: (i) revenue Rs 1,075 (25 bags @ Rs 415); (ii) Costs of production Rs 6,000;
7. Cost of pump: Rs. 30,000; Cost of well: Rs. 100,000.

Focus Group Discussions (FGDs)

The study carried out 6 FGDs in the AK basin in an area from near to the coastal fringe to the upper part of the basin. The area which currently sells water to the CMWSSB is also included in this region. Each FGD included 10 farmers representing poor and non-poor households in the village to discuss agricultural issues relating to water, crop calendar and budgets. These data and information provide specific agricultural figures in the area studied and they are combined and analysed below.

FI.4.2 Land use and cropping patterns

Land use

The Chennai Basin Group has a total area of 7,282km^2, out of which 5,542 km^2 lies in Tamilnadu and the rest in Andhra Pradesh. Details are given in Table F4-1.

Table F4-1: Land use

No	Geographical area	Area (ha)	%
		554,200	**100**
1	Forest	28,264	5.1
2	Barren & uncultivable wastes	17,734	3.2
3	Land put to non-agriculture	145,75	26.3
4	Cultivable waste	12,192	2.2
5	Permanent pastures and grazing land	12,192	2.2
6	Current fallow	74,817	13.5
7	Other fallow	54,649	9.5
8	Land under miscellaneous crops and groves	15,518	2.8
9	Net area sown	195,078	35.2
	Area sown more than once	58,302	10.5
	Gross area sown	253,380	45.7
	Cropping intensity		129.9

Source: State Frame Work Water Resources Plan, Chennai Basin Group, Prepared by IWS No: 3/97

Crop calendar

The study was carried out through 6 Focus Group Discussions (FGDs) in the AK basin to obtain basic information on the prevailing cropping patterns in the area. The following cropping patterns in Table F4-2 have been generated based on information collected in March-April 2004 and results from the Chennai Basin Group study prepared by IWS, 1997.

Table F4-2: Crop calendar in the A-K Basin

No	Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Rainfall seasons												
	SW Monsoon						▬	▬	▬	▬			
	NW Monsoon										▬	▬	▬
	Irrigated crops												
1	Paddy (Samba)							xxxxx	**xxxx**	**xxxx**	**xxxx**	**xxxx**	xxxxx
2	Paddy (Navarai)	**xxxx**	**xxxx**	**xxxx**	xxxxx								xxxxx
3	Paddy (Sornavari)				xxx	**xxxx**	**xxxx**	**xxxx**	xxxxx				
4	Groundnut	**xxxx**	**xxxx**	**xxxx**	xxxxx								xxx
5	Sugarcane	xxxx	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	xxxx	
6	Cumbu	xxxx	**xxxx**	**xxxx**	xxxx								
7	Vegetables		xxxx	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	xxxx				
8	Pulses	xxxx	**xxxx**	**xxxx**	xxxx								
9	Gingelly	xxxx	**xxxx**	**xxxx**	xxxx								
10	Chillies	xxxx	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	xxxx					
	Rain-fed crops												
1	Groundnut						xxxx	**xxxx**	**xxxx**	**xxxx**	xxxx		
2	Milet/pulses	**xxxx**	xxxx								xxxx	**xxxx**	**xxxx**

Note: xxxx Land preparation & harvesting time; **xxxx** main season

Cropping patterns

Five cropping patterns for irrigated areas and three cropping patterns for rain-fed areas were identified:

Irrigated areas:
1. Paddy (Samba) + Paddy (Navarai); 2. Paddy (Samba) + Paddy (Sornavari);
3. Paddy (Samba) + Vegetables; 4. Paddy (Samba) + Groundnut/pulses + Paddy (Sonavari); 5. Sugarcane.

Rain-fed areas
1. Groundnut; 2. Millets/pulses; 3. Groundnut + Millets/pulses.

Paddy is the main crop grown in the Chennai Basin area. There are about 132,000 ha of paddy grown out of a total of 190,000 ha of crops grown each year. See Table F4-3.

Table F4-3: Area of the crops

No	Crops	Season	Area (ha)	R1 (%)	R2 (%)
1	Paddy	Samba (Aug-Jan)	79,390	60.3	41.8%
		Navarai (Jan-Mar)	29,205	22.2	15.4%
		Sornavari (Apr-Jul)	23,070	17.5	12.1%
	Sub-total		***131,665***	***100%***	
2	Groundnut	December-April	37,622	19.8	19.8%
3	Sugarcane	January-November	8,546	4.5	4.5%
4	Cumbu	March-June	5,395	2.8	2.8%
5	Vegetables	February-July	3,545	1.9	1.9%
6	Black/Greengram	February-April	1,279	0.7	0.7%
7	Gingelly	January-May	1,039	0.5	0.5%
8	Chilies	February-July	1,019	0.5	0.5%
	Total		**190,110**	**100%**	**100%**

Source: State Frame Work Water Resources Plan-Chennai Basin Group Prepared by IWS No: 3/97;
Note: R1 (%) Percentage of cropped area for paddy and non-paddy;
R2(%) Percentage of cropped area on a unit of land per year (including paddy & non-paddy).

Table F4-4: Crop yields in Chennai Basin Group (kg/ha)

Crops	District	87-88	88-89	89-90	90-91	91-92
Paddy	Chengai-MGR	2,593	3,170	2,984	3,206	3,383
	North Arcot	2,867	3,154	3,307	2,918	3,167
Cholam	Chengai-MGR	1,329	932	1,184	1,265	1,214
	North Arcot	1,484	1,466	1,760	1,171	759
Ragi	Chengai-MGR	1,885	1,792	1,790	1,351	1,994
	North Arcot	2,182	2,574	2,316	2,055	2,157
Green-gram	Chengai-MGR	400		297	313	467
	North Arcot	400	400	418	467	437
Black-gram	Chengai-MGR	472	410	394	423	503
	North Arcot	472	410	426	423	503
Groundnut*	Chengai-MGR	1,770	2,433	1,621	1,547	1,827
	North Arcot	1,985	1,579	962	1,229	1,731
Groundnut**	Chengai-MGR	1,404	1,093	866	892	1,014
	North Arcot	910	755	1,060	1,445	1,764
Gingelly	Chengai-MGR	440	372	340	301	391
	North Arcot	511	386	464	351	447
Chillies	Chengai-MGR	1,188	1,252	1,065	1,039	860
	North Arcot	1,188	1,252	1,065	1,039	860
Sugarcane	Chengai-MGR	97,000	106,000	119,000	86,000	113,000
	North Arcot	78,000	88,000	71,000	77,000	67,000

Source: State Frame Work Water Resources Plan-Chennai Basin Group Prepared by IWS No: 3/97;
Note: * Irrigated; ** Non irrigated

FI.4.3 Farm size and cultivation techniques

Farm size

Most farmers (82%) in the Chennai Basin are marginal with a land holding of less that 1ha. Farmers with a land holding of 1-2 ha account for 10%, medium farmers with land holding 2-5ha, for 6%. Farmers with land holding above 5ha comprise only 2%. See Table F4-5.

Table F4-5: Land holding for agriculturists

Category	Farm size (ha)	Number of HH	%
Marginal	Below 1.0	289,869	81.8
Small	1.0-2.0	36,833	10.4
Medium	2.0-5.0	21,956	6.2
Large	Above 5.0	5,664	1.6
Total		354,322	100

Source: Scott Wilson Piesold, Second Chennai Water Supply Project, March 2003

Cultivation techniques

Most farmers in the A-K basin rely on irrigation water from wells and tanks to ensure a good crop. They use 100% of irrigation water in navari and sornavari but 80-90% during samba with about 10-20% coming from rain. All irrigation in the basin is supplied through a network of small channels to feed bunded fields. Basin irrigation is used for paddy and furrow irrigation for vegetables.

Details for paddy are given in Table F4-6 and for groundnut in Table F4-7.

Table F4-6: Main features of paddy farming in A-K basin (per ha)

No	Input/Items	Descriptions
1	Varieties	ADT-43, 105 days for navari & sornavari; Rs 1200-1500/ha BPT-5204, 130 days, lower yielding but better price, for samba
2	Nurseries	Started 30 days before transplanting. Cost of seed: Rs 1240-1480 per ha; Samba: July; Navari: December; Sornavari: April
3	Land preparation	All done by machine –ploughing, rotavator, rolling: Costs of Rs 2970-4700 per ha including nursery & paddy field.
4	Transplanting	All done by labour with cost of Rs 2220-2470 per ha
5	Fertilising	Complex 17-17-17: 5-7 bags/ha or alternatively DAP; Urea- 5 bags/ha; Potash- 3-4 bags/ha; Ammonium sulphate- 2 bags/ha; Manure- Rs 500-1000 per ha.
6	Pest control	Usually applied 2 times depending on pest/disease: Cost of Rs 1200-1500 per ha.
7	Weeding	1st weeding after 35 days of planting (chemicals) 2nd weeding after 65 days of planting (chemicals) Total cost of Rs 800-1200 per ha
8	Harvesting	Samba season in December; Navari season in April; Sornavari season in August; Combine harvester, cost of Rs 2500-3000 per ha
9	Yields	Samba season of BPT-5204: 25bags/are (62 bags/ha); Navari season of ADT-43: 20 bags/acre (49 bags/ha); Sornavari season of ADT-43: 25 bags/acre (62 bags/ha); Price varies from Rs 400-500 per bag.
10	Well & pump	Annualised capital cost of well and pump (Rs 100,000-145,000) for serving an area of 6-8 acres. Cost of irrigation system would be Rs 670/acre/crop (Rs 1660/ha/crop) in 3 crops system and Rs 1,000/acre/crop (Rs 2470/ha/crop) in 2 crops system
11	Power	Currently farmers do not pay for electricity, however, if the cost of electricity is considered, at Rs 3.85/kWh, then the cost would be Rs 1,700 – 1,900 per crop per acre (Rs 4200-4700/ha/crop).

Source: Farmer interviews, Agricultural FGDs, Second Chennai Water Supply Project, Mar 2003- Scott Wilson Piesold, and DFID research team analysis.

The frequency of irrigation is on alternate days for clay soils and daily for sandy soils. Sprinkler and drip irrigation are very rare in the area. The agricultural FGDs indicated that only one farmer in one location used drip irrigation for a mango garden.

Paddy nurseries are started about 30 days before transplanting and paddy duration is about 105-130 days depending on varieties. Transplanting is done by hand but land preparation is mainly by machines.

Farmers in FGDs said that due to drought and poorer water quality, the paddy yield is reduced from 4.5-5.0 tons/ ha to 3.7-4.5 tons/ha. Fertilisers of 5-7 bag/ha of DAP or complex, 5 bags/ha of urea, 3-4 bags/ha of potash, 2 bags/ha of ammonium sulphate and Rs 500-1000/ha of manure are used.

Table F4-7: Main features of groundnut farming in A-K basin (per ha)

No	Input/Items	Descriptions
1	Varieties	TMV-7, TMV-2, VR-12. Seed cost Rs 6200/ha
2	Land preparation	All done by machine–ploughing, rotovator, disking: Costs of Rs 2,470 per ha.
3	Planting	Directly seeded, all by labour with cost of Rs 1200-1300 per ha.
4	Fertilizing	Complex 17-17-17: 2 bags/ha or alternatively DAP; Urea: 0-2 bags/ha; Potash: 5 bags/ha; Gypsum: 0-2 bags/ha; Manure: Rs 1000-2000/ha.
5	Pest control	Usually applied 2 times depending on pest/disease: Cost of Rs 1200-1500/ha.
6	Weeding	Chemicals Rs 1000/ha Labour cost Rs 1500/ha
7	Harvesting	All by labour, cost of Rs 3000/ha
8	Yields	49 bags/ha; Rs 600 per bag.
9	Well & pump	Annualized capital cost of well and pump (Rs 100,000-145,000) for serving an area of 6-8 acres. Cost of irrigation system would be Rs 670/acre/crop (Rs 1660/ha/crop) in 3 crops system and Rs 1,000/acre/crop (Rs 2470/ha/crop) in 2 crops system
10	Power	Currently farmers do not pay for electricity, However, if the cost of electricity is considered at Rs 3.85/kWh, then the cost would be about Rs 530 per acre per crop (Rs 1310/ha/crop).

Source: Farmer interviews, Agricultural FGDs, Second Chennai Water Supply Project, Mar 2003- Scott Wilson Piesold, and DFID research team analysis.

FI.4.4 Crop water requirement and irrigation management

Crop water requirement

Net and gross water requirements were calculated by the Institute for Water Studies in 1997 for the Chennai Basin Group. These were based on FAO-24 guideline using standard factors for ETo (Penman-Montieth), crop coefficients (Kc). The infiltration rate used for paddy fields in flood plains with mixed alluvials and vertisols was taken to be approximately 2.0 mm/day. The net water requirement is presented in Table F4-8.

Irrigation efficiency

Irrigation efficiency depends on the type of irrigation scheme. In canal and tank irrigation schemes, water conveyance losses from a head-works to the irrigated fields are usually high due to evaporation from the water body of the canals, seepage and infiltration losses which partly contribute to evaporation from the soil and partly recharge to the aquifer (the latter part may be considered as a loss in irrigation but not a loss in the water balance as a whole).

The IWS estimated "irrigation efficiency" (water consumed through evapo-transpiration as a percentage of the water supplied from the source) is 40% for canal and/or tank schemes. The "efficiency of water use" is higher due to the return of water to the aquifer.

The Department of Irrigation has planned to improve overall "irrigation efficiency" in the Chennai basin group[2] from its current level of 40% to 60% in the future.

The "irrigation efficiency" from private wells, which are located close to the middle of the field or a short distance from the field is estimated by the IWS at 75%. Generally, there is little opportunity to improve irrigation efficiency by changing from traditional irrigation (basin/furrow method) as rice is the principal crop. Where well irrigation is combined with sprinkler and/or drip irrigation techniques an "irrigation efficiency" of 85% might be obtained but the water saving (i.e. reduction in evaporative losses) would be small.

The estimate of the irrigation water requirements from head-works (tanks) and from wells is presented in Table F4-8.

Table F4-8: Irrigation water requirement at headworks or well by different technique

		Season (month-Month)	Duration (days)	Net WR (mm)	Tank Irrigation WR (m^3/ha)	Well Irrigation WR (m^3/ha)	Improved Tank WR (m^3/ha)	Drip/ Sprinkler WR (m^3/ha)
	"Efficiency"				**40%**	**75%**	**60%**	**85%**
1	Paddy	Samba	135	1,000	22,222	13,333	16,667	
		Navarai	105	1,082	24,044	14,427	18,033	
		Sornavari	105	1,082	24,044	14,427	18,033	
2	Groundnut	12-4	105	302	6,711	4,027	5,033	3,553
3	Sugarcane	1-11	300	1,566	34,800	20,880	26,100	18,424
4	Cumbu	3-6	90	322	7,156	4,293	5,367	3,788
5	Vegetables	2-7	135	475	10,556	6,333	7,917	5,588
6	Pulses	2-4	65	250	5,556	3,333	4,167	2,941
7	Gingelly	1-5	85	250	5,556	3,333	4,167	2,941
8	Chillies	2-7	165	630	14,000	8,400	10,500	7,412

Source: State Frame Work Water Resources Plan-Chennai Basin Group Prepared by IWS No: 3/97 and DFID research team estimates.

Total evaporation losses (TEL) comprise crop consumptive use and all other evaporation from soils and surface water body during the crop season. The TEL are estimated at 60% (tank irrigation), 70% (improved tank irrigation), 80% (well irrigation) and 87% (sprinkler/drip irrigation) of the total irrigation water requirement.

By improving surface tank irrigation, water saving could be 1,600-1,800 m^3/ha-paddy; 2,610 m^3/ha-sugarcane; 503 m^3/ha-groundnut; 400-1000 m^3/ha-vegetables. Sprinkler/drip irrigation could be developed from well irrigation for non-paddy crop. Water saving could be 676 m^3/ha-sugarcane, 100-200 m^3/ha-upland crops. Details are given in Table F4-9. More details are in Attachment FI-2 and 3.

[2] State Framework Water Resources Plan for Chennai Basin Group, March, 1997;

Table F4-9 Total water losses -crop uses & evaporation (m^3/ha)

		Season (month-Month)	Tank Irrigation WR (m^3)	Well Irrigation WR (m^3)	Improved Tank WR (m^3)	Drip/ Sprinkler WR (m^3)	Water saved (m^3/crop/ha)	
							IMP	**Drip**
	TEL (%)		**60%**	**80%**	**70%**	**87%**		
1	Paddy	Samba	13,333	10,667	11,667	-	**1,667**	
		Navarai	14,427	11,541	12,623	-	**1,803**	
		Sornava	14,427	11,541	12,623	-	**1,803**	
2	Groundnut	12-4	4,027	3,221	3,523	3,091	**503**	**130**
3	Sugarcane	1-11	20,880	16,704	18,270	16,028	**2,610**	**676**
4	Cumbu	3-6	4,293	3,435	3,757	3,296	**537**	**139**
5	Vegetables	2-7	6,333	5,067	5,542	4,862	**792**	**205**
6	Pulses	2-4	3,333	2,667	2,917	2,559	**417**	**108**
7	Gingelly	1-5	3,333	2,667	2,917	2,559	**417**	**108**
8	Chillies	2-7	8,400	6,720	7,350	6,448	**1,050**	**272**

Source: State Frame Work Water Resources Plan-Chennai Basin Group Prepared by IWS No: 3/97 and DFID research team estimates. IMP- Improved Surface Irrigation.

FI.4.5 Crop net benefits

Crop-budgets were collected from the agricultural FGDs together with data from several visits to the A-K basin and findings from the Second Chennai Water Supply Project. Four main crop-budgets namely Paddy (Samba), Paddy (Navari), Paddy (Sornavari) and Groundnut have been analysed for the purpose of the study.

The cost of the typical irrigation scheme in the area consists of a well (Rs 130,000) and pump set (Rs 30,000). It is assumed that replacement of a pump set would be made each 10 years. Each pump can irrigate up to 8 acres. The annualised cost of the irrigation system would be Rs 666 per crop per acre (Rs 1646/ha/crop) in 3 cropping areas and Rs 1,000 per crop per acre (Rs 2471/ha/crop) in 2 cropping area. See Appendix FI.

1kW is equal to 1000 m3/day of water raised through 8.81m at 100% pump efficiency (i.e. 1 kWh can lift 41.7 m^3 through 8.81m). It is assumed that with a dynamic head of 20m and pump efficiency of 65%, 1 kWh would lift 12m^3. If the power cost is Rs 3.85 per kWh, the cost of pumping is Rs 0.321 per m^3.

Financial and economic analyses of crop cultivation have been carried out for representative main crops.

The financial analysis is based on the farmer's perspective, and therefore all taxes and transfer payments are included in the financial analysis. The financial net benefit is the total revenue, after all production costs during cultivation of the crop that the farmer actually has to pay (in cash or kind) have been deducted.

The economic analysis is based on the society point of view. Any item that reduces GDP is a cost and any item that adds to GDP is a benefit. Taxes and transfer payments are, therefore, excluded from the economic account. The cost of power for pumping water for irrigation, which is currently not paid by the farmer, must be included in the economic analysis to identify the economic net benefit of the crop.

Financial net benefits of the crop are Rs 2,395 per acre for paddy (Samba), Rs 1,930 for paddy (Navarai), Rs 2,495 for Paddy (Sornavari) and Rs 2,490 for groundnut.

Considering the cost of electricity for pumping irrigation, the economic net benefits per acre from crop cultivation would be Rs 714, 107, 672, and 2017 for paddy (Samba), paddy (Navarai), paddy (Sornavari), and groundnut respectively. Since the gross water requirement for groundnut is much lower than paddy, a lower cost of pumping irrigation water results. The economic net benefit from groundnut is much higher than paddy despite the fact that they have almost the same financial net benefits. See Table F4-10 and details in the attachment: Crop-budgets.

Table F4-10: Net benefit of crops per acre

No	Items	Paddy (Samba)	Paddy (Navarai)	Paddy (Sornavari)	Groundnut
1	Gross WR (m^3)	5,396	5,838	5,838	1,630
2	Yield (bag)	25	22	25	20
3	Price (Rs/bag)	450	450	450	600
4	Revenue (Rs)	11,250	9,900	11,250	12,000
5	Production cost (Rs)	8,855	7,970	8,755	9,510
5.1	Land preparation (Rs)	1,500	1,500	1,500	1,000
5.2	Seed (Rs)	500	500	500	2,500
5.3	Fertilizers (Rs)	2,805	2,220	2,805	1,870
5.4	Insecticides (Rs)	600	500	500	550
5.5	Herbicides (Rs)	400	400	400	400
5.6	Total Labour (Rs)	1,000	1,000	1,000	2,340
5.7	Cost of well & pump* (Rs)	800	800	800	800
5.8	Harvesting by machine (Rs)	1,200	1,000	1,200	0
5.8	Land tax (Rs)	50	50	50	50
6	Pumping irrigation cost (Rs)	1,731	1,873	1,873	523
	Financial Net Benefit (Rs)	**2,395**	**1,930**	**2,495**	**2,490**
	Economic Net Benefit (Rs)	**714**	**107**	**672**	**2,017**

Note: * Cost of well and pump is an average annuity per crop per acre

FI.4.6 Economic value of water in agriculture

Considering private well irrigation with an “irrigation efficiency” of 75% and the TEL as 80% of gross water requirement, the value of water used by crops in evaporation and transpiration in agriculture is highest for groundnut. This is followed by Paddy (Samba), Paddy (Sornavari), and Paddy (Navarai). The financial value of water varies from Rs 0.40-0.60 per m^3 for paddy and Rs 1.90 per m^3 for groundnut. However, considering the power for pumping as the cost in economic terms, the value of water is Rs 0.02-0.17 per m^3 for paddy and Rs 1.55 per m^3 for groundnut. See Table F4-11.

Table F4-11: Value of water by crops in agriculture

No	Items	Paddy (Samba)	Paddy (Navarai)	Paddy (Sornavari)	Groundnut
1	TEL (m^3/acre)	4,317	4,671	4,671	1,304
2	Financial NB (Rs/acre)	2,395	1,930	2,495	2,490
3	Economic NB (Rs/acre)	714	107	672	2,017
4	Financial value (Rs/m^3)	0.555	0.413	0.534	1.910
5	Economic value (Rs/m^3)	0.165	0.023	0.144	1.547

Economic Net Benefit per hectare is Rs 2,029 for two paddy cropping pattern, Rs 3,689 for triple paddy cropping pattern and Rs 6,748 for paddy-groundnut cropping pattern. Average economic Net Benefit in the AK basin would be about Rs 4,200 per ha. The economic values of water are Rs 0.091/m^3 for double paddy, Rs 0.109/m^3 for triple paddy, and Rs 0.486/m^3 for paddy-groundnut land. Details are presented in Table F4-12.

CMWSSB buys water from farmers who are living close to the well-fields. Metro-water pays Rs 25/hr pumping to the farmer for 18 hrs per day to get about 400 m^3 per day. Total revenue from selling water is Rs 450 per day. If the farmer sells water with an amount equivalent to cultivation of an acre growing double paddy to CMWSSB, he would get Rs 10,111 per acre, meanwhile financial net benefit from cultivation of 2 paddy crops is Rs 4,325 per acre. By selling the "water right" to Metrowater, the farmer could gain about 2.3 times that from his crops.

Table F4-12: Value of water by cropping patterns

No	Items	2 Paddy (Samba-Navarai)	3 Paddy (Sam-Nav-Sor)	Paddy (Sam) Groundnut
1	TEL (m3/acre)	8,987	13,658	5,620
2	TEL (m3/ha)	22,208	33,749	13,888
3	Financial NB (Rs/acre)	4,325	6,820	4,885
4	Economic NB (Rs/acre)	821	1,493	2,731
5	Financial NB (Rs/ha)	10,687	16,852	12,071
6	Economic NB (Rs/ha)	2,029	3,689	6,748
7	Financial value (Rs/m3)	0.481	0.499	0.869
8	Economic value (Rs/m3)	0.091	0.109	0.486

FI.5. ECONOMIC COST OF WATER SUPPLY

FI.5.1 Overall Situation of Water Supply in Chennai

Water supply

The total amount of water supply from CMWSSB during April 2002 to February 2003 was 334.9 MLD of which 65.46 MLD arises from the well-fields and 269.44 MLD from treated surface water. The cost of water supply (including transmission, treatment and distribution but also waste disposal) in Chennai Metropolitan was Rs 19.16 per m^3 in 2003[3].

At a subsidized flat rate of Rs 50 per month for consumers (assuming 5 persons in a family and supply rate of 70 lpcd) every domestic consumer is subsided to the extent of Rs 142 per month. For the consumer supplied at a rate of 40 lpcd, the monthly subsidies on water would come to Rs 65 per household[4].

Many parts of the city currently lack piped water. People purchase water from private tankers. The cost paid (March 2004) was Rs 500-600 per tanker (11-12m^3/tanker), equivalent to Rs 45-50 per m^3.

The "Hindu" newspaper, 7 March, 2004, described the hardship of households in Chennai due to the high price of tanker-water. The prices of tanker-water quoted were relatively cheap for` Bangalore (Rs 30-40 per m^3), followed by Chennai (Rs 50-60 per m^3) and Nagpur (Rs 60-90 per m^3). The private tanker in Bangalore can get a margin of 36% of the price of water sold (they sell 37 MLD with annual revenue of Rs 39.4 crores having a net profit of Rs 14 crores).

Other sources of water for domestic purposes are private bore-wells. The domestic and industrial FGDs carried out by the research team in March 2004 showed that some household and industrial units have their own well. They use well water for washing and bathing rather than for drinking. The cost of water from the private well varies significantly depending on "economic scale". Costs of water from a private bore-well (including well, pump and power costs) are respectively Rs 5.30, 8.99 and 11.37 per m^3 in the case of Automobile industry, domestic household, and EPS-Industry. See the Table F5-1 and Appendix FI.

[3] Cost of water supply, Prepared by Costing Department, The CMWSSB - April, 2003;
[4] Cost of water supply, Prepared by Costing Department, The CMWSSB - April, 2003;

Table F5-1: Cost of water from private well

No	Items	Household	Auto-Ind	EPS-Ind
1	Water pumped (m^3/day)	1.2	20	6
2	Cost of water (Rs/m^3)	8.99	5.30	11.37

Cost of Operation & Maintenance

The Financial Analysis wing of CMWSSB has carried out a cost analysis of the operation of well-fields in a period of 5 years from 1997/1998 to 2002/2003. The average direct O&M cost for well water during 5 years is Rs 4.30 per m^3. If depreciation of the equipment and assets are taken into account, the total cost of well-field water would be Rs 9.12 per $m^{3,}$ broken down as follows:

Power cost

The average cost of power for water supply from well fields would be Rs 1.34 per m^3 at current price. See Table F5-2.

Table F5-2: Electricity cost for well-water

Period	Quantity (MLD)	Rs per m^3 (Current price)	PV (6%)* 2000/01 price)	kWh/m^3
1997-1998	51.06	1.11	1.32	0.64
1998-1999	40.02	1.54	1.75	0.88
1999-2000	46.77	1.37	1.45	0.79
2000-2001	82.74	1.17	1.17	0.59
2002-2003	65.46	1.50	1.42	NA
Average	57.21	1.34	1.42	0.725

Source: Financial Analysis Wing; * Considering inflation in price

Manpower cost

There has been an improvement in management efficiency in the water supply sector and there has been a sharp reduction in the number of employees in the last five years. The average cost of an employee is Rs 1.97 per m^3 at current prices.

Table F5-3: Employee cost for well water

	Qty (MLD)	Rs per kl (actual)	PV (6%) 00/01 price	No of Employees	Employee per m^3
1997-1998	51.06	2.06	2.45	598	11.71
1998-1999	40.02	3.13	3.52	592	14.79
1999-2000	46.77	2.71	2.87	496	10.58
2000-2001	82.74	1.07	1.07	268	3.24
2002-2003	65.46	0.88	0.83	NA	NA
Average	57.21	1.97	2.15	488	10.08

Source: Financial Analysis Wing

Other O&M costs

Other O&M costs consist of annual maintenance & reparation of mechanical equipment. These costs are of Rs 0.99 per m^3 on average.

Table F5-4: O&M costs (excl. power & employment costs)

Period	Qty (MLD)	Rs per m^3 (actual)	PV (6%) 00/01 price
1997-1998	51.06	0.68	0.81
1998-1999	40.02	0.91	1.02
1999-2000	46.77	0.88	0.93
2000-2001	82.74	0.75	0.75
2002-2003	65.46	1.72	1.53
Average	57.21	0.99	1.01

Note: Financial Analysis Wing

Direct O&M cost

The average direct O&M cost for well water is Rs 4.30 per m^3. If depreciation of the equipment and assets are taken into account, the total cost of well-field water would be Rs 9.12 per m^3. See Table F5-5.

Table F5-5: Direct and Total cost of well-field water

Period	Qty (MLD)	Direct cost (Rs/ m^3)	Total cost (Rs/ m^3)
1997-1998	51.06	3.85	6.78
1998-1999	40.02	5.58	12.99
1999-2000	46.77	4.96	9.82
2000-2001	82.74	2.99	5.64
2002-2003	65.46	4.10	10.38
Average	57.21	4.30	9.12

Note: Direct cost including power, chemicals, employment and other O&M;
Total cost - direct cost + depreciation + interest + allocated overhead

FI.5.2 Development of Additional Water Supply (SDI)[5]

Surface water supply

Chennai Water Supply Augmentation Project I[6]. The proposal is to draw 180 MLD of raw water from Veeranam lake, treat it and supply it to Chennai City by pipeline over a distance of 230 km. The total cost of the investment is Rs 720 Crores (Rs 7,200 million) with anticipated quantity of water supplied of 180 MLD.

Assuming that:

1. The direct O&M cost is the same as the current level of Rs 2.56 per m^3;
2. Replacement of equipment after 10 years operation is 20% of total cost;
3. Discounted rate of 12% per year; and
4. Project life is 30 years.

The cost of water supply from the lake would be Rs 17.7 per m^3 (i.e. present value of costs is Rs 9,365 million to produce 529 million m^3). Details in Attachment F1-10: - Economic cost of water from Lake Veeranam.

Well-field water supply

Forty-five deep borewells[7] (average depth of 250m; 2 MLD each) with an additional pipeline of 15 km from each well for interconnection are proposed. Water from these wells will be pumped and collected in a large sump and then pumped to Kadampuliyur to flow from there by gravity to Chennai. Total cost of construction of 45 wells would be Rs 49 crores (Rs 490 million).

Cost of water supply from the well-field would be Rs 6.12 per m^3 (i.e. Net present value of costs is Rs 1,620 million to produce 265 million m^3). Details in Attachment FI-11: Economic cost of water from well-field.

[5] SDI refers to Supply Option described in Annex B.
[6] Chennai Metrowater – A Profile;
[7] The Hindu News Paper, Vadakuthu, March 11, 2004;

FI.5.3 Desalination (SD2)

In order to augment local sources, Reverse Osmosis Plants have been constructed and put in use to treat the brackish water to drinking water standards and distribute to the economically weaker sections at Velachery, Nochikuppam, Ayodyakuppam & Kasimedu;

From the WB Report, "The regional Desalination Study for Middle East, North America and Central Asia showed that energy use for seawater desalination is in the range of 3-15 kWh/m^3 depending on the technology used (Distillation plant at the top end and RO and ED at the low end).

The capital cost of desalination plant is strongly dependent on the salinity level of the water. The capital cost for RO 50 m^3/day varies from US$ 25,000 (for 2000 mg/l TDS) to US$ 31,000 (for 10,000 mg/l TDS) and US$ 60,000 (for 35,000 mg/l TDS). The O&M cost per m^3 from 50 m^3/day RO plant varies from US$ 0.35 (for 2,000 mg/l TDS) to US$ 0.65 (for 10,000 mg/l TDS) and US$ 1.32 (for 35,000 mg/l TDS)[8].

The proposal for a sea water desalination plant[9] in Chennai is estimated to cost Rs 1,500 crores (Rs15,000 million) for anticipated throughput of 300 MLD. Assuming new technologies such as RO or ED are used, the power consumption would be 5-10 kWh/m^3. The cost of desalination water would be between Rs 37 and Rs 56 per m^3 at the plant. Details are given in the Table F5-6.

Table F5-6: Cost of desalinated water by level of power consumption

Power (kWh/m3)	5	6	7	8	9	10
Cost of water (Rs/m3)	37	41	45	49	53	56
Cost of water (US$/m3)	0.84	0.93	1.02	1.11	1.20	1.27

Recent technology of desalination plants in the world shows that the cost of water would be from US$ 0.45 to 1.09 per m^3 produced at the plant. See Table F5-7 below.

Table F5-7: BOOT Contract costs in the world

	Tampa Bay	Trinidad	Larnaca	Dhekelia	Singa-pore	Ash-kelon	Algeria
Capacity, t/d	95,000	135,000	40,000	40,000	136,000	274,000	200,000
Salinity, ppt	26	38	40	40		40	40
Energy cost ($/kWh	0.04	0.04	0.057	0.057			
Contract term, (years)	30	23	10	10	20	25	25
Contract year			2000	1996	2002	2002	2003
First year price (US$/m3)	0.46	0.71	0.73	1.09	0.45	0.52	0.818
• Capital recovery	0.21		0.37	0.56		0.3	
• Non-capital recovery	0.25		0.43	0.53		0.22	

Source: The WB Group, BRL, DHV

FI.5.4 New Water Treatment Facilities (SD4)

In a list of major infrastructure projects in the pipeline, Chembarambakkam water treatment plant (partly French assistance) would cost Rs 200 Crores (Rs2,000 million) for producing 530 MLD.

Total direct O&M cost[10] including power, chemical, operation & maintenance in existing treatment plants at Kilpauk is Rs 2.31 per m^3 (for 96 MLD), Rs 1.19 per m^3 (for 173 MLD), and Rs 1.59 per m^3 (for 269 MLD).

[8] National Dry Land Salinity Program – July 2002: Economic & Technical Assessment of Desilination Technology in Australia
[9] Chennai Metrowater – A Profile;
[10] Costing Department, The CMWSSB, April 2003;

Assuming that

1. The direct O&M cost is Rs 1.59 per kl, the same as for the existing treatment plant (269MLD);
2. Replacement of equipment after 10 years operation at 20% of total cost;
3. Discount rate of 12% per year;
4. Project life of 30 years.

The cost of treating water would be Rs 2.85 per m^3 (Net present value of costs is Rs 4,447 million to produce 1,558 million m^3). Details in Appendix FI-14: Economic cost of water treated.

FI.5.5 SD5 - Improve / Extend Water Distribution System (fixed infrastructure)

There is no relevant information available from Chennai, so far, concerning improvement or extension of water distribution systems that the research team can use in the economic analysis for distribution cost of water.

The Costing Department, CMWSSB has carried out an analysis of the cost of water in April, 2003. The analysis showed that distribution cost of water in some areas is Rs 7.42 per m^3.

FI.5.6 SD6 - Improve / Extend Water Distribution System (tankers)

At present (January 2004), the water agency is providing 125 MLD to domestic consumers and 50 MLD to industry. For sustaining the supply, the water agency is drawing about 105 MLD from its own wells and nearby private agricultural wells in the northwestern fringe of the city. Beside, Metrowater gets 70 MLD from wells located in "outlying areas".

This quantum is transported to 21 filling points through 1,700 tanker-lorries. In addition to these tankers, Metrowater has hired 1,100 lorries for distributing water to the public.

Table F5-8: Tanker-lorries in Chennai City

Items	Nov 03	Jan 04	Mar 04	May 04*
No of tanker lorries hired**	595	726	1,100	1,300
No of daily trips	6,733	7,555	9,500	12,000
No of tanks installed	10,030	10,430	11,315	13,500
No of pumps installed	5,500	6,500	7,000	7,500
Daily expenditures (mil Rs)	5.5	7.0	8.5	10

Note: * projected; ** tanker lorries hired for public supply NOT including 1,700 tanker lorries owned by Metrowater;
Source: The Hindu Newspaper-Chennai March 12, 2004.

FI.5.7 SD7 - Retention Dams & Reservoirs

Chennai Water Supply Augmentation Project II proposes to construct checkdams across rivers Kosastalayar and Palar to improve storage capacity. The total cost is estimated at Rs 110 Crores for an anticipated quantity of 40 MLD.

Assuming that

1. The direct O&M cost is 2% of the capital to maintain the dam & operation of the system;
2. Large scale reparation is taken as 10% of the capital at each 5 year interval;
3. Discount rate of 12% per year;
4. Project life of 30 years.

The cost of keeping water available in the reservoir and/or aquifer would be Rs 11 per m^3 (Net present value of costs is Rs 1,299 million to produce 118 million m^3). Details in Appendix FI-15: Economic cost of water in Check-dams.

FI.5.8 SD9 - Increase Abstraction from Surface Water Sources

There is little opportunity for this option since surface water sources in the Case Study area are very limited. Most of the rivers are dry in the hot season.

FI.5.9 SD10 - Rain harvesting

According to research[11] on rain harvesting, an open earthen channel for 100 l/s with collection pipe 450mm and open well of 5.5 x 5 x 12.5 m would cost of Rs 48,000. The theoretical annual water harvesting potential from roof, road and adjoining fields is estimated to be 1821 m^3, 1736m^3 and 5000m^3 respectively with total of 8,557m^3. The actual measurements after implementation of the entire system during one year of observation showed a quantum of 3,800m^3 in the well.
Assuming that

1. The life of the rain harvesting system is 10 years with 2% of O&M cost per year;
2. Discount rate of 12% per year; and
3. Contribution of rain harvesting facilities of 60% of 3,800m^3 per year.

The cost of water from rain-harvesting would be Rs 3.75 per m^3 (Net present value of costs is Rs 48,281 to produce 12,883 m^3). Details in Appendix FI-16: Economic cost of water in Rain-harvesting.

Tamil Nadu has an intensive program to promote construction of rain-harvesting facilities to recharge the aquifer. Depending on the type of facility, the cost varies from Rs 650 per unit of percolation pit to Rs 7,500 per unit of recharge well with deep and large diameter. Some standard unit costs[12] for house/building are given below:

- Percolation pit Rs 650/unit
- Percolation pit with bore Rs 1,200/unit
- Recharge Trench Rs 650/meter
- Recharge Trench with bore Rs 900/meter
- Recharge well (shallow/small diameter) Rs 4,100/unit
- Recharge well (deep/large diameter) Rs 7,500/unit

FI.5.10 SA2 - Treat / Use Wastewater

Chennai City Rivers Conservation Project has a cost of Rs 720.15 Crores; Rs 70.22 Crores for intercepting, diverting, conveying and Rs 40.45 Crores for expanding the capacity of the existing 4 sewage treatment plants from 268 to 532 MLD.

Recycling of waste water through treatment will also yield a major result for ecopark and water for farmers to irrigate crops. In the recycling, the cost of water treatment is Rs 22 lakhs per million m^3 per year[13] (Rs 2.20 per m^3).

[11] Dr. K. Ramaswamy- Dr. T. Thangaraj, Horticultural College and Research Institute, Periyakulam
[12] Tamil Nadu – Rain Harvesting Program;
[13] Publication of the French Research Institutes in India No: 2/2002: The water & sanitation scenario in Indian Cities

Sewage collected from the city is conveyed through various pumping stations to the Sewage Treatment Plants located at Kodungaiyur, Koyambedu, Nesapakkam and Perungudi for treatment & disposal. According to Costing Department, CMWSSB, the cost of treatment of wastewater for reuse in industry and irrigation of parkland would be Rs 2.88 per m^3.

FI.5.11 SA9 - Cloud Seeding

Cloud seeding was studied in the mid 1940s by scientists at the General Electric Laboratory in the US. Cloud seeding involves scattering fine particles in the clouds to accelerate natural process which lead to rain. The chemicals are scattered by aircraft or using ground generators. The most realistic approach to modifying weather is to take advantage of situations in which a relatively small human-induced disturbance in the system could substantially alter the natural evolution of atmospheric processes.

Tamil Nadu has tried cloud seeding several times since the mid 1970s. The last attempt was in 1993. Individual storm clouds can give rainfall increases of 20% or more when seeded[14]. Cloud seeding costs only Rs 100 million compared to amount of Rs 15,000 million spent on drought relief during the last financial year[15].

Even today several countries have operational weather modification programs involving cloud seeding. A large amount of work has been done in US and Australia but it has not been clearly shown that cloud seeding could be an economic method for harvesting water. However, it is a possible technical option to augment water supply especially in the desert and arid areas.

[14] Weather Modification Inc, US Company took cloud seeding in Karnata, Maharashtra, Andhra Pradesh - The Hindu November 19, 2003;
[15] Dr. Vijay Gore, Karnataka's Development Commissioner told the Hindu;

FI.6. COST OF WATER SAVED IN DEMAND MANAGEMENT OPTIONS

A number of demand management options have been examined below and the net cost of water saved has been estimated for these options

FI.6.1 DT2 - Water Saving Devices

The option relates to better plumbing at household level and using water saving devices to increase water use efficiency. It includes high technology shower/taps, toilet flushing. So far no information on (i) cost of water saving devices; (ii) amount of water saved; (iii) application percentage (number of HH applying saving devices compared to number of HH connected to WS) has been obtained.

FI.6.2 DT3 - Recycling of Industrial Water/Re-use of water

Metrowater is encouraging recycling of wastewater by providing secondary treated sewage to the Chennai Petroleum Corporation Ltd. and Madras Fertilizer Ltd. at Manali and raw sewage to a private power corporation at Basin Bridge. The CMWSSB is programmed to construct a RO Plant of 50 MLD capacity to treat secondary treated sewage so as to supply to industries in lieu of the clear water. The cost is estimated Rs200 Crores.

According to Costing Department, CMWSSB, the cost of treatment of wastewater for reuse in industry and irrigation of park would be Rs 2.88 per m^3.

It is assumed

1. The life of RO plant is 30 years;
2. Replacement is at 10 year-intervals at a cost of 20% of the total capital cost;
3. O&M cost as power consumption is of 5 kWh/m^3 and the cost of secondary treated wastewater is Rs 2.88 per m^3;
4. Discount rate is 12% per year.

Cost of water from RO plant for industry uses would be Rs 36 per m^3 (Net present value of costs is Rs 5,223 million to produce 147 million m^3). Details in Appendix FI-13: Economic cost of water from RO plant for industry.

FI.6.3 AT1 - Improve efficiency of Surface Irrigation System

As stated in the State Framework Water Resources Plan Prepared by IWS No 1/99, future development should be based on, among others, improving the overall irrigation efficiency. The tank irrigation system in the Chennai basin group serves about 34% of irrigated cropped area of 190,110ha with total net crop water requirement of 1,653 MCM per year. At present the irrigation efficiency of the system is very low in a range of 30-40%. Modernisation of tank irrigation would increase irrigation efficiency up to 60%. The cost would be in an order of Rs 10,780 - 25,310 (US$ 240-580) per ha[16] of irrigated command area depending on specific project. An average cost of modernisation of 10 tanks proposed in phase 1 would be Rs 15,660 (US$ 356) per ha. See Table F6-1.

Assuming project life of 30 years, social discounted rate of 12% per year, annuity of the capital cost of Rs 15,660 (US$ 356) would be Rs 1,944 (US$ 44) per ha.

Paddy and groundnut are the two main crops in the A-K basin. Improvement of surface irrigation would generate water savings of 3,470 m^3/ha for double paddy, 5,273 m^3/ha for

[16] Consultants estimate;

triple paddy and 2,170 m^3/ha for paddy-groundnut. See details in Appendix FI-3. The average water savings from the action would be in order of 3,600 m^3/ha per year.

Cost of water saving from improvement of irrigation efficiency would be Rs 0.54 per m^3 (Rs 1,944 / 3,600 m^3).

Table F6-1: List of planned tank irrigation schemes modernised in Phase 1 (Chennai-MGR)

No	Tank	Taluk	Ayacut in ha	Total Cost (Rs lakhs)	Cost per ha (Rs 1000)	Cost per ha (US$)
1	Panapakam	Gummidipoondi	195.14	29.75	15.25	347
2	Eguvarpalayam	Gummidipoondi	111.81	28.30	25.31	575
3	Rettambedu	Gummidipoondi	158.64	17.10	10.78	245
4	Enathimelpakkam	Gummidipoondi	147.62	19.19	13.00	295
5	Annappanaickenk	Gummidipoondi	133.44	22.00	16.49	375
6	Puvalambedy	Gummidipoondi	101.01	14.32	14.18	322
7	Peruvoyam	Gummidipoondi	116.38	20.24	17.39	395
8	Sekkanyam	Poneri	149.50	19.64	13.14	299
9	Madarapakkam	Poneri	105.75	12.81	12.11	275
10	Kilikodi	Poneri	105.35	24.10	22.88	520
	TOTAL		1324.64	207.45	15.66	356

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FI.6.4 AT2 - Introduce Sprinkler and Drip Irrigation System

Sprinkler irrigation system

The development of sprinkler and drip irrigation[17] in recent years has been considerable, mainly due to the pressing demand or water from other sectors, a fact which has encouraged governments and farmers to find water saving technique for agriculture.

Sprinkler irrigation was not widely used in India before the 1980s. Although no statistics are available on the total area under sprinkler irrigation, more than 200,000 sprinkler sets[18] were sold between 1985 and 1996 (about 65,000 for 1995-96). The annual growth rate of the sprinkler irrigated area in India is about 25 percent. This area can be estimated at about 0.7 million ha in 1996. The cost of installation of sprinkler irrigation depends upon a number of factors such as type of crop, the distance of the water source, spacing, and nature of terrain. The approximate capital cost (excluding pump cost) ranges from Rs16,000 to Rs20,000 per ha. Assuming the life of sprinkler irrigation is 15 years, discounted rate of 12% per year, an annuity of the capital cost of sprinkler is Rs 2,350-2,940 (US$ 53-67) per ha.

The application of this irrigation technique is limited to vegetables, groundnut, chillies, alfalfa etc. but not for paddy where flooded irrigation is required. From the FGDs carried out by the research team, there is no report on using a sprinkler system in the area.

Water saving from the application of sprinkler irrigation would be 269m^3/ha for vegetables-groundnut and 676 m^3/ha for sugarcane. The cost of water saving from sprinkler irrigation would be Rs 3.50-10.9 per m^3.

Drip irrigation system

Drip irrigation is expanding rapidly in India. This can be partly explained by the subsidies offered by the Government to adopt drip systems. From about 1,000 ha in 1985 the area under drip irrigation increased to 70,860 ha in 1991, mainly in Maharashtra (32,924 ha),

[17] Aquastat Website Indian profile -irrigation techniques
[18] according to the National Committee on the Use of Plastics in Agriculture

Andhra Pradesh (11,585 ha) and Karnataka (11,412 ha). The drip irrigated crops are mainly orchards (39,140 ha), whose main crops are grapes (12,000 ha), bananas (6,500 ha) pomegranates (5,440 ha) and mangoes (4,750 ha). Drip irrigation is also used for sugar cane (3,900 ha) and coconut (2,600 ha). The average cost of drip irrigation development ranges from Rs 30,000-40,000 per ha, but a farmer can receive a subsidy up to Rs 15,000.

Assuming the average life of a drip irrigation system is 7 years (10 years for main pipework and 5 year for driplines), discounted rate of 12% per year, an annuity of the capital cost is Rs 6,674-8,765 (US$ 150-200) per ha.

There are a few farmers in the A-K Basin using drip irrigation for gardens. Water saving from using sprinkler/drip irrigation for gardens would be about 676 m^3/ha per year. Cost of water saving from drip irrigation would be Rs 9.7-12.9 per m^3.

FI.6.5 AA3 - Change Land-use and AA4 Crop area prohibition

Interviewing farmers in the A-K basin showed that market prices per acre are respectively, Rs 100,000 and Rs 150,000 for “wet” land having no access road and for “wet” land with some access. If the land is next to a road, the price of land would be Rs 1 million per acre. (This is equivalent to Rs 247,100; Rs 370,700; and Rs 2.471 million per ha of agricultural land). Considering the financial annual net return of Rs 5,343 per acre, the financial price of land would be Rs 44,370 per acre, which is lower than the market price of land. This has an implication for the progress of urbanization in the suburban area putting the price of agricultural land higher than its real value from agriculture.

The economic value of agricultural land is the present value of the economic net benefit stream generated from crop cultivation for 50 years at the discounted rate of 12% per year. The average economic net benefit in the A-K basin would be about Rs 4,200 per ha as detailed in section 4.6 of the Annex. It is estimated that the economic value of agricultural land would be Rs 34,880 per ha.

Changing land use from paddy-paddy to non-cropped land would cause a loss to the national economy of Rs 2,029 per ha per year. However, water saved by not using it for irrigation would amount of 22,028 m^3/ha per year. The economic cost of water in changing land use would be Rs 0.091 per m^3 saved.

FI.6.6 AA5 - Change Cropping Patterns

This option relates to a change of cropping pattern from high irrigation water requirement to lower irrigation water requirement (normally from paddy and sugarcane to upland crops). It would require agricultural extension services to classify land suitability and markets for new products. In the A-K basin, the main cropping patterns are paddy-paddy, paddy-paddy-paddy, and paddy-groundnut.

The potential of water saving in replacing two paddies (22,208 m^3/ha) by paddy-groundnut (13,888 m^3/ha) would be 8,320 m^3/ha/year.

For the purpose of reducing water requirement for irrigation, groundnut would be a promising crop for extension. Other crops such as vegetables, chillies etc should be in a list of crop diversification program for saving water. However, changing the cultivation custom, creating market channels for products would require time and efforts. Cost estimates are required for agricultural extension work and associated demonstration farms to convince farmers of the changes needed.

FI.6.7 Virtual Water (imported agricultural commodities)

To save available water in the country for other uses than agriculture, countries may adopt a policy of importing agricultural commodities which consume a large amount of water during cultivation.

India is one of the rice exporting countries in the world market. It is estimated that about 3,000 to 3,800 m^3 of water is required to produce 1 ton of rice for export. The economic net benefit for cultivation of paddy is Rs 86-508 per ton of rice depending on seasons. The cost of "virtual water" for paddy is in a range of Rs 0.023-0.165 per m^3, if the action of reduction of rice export is taken to "buy" the water. See details in Table F6-2.

Table F6-2: Estimation value of virtual water

No	Items	Paddy (Samba)	Paddy (Navarai)	Paddy (Sornavari)	Sugarcane
1	Total Evaporation Losses (m^3/acre)	4,317	4,671	4,671	8,450
2	Yield per acre (ton of paddy)	1.875	1.65	1.875	44.516
3	Rice equivalent* (ton)	1.406	1.238	1.406	4.452
4	Water required to produce 1 ton (m^3)	3,070	3,773	3,322	1,898
5	Economic NB (Rs/ton of rice)	508	86	478	NA
6	Cost of water (Rs/m^3)	0.165	0.023	0.144	NA
7	Cost of water (US cent/m^3)	0.004	0.001	0.003	NA

Note: Conversion factor from paddy to rice: 75%

FI.7. Summary of Results

Table F7-1: Cost of water produced and/or saved by options (Rs/m^3)

Option	Description	Cost of Water	Water saved (m3/ha)	Status of water available at			
				Aqui-fer	Sur-face	Distri-bution	Con-sumer
SD1/SA1	Develop add GW	6.12				X	
	Develop add surface	17.7				X	
SD2	Desalination	45				X	
SD3	Blending water supply					X	
SD4	New water treatment	2.85			X		
SD5	Extend water distribution	7.42				X	
SD6	Extend tanker distribution					X	
SD7/SA4	Retention dams	11.0		X			
SD8/SA5	Aquifer recharge			X			
SD9/SA6	Increased surface water				X		
SD10/SA7	Rain harvesting	3.75		X			
SD11/SA8	Trans basin water transfer				X		
SA2	Treat wastewater for re use	2.2-2.9			X		
DD1	Reduce consumer loss						X
DT3	Recycling of industry water	36				X	
AT1	Improve surface irrigation	0.54	3,600	X			
AT2	Introduce sprinkler	3.5-10.9	269-676	X			
	Introduce drip irrigation	9.7-13.0	676	X			
AA3	Change land use	0.09	22,208	X			
AA4	Crop area restriction			X			
AA5	Change cropping pattern		8,320	X			
AA7	Water tariff			X			

PART II JORDAN CASE STUDY (AL-JAFR SHOUBAK)

FI.1. The Case Study Area

The Case Study areas selected for study by the Ministry of Water and Irrigation are in Ma'an Governorate in southern Jordan.

FI.2. Overall economy

FI.2.1 Economy of Jordan

The economy of Jordan is mainly reliant on the tertiary sector which consists of trading, business and services (about 73%). This is followed by the secondary sector (about 22%) which consists of manufacturing, construction, electricity, gas and water. The primary sector contributes a small portion to GDP (about 5%) which consists of agriculture, hunting, forestry and fishing (2%) and mining & quarrying (3%). See Table F2-1.

Real GDP growth rates were about 3% per annum in 1998 and 1999, 4% in 2001 and 5% in 2002. GDP per capita were US$ 1,718 in 2001 and US$ 1,762 in 2002. Annual inflation rate is 3.3% per annum and the official un-employment rate is 16%.

Phosphate represents a significantly natural resource of Jordan and it is expected to expand considerably as pressure continues on world wide agricultural productivity. Other materials such as glass, sand, potash, bromine have shown significant growth. Tourism also presents a major source of income generation of foreign exchange.

The total agricultural area of Jordan is 2.61 million dunum, 0.75 million dunum of which is irrigated. The remaining 71% area is rain-fed with field crops prevailing. Vegetables and fruit trees are usually irrigated and Jordanian farmers have applied high technology in irrigation such as drip and sprinkler.

Availability of land and water resources is limited in Jordan; however the country exports his high quality agricultural commodities (vegetables and fruit) with an exported value of 92 JD million in 2002. Jordan imports annually about 59,000 tons of wheat & barley and about 36,800 tons of fruits with total value of 93 JD million in 2002.

According to 2002 statistics, the population of the country was 5.33 million. The population density varies from 3.1 person/km^2 in Ma'an Governorate to 586.5 person/km^2 in Irbid Governorate. The capital of the Kingdom is Amman with an area of 8,231 km^2 serving 2.03 million people.

Table F2-1: Selected Economic Indicators Jordan (JD M Current prices)

	ECONOMIC ACTIVITIES	1994	1995	1996	1997	1998	1999	2000	2001
1	**Primary Sector**	**295.6**	**330.9**	**312.3**	**318.2**	**315.1**	**279.7**	**292.4**	**300.7**
	Agricultural, hunting, forestry & fishing	192.9	173.7	158.6	148.3	144.7	115.9	120.9	124.3
	Mining & quarrying	102.7	157.2	153.7	169.9	170.4	163.8	171.5	176.4
2	**Secondary Sector**	**972.6**	**1,005.3**	**929.2**	**980.0**	**1,077.8**	**1,086.7**	**1,135.5**	**1,208.5**
	Manufactoring	585.9	606.8	570.0	621.6	742.0	750.3	797.8	836.9
	Construction	301.8	300.1	254.8	240.5	214.6	207.1	203.3	231.0
	Electricity, gas & water	84.9	98.4	104.4	117.9	121.2	129.3	134.4	140.6
3	**Tertiary Sector**	**2,496.8**	**2,757.6**	**2,979.4**	**3,234.1**	**3,425.7**	**8,581.3**	**3,827.7**	**4,030.7**
	Trading, restaurant & hotels	386.0	406.3	425.9	510.3	523.4	5,543.2	588.9	618.6
	Transport, storage & communication	533.4	581.9	642.7	672.7	717.1	762.2	819.7	879.2
	Finance, insurance, real estate & business	749.3	828.2	882.2	918.5	979.1	990.6	1,072.0	1,135.4
	Community, social & personal services	107.7	128.3	144.4	178.3	200.3	224.3	235.3	250.8
	Producer of government services	667.3	756.6	827.4	896.2	943.2	995.7	1,042.2	1,077.1
	Producer of private non profit services	47.1	50.4	51.5	52.9	56.0	57.4	59.9	58.2
	Domestic services of households	6.0	5.9	5.3	5.2	6.6	7.9	9.7	11.4
4	**TOTAL 1, 2, 3**	**3,765**	**4,094**	**4,221**	**4,532**	**4,819**	**9,948**	**5,256**	**5,540**
	Less: Imputed bank service charge	73.9	75.0	77.3	81.0	107.5	93.5	111.4	123.0
	GDP at Current basic prices	3,691	4,019	4,144	4,451	4,711	9,854	5,144	5,417
	Plus: Net tax on product	667.1	695.5	768.7	686.2	889.6	913.2	845.0	893.8
5	**GDP at current market prices**	**4,358**	**4,714**	**4,912**	**5,138**	**5,601**	**10,767**	**5,989**	**6,311**
	SECTORS CONTRIBUTION TO GDP								
1	**PRIMARY**	**7.9%**	**8.1%**	**7.4%**	**7.0%**	**6.5%**	**2.8%**	**5.6%**	**5.4%**
2	**SECONDARY**	**25.8%**	**24.6%**	**22.0%**	**21.6%**	**22.4%**	**10.9%**	**21.6%**	**21.8%**
3	**TERTIARY**	**66.3%**	**67.4%**	**70.6%**	**71.4%**	**71.1%**	**86.3%**	**72.8%**	**72.8%**
	Agricultural, hunting, forestry & fishing	5.1%	4.2%	3.8%	3.3%	3.0%	1.2%	2.3%	2.2%

Source: Statistics, The Hashemite Kingdom of Jordan

Table F2-2: Cropped area in Jordan 2002 ('000 dunum)

Crop	Non-irrigated	Irrigated	Total
Fruit trees	526.9	356.1	883
Field crops	1305.9	74.3	1380.2
Vegetables	23.7	318.9	342.6
Total	1856.5	749.3	2605.8

Source: Agricultural Statistics 2002, The Hashemite Kingdom of Jordan

FI.2.2 Economy of the Case Study areas

The Case Study areas in Shoubak District and Al Jafr Sub-district are in Ma'an Governorate. The population of Ma'an Governorate was about 104,000 in 2002 representing 2% of the Kingdom's population. The population of Shoubak District was 13,075 and of Al Jafr was 11,850.

According to agricultural statistics in 2002, the Ma'an Governorate contributed about 5 % of fruit production and 8% of the vegetable production of the nation. The total agricultural land of Ma'an governorate is about 263,000 dunum of which more than 94,000 dunum (35.8%) is irrigated, the remaining is rain-fed with variable yields depending on the rainfall. Agricultural areas in Shoubak District total 101,386 dunum (19,867 dunum irrigated and 81,521 dunum rain-fed) and Al Jafr has a total of 40,479 dunum all of which is irrigated.

FI.3. PRICES

FI.3.1 Agricultural inputs and outputs

Irrigation water fees were introduced in Jordan in 1961 for schemes operated and maintained by Government. The charge was 1 fils/m^3 for an amount up to the limit of 1800m^3/month and 2 fils/m^3 for any amount exceeding that limit. In 1974 the irrigation water fees were raised to 3 fils/m^3 regardless of the amount of consumption. In 1988 the Council of Ministries agreed to raise the fee to 8.4 fils/m^3 to cover partial O&M costs of Government run schemes.

Later, in 1995, the Irrigation Water Charge was 11.2 fils/m^3 for less than 1000 m^3 per month per farm, 16.8 fils/m^3 for 1001-2000 m^3 per month, 28 fils/m^3 for 2001-3000 m^3 per month and 49 fils/m^3 for farm using more than 3000 m^3 per month.

The irrigation fees vary from place to place and from system to system. The farmers in Al Zubariya village, Shoubak district use wells belonging to a society run by a Cooperative. The water is pumped from wells to a collection tank of 130m^3, then pumped from the tank into a distribution system. The water charge to the farmer varies from 70 fils/m^3 to 250 fils/m^3 depending on consumption (See Table F3-1).

Meanwhile, the farmers in the Department of Agriculture Farm in Al Jafr town pay water fees by the hour for water supplied by the Department pumped from wells. The time allocated to irrigate 1 dunum is 1.5 hrs at a cost of 1.4 JD/hr. This cost is discounted by 25-35% depending on the distance from well to farm to take into account the conveyance losses. The water pumped from one of the wells supplying a farm was measured by the team during a visit to farm. It is in order of 80-90 m^3/hr. Assuming the partly lined canal conveyance efficiency is 70% on average, the amount of water delivered to the farm would be 84-95 m^3 in 1.5 hrs of irrigation with the cost of JD 2.1. This is equivalent to 22-25 fils/m^3.

Table F3-1: Irrigation water fees in Al Zubariya village

No	Amount use per month/farm (m^3)	Water fees (Fils/m^3)
1	1-100	70
2	100-200	150
3	200-300	200
4	more than 300	250

Source: FGD survey, April 2004

Financial cost analysis for irrigation water applying a discount rate of 6% showed that, the farmers who use their own well spend 44 fils/m^3 in Al Jarbakabeera village, Shoubak District, 36 fils/m^3 in Al Jafr sub-district and 379 fils/m^3 in Sabeeh Al Masry Farm to cover all capital and O&M costs of getting the water from the ground. See Table F3-2.

Table F3-2: Cost of pumped water for irrigation

Location/farm	Depth of well (m)	Capital cost (JD)	O&M cost (JD/yr)	Pump capacity (m^3/hr)	Cost of water (fils/m^3)
Department of Agriculture Farm, Al Jafr	54	25,560	3,360	64	36
Al Jabakabeera, Athruk, Shoubak	150	33,100	4,593	70	44
Sabeek Al Masry Farm, Shoubak	360	47,000		57	379

Note: for details see Tables FII-13 to FII-15

Table F3-3: Farm-gate prices 2003 for selected agricultural inputs/outputs

Items	Unit	Unit price (JD)	Unit price (US$)
DAP	Kg	0.160	0.23
Amonic Sulfate	Kg	0.125	0.18
Super Phosphate 3	Kg	0.204	0.29
Urea	Kg	0.150	0.21
Manure	Ton	25	35.71
Drip irrigation system	Per Dunum	100	143
Tomatoes	Kg	0.055-0.070	0.08-0.10
Potatoes	Kg	0.115	0.16
Dry Onion	Kg	0.140	0.20
Watermelons	Kg	0.066	0.09
Wheat	Kg	0.200	0.29
Barley	Kg	0.120	0.17
Clovers	Kg	1.500	2.14
Olives	Kg	0.250	0.36
Apples	Kg	0.200	0.29
Apricot/stone fruits	Kg	0.300	0.43

Source: FGDs and Farm's interviews

FI.3.2 Power and fuels

The power tariff for farming enterprises is 41 fils/kWh.

Fuels prices are currently at 0.15 JD/litre for diesel, 0.33 JD/litre for petroleum and 0.435 JD/litre for super petroleum.

FI.3.3 Un-skilled labour

The FGDs indicated that farm activities are done by both family and hired labour. The cost of un-skilled labour working on the farm is 5 JD per working-day. Some big farms have permanent labour (expatriates from Egypt) working on the farm who are paid 100 JD per month plus accommodation and other items.

FI.3.4 Domestic water supply

The price of domestic water to consumers in Jordan increases with the amount of water consumed. It follows a progressive tariff system. The current domestic price in Shoubak District is designed on an incremental basis for additional water consumed and is summarized as in Table F3-4.

Table F3-4: Domestic tariff in Shoubak District (JD/m3)

Water used (m^3/quarter)	Water charge	Sewage charge	Total
0-20	0.100	0.034	0.134
21-40	0.114	0.038	0.152
41-70	0.238	0.093	0.331
71-100	0.435	0.190	0.625
101-130	0.632	0.287	0.919
Over 130	0.850	0.392	1.242

Source: Water Authority in Petra

FI.3.5 Opportunity cost of capital

The opportunity cost of capital depends on several factors in the economy of the nation. Water resources infrastructure projects have used discounted rates at 8%, 10% and 12% in economic analyses. An average 10% of social discounted rate has been used for the study in identification of economic cost of water.

FI.4. AGRICULTURE

FI.4.1 Key notes from field visits to Shoubak and Al Jafar

Three agricultural FGDs were undertaken in Shoubak and two in Al Jafr. Most of farmers in the area grow one annual rain-fed crop (wheat or barley) in the winter season. The yield of these crops varies very much depending on the rainfall intensity and frequency during the season. The average yield for rain-fed cultivation is about 100 kg/dunum for wheat and 150 kg/dunum for barley.

All vegetables are irrigated with drip irrigation systems. Depending on season, they may be grown in open fields and/or under cloche/green house. Most farms grows only one crop of vegetables between April and September.

Fruit trees in Jordan are mainly irrigated. In addition to the planting of trees in garden areas adjacent to houses, there are several specialist fruit tree farms of between 300 and 2,300 dunum each in the Shoubak area. Olives, apples, apricot, other stone fruits and grapes are grown on a large scale on these farms.

The study team visited two big fruit farms in Shoubak. Water for irrigation is pumped from three wells at a depth of more than 300m. Irrigation water is applied for 8 months of the year (no irrigation in December-March). The amount of irrigation reported by the farm manager was 2.5 m^3/dunum/day (600 m^3/dunum/year) for fruit trees, and 5 m^3/dunum/day (450-500 m^3/dunum/crop) for vegetables. These figures are different from the estimates made in PRIDE, August 1992: A Water Management Study for Jordan who estimated 4-5 m^3/dunum/day for fruit trees, and 2-3 m^3/dunum/day vegetables.

Information on pump capacity reported by farm-2 (maximum rate of 2,240 m^3/day) seems to be much lower than the water required for irrigation at 2.5 m^3/day for 2,300 dunums (4,250 m^3/day). It would result in high cost per m^3 of irrigation water.

The cost for drip irrigation facilities including supply pipes to tanks, distribution pipes, drip pipes and fittings, was reported to be 107-153 JD/dunum.

The manager of the Department of Agricultural Farm in Al Jafr gave the following data on fuel consumption for pumping water: it requires 70 litres to pump 10 hrs a day (@ 0.15 JD/litre). Fuel would cost 2520 JD/well/8 months. The farm employs 3 labourers to run 5 wells (@350JD/month/3 labors). Labour would cost 840 JD/year/well.

The electricity bill for operation of wells reported by big farms is as follows and includes all other electricity consumption by other applicants in the farms. It is based on a power theory (i) 1000 m^3/day of water raised through 8.81m required 1 kW at pump efficiency of 100% (equivalent to raise 367.08 m^3 through 1 meter would require 1 kWh); (ii) assuming pump efficiency of 65%, depending on the dynamic head of each well, the amount of water pumped by using 1 kWh can be determined for estimating electricity costs in operation of the well (1 kWh can lift 1.34 m^3 at a dynamic head of 178m in a case of Farm-1 or 0.83 m^3 at a dynamic head of 290m in Farm-2). The electricity rate was 0.041 JD/kWh. Power costs for pumping one m^3 are 31 fils in Farm 1 - Sabeek Al Masry and 50 fils in Farm 2 - Abdeh Khalek.

FI.4.2 Land use and cropping patterns

Land use

Land use in Ma'an Governorate consists of field crops (68.6%), fruit trees (21.1%) and vegetables (10.3%). Land use in Shoubak is field crops (79.9%), fruit trees (19.7%) and vegetable only 0.4%. In Al Jafr vegetables predominate (55.3%) with field crops (34.6%) and fruit trees (10.1%). Details are given in the table below.

Table F4-1: Land use in Shoubak and Al Jafr and % of Ma'an - 2002

Crops	Irrigation	Trees	Ma'an (dunum)	Shoubak (dunum)	% of Ma'an	Al Jafr (dunum)	% of Ma'an
Fruit trees							
	Irrigated	Olives	15,392	1,969	13	1,597	10
	Irrigated	Grapes	3,275	300	9	957	29
	Irrigated	Others	33,124	17,187	52	1,540	5
	Non-irrigated	Olives	2,123	353	17		
	Non-irrigated	Grapes	589	200	34		
	Non-irrigated	Others	1,091	3	0		
Vegetables							
Winter			8,727			7,980	91
Summer	Irrigated		18,562	409	2	14,410	78
Field crops							
Winter	Irrigated		14,099			12,944	92
	Non-irrigated	Cultivated	161,677	80,240	50		
		Harvested	145,330	70,183	48		
Summer		Cultivated	4,305	725	17		
		Harvested	3,501	510	15		
Clovers/alfalfa	Irrigated		1,085			1,051	97
Total	Irrigated		94,266	19,867	21	40,479	43
	Non-irrigated		169,035	81,521	48		
Grand total			**263,299**	**101,386**	**39**	**40,479**	**15**
Percentage of crop type in			Ma'an	Shoubak		Al Jafr	
Fruit trees			21.1%	19.7%		10.1%	
Vegetables			10.3%	0.4%		55.3%	
Field crops			68.6%	79.7%		34.6%	

Source: Agricultural statistics, Department of Agriculture, Ma'an Governorate.

Crop calendar

Fruit trees provide perennial crops. Most trees are planted between January and March. First harvest is normally four to five years after planting. Harvesting periods are June to August for apples, November to December for olives, August for grapes, the first 2 weeks of July for apricots, June to July for other stone fruits and September for Pistachcio Aleppo.

Vegetables are planted from the middle of April and harvested in August, except for potatoes which are harvested in October. Some farms grow three tomato crops in a year; planting times are in February, May and July with harvesting times in July, October and November respectively.

Wheat is planted in November-December and harvested in May and June. Barley is planted in October-November and harvested in April-May.

Cropping patterns

There are three groups of crops which are classified and recorded by the Ministry of Agriculture in Jordan. These are (i) fruit trees (olives, apples, citrus, stone fruits etc.); (ii) vegetables (tomatoes, cauliflower, potatoes, melons, onions, etc.); and field crops (wheat, barley, clover, etc.).

The fruit trees and vegetables are mostly cultivated under drip irrigation in open fields and/or in green houses. Field crops are largely rain-fed. The average yield for irrigated wheat is 3.5 ton/ha where supplementary irrigation is available and up to 6 ton/ha under permanent irrigation. The rain-fed yield of wheat varies between 0.7-1.4 ton/ha. The yield of barley was 2.5 ton/ha for irrigated and 0.6-1.5 ton/ha for rain-fed.

Generally, field crops are grown during the winter season and two or three vegetables crops are grown per year in a green house or in open field under cloche. Typical crop calendars are given in the table below.

Table F4-2: Crop calendar in the Study Area

No	Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Apples	PPP	PPP	XXXX	XXXX	XXXX	**HHHH**	**HHHH**	**HHHH**	XXXX	XXXX	XXXX	XXXX
2	Olives	PPP	PPP	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	**HHHH**	**HHHH**
3	Grape	XXXX	PPP	PPP	PPP	XXXX	XXXX	XXXX	**HHHH**	XXXX	XXXX	XXXX	XXXX
4	Apricot	PPP	PPP	XXXX	XXXX	XXXX	XXXX	**HH**XX	XXXX	XXXX	XXXX	XXXX	XXXX
5	Stone fruits	PPP	PPP	XXXX	XXXX	XXXX	**HHHH**	**HH**XX	XXXX	XXXX	XXXX	XXXX	XXXX
6	Pistacchio-Aleppo	PPP	PPP	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	**HHHH**	XXXX	XXXX	XXXX
7	Vegetables				PP	PPXX	XXXX	XXXX	**HHHH**				
8	Potatoes				PP	PPXX	XXXX	XXXX	XXXX	XXXX	**HHHH**		
9	Tomatos		PPXX	XXXX	XXXX	XX**HH**	**HHHH**	**HH**					
10	Tomatos					PPP	XXXX	XXXX	XX**HH**	**HHHH**	**HH**		
11	Tomatos							PP	XXXX	XXXX	**HHHH**	**HHHH**	
12	Watermelons		PP	XXXX	XXXX	**HH**							
					PPPP	XXXX	XXXX	**HH**					
13	Fodder crops/ Clover	XXXX	XXXX	XXXX	PPP	XXXX	XXXX	XXXX	XXXX	XXXX	PPPP	XXXX	XXXX
14	Wheat	XXXX	XXXX	XXXX	XXXX	**HHHH**	**HH**					PP	PPP
15	Barley	XXXX	XXXX	XXXX	**HHHH**	**HH**					PP	PPP	XXXX

Note: PPP Land preparation & planting; HHH harvesting time; XXXX main season

FI.4.3 Farm size and cultivation techniques

Farm size

The FGDs carried out by the research team during April 15-20, 2003 in Shoubak and Al Jafar showed that farm sizes in Shoubak are generally smaller than in Al Jafar. In Shoubak, 40% of farming households interviewed are smaller than 5 ha; 28% of households are larger than 10 ha. Meanwhile in Al Jafar most farming households interviewed are greater than 5 ha and 46% of households larger than 10 ha.

However, irrigated land is only a small portion (37%) of the farmed agricultural land in Shoubak since rain-fed wheat/barley is widely cultivated. The information of irrigated land in Al Jafar is affected by the number of nomadic households using the Department of Agriculture's Farm who do not cultivate and irrigate their land regularly.

Table F4-3: Farm size distribution

Farm size	Agricultural land		Irrigated land	
	Shoubak	Al Jafar	Shoubak	Al Jafar
< 0.5ha			24%	38%
0.5-1ha	8%		12%	0%
1-2.5ha	12%		20%	15%
2.5-5ha	20%		28%	8%
5-10ha	32%	54%	8%	8%
>10ha	28%	46%	8%	31%

FI.4.4 Crop water requirement and irrigation management

Crop water requirement

Net irrigation water requirements vary within the Ma'an Governate and differ between the two study areas.

The Jafar Basin is located in two agro-climatic zones (zone 11 and zone 12). The study area is within zone 11 and the net irrigation requirements are given in Table F4-4A below.

Table F4-4A: Net Irrigation Requirement for zone 11 (mm); Jafer Basin is part of this zone

DESCRIPTION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Aut_Fruit	0	0	0	67.8	104	166	175	160	131	24	0	0	**829**
BBeans_Peas_Smr	0	0	39.5	112	194	277	246	0	0	0	0	0	**869**
BBeans_Peas_Wntr	44	73.7	119	149	0	0	0	0	0	0	39.7	36	**461**
Carrot_Smr	0	0	39.1	132	192	254	244	0	0	0	0	0	**861**
Carrot_Wntr	36	0	0	0	0	0	0	0	39.1	94	63	45.5	**277**
Citrus	44	63	95.9	137	150	170	175	160	131	82	46.1	43.9	**1298**
Crucifers_Smr	0	0	0	40.5	144	240	216	0	0	0	0	0	**640**
Crucifers_Wntr	0	0	0	0	0	0	0	40.5	130	102	66.8	3.99	**343**
Cucmbr_Smr	0	0	0	50	146	234	187	0	0	0	0	0	**617**
Cucmbr_Wntr_Plstc	0	0	0	0	0	0	50	18.4	108	83	-7.2	0	**252**
Early_Fruit	0	50	78.6	164	234	279	287	186	0	0	0	0	**1,278**
EggP_Smr	0	0	0	47.2	133	163	207	228	197	121	13.9	0	**1,110**
EggP_Wntr	0	0	0	0	0	47.2	173	165	170	121	67.2	-5.3	**739**
G_Beans_Smr	0	0	0	40.5	135	231	214	0	0	0	0	0	**620**
G_Beans_Wntr_Plstc	0	0	0	0	0	0	41	14.5	95.8	87	6.14	0	**244**
Grapes	0	0	0	50	73.2	168	212	194	149	15	0	0	**863**
J_Malok_Smr	0	0	0	0	37.6	176	212	147	0	0	0	0	**573**
Late_Fruit	0	0	50	108	188	281	293	268	214	60	0	0	**1,462**
Lett_Spin_Smr	0	0	39.3	132	187	225	0	0	0	0	0	0	**583**
Lett_Spin_Wntr	0	0	0	0	0	0	0	0	38.1	101	61	28	**228**
Melons_Smr	0	48	83.4	160	141	0	0	0	0	0	0	0	**433**
O_Veg_Smr	0	0	0	39.7	153	198	240	232	155	0	0	0	**1,018**
O_Veg_Wntr	0	0	0	0	0	0	40	165	148	110	65.1	12.4	**540**
O_Veg_Wntr_Plstc	0	0	0	0	0	0	30	11.4	51.8	76	46.7	1.51	**218**
Okra_Smr	0	0	0	0	45	153	199	225	136	0	0	0	**759**
Olives	62	57.6	89.4	132	149	170	175	160	131	31	0	0	**1,157**
Onion_Grlc_Wntr	46	64.7	81.1	0	0	0	0	0	37.8	95	62.3	44	**430**
Peppr_Smr	0	0	39.1	124	165	238	261	239	151	0	0	0	**1,218**
Potato_Smr	0	39.1	83.3	174	234	224	0	0	0	0	0	0	**754**
Squash_Smr	0	0	50	116	178	169	0	0	0	0	0	0	**513**
Squash_Wntr	0	0	0	0	0	0	50	145	140	110	8.87	0	**454**
Tomato_Smr	0	0	50	115	198	278	201	0	0	0	0	0	**842**
Turn_Radi_Wntr	0	0	0	0	0	0	0	39.1	133	92	63	32.3	**360**
Wheat & Barley_Wntr	45	74.4	119	189	24.1	0	0	0	0	100	40.5	33.3	**626**

Source: Ministry of Water and Irrigation, 2004

The Shoubak Study Area is located in zone 9 and the net irrigation requirements are given in Table F4-4B below.

Table F4-4B: Net Irrigation Requirement for zone 9 (mm); Shoubak Basin is part of this zone

DESCRIPTION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Aut_Fruit	0	0	0	67.1	90.85	138	135	128	112	23.7	0	0	**694**
BBeans_Peas_Smr	0	39.5	47.3	131	196.6	190	0	0	0	0	0	0	**605**
BBeans_Peas_Wntr	38.3	39.3	40.7	0	0	0	0	0	0	39.5	49.8	24.9	**232**
Carrot_Wntr	33.9	22.1	0	0	0	0	0	0	0	36.4	54.33	27.2	**174**
Crucifers_Smr	0	0	40.5	98	157.6	208	155	0	0	0	0	0	**660**
Crucifers_Wntr	0	0	0	0	0	0	41	123	140	119	27.55	0	**450**
Cucmbr_Smr	0	0	0	50	125.5	181	192	120	0	0	0	0	**669**
Early_Fruit	0	50	51.5	135	197.7	231	221	139	0	0	0	0	**1024**
EggP_Smr	0	0	47.3	95.5	139.5	201	201	131	0	0	0	0	**815**
G_Beans_Smr	0	0	0	40.5	119.8	193	155	0	0	0	0	0	**509**
Grapes	0	0	0	50	65.38	141	163	155	127	14.7	0	0	**716**
Late_Fruit	0	0	50	91.2	161.7	233	226	215	181	58.6	0	0	**1216**
Lett_Spin_Wntr	0	0	0	0	0	0	0	37	129	99.6	65.52	12.3	**343**
Melons_Smr	0	0	0	0	48	146	184	125	0	0	0	0	**503**
Olives	50	30	60.6	111	128.3	141	135	128	112	30.3	0	0	**925**
Onion_Grlc_Wntr	32.1	32.1	67	108	0	0	0	0	0	36.4	52.28	26.3	**354**
Squash_Smr	0	0	0	50	116.3	155	179	112	0	0	0	0	**612**
Tomato_Smr	0	0	50	95.9	168.5	230	142	0	0	0	0	0	**687**
Turn_Radi_Wntr	0	0	0	0	0	0	0	36.4	119	94.1	65.5	16.8	**332**
Wheat & Barley_Wntr	24.3	36.7	79.2	152	15.15	0	0	0	0	0	100	12.9	**420**

Source: Ministry of Water & Irrigation, 2004

The net irrigation requirements for each crop given in the tables above represents the weighted net irrigation requirement for three irrigation methods (surface, sprinkler and drip) in each irrigation centre averaged for all settlements in the same zone.

In Al Jafar net irrigation water requirements are between 829 and 1462 m^3/dunum/year for fruit trees, 218 and 1218 m^3/dunum/year for vegetables and 626 m^3/dunum/year for winter wheat and barley.

In Shoubak the corresponding figures are 694-1216 m^3/dunum/year for fruit trees; 232-815 m^3/dunum/year for vegetables and 420 m^3/dunum/year for wheat and barley.

Irrigation management and efficiency

PRIDE in their Water Management Study for Jordan state that the following irrigation techniques are used in Ma'an Governorate with the following assumed efficiencies: In 84,000 dunums, there are 2,000 dunums basin irrigation with efficiency of 60%, 34,000 dunums drip irrigation with efficiency of 85% and 48,000 dunums sprinkler irrigation with efficiency of 70%.[19]

The research team carried out five Focus Group Discussions (FGDs) and two interviews with private farming enterprises in Shoubak and Al Jafr. The preliminary findings are listed below:

1. Agricultural household in Shoubak seem to be under-irrigating their crops since the amount of water applied varies from 71-267 m3/year/dunum for apples and olives. Irrigation techniques are mainly drip irrigation;

[19] PRIDE, August 1992: A Water Management Study for Jordan;

2. The Department of Agriculture Farm in Al Jafr sub-district. Total farm land is 2500 dunums and each household (these are generally Bedouin families who the Government is encouraging to settle) has 50 dunums for cultivation 25 dunums for folder crops (clovers), 12.5 dunum for fruit trees/vegetables and 12.5 dunum for field crops (wheat/barley). The 2500 dunum are supplied by four wells each with a capacity of 80-90 m3/hr. Operating time is 10 hrs per day from 7:00 am to 5 pm. During summer time, the water is not sufficient for irrigation. Irrigation techniques applied in the farm is flooding and basin irrigation. If we assume a conveyance efficiency of 65% for partly concrete and partly earth channel, a pumping rate of $80m^3$/hr, an irrigation time allocation of 1.5 hrs per dunum and irrigation frequency for berseem/clover of once a month for 8 months, the depth of irrigation water would be 78mm for each irrigation and total amount of water irrigated in a year would be 624 m^3/dunum. There are two critical points relating to irrigation management in this model: (i) the irrigation water applied in each period is much greater than the optimum (resulting in low on-farm application efficiency; (ii) the time between irrigation applications is too long (one month) resulting in in-sufficient water overall for the crop and hence a low crop yield. Although the total amount of irrigation water for field crops of 624 m3/dunum/year seems about right, the irrigation application is not effective and results in an overall under irrigation;

3. Private farming enterprises in Shoubak have a farm size of between 300 and 2300 dunum with mainly apples, stone fruits, olives and vegetables. All farms have their own wells and supply irrigation water during the 8 months between April and November. Drip irrigation is used and in case of vegetables they are grown in green houses or covered by cloche. In terms of irrigation techniques, these farms are highly efficient. No figures on total water used by the farms for trees and/or field crops were available from the farms except that the irrigation rate was reported as $2.5m^3$/dunnum/day for fruit trees and as 5 m^3/dunnum/day for vegetables.

FI.4.5 Crop net benefits

Estimates of the crop net benefit is based on crop-budgets collected by the research team during the course of study. For the purpose of comparison with other annual crops, a concept of the annuity of the net benefit stream is applied for fruit trees and fodder crops (berseem/clover) which have negative or low net benefit in the first few years of establishment.

There is limited information on the cost of water for irrigation in the study area. There are 3 locations in Shoubak namely: Al Jarbakabeera Village, Sabeek Al Masry Farm-1 and Abdeh Khalek Farm-2. There is inconsistent information provided by Farm-2 as mentioned in section 4.1 therefore cost information in this farm is not taken in to account. The cost of getting water from wells for irrigation in Shoubak varies from 49 fils to 493 fils per m^3. The average cost of irrigation water in Shoubak would be at 271 fils/m^3

In Al Jafr Town, there are 6 agricultural households using their private well for irrigation. Average depth of well is 54m and average pump capacity of 64 m^3/hr. The cost of irrigation water in Al Jafr would be 41 fils/m^3.

The cost of drip irrigation system is taken as 130 JD/dunum/7 years, the cost of cloth/plastic cloche cover as 10 JD/dunum/year OR the cost of green houses at 100 JD/dunum/year.

Economic net benefits are very sensitive to the cost of irrigation water. The net benefits for different crops are based on crop-budgets collected by the Consultants economists and were checked during the field survey. The different costs of water are primarily affected by the cost of pumping. The cost of irrigation water in Shoubak is 6-7 times that in Al Jafr. Net benefits of fruit trees vary from 100-160 JD per dunum in Al Jafr and from 10-20 JD per dunum in Shoubak. Net benefits of vegetables are 160-330 JD/dunum in Jafr and 40-210 JD/dunum in Shoubak. Irrigated field crops are only in Al Jafr and their net benefits are 110 JD/dunum for clovers and 6-9 JD/dunum for Wheat and Barley. See Table F4-5. Details are given in Attachments FII-1 to FII-12

FI.4.6 Economic value of water in agriculture

As mentioned in Section 4, irrigation water use reported by farmers is different from PRIDE estimates. However, current agricultural practices would be considered for the purpose of estimation of value of irrigation water by different fruits and crops. Amounts of irrigation water are 400 m^3/dunum/year for olives, 600 m^3/dunum/year for other fruits, 500 m^3/dunum/season for vegetables, 800 m^3/dunum/year for clovers, and 350 m^3/dunum/crop for wheat & barley.

This would result in an economic value of water of 0.25-0.27 JD/m^3 in Al Jafr and of 0.02-0.04 JD/m^3 in Shoubak for fruit trees; of 0.32-0.66 JD/m^3 in Al Jafr and of 0.08-0.43 JD/m^3 in Shoubak for vegetables; of 0.14 JD/m^3 for berseem/clover and of 0.02-0.03 JD/m^3 for wheat and barley in Al Jafr. See Table F4-5.

Table F4-5: Economic crop NB and value of water in agriculture

Fruits/crops	Irrigated water (m3/dunum/year)	Jafr		Shoubak	
		Net benefit (JD/ha)	JD/m3	Net benefit (JD/ha)	JD/m3
Olives	400	109	0.273	17	0.043
Apples	600	151	0.252	13	0.022
Stone fruits	600	156	0.260	18	0.030
Tomatoes out house	500	158	0.316	43	0.086
Tomatoes in house	500	282	0.564	167	0.334
Watermelons	500	329	0.657	214	0.427
Dry Onion	500	156	0.312	41	0.082
Cloves	800	111	0.139		
Wheat	350	9	0.025		
Barley	350	6	0.018		

FI.5. ECONOMIC COST OF WATER SUPPLY

FI.5.1 Overall Situation of Water Supply in the Study Area

Water supply

Information from seven domestic FGDs in Shoubak and Al Jafr show that all respondents get domestic water either from the Water Authority of Jordan (WAJ) or wells managed by the Society. Only 10% of respondents in AJDOM6 (see Table below) Al Jafr get water from a tanker and 10% of respondents in PRETEST (see Table below) in Shoubak buy bottled water as additional for their drinking water beside water from WAJ and society. See Table F5-1.

Table F5-1: Status of domestic water supply in the study area

No	Reference	Village	District	Gov	Water source (%)			
					WA	Society	Tankers	Bottle
1	PRETEST	Al Zubayriya	Shoubak	Ma'an	10	90		10
2	ASDOM1	Bir el Dabagat	Shoubak	Ma'an	100			
3	ASDOM2	Juhaier	Shoubak	Ma'an	100			
4	ASDOM3	Al Baq'a	Shoubak	Ma'an	100			
5	AJDOM4	Al Jafr	Al Jafr	Ma'an	100			
6	AJDOM5	Al Jafr	Al Jafr	Ma'an	100			
7	AJDOM6	Al Jafr	Al Jafr	Ma'an	90		10	

Source: FGDs, April, 2004

FI.5.2 SD1- Develop Additional Water Supply

Surface water supply

Surface water resources in Jordan have been developed to a large degree to be used mainly for irrigation[20]. These include construction of five dams on Hidan, Wala, Mujib, Kerak and Hasa Wadis with total additional captured water of 60 MCM/year. Construction cost of these dams exceeds JD 2.6 per m^3 (US$ 3.8 per m^3).

Well-field water supply

The Water Resources Study of the Jafr Basin prepared by JICA in Jan 1990 identified the potential yields from two proposed well-fields: (i) South of Hasa with a potential of 5 MCM/year drawn from the B2/A7 aquifer; and (ii) East of Ma’an where the preliminary yield estimate was between 5 and 7.5 MCM/year from the A1-6 aquifer.

(i) In the late 1990s, a new well-field (RUWAQ) was drilled by the Water Authority of Jordan South of Hasa to provide drinking water to Tafila Governorate. The anticipated abstraction from this well-field, once the Tafila national carrier had been installed, was about 5 MCM/year. The abstraction from the well-field in 2003 was 1.2 MCM, although the available resources are assessed to be 5MCM/year.

(ii) The East of Ma’an well-field is located about 20km to the north of the Shediyya mines and is estimated to produce 5 MCM/year from ten production wells.

The average annual run-off at the proposed recharge dam is estimated to be 8.7 MCM/year, providing 5.4 MCM/year to Group A aquifers for the downstream Hasa well-field and 3.3 MCM/year to Group B aquifers providing a major source downstream to the Ma’an well-field.

[20] Water Resources of Jordan Present Status & Future Potentials, by Elias Salamesh & Helen Banayan, 1993;

The investment cost of well construction is however small as JD 1.75 million for South Hasa well-field and JD 1.25 million for East Ma'an by assuming the unit rate of drilling at JD 250 per m lump sum. While the cost of electric facilities (transformer, control panels, remote control panel and flow meter, transmission line and collecting pipes will be in the range of 100-200% of the cost of well construction.

Assuming that

1. management cost for each well-field would be 100,000 JD/year;
2. discounted rate of 10% per year;
3. project life of 30 year;
4. replacement as 20% of the well and pump investment;
5. electricity rate of 41 fils/kWh.

The cost of additional water from the two well-fields (excluding transmission and distribution) would be between 0.073-0.093 JD/m^3.

FI.5.3 SD2 - Desalination

From the WB "The regional Desalination Study for Middle East, North America and Central Asia showed that energy use for seawater desalination is in the range of 3-15 kWh/m^3 depending to technology used (Distillation plant at the top end and RO and ED at the low end).

Recent technology of desalination plants in the world shows that the cost of water would be from US$ 0.45 to 1.09 per m^3 produced at the plant. See Table F5-7 bellow.

E.Salameh et al (in 1993) [21] quoted the unit cost of sea water desalination as between US$ 1-2 per m^3. At Aqaba in Jordan, a proposed site for seawater desalination, the estimated cost for desalination and pumping the water to other place in Jordan may cost as much as US$ 3-5 per m^3.

Table F5-2: BOOT Contract costs in the world

	Tampa Bay	Trinidad	Larnaca	Dhekelia	Singa-pore	Ash-kelon	Algeria
Capacity, t/d	95,000	135,000	40,000	40,000	136,000	274,000	200,000
Salinity, ppt	26	38	40	40		40	40
Energy cost ($/kWh	0.04	0.04	0.057	0.057			
Contract term, y	30	23	10	10	20	25	25
Contract year			2000	1996	2002	2002	2003
First year price (US$/m3)	0.46	0.71	0.73	1.09	0.45	0.52	0.818
• Capital recovery	0.21		0.37	0.56		0.3	
• Non-capital recovery	0.25		0.43	0.53		0.22	

Source: The WB Group, BRL, DHV

FI.5.4 SD5 - Improve / Extend Water Distribution System (fixed infrastructure)

The Water Resources Study of the Jafr Basin identified two potential well-fields. The total cost of this proposal was 140 JD million of which about 3.75 JD million was required for

[21] Water Resources of Jordan Present Status & Future Potentials, by Elias Salamesh & Helen Banayan, 1993

the Ma'an well-field and about 5.25 JD million for the Hasa well-field. The remaining 131 JD million would be for collecting and transferring water network to the main.

Annuity of the capital of 131 JD million in 50 years at a discounted rate of 10% will be 13.21 JD million per year to convey 20 MCM per year. It results in 0.660 JD/m^3.

FI.5.5 SD7 - Retention Dams & Reservoirs

The Water Resource Study of Jafr Basin estimated that cost of construction of 6 recharge dams would be 18.774 JD million to provide additional 23.8 MCM/year for local utilizing surface water and recharging to the aquifers.

FI.5.6 SD8 - Aquifer Recharge

See SD7

FI.5.7 SD9 - Increase Abstraction from Surface Water Sources

The opportunity for this in the Case Study area is poor as surface water sources are very limited.

FI.5.8 SD10 - Water harvesting

The term "Water harvesting" in Jordan relates to the collection of rain water in desert wadis through check dams to increase water infiltration to aquifers and to reduce the amount of flood water lost to the area. Water Resources of Jordan Present Status & Future Potentials, by Elias Salameh & Helen Banayan, 1993 estimated that if this technique is applied, it will add 30-50 MCM/year more to the present water resources in the country. There are no data available so far for evaluating the cost of water generated by this option.

Assuming that:

1. the project life of 30 years;
2. discounted rate of 10%;
3. O&M cost for concrete dams would be 1% of capital cost per year.

The cost of water from recharge dams would be 0.084 JD/m^3 (Net Present Value of cost = 18.84 JD million, Net Present Value of water = 224 MCM). Details are in an Attachment FII-18.

Table F5-3: Estimated cost for recharge dams

Recharge dam (Wadi)	A1 Nijil	A2 Marma	A3 El Arja	B1 Wheida	B2 Wheida	B3 El Huseinan	Total
Catchment (km2)	34.3	32.2	31.1	55.7	135.9	71.7	360.9
Ave. Annual Flow (MCM)	1.5	1.9	2	0.8	1.6	0.9	8.7
Max. inflow (MCM)	5.6	9.1	12	3.6	8.9	4.8	44
Gross Storage (MCM)	3.7	6	8.5	2.4	4.2	2	26.8
Effective storage (MCM)	3.2	5.3	7.8	2.1	3.7	1.7	23.8
Dam height (m)	19	18	39	20	19	10	125
Dam concrete (1000m3)	48	54	125	25	38	8	298
Cost of dam (1000 US$)	4,320	4,860	11,250	2,250	3,420	720	26,820
Cost of dam (1000 JD)	3,024	3,402	7,875	1,575	2,394	504	18,774

Source: JICA, Jan. 1990, The Water Resource Study of Jafr Basin

FI.5.9 SD11 - Trans Basin Water Transfer (import)

The water import plan as a result of the Peace Treaty between the Hashemite Kingdom of Jordan and the State of Israel has been in placed. Israel needs to supply an additional 50 MCM to Jordan in addition to the desalinated 10 MCM from saline springs[22]. The project consists of pipelines of different diameters, pumping stations, chlorinating units and telemetry system.

[22] Ministry of Water and Irrigation, Jordan – http://www.mwi.gov.jo;

The total capital cost of the project is estimated at JD 100 million, according to the Jordanian plan, the construction of the project would start in 2006 and continue for 3 years.

The economic analysis by the MWI for the project showed that the Average Incremental Cost (AIC) of water in the project was 0.91 JD/m^3, 0.89 JD/m^3 and 0.87 JD/m^3 for discounted rate of 12%, 10% and 8% respectively. The calculated unit costs are not included operation and maintenance costs of producing and distributing.

Cost of imported water at Amman by pipe would be 1.54-1.65 US$/$m^3$ (from Turkey), 1.13 US$/$m^3$ (from Iraq), 0.68 US$/$m^3$ (from Lebanon). See Table F5-4.

Imported water by sea using tankers is estimated to cost between 0.84-1.41 US$/$m^3$ to Amman depending on tanker size.

Table F5-4: Unit water cost by options to Jordan

Options	Sub-option	MCM/y	Delivery point	Cost (US$/m3)	To Amman
Imported by sea	Used tankers	200	Dead coast	0.83	1.12
	New water tanker	200	Dead coast	1.12	1.41
	Large vinyl bags	200	Dead coast	0.55	0.84
Imported by land	Pipe from Turkey	150	Lower Jordan river	1.44	1.65
		200		1.36	1.54
	Pipe from Iraq	150	Lower Jordan river	0.94	1.13
	Pipe from Lebanon	150	Lower Jordan rover	0.15	0.68

Source: GTZ 1998

FI.5.10 SA2 - Treat / Use Wastewater

Using wastewater for agriculture has been encouraged by the Water Authority of Jordan for saving the scarce water resources by integrating the treatment of sewage from various communities and/or towns and cities.

The total potential water produced from wastewater treatment would be 470 MCM[23] in the year 2040 with investment of 2,221 M US$. The unit cost of water treated would be US$ 0.52 per m^3. The use of treated wastewater for agricultural purposes has been implemented in Ma'an to serve a target population of 27,000 (treated quantity 0.76 MCM/year) at a capital cost of US$261,000, O&M US$ 6,943/yr (JICA 2001).

FI.5.11 SA9 - Cloud Seeding

Cloud seeding was investigated in the mid-1940s by scientists at the General Electric Laboratory in the US. Cloud seeding involves scattering fine particles in the clouds to accelerate natural process which lead to rain. The chemicals are scattered by aircraft or using ground generators. The most realistic approach to modifying weather is to take advantage of situations in which a relatively small human-induced disturbance in the system could substantially alter the natural evolution of atmospheric processes.

Cloud seeding was practised in Jordan in the year 1986-1990. It would be economically feasible if it could guarantee more rainfall for crop in dry season to rescue crop from drought.

Even today several countries have operational weather modification programs involving cloud seeding. A large amount of work has been done in US and Australia but it has not

[23] IWRA, Water International, Volume 28,Number 1, March 2003;

clearly shown that cloud seeding could be an economic method for harvesting water. However, it is a possible technical option to augment water supply especially in the desert and arid areas.

FI.6. COST OF WATER SAVED IN DEMAND MANAGEMENT OPTIONS

FI.6.1 DT1 - Reduce Water Loss (leakage control)

Unaccounted for water (UFW) in municipal systems is the difference between total amount of water produced and amount of water delivered to the users. It consists of (i) transmission loss; (ii) meter under-registration and accuracy; (iii) public uses; (iv) leakage and illegal use. The overall UFW in Jordan is high, about 52% in 2001. That of the Ma'an governorate is of 54%.

The large proportion of UFW is leakage at about 30%. Hence the potential water saving is large in Jordan and is in the order of 15-16% by improving and rehabilitating the existing distribution network and household connections. Water supplied in Ma'an was 7.7 MCM/year and the potential of water saving by leakage control would be 1.2 MCM/year.

Preliminary estimates of the cost of projects and potential water saving in different Governorates showed that the projects implemented during 1993-1997 with total cost of 51.7 M JD could save a total water of 20.1 MCM/year and proposed projects implemented during 2005-2010 with total cost of 23.1 M JD could save 10.3 MCM/year. The cost of water saved from this option is estimated to be between 0.216 – 0.248 JD/m^3.

FI.6.2 DT2 - Water Saving Devices

The option relates to better plumbing at household level and using water saving devices to increase water use efficiency. It includes high technology shower/taps, toilet flushing. Currently there are several types of (i) toilets with 6-10 litres flush comparing to "traditional one" of 15 litres; (ii) Faucets of 6 litres/minute compared to that of 20 litres/minute; (iii) washing machine using 60-70 litres/load compared to 100-120 litres/load.

This has a potential for water savings, however, water saving faucets always require high pressure in a pipe. This may limit the scope of application.

It was estimated in A Water Management Study for Jordan by PRICE that total cost of replacement of water saving devices would be JD 1.3 million.

FI.6.3 DT3 - Recycling of Industrial Water

Internal Water Resources Association, Water International, Volume 28, Number 1, P1-10, Mar 2003: Control Management Study of Jordan's Water Resources by Dr. Adnan H. Al-Salihi, University of Jordan and Dr. Sawsan K. Himmo Engineering & Environment Co, Amman, Jordan has estimated a unit cost of treated wastewater in Jordan. It would be about 0.364 JD/m^3.

FI.6.4 DA4 - Domestic Water Tariff

The main objectives of water pricing is to facilitate a better water use policy and pricing would serve as reallocating resource to the most efficient water users to reduce the Dead Weight Loss to the society when water price is below production cost.

The Government of Jordan assigned a stepped domestic tariff which is reviewed from time to time, taking into account cost recovery, customer willingness and ability to pay, social and health effects. The price for the lowest step (0-20 m^3) is 0.1 JD per m^3 and about 38% of subscribers were within this step consuming about 10% of the municipal water[24].

Increasing steps in water tariffs can provide an opportunity for shifting water from one user to another which always has economic benefit by transferring the last m^3 of water with lower marginal value to a higher one. This transferring water does not provide more water supply as a whole but re-allocate water among the users and/or saving the water for new connections.

FI.6.5 AT1 - Improve efficiency of Surface Irrigation System

Most of irrigation systems in Jordan are drip irrigation which can reach a high efficiency. Farmers may also use green houses or plastic cloche for vegetables to reduce evaporation losses.

Al Jafr, Department of Agriculture Farm in Ma'an Qasaba District has 2500 dunums to settle nomadic people in the area. Each household has 50 dunums for cultivation.

The farms have been supplied by 4 wells with capacity of 80-90 m3/hr each. Operating time is 10 hrs per day from 7:00 AM to 5:00 PM. During summer time water is not sufficient for irrigation.

The Irrigation techniques applied on these farms is by flooding and basin irrigation. At present it appears that farmers are applying too much water at the time of irrigation, resulting in bigger losses than necessary on the farm due to saturated zone penetrating far beyond the root zone. Water is conveyed from the wells to the farm by open channel partly concrete and partly earth. Overall irrigation efficiency of the farm would be about 40%. However, much of the wasted water returns to the aquifer.

There is a potential to improve irrigation efficiency on the farm by (i) reducing conveyance losses by improvement of canal system; (ii) reducing on-farm application losses by increasing irrigation frequency and reducing water depth in each irrigation application. Costs of the improvement are not available for further analysis of unit cost of water saved by the option.

FI.6.6 AT2 – Introduce Sprinkler and Drip Irrigation System

Since irrigated agriculture in Jordan in the study area is largely applied through drip and sprinkler application, there is no significant potential for water saving by this option.

[24] PRIDE August, 1992: A Water Management Study for Jordan

FI.6.7 AT3 - Change Land-use

This option relates to change agricultural land into other non-crop land for saving the water in the aquifer. There are 4 main groups of tree/crops:

1. Fruit trees which consume about 6,000 m^3/ha/year;
2. Clovers which consume about 8,000 m^3/ha/year;
3. Vegetables which consume about 5,000 m^3/ha/year;
4. Wheat & Barley which consume about 3,500 m^3/ha/year.

Changing land use to non-agriculture would result in an economic loss for the society. An analysis of unit cost of water saved by changing land use shows that to minimize the loss for the society, priority of changing land use would start from wheat and barley which have low economic value of irrigation water. It would followed by clovers and fruit trees.

FI.6.8 Virtual Water (imported agricultural commodities)

To save available water in the country for other uses than agriculture, many countries adopt a policy of importing agricultural commodities which would otherwise consume large amount of water in-country during cultivation.

It is estimated that to produce one ton of wheat or barley would require 1,200-1,500 m^3 of water. Every year Jordan imports about 636,000 ton of wheat & barley for domestic consumption. This results in importation of virtual water of about 800 MCM/year.

Since the economic value of water in producing wheat and barley in Jordan is as low as 0.019-0.026 JD/m^3, it would be economically justifiable to reduce irrigated wheat & barley to save water for other uses and increase the import of these agricultural commodities.

FI.7. Summary of Results

Table F7-1: Cost of water produced and/or saved by options (JD/m^3)

Option	Description	Cost of Water	Water saved	Status of water available at			
				Aqui-fer	Sur-face	Distri-bution	Con-sumer
SD1/SA1	Develop additional GW	0.073-0.093			X		
	Develop additional surface	2.60			X		
SD2	Desalination	0.70-1.40			X		
SD3	Blending water supply						
SD4	New water treatment						
SD5	Extend water distribution	0.66				X	
SD6	Extend tanker distribution						
SD7/SA4	Retention dams	0.084		X			
SD8/SA5	Aquifer recharge			X			
SD9/SA6	Increased surface water				X		
SD10/SA7	Rain harvesting				X		
SD11/SA8	Trans basin water transfer	0.476-1.155			X		
SA2	Treat/use wastewater	0.364			X		
DD1	Reduce consumer loss	0.216-0.248	30 Mm^3/year				X
DD2	Recycling of industry water	0.364			X		
AT1	Improve surface irrigation				X		
AT2	Introduce sprinkler/				X		
	drip irrigation				X		
AA3	Change land use	0.02-0.66	3500-8,000 m^3/ha	X			
AA4	Crop area restriction			X			
AA5	Change cropping pattern			X			

Abbreviations and acronyms

	Description
A-K Basin	Araniyar-Kottalaiyar Basin
Annuity	Annual constant payments for a present capital investment
CMWSSB	Chennai Metro Water Supply & Sanitation Board
Crore	1 Crore = 10 million
DFID	Department for International Development, UK
Dunum	Jordanian land measurement (1 dunum = 0.1 ha)
ED	Electro Dialysis
FGD	Focus Group Discussion
fil	0.001 Jordanian Dinars
ft	Feet = 304.8 mm
GDP	Gross Domestic Products
ha	Hectare (1 hectare = 2.471 Acres)
HH	Household
Hp	Horse power = 0.7457 kW
IMP	Improved irrigation
IWS	Institute for Water Studies, Chennai, India
JD	Jordanian Dinar; 1US$=0.7 JD
kl	Kilo Litre = m^3
lakh	1 lakh = 0.1 million
lpcd	Litre per capita per day
MCM	Million Cubic Metre
MLD	Million Litre per Day = 1000 m^3/day
NB	Net Benefit = Total revenue – Total costs (including family labours)
NPV	Net Present Value
O&M	Operation & Maintenance cost
ppt	Part per thousand (1/1000)
PV	Present value
RO	Reverse Osmosis
Rs	Rupees (Indian currency); 1US$ = 44 Rs
tank	Lake or Reservoir
TEL	Total Evaporation Losses = Crop consumptive uses + other evaporations
US$	US Dollar
WB	The World Bank
WR	Water Requirement
MWI	Ministry of Water and Irrigation
WA	Water Authority

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REPORT ON CASE STUDIES

ANNEX F ECONOMIC DATA AND AGRICULTURE

APPENDIX
FI-1 to FI-16 (Chennai Case Study)

Attachment FI-1: Summary information on crop-budgets from FGDs – Chennai Case Study

CROP-BUDGETS PER ACRE (For annual crops)

			Paddy									Groundnut					
		Unit	AGR-1	AGR-2	AGR-3	AGR-4	AGR-5		Max	Min	Average	AGR-1	AGR-4		Max	Min	Average
I	**Crop Yield**	bag=75kg	22	25	20	20	20		25	20	21	20	20		20	20	20
II	**Production cost**																
1	Land preparation	R	1,900	1,200	1,900	1,900	1,900		1,900	1,200	1,760	1,000	1,000		1,000	1,000	1,000
2	Seed	Rs	600	500	500	500	500		600	500	520	2,500	2,700		2,700	2,500	2,600
3	Fertilizers											0	0		0	0	0
	Complex (17-17-17)	bag	2	3	2	2	2		3.0	2.0	2.2	1.0	0.0		1	0	1
	DAP	bag	0	0	0	0	0		0.0	0.0	0.0	0.0	1.0		1	0	1
	Urea	bag	2	2	2	2	2		2.0	2.0	2.0	1.0	0.0		1	0	1
	Potash	bag	1	0	1.5	1	1		1.5	0.0	0.9	2.0	2.0		2	2	2
	Ammonium chloride	bag	1	0	1	1	1		1.0	0.0	0.8	0.0	0.0		0	0	0
	Gypsum	bag	0	0	0	0	0		0.0	0.0	0.0	2.0	0.0		2	0	1
	Manuring	Rs	400	400	200	200	200		400	200	280	400	800		800	400	600
	Others	Rs	0	0	0	0	0		0	0	0	0	0		0	0	0
4	Insecticides	Rs	600	500	500	500	500		600	500	520	600	300		600	300	450
5	Herbicides	Rs	200	300	0	0	0		300	0	100	0	0		0	0	0
6	Total Labour		1,500	1,200	1,500	1,500	1,500		1,500	1,200	1,440	0	0		0	0	0
	Land preparation	Rs	0	0	0	0	0		0	0	0	0	0		0	0	0
	Transplanting/sowing	Rs	1,000	0	900	900	900		1,000	0	740	500	540		540	500	520
	Fertilizing	Rs	0	0	280	280	280		280	0	168	0	0		0	0	0
	Weeding	Rs	500	0	320	320	320		500	0	292	1,000	480		1,000	480	740
	Harvesting	Rs	0	0	0	0	0		0	0	0	1,200	1,200		1,200	1,200	1,200
	Others	Rs	0	0	0	0	0		0	0	0	0	0		0	0	0
	Of which Hired Labour	Rs	0	0	0	0	0		0	0	0	0	0		0	0	0
7	Capital cost of well & pump	Rs	913	200	716	795	795		913	200	684	913	1,233		1,233	913	1,073
8	Harvesting by machine	Rs	1,200	1,000	1,000	1,000	1,000		1,200	1,000	1,040	0	0		0	0	0
9	Transporting home	Rs	0	0	200	0	0		200	0	40	0	0		0	0	0
10	Packing materials	Rs	0	0	0	0	0		0	0	0	0	0		0	0	0
11	Land tax	Rs	0	0	25	0	0		25	0	5	0	40		40	0	20
12	Pumping irrigation cost*	Rs	2,289	0	2,518	2,598	2,598		2,598	0	2,000	2,289	3,035		3,035	2,289	2,662

Note: * economic cost, including the cost of power currently subsidized for irrigation by the Government

Attachment FI-2: Estimate of Total irrigation water and total evaporation losses by crops

	Irrigation efficiency*		Duration (day)	Area (ha) Chennai Basin	Net WR (mm)	Gross water irrigation by crop (m3/ha) Tank 45%	Pump 75%	Imp-Tank 60%	Sprinkler 85%	Drip 85%	IMP	SPRINK DRIP
1	Paddy	Samba	135	79390	1,000	22,222	13,333	16,667			**5,556**	
		Navarai	105	29205	1,082	24,044	14,427	18,033			**6,011**	
		Sornavari	105	23070	1,082	24,044	14,427	18,033			**6,011**	
2	Groundnut	12-4	105	37622	302	6,711	4,027	5,033	3,553	3,553	**1,678**	**474**
3	Sugarcane	1-11	300	8546	1,566	34,800	20,880	26,100	18,424	18,424	**8,700**	**2,456**
4	Cumbu	3-6	90	5395	322	7,156	4,293	5,367	3,788	3,788	**1,789**	**505**
5	Vegetables	2-7	135	3545	475	10,556	6,333	7,917	5,588	5,588	**2,639**	**745**
6	Pulses	2-4	65	1279	250	5,556	3,333	4,167	2,941	2,941	**1,389**	**392**
7	Gingelly	1-5	85	1039	250	5,556	3,333	4,167	2,941	2,941	**1,389**	**392**
8	Chillies	2-7	165	1019	630	14,000	8,400	10,500	7,412	7,412	**3,500**	**988**

	Total Evaporation Losses†		Duration (day)	Area (ha) Chennai Basin	Net WR (mm)	Total Evaporation Losses (TEL) by Crop (m3/ha) Tank 60%	Pump 80%	Imp-Tank 70%	Sprinkler 87%	Drip 87%	IMP	SPRINK DRIP
1	Paddy	Samba	135	79390	1,000	13,333	10,667	11,667	-	-	**1,667**	
		Navarai	105	29205	1,082	14,427	11,541	12,623	-	-	**1,803**	
		Sornavari	105	23070	1,082	14,427	11,541	12,623	-	-	**1,803**	
2	Groundnut	12-4	105	37622	302	4,027	3,221	3,523	3,091	3,091	**503**	**130**
3	Sugarcane	1-11	300	8546	1,566	20,880	16,704	18,270	16,028	16,028	**2,610**	**676**
4	Cumbu	3-6	90	5395	322	4,293	3,435	3,757	3,296	3,296	**537**	**139**
5	Vegetables	2-7	135	3545	475	6,333	5,067	5,542	4,862	4,862	**792**	**205**
6	Pulses	2-4	65	1279	250	3,333	2,667	2,917	2,559	2,559	**417**	**108**
7	Gingelly	1-5	85	1039	250	3,333	2,667	2,917	2,559	2,559	**417**	**108**
8	Chillies	2-7	165	1019	630	8,400	6,720	7,350	6,448	6,448	**1,050**	**272**

* Irrigation efficiency used here = Total Evaporation losses ÷ water abstracted from source
† Total Evaporation losses (TEL) = Crop Evapotranspiration plus other evaporative losses from ground and surface water

Attachment FI-3: Estimation of Total irrigation water and total evaporation losses by cropping pattern

Cropping patterns — **Gross water irrigation by cropping pattern (m3/ha/year)**

			Net WR (mm)	Tank	Pump	Imp-Tank	Sprinkler	Drip	**IMP**	**SPRINK**
	Irrigation efficiency			45%	75%	60%	85%	85%		
1	2 Paddy crops		2082	46,267	27,760	34,700			**11,567**	
2	3 Paddy crops		3164	70,311	42,187	52,733			**17,578**	
3	Paddy-groundnut		1302	28,933	17,360	21,700			**7,233**	
4	Vegetables-groundnut		624	13,867	8,320	10,400	7,341	7,341	**3,467**	**979**
5	Sugarcane		1566	34,800	20,880	26,100	18,424	18,424	**8,700**	**2,456**

Cropping patterns — **Total Evaporation Losses by cropping pattern (m3/ha/ha)**

			Tank	Pump	Imp-Tank	Sprinkler	Drip	**IMP**	**SPRINK**
	Total Evaporation Losses		60%	80%	70%	87%	87%		
1	2 Paddy crops		27,760	22,208	24,290	-	-	**3,470**	
2	3 Paddy crops		42,187	33,749	36,913	-	-	**5,273**	
3	Paddy-groundnut		17,360	13,888	15,190	-	-	**2,170**	
4	Vegetables-groundnut		8,320	6,656	7,280	6,387	6,387	**1,040**	**269**
5	Sugarcane		20,880	16,704	18,270	16,028	16,028	**2,610**	**676**

Attachment FI-4: Cost of water for irrigation from well (2 crops/year)

Cost of Well Irrigation System for 2 paddy crops per year

Depth=80', Diameter=7", Submersible pump Discount rate 12%
Farm size (Acres) 14.0 1 well for 8.0 acres
Water pumped for irrigation per year per acre (m3) 11,234
Price for electricity (Rs/kWh): 3.85 m3/kWh= 12

Year	Investment (Rs/-)	Replacement (Rs/-)	Capital cost (Rs/-)	Power (Rs/-)	Total cost (Rs/-)	Power kWh	Total water (m3/year)
1	130,000		130,000	28,835	158,835	7,490	89,875
2			-	28,835	28,835	7,490	89,875
3			-	28,835	28,835	7,490	89,875
4			-	28,835	28,835	7,490	89,875
5			-	28,835	28,835	7,490	89,875
6			-	28,835	28,835	7,490	89,875
7			-	28,835	28,835	7,490	89,875
8			-	28,835	28,835	7,490	89,875
9			-	28,835	28,835	7,490	89,875
10		30,000	30,000	28,835	58,835	7,490	89,875
11			-	28,835	28,835	7,490	89,875
12			-	28,835	28,835	7,490	89,875
13			-	28,835	28,835	7,490	89,875
14			-	28,835	28,835	7,490	89,875
15			-	28,835	28,835	7,490	89,875
16			-	28,835	28,835	7,490	89,875
17			-	28,835	28,835	7,490	89,875
18			-	28,835	28,835	7,490	89,875
19			-	28,835	28,835	7,490	89,875
20		30,000	30,000	28,835	58,835	7,490	89,875
21			-	28,835	28,835	7,490	89,875
22			-	28,835	28,835	7,490	89,875
23			-	28,835	28,835	7,490	89,875
24			-	28,835	28,835	7,490	89,875
25			-	28,835	28,835	7,490	89,875
26			-	28,835	28,835	7,490	89,875
27			-	28,835	28,835	7,490	89,875
28			-	28,835	28,835	7,490	89,875
29			-	28,835	28,835	7,490	89,875
30			-	28,835	28,835	7,490	89,875
NPV			128,841		361,110		723,956
Cost of water without power cost (Rs/m3):							0.178
Cost of water with power cost (Rs/m3):							0.499

Paddy-paddy Farm (8 acres)

Irrigation cost without power cost:		1,000 Rs per crop
Irrigation cost including power cost:		2,802 Rs per crop
Power cost (subsidized by the Government):		0.321Rs/m3
Paddy (Samba)	5,396	1,731 Rs/crop
Paddy (Navarai/Sornavarai)	5,838	1,873 Rs/crop

Attachment FI-5: Cost of water for irrigation from well (3 crops/year)

Cost of Well Irrigation System for 2 paddy + groundnut per year

Depth=80', Diameter=7", Submersible pump — Discounted rate 12%
Farm size (Acre) 14.0 — 1 well for 8.0 acres
Water pumped for irrigation per year per acre (m3) 12,864
Price for electricity (Rs/kWh): 3.85 — m3/kWh= 12

Year	Investment (Rs/-)	Replacement (Rs/-)	Capital cost (Rs/-)	Power (Rs/-)	Total cost (Rs/-)	Power kWh	Total water (m3/year)
1	130,000		130,000	33,017	163,017	8,576	102,911
2			-	33,017	33,017	8,576	102,911
3			-	33,017	33,017	8,576	102,911
4			-	33,017	33,017	8,576	102,911
5			-	33,017	33,017	8,576	102,911
6			-	33,017	33,017	8,576	102,911
7			-	33,017	33,017	8,576	102,911
8			-	33,017	33,017	8,576	102,911
9			-	33,017	33,017	8,576	102,911
10		30,000	30,000	33,017	63,017	8,576	102,911
11			-	33,017	33,017	8,576	102,911
12			-	33,017	33,017	8,576	102,911
13			-	33,017	33,017	8,576	102,911
14			-	33,017	33,017	8,576	102,911
15			-	33,017	33,017	8,576	102,911
16			-	33,017	33,017	8,576	102,911
17			-	33,017	33,017	8,576	102,911
18			-	33,017	33,017	8,576	102,911
19			-	33,017	33,017	8,576	102,911
20		30,000	30,000	33,017	63,017	8,576	102,911
21			-	33,017	33,017	8,576	102,911
22			-	33,017	33,017	8,576	102,911
23			-	33,017	33,017	8,576	102,911
24			-	33,017	33,017	8,576	102,911
25			-	33,017	33,017	8,576	102,911
26			-	33,017	33,017	8,576	102,911
27			-	33,017	33,017	8,576	102,911
28			-	33,017	33,017	8,576	102,911
29			-	33,017	33,017	8,576	102,911
30			-	33,017	33,017	8,576	102,911
	NPV		128,841		394,801		828,968
	Cost of water without power cost (Rs/m3):						0.155
	Cost of water with power cost (Rs/m3):						0.476

Paddy-paddy-groundnut Farm (8 acres)

Irrigation cost without power cost:		666	Rs per crop
Irrigation cost including power cost:		2,042	Rs per crop
Power cost (subsidized by the Government):		0.321	Rs/m3
Paddy (Samba)	5,396	1,731	Rs/crop
Paddy (Navarai/Sornavarai)	5,838	1,873	Rs/crop
Groundnut	1,630	523	Rs/crop

Attachment FI-6: Typical Crop Budgets in A-K Basin

CROP-BUDGETS PER ACRE (For annual crops) Tank irrigation 60% Well irrigation 75%

			WELL IRRIGATION		**m3**			**m3**
			Net WR: 1000mm		**5,396**	Net WR=1082mm		**5,838**
			Paddy (Samba)			Paddy (Navarai)		
		Unit	**Quantity**	**Price**	**Value**	**Quantity**	**Price**	**Value**
I	**Crop Yield**	bag=75kg	**25**	**450**	**11,250**	**22**	**450**	**9,900**
II	**Production cost**				**8,855**			**7,970**
1	Land preparation	Rs			1,500			1,500
2	Seed	kg			500			500
3	Fertilizers				2,805			2,220
	Complex (17-17-17)	bag	3	460	1,380	2	460	920
	DAP	bag		480			480	
	Ure	bag	2	250	500	2	250	500
	Potash	bag	1.5	250	375	1	250	250
	Ammonium chloride	bag	1	250	250	1	250	250
	Gymsum	bag						
	Manuring	ton			300			300
	Others	Rs						
4	Insecticides	Rs			600			500
5	Herbicides	Rs			400			400
6	Total Labour				1,000			1,000
	Land preparation	working-day						
	Transplanting/sowing	working-day			1,000			1,000
	Fertilizing	working-day						
	Weeding	working-day						
	Harvesting	working-day						
	Others	working-day						
	In which Hired Labour	working-day						
7	Capital cost of well & pump	Rs			800			800
8	Harvesting by machine	Rs			1,200			1,000
9	Transporting home	Rs						
10	Packing materials	Rs						
11	Land tax	Rs			50			50
12	Pumping irrigation cost*	m3	5,396	0.321	**1,731**	5,838	0.321	**1,873**
	Financial Net Benefit	**Rs**			**2,395**			**1,930**
	Economic Net Benefit*	**Rs**			**714**			**107**

Note: * economic cost including the cost of power and deducting taxes

Attachment FI-6: Typical Crop Budgets in A-K Basin (Continued)

CROP-BUDGETS PER ACRE (For annual crops) Tank irrigation 60% Well irrigation 75%

			WELL IRRIGATION					
					m3			**m3**
			Net WR: 1082mm		**5,838**	Net WR=302mm		**1,630**
			Paddy (Sornavari)			Groundnut		
		Unit	**Quantity**	**Price**	**Value**	**Quantity**	**Price**	**Value**
I	**Crop Yield**	bag=75kg	**25**	**450**	**11,250**	**20**	**600**	**12,000**
II	**Production cost**				**8,755**			**9,510**
1	Land preparation	Rs			1,500			1,000
2	Seed	kg			500			2,500
3	Fertilizers				2,805			1,870
	Complex (17-17-17)	bag	3	460	1,380	1	460	460
	DAP	bag		480			480	
	Ure	bag	2	250	500	1	250	250
	Potash	bag	1.5	250	375	2	250	500
	Ammonium chloride	bag	1	250	250		250	0
	Gymsum	bag				1	60	60
	Manuring	ton			300			600
	Others	Rs						
4	Insecticides	Rs			500			550
5	Herbicides	Rs			400			400
6	Total Labour				1,000			2,340
	Land preparation	working-day						
	Transplanting/sowing	working-day			1,000			540
	Fertilizing	working-day						
	Weeding	working-day						600
	Harvesting	working-day						1,200
	Others	working-day						
	In which Hired Labour	working-day						
7	Capital cost of well & pump	Rs			800			800
8	Harvesting by machine	Rs			1,200			
9	Transporting home	Rs						
10	Packing materials	Rs						
11	Land tax	Rs			50			50
12	Pumping irrigation cost*	m3	5,838	0.321	**1,873**	1,630	0.321	**523**
	Financial Net Benefit	**Rs**			**2,495**			**2,490**
	Economic Net Benefit*	**Rs**			**672**			**2,017**

Note: * economic cost including the cost of power and deducting taxes

Attachment FI-7: FGD- Domestic Households

Economic Cost of Water From Bored-well (Household)
Information from Chennai News, March, 10 2004

Rs 40 per feet depth	12%
Family size (person):	6
Water required (liter per capita per day)	200
Power standard (Rs/m3)	0.321

Year	Investment (Rs/-)	Replacement (Rs/-)	O&M (Rs/-)	Power (Rs/-)	Total cost (Rs/-)	Total water (KL/year)
1	30,000		100	141	30,241	438
2			100	141	241	438
3			100	141	241	438
4			100	141	241	438
5			100	141	241	438
6			100	141	241	438
7			100	141	241	438
8			100	141	241	438
9			100	141	241	438
10		7,000	100	141	7,241	438
11			100	141	241	438
12			100	141	241	438
13			100	141	241	438
14			100	141	241	438
15			100	141	241	438
16			100	141	241	438
17			100	141	241	438
18			100	141	241	438
19			100	141	241	438
20		7,000	100	141	7,241	438
21			100	141	241	438
22			100	141	241	438
23			100	141	241	438
24			100	141	241	438
25			100	141	241	438
26			100	141	241	438
27			100	141	241	438
28			100	141	241	438
29			100	141	241	438
30			100	141	241	438
	NPV				31,703	3,528
	Cost of water (Rs/m3):					8.99

Attachment FI-8: FGD- Hotel

Economic Cost of Water From Bored-well (Hotel)
Residential Hotel, 49 GN Chetty Road, Chennai

Depth 60m, NOT USED DUE TO POOR QUALITY 12%
Operating time (hrs/day): 16 365days
Normal quantity of water pumped (m3) 80
Power standard (Rs/m3) 0.321

Year	Investment (Rs/-)	Replacement (Rs/-)	O&M (Rs/-)	Power (Rs/-)	Total cost (Rs/-)	Total water (m3/year)
1	130,000		1,000	9,373	140,373	29,200
2			1,000	9,373	10,373	29,200
3			1,000	9,373	10,373	29,200
4			1,000	9,373	10,373	29,200
5			1,000	9,373	10,373	29,200
6			1,000	9,373	10,373	29,200
7			1,000	9,373	10,373	29,200
8			1,000	9,373	10,373	29,200
9			1,000	9,373	10,373	29,200
10		30,000	1,000	9,373	40,373	29,200
11			1,000	9,373	10,373	29,200
12			1,000	9,373	10,373	29,200
13			1,000	9,373	10,373	29,200
14			1,000	9,373	10,373	29,200
15			1,000	9,373	10,373	29,200
16			1,000	9,373	10,373	29,200
17			1,000	9,373	10,373	29,200
18			1,000	9,373	10,373	29,200
19			1,000	9,373	10,373	29,200
20		30,000	1,000	9,373	40,373	29,200
21			1,000	9,373	10,373	29,200
22			1,000	9,373	10,373	29,200
23			1,000	9,373	10,373	29,200
24			1,000	9,373	10,373	29,200
25			1,000	9,373	10,373	29,200
26			1,000	9,373	10,373	29,200
27			1,000	9,373	10,373	29,200
28			1,000	9,373	10,373	29,200
29			1,000	9,373	10,373	29,200
30			1,000	9,373	10,373	29,200
	NPV				212,399	235,211
	Cost of water (Rs/m3):					0.90

Attachment FI-9: FGD- Industry

Economic Cost of Water From Open-well (Industry)
EPS-Industry, Concord Avai Dvt ltd, 3/229 Old Mahalibaripuram Road, Chennai
Depth 7m, Hp=3 D=4.6m 12%
Operating time (hrs/day): 1 300days
Normal quantity of water pumped (m3/day) 6.0
Power standard (Rs/m3) Rs 0.321/m3 with 20 m depth 0.11

Year	Investment (Rs/-)	Replacement (Rs/-)	O&M (Rs/-)	Power (Rs/-)	Total cost (Rs/-)	Total water (m3/year)
1	160,000		2,000	202	162,202	1,800
2			2,000	202	2,202	1,800
3			2,000	202	2,202	1,800
4			2,000	202	2,202	1,800
5			2,000	202	2,202	1,800
6			2,000	202	2,202	1,800
7			2,000	202	2,202	1,800
8			2,000	202	2,202	1,800
9			2,000	202	2,202	1,800
10		10,000	2,000	202	12,202	1,800
11			2,000	202	2,202	1,800
12			2,000	202	2,202	1,800
13			2,000	202	2,202	1,800
14			2,000	202	2,202	1,800
15			2,000	202	2,202	1,800
16			2,000	202	2,202	1,800
17			2,000	202	2,202	1,800
18			2,000	202	2,202	1,800
19			2,000	202	2,202	1,800
20		10,000	2,000	202	12,202	1,800
21			2,000	202	2,202	1,800
22			2,000	202	2,202	1,800
23			2,000	202	2,202	1,800
24			2,000	202	2,202	1,800
25			2,000	202	2,202	1,800
26			2,000	202	2,202	1,800
27			2,000	202	2,202	1,800
28			2,000	202	2,202	1,800
29			2,000	202	2,202	1,800
30			2,000	202	2,202	1,800
	NPV				164,853	14,499
	Cost of water (Rs/m3):					11.37

Attachment FI-10: Surface water from lake

Economic Cost of Water From lake (Metrowater Project)
Chennai water supply augmentation project 1 12%
The proposal is to draw 180 MLD of raw water from Veeranam lake, treat it and supply to Chennai City and conveyance for a length of 230 km, 720 crore
Direct O&M cost standard from Chennai Metrowater 4.3 Rs per m3
Replacement assumed 20% of investment at 10 year-interval

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Total cost (Rs Mil)	Total water (Mm3/year)
1	7,200		283	7,483	66
2			283	283	66
3			283	283	66
4			283	283	66
5			283	283	66
6			283	283	66
7			283	283	66
8			283	283	66
9			283	283	66
10		1,440	283	1,723	66
11			283	283	66
12			283	283	66
13			283	283	66
14			283	283	66
15			283	283	66
16			283	283	66
17			283	283	66
18			283	283	66
19			283	283	66
20		1,440	283	1,723	66
21			283	283	66
22			283	283	66
23			283	283	66
24			283	283	66
25			283	283	66
26			283	283	66
27			283	283	66
28			283	283	66
29			283	283	66
30		1,440	283	1,723	66
	NPV			9,365	529
	Cost of water (Rs/m3):				17.70

Attachment FI-11: Additional Water from Bore-well

Economic Cost of Water From Bored-well (Metrowater Project)
45 bore-wells at Vadakuthu (Depth=250m, 2 MLD each) 12%
with an additional pipeline of 15 km from each well for interconnection.
Water from these wells will be pumped and collected in a sump
Direct O&M cost standard from Chennai Metrowater 4.3 Rs per m3
Replacement assumed 20% of investment at 10 year-interval

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Total cost (Rs Mil)	Total water (Mm3/year)
1	490		141.26	631	33
2			141	141	33
3			141	141	33
4			141	141	33
5			141	141	33
6			141	141	33
7			141	141	33
8			141	141	33
9			141	141	33
10		98	141	239	33
11			141	141	33
12			141	141	33
13			141	141	33
14			141	141	33
15			141	141	33
16			141	141	33
17			141	141	33
18			141	141	33
19			141	141	33
20		98	141	239	33
21			141	141	33
22			141	141	33
23			141	141	33
24			141	141	33
25			141	141	33
26			141	141	33
27			141	141	33
28			141	141	33
29			141	141	33
30		98	141	239	33
	NPV			1,620	265
	Cost of water (Rs/m3):				6.12

Attachment FI-12: Desalination plant

Economic Cost of Water From Desalination Plant (Metrowater Project)
Capital cost of the plant Rs 15,000 million 12%
Anticipated output 300 MLD
Assuming power consumption rate (kWh/m3) 7
Power cost (Rs/kWh): 3.85
Other O&M cost (Rs/m3) 2
Cost of desalinated water below does not include conveyance & distribution cost
Replacement assumed 20% of investment at 10 year-intervals

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Other O&M	Total cost (Rs Mil)	Total water (Mm3/year)
1	7,500		2,951	219	10,670	110
2	7,500		2,951	219	10,670	110
3			2,951	219	3,170	110
4			2,951	219	3,170	110
5			2,951	219	3,170	110
6			2,951	219	3,170	110
7			2,951	219	3,170	110
8			2,951	219	3,170	110
9			2,951	219	3,170	110
10		3,000	2,951	219	6,170	110
11			2,951	219	3,170	110
12			2,951	219	3,170	110
13			2,951	219	3,170	110
14			2,951	219	3,170	110
15			2,951	219	3,170	110
16			2,951	219	3,170	110
17			2,951	219	3,170	110
18			2,951	219	3,170	110
19			2,951	219	3,170	110
20		3,000	2,951	219	6,170	110
21			2,951	219	3,170	110
22			2,951	219	3,170	110
23			2,951	219	3,170	110
24			2,951	219	3,170	110
25			2,951	219	3,170	110
26			2,951	219	3,170	110
27			2,951	219	3,170	110
28			2,951	219	3,170	110
29			2,951	219	3,170	110
30		3,000	2,951	219	6,170	110
	NPV				39,588	882
	Cost of water (Rs/m3):					45

Attachment FI-13: Water from RO plant for Industry

Economic Cost of Water From RO Plant for Industry (Metrowater Project)
Capital cost of the plant Rs 2,000 million 12%
Anticipated output 50 MLD
Assuming power consumption rate (kWh/m3) 5
Power cost (Rs/kWh): 3.85
Other O&M cost as secondary treated (Rs/m3) 2.88
Cost of desalinated water does not include conveyance & distribution cost
Replacement assumed 20% of investment at 10 year-interval

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Other O&M	Total cost (Rs Mil)	Total water (Mm3/year)
1	2,000		351	53	2,404	18
2			351	53	404	18
3			351	53	404	18
4			351	53	404	18
5			351	53	404	18
6			351	53	404	18
7			351	53	404	18
8			351	53	404	18
9			351	53	404	18
10		400	351	53	804	18
11			351	53	404	18
12			351	53	404	18
13			351	53	404	18
14			351	53	404	18
15			351	53	404	18
16			351	53	404	18
17			351	53	404	18
18			351	53	404	18
19			351	53	404	18
20		400	351	53	804	18
21			351	53	404	18
22			351	53	404	18
23			351	53	404	18
24			351	53	404	18
25			351	53	404	18
26			351	53	404	18
27			351	53	404	18
28			351	53	404	18
29			351	53	404	18
30		400	351	53	804	18
	NPV				5,223	147
	Cost of water (Rs/m3):					36

Attachment FI-14: New Water Treatment Plant

Economic Cost of Water Treated (Metrowater Project)
Chembarambakkam water treatment plant (partly French assistance)
Construction of new treatment plant, cost of Rs 200 crore
Production of 530 MLD of treated water
Direct O&M cost standard from existing treatment plant (Rs/m3) 1.59
Replacement assumed 20% of investment at 10 year-interval

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Total cost (Rs Mil)	Total water (Mm3/year)
1	2,000		308	2,308	193
2			308	308	193
3			308	308	193
4			308	308	193
5			308	308	193
6			308	308	193
7			308	308	193
8			308	308	193
9			308	308	193
10		400	308	708	193
11			308	308	193
12			308	308	193
13			308	308	193
14			308	308	193
15			308	308	193
16			308	308	193
17			308	308	193
18			308	308	193
19			308	308	193
20		400	308	708	193
21			308	308	193
22			308	308	193
23			308	308	193
24			308	308	193
25			308	308	193
26			308	308	193
27			308	308	193
28			308	308	193
29			308	308	193
30		400	308	708	193
	NPV			4,447	1,558
	Cost of water (Rs/m3):				2.85

Attachment FI-15: Check-dams at Kosastalayar and Palar rivers

Economic Cost of Water in Checkdam (Metrowater Project)
Chennai water supply augmentation project II: 12%
Construct checkdams across rivers Kosastalayar and Palar
The cost is estimated Rs 110 Crores for anticipated quantity of 40 MLD
Direct O&M cost of the dam is taken as 2% of the capital
Large scale reparation cost of 10% of the capital after each 5 years

Year	Investment (Rs Mil)	Replacement (Rs Mil)	O&M (Rs Mil)	Total cost (Rs Mil)	Total water (Mm3/year)
1	1,100		22	1,122	15
2			22	22	15
3			22	22	15
4			22	22	15
5		110	22	132	15
6			22	22	15
7			22	22	15
8			22	22	15
9			22	22	15
10		110	22	132	15
11			22	22	15
12			22	22	15
13			22	22	15
14			22	22	15
15		110	22	132	15
16			22	22	15
17			22	22	15
18			22	22	15
19			22	22	15
20		110	22	132	15
21			22	22	15
22			22	22	15
23			22	22	15
24			22	22	15
25		110	22	132	15
26			22	22	15
27			22	22	15
28			22	22	15
29			22	22	15
30		110	22	132	15
	NPV			1,299	118
	Cost of water (Rs/m3):				11.04

Attachment FI-16: Rain-water Harvesting

Economic Cost of Water in Rain Harvesting			
Rain-harvesting program in Tamil Nadu			12%
Construction cost (Rs)		48,000	
Expected amount of water kept (m3)	60%	3,800	2280
Direct O&M cost is taken as 2% of the capital		2%	
Life of the system (years)		10	

Year	Investment (Rs)	Replacement (Rs)	O&M (Rs)	Total cost (Rs)	Total water (m3/year)
1	48,000		960	48,960	2,280
2			960	960	2,280
3			960	960	2,280
4			960	960	2,280
5			960	960	2,280
6			960	960	2,280
7			960	960	2,280
8			960	960	2,280
9			960	960	2,280
10			960	960	2,280
	NPV			48,281	12,883
	Cost of water (Rs/m3):				3.75

REPORT ON CASE STUDIES

ANNEX F ECONOMIC DATA AND AGRICULTURE

APPENDIX
FII-1 to FII-16 (Shoubak and Al Jafr, Jordan Case Study)

Attachment FII-1: Crop-budget for Olives per Dunum

		Unit	Unit Price	Qty-1	Qty-5	Qty-10+	Value 1	Value-5	Value-10+
I	**Yield**	**Kg**	**0.25**	**0**	**800**	**2000**	**0**	**200**	**500**
II	**Production cost**						**186**	**153**	**245**
1	**Plants**	**Tree**	**5**	**20**			**100**	**0**	**0**
2	**Fertilizaer**						**3.908**	**16.784**	**38.16**
	DAP	Kg	0.160				0	0	0
	Amonic Sulfate	Kg	0.125	8	20	40	1	2.5	5
	Super Phosphate 3	Kg	0.204	2	6	10	0.408	1.224	2.04
	Potasium Solfate	Kg	1.112		5	10	0	5.56	11.12
	Manure	Ton	25	0.1	0.3	0.5	2.5	7.5	12.5
	Other-Iron	Kg	15			0.5	0	0	7.5
3	**Water**	**CM**	**0.15**	**200**	**200**	**200**	**30**	**30**	**30.0**
4	**Pesticides**	**JD**	**1**	**5**	**15**	**30**	**5**	**15**	**30**
5	**Hired Machine**						**9.4**	**17.5**	**31**
	Land Preperation	Hour	4	1	1	1	4	4	4
	Pesticides	Hour	27	0.2	0.5	1	5.4	13.5	27
6	**Labours**						**20**	**51.5**	**88.6**
	Harvesting	Man/Day	5		1	2	0	5	10
	Pesticides	Man/Day	10	1	3	5	10	30	50
	Cutting	Man/Day	15		0.1	0.24	0	1.5	3.6
	Other	Man/Day	5	2	3	5	10	15	25
7	**Packaging**	**Box**	**0.05**	**0**	**100**	**200**	**0**	**5**	**10**
8	**Drip pipes**	**JD**	**1**	**130**			**17.7**	**17.7**	**17.7**
	Net Benefit (JD/Dunum)						**-186**	**47**	**255**
	Net Benefit ANNUITY Interest rate 6%, 50 years (JD/Dunum)						**149**		
	Net Benefit ANNUITY Interest rate 10%, 50 years (JD/Dunum)						**105**		

Attachment FII-2: Crop-budget for Apples per Dunum

		Unit	Unit Price	Qty-1	Qty-3	Qty-6+	Value 1	Value-3	Value-6+
	Yield	**Kg**	**0.2**	**0**	**800**	**3500**	**0**	**160**	**700**
	Production cost						**366**	**176**	**359**
	Plants	**Tree**	**1.75**	**160**			**280**	**0**	**0**
	Fertilizaer						**3.908**	**24.284**	**75.66**
	DAP	Kg	0.160				0	0	0
	Amonic Sulfate	Kg	0.125	8	20	40	1	2.5	5
	Super Phosphate 3	Kg	0.204	2	6	10	0.408	1.224	2.04
	Potasium Solfate	Kg	1.112		5	10	0	5.56	11.12
	Manure	Ton	25	0.1	0.3	1.7	2.5	7.5	42.5
	Other-Iron	Kg	15		0.5	1	0	7.5	15
	Water	**CM**	**0.15**	**200**	**200**	**200**	**30**	**30**	**30**
	Pesticides	**JD**	**1**	**5**	**20**	**30**	**5**	**20**	**30**
	Hired Machine						**9.4**	**17.5**	**79.6**
	Land Preperation	Hour	4	1	1	1	4	4	4
	Pesticides	Hour	27	0.2	0.5	2.8	5.4	13.5	75.6
	Labours						**20**	**51.5**	**88.6**
	Harvesting	Man/Day	5		1	2	0	5	10
	Pesticides	Man/Day	10	1	3	5	10	30	50
	Cutting	Man/Day	15		0.1	0.24	0	1.5	3.6
	Other	Man/Day	5	2	3	5	10	15	25
	Packaging	**Box**	**0.1**	**0**	**150**	**375**	**0**	**15**	**37.5**
	Drip pipes	**JD**	**1**	**130**			**17.7**	**17.7**	**17.7**
	Net Benefit (JD/Dunum)						**-366**	**-16**	**341**
	Net Benefit ANNUITY Interest rate 6%, 20 years (JD/Dunum)						**191**		
	Net Benefit ANNUITY Interest rate 10%, 20 years (JD/Dunum)						**155**		

Attachment FII-3: Crop-budget for Apricot & Stone Fruits per Dunum

		Unit	Unit Price	Qty-1	Qty-3	Qty-6+	Value 1	Value-3	Value-6+
	Yield	**Kg**	**0.3**	**0**	**800**	**2000**	**0**	**240**	**600**
	Production cost						**286**	**176**	**298**
	Plants	**Tree**	**4**	**50**			**200**	**0**	**0**
	Fertilizaer						**3.908**	**24.284**	**50.66**
	DAP	Kg	0.160				0	0	0
	Amonic Sulfate	Kg	0.125	8	20	40	1	2.5	5
	Super Phosphate 3	Kg	0.204	2	6	10	0.408	1.224	2.04
	Potasium Solfate	Kg	1.112		5	10	0	5.56	11.12
	Manure	Ton	25	0.1	0.3	1	2.5	7.5	25
	Other-Iron	Kg	15		0.5	0.5	0	7.5	7.5
	Water	**CM**	**0.15**	**200**	**200**	**200**	**30**	**30**	**30**
	Pesticides	**JD**	**1**	**5**	**20**	**30**	**5**	**20**	**30**
	Hired Machine						**9.4**	**17.5**	**31**
	Land Preperation	Hour	4	1	1	1	4	4	4
	Pesticides	Hour	27	0.2	0.5	1	5.4	13.5	27
	Labours						**20**	**51.5**	**88.6**
	Harvesting	Man/Day	5		1	2	0	5	10
	Pesticides	Man/Day	10	1	3	5	10	30	50
	Cutting	Man/Day	15		0.1	0.24	0	1.5	3.6
	Other	Man/Day	5	2	3	5	10	15	25
	Packaging	**Box**	**0.1**	**0**	**150**	**500**	**0**	**15**	**50**
	Drip pipes	**JD**	**1**	**130**			**17.7**	**17.7**	**17.7**
	Net Benefit (JD/Dunum)						**-286**	**64**	**302**
	Net Benefit ANNUITY Interest rate 6%, 20 years (JD/Dunum)						**188**		
	Net Benefit ANNUITY Interest rate 10%, 20 years (JD/Dunum)						**160**		

Attachment FII-4: Crop-budget for Tomatoes per Dunum

			Planted Out-house			Planted in-house		
		Unit	Unit Price	Quantity	Value	Unit Price	Quantity	Value
I	**Yield**	**Kg**	**0.055**	**12000**	**660**	**0.07**	**25000**	**1750**
II	**Production cost**				**548**			**1514**
1	**Plants**	**Tree**	**0.012**	**2500**	**30**	**0.025**	**2500**	**62.5**
2	**Fertilizaer**				**101.2**			**129.74**
	DAP	Kg	0.160		0	0.160		0
	Amonic Sulfate	Kg	0.125		0	0.125		0
	Super Phosphate 3	Kg	0.204	50	10.2	0.204	60	12.24
	Urea	Kg	0.150	40	6	0.150	50	7.5
	Manure	Ton	25	1	25	25	2	50
	Other	Kg	1.2	50	60	1.2	50	60
3	**Water**	**CM**	**0.15**	**500**	**75**	**0.15**	**500**	**75**
4	**Pesticides**	**JD**	**1**	**60**	**60**	**1**	**110**	**110**
5	**Soil Sterilization**	**Lb**				**1.65**	**100**	**165**
5	**Black Mulch**	**Kg**	**1**	**35**	**35**	**1**	**43**	**43**
6	**Hired Machine**				**8.2**			**21.6**
	Land Preperation	Hour	3.5	1.2	4.2	3.5	1.6	5.6
	Wedding	Hour	2	2	4	2	8	16
7	**Labours**			**20**	**98**			**461**
	Cultivating	Man/Day	5	2	10	5	4	20
	Harvesting	Man/Day	5	9	45	5	50	250
	Planting	Man/Day	5	1.6	8	5	3.2	16
	Weeding	Man/Day	5	7	35	5	35	175
8	**Packaging**	**Box**	**0.075**	**1500**	**112.5**	**0.075**	**4375**	**328.1**
9	**Drip pipes**	**JD**	**1**	**130**	**17.7**	**1**	**130**	**17.7**
10	**Housing/cloths**	**JD**	**1**	**10**	**10**	**1**	**100**	**100**
	Net Benefit (JD/Dunum)				**112**			**236**

Attachment FII-5: Crop-budget for Watermelons and Dry Onion per Dunum

			Water melons			Dry Onion		
		Unit	Unit Price	Quantity	Value	Unit Price	Quantity	Value
I	**Yield**	**Kg**	**0.066**	**10000**	**660**	**0.14**	**4000**	**560**
II	**Production cost**				**377**			**449**
1	**Plants/bulbs**	**plants**	**0.034**	**2000**	**68**	**1.26**	**60**	**75.6**
2	**Fertilizaer**				**53.6**			**54.4**
	DAP	Kg	0.160		0	0.16		0
	Amonic Sulfate	Kg	0.125		0	0.125		0
	Super Phosphate 3	Kg	0.204	30	6.1	0.15	50	7.5
	Urea	Kg	0.150	30	4.5	0.15	50	7.5
	Manure	Ton	25	1	25	25	1	25
	Other	Kg	1.2	15	18	1.2	12	14.4
3	**Water**	**CM**	**0.15**	**500**	**75**	**0.15**	**500**	**75**
4	**Pesticides**	**JD**	**1**	**50**	**50**	**1**	**25**	**25**
5	**Soil Sterilization**	**Lb**						
5	**Black Mulch**	**Kg**	**1**	**35**	**35**	**1**		**0**
6	**Hired Machine**				**8.6**			**6.8**
	Land Preperation	Hour	3.5	1.2	4.2	3.5	1.2	4.2
	Wedding	Hour	2	2.2	4.4	2	1.3	2.6
7	**Labours**				**59**			**70**
	Cultivating	Man/Day	5	1.6	8	5	2	10
	Harvesting	Man/Day	5	6	30	5	4	20
	Planting	Man/Day	5	1.2	6	5	3	15
	Weeding	Man/Day	5	3	15	5	5	25
8	**Packaging**	**Box**			**0**	**0.5**	**250**	**125**
9	**Drip pipes**	**JD**	**1**	**130**	**17.7**	**1**	**130.0**	**17.7**
10	**Housing/cloths**	**JD**	**1**	**10**	**10**	**1**		
	Net Benefit (JD/Dunum)				**283**			**111**

Attachment FII-6: Crop-budget for Wheat & Barley per Dunum

			Irrigated Wheat			Irrigated Barley		
		Unit	Unit Price	Quantity	Value	Unit Price	Quantity	Value
I	**Yield**	**Kg**	**0.2**	**300**	**60**	**0.12**	**500**	**60**
II	**Production cost**				**51**			**53**
1	**Seeds**	**Kg**	**0.2**	**12**	**2.4**	**0.17**	**13**	**2.21**
2	**Fertilizers**				**12.4**			**12.4**
	DAP	Kg	0.160		0	0.160		0
	Amonic Sulfate	Kg	0.125	50	6.25	0.125	50	6.25
	Super Phosphate 3	Kg	0.204	30	6.12	0.204	30	6.12
	Urea	Kg	0.150		0	0.150		0
	Manure	Ton	25		0	25		0
	Other	Kg	1.2		0	1.2		0
3	**Water**	**CM**	**0.04**	**350**	**14**	**0.04**	**350**	**14**
4	**Pesticides**	**JD**	**1**	**7.5**	**7.5**	**1**	**7.5**	**7.5**
5	**Hired Machine**				**5.4**			**5.4**
	Agri. Seed	Hour	10	0.1	1	10	0.1	1
	Land Preperation	Hour	5	0.5	2.5	5	0.5	2.5
	Pesticides	Hour	27	0.04	1.08	27	0.04	1.08
	Fertilizing	Hour	10	0.08	0.8	10	0.08	0.8
6	**Labours**		**7**	**1**	**7**	**7**	**1**	**7**
7	**Packaging**	**bags**	**0.4**	**6**	**2.4**	**0.4**	**12**	**4.8**
8	**Irrigation system**	**JD**	**1**		**0.0**	**1**		**0.0**
	Net Benefit (JD/Dunum)				**9**			**7**

Attachment FII-7: Crop-budget for Clovers/Folder crops per Dunum

		Unit	Unit Price	Qty-1	Qty-2	Qty-3-7	Value-1	Value-2	Value-3-7
I	**Yield**	**Box (20kg)**	**1.5**	**20**	**150**	**200**	**30**	**225**	**300**
II	**Production cost**						**99**	**119**	**134**
1	**Seeds**	**Kg**	**24**	**1**	**0**	**0**	**24**	**0**	**0**
2	**Fertilizers**						**12.4**	**12.4**	**12.4**
	DAP	Kg	0.160				0	0	0
	Amonic Sulfate	Kg	0.125	50	50	50	6.25	6.25	6.25
	Super Phosphate 3	Kg	0.204	30	30	30	6.12	6.12	6.12
	Urea	Kg	0.150				0	0	0
	Manure	Ton	25				0	0	0
	Other	Kg	1.2				0	0	0
3	**Water**	**CM**	**0.04**	**600**	**800**	**800**	**24**	**32**	**32**
4	**Pesticides**	**JD**	**1**	**7.5**	**7.5**	**7.5**	**7.5**	**7.5**	**7.5**
5	**Hired Machine**						**11.4**	**46.9**	**61.9**
	Agri. Seed	Hour	10	0.1			1	0	0
	Land Preperation	Hour	5	0.5			2.5	0	0
	Pesticides	Hour	27	0.04	0.04	0.04	1.08	1.08	1.08
	Fertilizing	Hour	10	0.08	0.08	0.08	0.8	0.8	0.8
	Harvesting	per box	0.3	20	150	200	6	45	60
6	**Labours**		**5**	**4**	**4**	**4**	**20**	**20**	**20**
7	**Irrigation system**	**JD**	**1**				**0**	**0**	**0**
	Net Benefit (JD/Dunum)						**-69**	**106**	**166**
	Net Benefit ANNUITY Interest rate 6%, 7 years (JD/Dunum)						**117**		
	Net Benefit ANNUITY Interest rate 10%, 7 years (JD/Dunum)						**112**		

Attachment FII-8: Unit cost of water for irrigation from well

Average Cost of Water For Irrigation from Well in Al Jafr Sub-district

From FGDs with 6 agricultural HHs, average figures are as below:

Depth=54m, Diameter=7", Submersible pump Discounted rate 6% 10%

Irrigated area (Dunum): 214 Average pump capacity (M3/hr): 64

Pumping time 10 hrs per day in 8 months 2400

Fuel 16,800 l/y @0.15JD/l = 2,520 JD/y + Management 840 JD/y/well

Year	Investment (JD)	Replacemen (JD)	O&M cost (JD)	Licence (JD)	Total cost (JD)	Total water (m3/year)
1	25,500		3,360	1,300	30,160	153,600
2			3,360		3,360	153,600
3			3,360		3,360	153,600
4			3,360		3,360	153,600
5			3,360		3,360	153,600
6			3,360		3,360	153,600
7			3,360		3,360	153,600
8			3,360		3,360	153,600
9			3,360		3,360	153,600
10		5,100	3,360		8,460	153,600
11			3,360		3,360	153,600
12			3,360		3,360	153,600
13			3,360		3,360	153,600
14			3,360		3,360	153,600
15			3,360		3,360	153,600
16			3,360		3,360	153,600
17			3,360		3,360	153,600
18			3,360		3,360	153,600
19			3,360		3,360	153,600
20		5,100	3,360		8,460	153,600
21			3,360		3,360	153,600
22			3,360		3,360	153,600
23			3,360		3,360	153,600
24			3,360		3,360	153,600
25			3,360		3,360	153,600
26			3,360		3,360	153,600
27			3,360		3,360	153,600
28			3,360		3,360	153,600
29			3,360		3,360	153,600
30			3,360		3,360	153,600
	NPV (6%)		46,250		75,971	2,114,278
	NPV (10%)		31,674		58,762	1,447,974
	Cost of water (JD/m3):			6%		0.036
	Cost of water (JD/m3):			10%		0.041

Attachment FII-8: Unit cost of water for irrigation from well (continued)

Cost of Water For Irrigation from Well in Al Jarbakabeera Village, Athruh Sub-district

From FGDs with 6 agricultural HHs, average figures are as below:

Depth=150m, Diameter=7", Submersible pump		Discounted rate	6%	10%
Irrigated area (Dunum):		Average pump capacity (M3/hr):	70	
Pumping time	10	hrs per day in 8 months	2400	
1 kWh could pump (m3):	1.84	Electricity rate (JD/kWh	0.041	

Year	Investment (JD)	Replacemen (JD)	O&M cost (JD)	Licence (JD)	Total cost (JD)	Total water (m3/year)
1	33,100		4,593	1,300	38,993	168,000
2			4,593		4,593	168,000
3			4,593		4,593	168,000
4			4,593		4,593	168,000
5			4,593		4,593	168,000
6			4,593		4,593	168,000
7			4,593		4,593	168,000
8			4,593		4,593	168,000
9			4,593		4,593	168,000
10		6,620	4,593		11,213	168,000
11			4,593		4,593	168,000
12			4,593		4,593	168,000
13			4,593		4,593	168,000
14			4,593		4,593	168,000
15			4,593		4,593	168,000
16			4,593		4,593	168,000
17			4,593		4,593	168,000
18			4,593		4,593	168,000
19			4,593		4,593	168,000
20		6,620	4,593		11,213	168,000
21			4,593		4,593	168,000
22			4,593		4,593	168,000
23			4,593		4,593	168,000
24			4,593		4,593	168,000
25			4,593		4,593	168,000
26			4,593		4,593	168,000
27			4,593		4,593	168,000
28			4,593		4,593	168,000
29			4,593		4,593	168,000
30			4,593		4,593	168,000
	NPV (6%)		63,219		101,433	2,312,492
	NPV (10%)		43,296		78,105	1,583,722
	Cost of water (JD/m3):			6%		0.044
	Cost of water (JD/m3):			10%		0.049

Attachment FII-8: Unit cost of water for irrigation from well (continued)

Economic Cost of Water For Irrigation in Sabeeh Al Masry Farm
Faysalieh Village, Shoubak District, Ma'an Governorate
Depth=360m, Diameter=10", Depth to static water=178m, Submersible pump.
Discharge (m3/hr) 57.0 Discounted rate 6% 10%
Water pumped in 24 hr for 8 months per year (m3) 10,944
Price for electricity (JD/kWh): 0.041 m3/kWh= 1.34

Year	Investment (JD)	Replacement (JD)	Capital cost (JD)	Power (JD)	Total cost (JD)	Power kWh	Total water (m3/year)
1	47,000		47,000	335	47,335	8,167	10,944
2			-	335	335	8,167	10,944
3			-	335	335	8,167	10,944
4			-	335	335	8,167	10,944
5			-	335	335	8,167	10,944
6			-	335	335	8,167	10,944
7			-	335	335	8,167	10,944
8			-	335	335	8,167	10,944
9			-	335	335	8,167	10,944
10		9,400	9,400	335	9,735	8,167	10,944
11			-	335	335	8,167	10,944
12			-	335	335	8,167	10,944
13			-	335	335	8,167	10,944
14			-	335	335	8,167	10,944
15			-	335	335	8,167	10,944
16			-	335	335	8,167	10,944
17			-	335	335	8,167	10,944
18			-	335	335	8,167	10,944
19			-	335	335	8,167	10,944
20		9,400	9,400	335	9,735	8,167	10,944
21			-	335	335	8,167	10,944
22			-	335	335	8,167	10,944
23			-	335	335	8,167	10,944
24			-	335	335	8,167	10,944
25			-	335	335	8,167	10,944
26			-	335	335	8,167	10,944
27			-	335	335	8,167	10,944
28			-	335	335	8,167	10,944
29			-	335	335	8,167	10,944
30			-	335	335	8,167	10,944
	NPV (6%)		52,519		57,129		150,642
	NPV (10%)		47,749		50,905		103,168
	Cost of water 6% (JD/m3)						0.379
	Cost of water 10% (JD/m3)						0.493

Attachment FII-8: Unit cost of water for irrigation from well (continued)

Economic Cost of Water For Irrigation in Abdeh Khalek Farm
Faysalieh Village, Shoubak District, Ma'an Governorate
Depth=350m, Diameter=12", Depth to static water=290m, Submersible pump.
Discharge (m3/hr) 50.0 Discounted rate 6% 10%
Water pumped in 24 hr for 8 months per year (m3) 9,600
Price for electricity (JD/kWh): 0.041 m3/kWh= 0.82

Year	Investment (JD)	Replacement (JD)	Capital cost (JD)	Power (JD)	Total cost (JD)	Power kWh	Total water (m3/year)
1	47,000		47,000	480	47,480	11,707	9,600
2			-	480	480	11,707	9,600
3			-	480	480	11,707	9,600
4			-	480	480	11,707	9,600
5			-	480	480	11,707	9,600
6			-	480	480	11,707	9,600
7			-	480	480	11,707	9,600
8			-	480	480	11,707	9,600
9			-	480	480	11,707	9,600
10		9,400	9,400	480	9,880	11,707	9,600
11			-	480	480	11,707	9,600
12			-	480	480	11,707	9,600
13			-	480	480	11,707	9,600
14			-	480	480	11,707	9,600
15			-	480	480	11,707	9,600
16			-	480	480	11,707	9,600
17			-	480	480	11,707	9,600
18			-	480	480	11,707	9,600
19			-	480	480	11,707	9,600
20		9,400	9,400	480	9,880	11,707	9,600
21			-	480	480	11,707	9,600
22			-	480	480	11,707	9,600
23			-	480	480	11,707	9,600
24			-	480	480	11,707	9,600
25			-	480	480	11,707	9,600
26			-	480	480	11,707	9,600
27			-	480	480	11,707	9,600
28			-	480	480	11,707	9,600
29			-	480	480	11,707	9,600
30			-	480	480	11,707	9,600
	NPV (6%)		52,519		59,127		132,142
	NPV (10%)		47,749		52,274		90,498
	Cost of water 6% (JD/m3)						0.447
	Cost of water 10% (JD/m3)						0.578

Attachment FII-9: Unit cost of water for domestic from well-field

Economic Cost of Water From East Ma'an Wellfield
JICA Jan 1990, Water Resources Study of the Jafr Basin
Depth=250m, Diameter=17" 1/2, Design head=125-150m, 20 Submersible pumps.

Discharge (70-90m3/hr)	80	Discounted rate	6% / 10%
Total water (MCM/year):	10	Operating time (hrs):	18
Price for electricity (JD/kWh):	0.041	1 kWh can pump ? M3	1.59

Year	Investment (JD)	Replacement (JD)	Electric facilities (JD)	Management (JD)	Power (JD)	Total cost (JD)	Power kWh	Total water (m3/year)
1	1,250,000		2,500,000	100,000	257,749	4,107,749	6,286,562	10,000,000
2				100,000	257,749	357,749	6,286,562	10,000,000
3				100,000	257,749	357,749	6,286,562	10,000,000
4				100,000	257,749	357,749	6,286,562	10,000,000
5				100,000	257,749	357,749	6,286,562	10,000,000
6				100,000	257,749	357,749	6,286,562	10,000,000
7				100,000	257,749	357,749	6,286,562	10,000,000
8				100,000	257,749	357,749	6,286,562	10,000,000
9				100,000	257,749	357,749	6,286,562	10,000,000
10		250,000		100,000	257,749	607,749	6,286,562	10,000,000
11				100,000	257,749	357,749	6,286,562	10,000,000
12				100,000	257,749	357,749	6,286,562	10,000,000
13				100,000	257,749	357,749	6,286,562	10,000,000
14				100,000	257,749	357,749	6,286,562	10,000,000
15				100,000	257,749	357,749	6,286,562	10,000,000
16				100,000	257,749	357,749	6,286,562	10,000,000
17				100,000	257,749	357,749	6,286,562	10,000,000
18				100,000	257,749	357,749	6,286,562	10,000,000
19				100,000	257,749	357,749	6,286,562	10,000,000
20		250,000		100,000	257,749	607,749	6,286,562	10,000,000
21				100,000	257,749	357,749	6,286,562	10,000,000
22				100,000	257,749	357,749	6,286,562	10,000,000
23				100,000	257,749	357,749	6,286,562	10,000,000
24				100,000	257,749	357,749	6,286,562	10,000,000
25				100,000	257,749	357,749	6,286,562	10,000,000
26				100,000	257,749	357,749	6,286,562	10,000,000
27				100,000	257,749	357,749	6,286,562	10,000,000
28				100,000	257,749	357,749	6,286,562	10,000,000
29				100,000	257,749	357,749	6,286,562	10,000,000
30				100,000	257,749	357,749	6,286,562	10,000,000
	NPV (6%)					8,679,641		137,648,312
	NPV (10%)					6,915,107		94,269,145
	Cost of water 6% (JD/m3)							0.063
	Cost of water 10% (JD/m3)							0.073

Attachment FII-9: Unit cost of water for domestic from well-field (Continued)

Economic Cost of Water From South Hasa Wellfield
JICA Jan 1990, Water Resources Study of the Jafr Basin
Depth=350m, Diameter=17" 1/2, Design head=150-175m, 20 Submersible pumps.

Discharge (70-90m3/hr)	80	Discounted rate	6%	10%	
Total water (MCM/year):		10	Operating time (hrs):		18
Price for electricity (JD/kWh):		0.041	1 kWh can pump ? M3		1.36

Year	Investment (JD)	Replacement (JD)	Electric facilities (JD)	Management (JD)	Power (JD)	Total cost (JD)	Power kWh	Total water (m3/year)
1	1,750,000		3,500,000	100,000	300,707	5,650,707	7,334,323	10,000,000
2				100,000	300,707	400,707	7,334,323	10,000,000
3				100,000	300,707	400,707	7,334,323	10,000,000
4				100,000	300,707	400,707	7,334,323	10,000,000
5				100,000	300,707	400,707	7,334,323	10,000,000
6				100,000	300,707	400,707	7,334,323	10,000,000
7				100,000	300,707	400,707	7,334,323	10,000,000
8				100,000	300,707	400,707	7,334,323	10,000,000
9				100,000	300,707	400,707	7,334,323	10,000,000
10		350,000		100,000	300,707	750,707	7,334,323	10,000,000
11				100,000	300,707	400,707	7,334,323	10,000,000
12				100,000	300,707	400,707	7,334,323	10,000,000
13				100,000	300,707	400,707	7,334,323	10,000,000
14				100,000	300,707	400,707	7,334,323	10,000,000
15				100,000	300,707	400,707	7,334,323	10,000,000
16				100,000	300,707	400,707	7,334,323	10,000,000
17				100,000	300,707	400,707	7,334,323	10,000,000
18				100,000	300,707	400,707	7,334,323	10,000,000
19				100,000	300,707	400,707	7,334,323	10,000,000
20		350,000		100,000	300,707	750,707	7,334,323	10,000,000
21				100,000	300,707	400,707	7,334,323	10,000,000
22				100,000	300,707	400,707	7,334,323	10,000,000
23				100,000	300,707	400,707	7,334,323	10,000,000
24				100,000	300,707	400,707	7,334,323	10,000,000
25				100,000	300,707	400,707	7,334,323	10,000,000
26				100,000	300,707	400,707	7,334,323	10,000,000
27				100,000	300,707	400,707	7,334,323	10,000,000
28				100,000	300,707	400,707	7,334,323	10,000,000
29				100,000	300,707	400,707	7,334,323	10,000,000
30				100,000	300,707	400,707	7,334,323	10,000,000
	NPV (6%)					10,773,067		137,648,312
	NPV (10%)					8,737,126		94,269,145
	Cost of water 6% (JD/m3)							0.078
	Cost of water 10% (JD/m3)							0.093

Attachment FII-10: Unit cost of water from Recharge Dams

Economic Cost of Water From Recharge Dams
JICA Jan 1990, Water Resources Study of the Jafr Basin
6 recharge dams, effective storage: 23.8 MCM, 18.774 Million JD
Total water (MCM/year): 23.8 Discounted rate 6% 10%

Year	Investment (JD)	Replacemer (JD)	O&M	Total cost (JD)	Total water (m3/year)
1	18,774,000		187,740	18,961,740	23,800,000
2			187,740	187,740	23,800,000
3			187,740	187,740	23,800,000
4			187,740	187,740	23,800,000
5			187,740	187,740	23,800,000
6			187,740	187,740	23,800,000
7			187,740	187,740	23,800,000
8			187,740	187,740	23,800,000
9			187,740	187,740	23,800,000
10			187,740	187,740	23,800,000
11			187,740	187,740	23,800,000
12			187,740	187,740	23,800,000
13			187,740	187,740	23,800,000
14			187,740	187,740	23,800,000
15			187,740	187,740	23,800,000
16			187,740	187,740	23,800,000
17			187,740	187,740	23,800,000
18			187,740	187,740	23,800,000
19			187,740	187,740	23,800,000
20		-	187,740	187,740	23,800,000
21			187,740	187,740	23,800,000
22			187,740	187,740	23,800,000
23			187,740	187,740	23,800,000
24			187,740	187,740	23,800,000
25			187,740	187,740	23,800,000
26			187,740	187,740	23,800,000
27			187,740	187,740	23,800,000
28			187,740	187,740	23,800,000
29			187,740	187,740	23,800,000
30			187,740	187,740	23,800,000
	NPV (6%)			20,295,530	327,602,981
	NPV (10%)			18,837,082	224,360,564
	Cost of water 6% (JD/m3)				0.062
	Cost of water 10% (JD/m3)				0.084

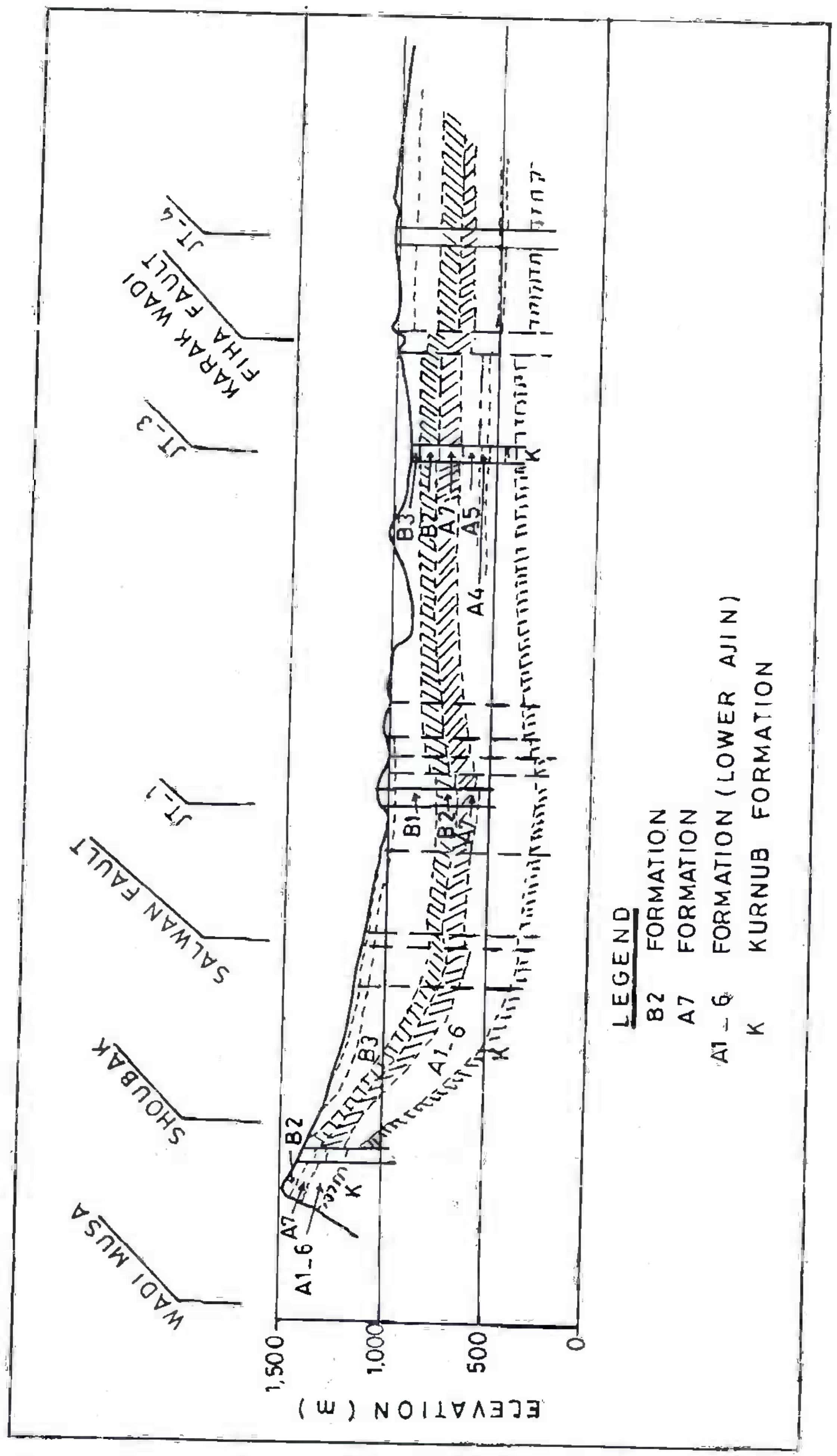

WADI MUSA
SHOUBAK
SALWAN FAULT
JT-1
JT-3
KARAK WADI FIHA FAULT
JT-4
ELEVATION (m)
1,500
1,000
500
0
B2
A7
A1_6
K
B3
B1
A5
A4
LEGEND
B2 FORMATION
A7 FORMATION
A1_6 FORMATION (LOWER AJLUN)
K KURNUB FORMATION

FIGURE 1

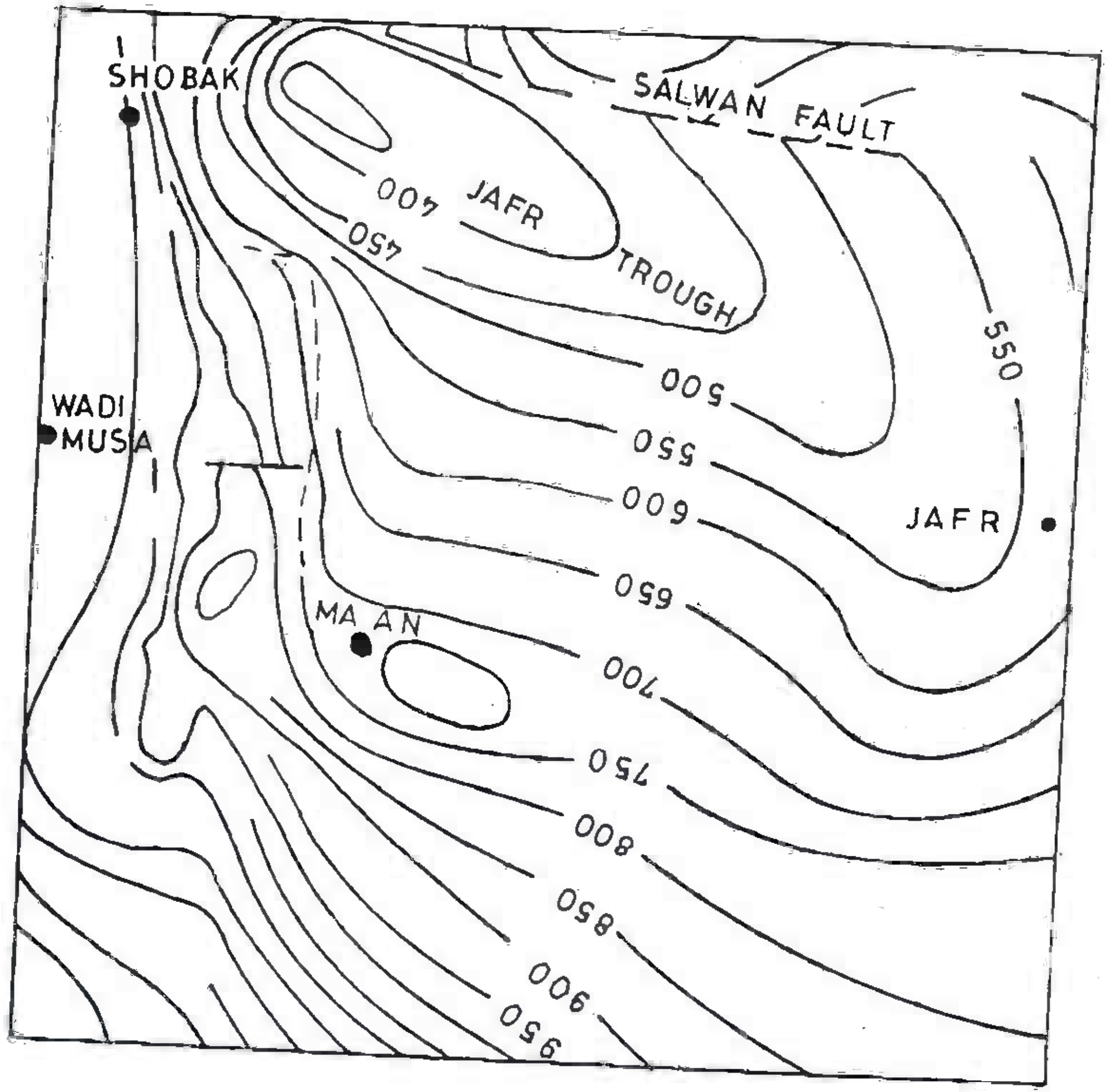

SHOBAK
SALWAN FAULT
JAFR
TROUGH
400
450
500
550
600
650
700
750
800
850
900
950
550
WADI
MUSA
JAFR
MA AN

FIGURE 2

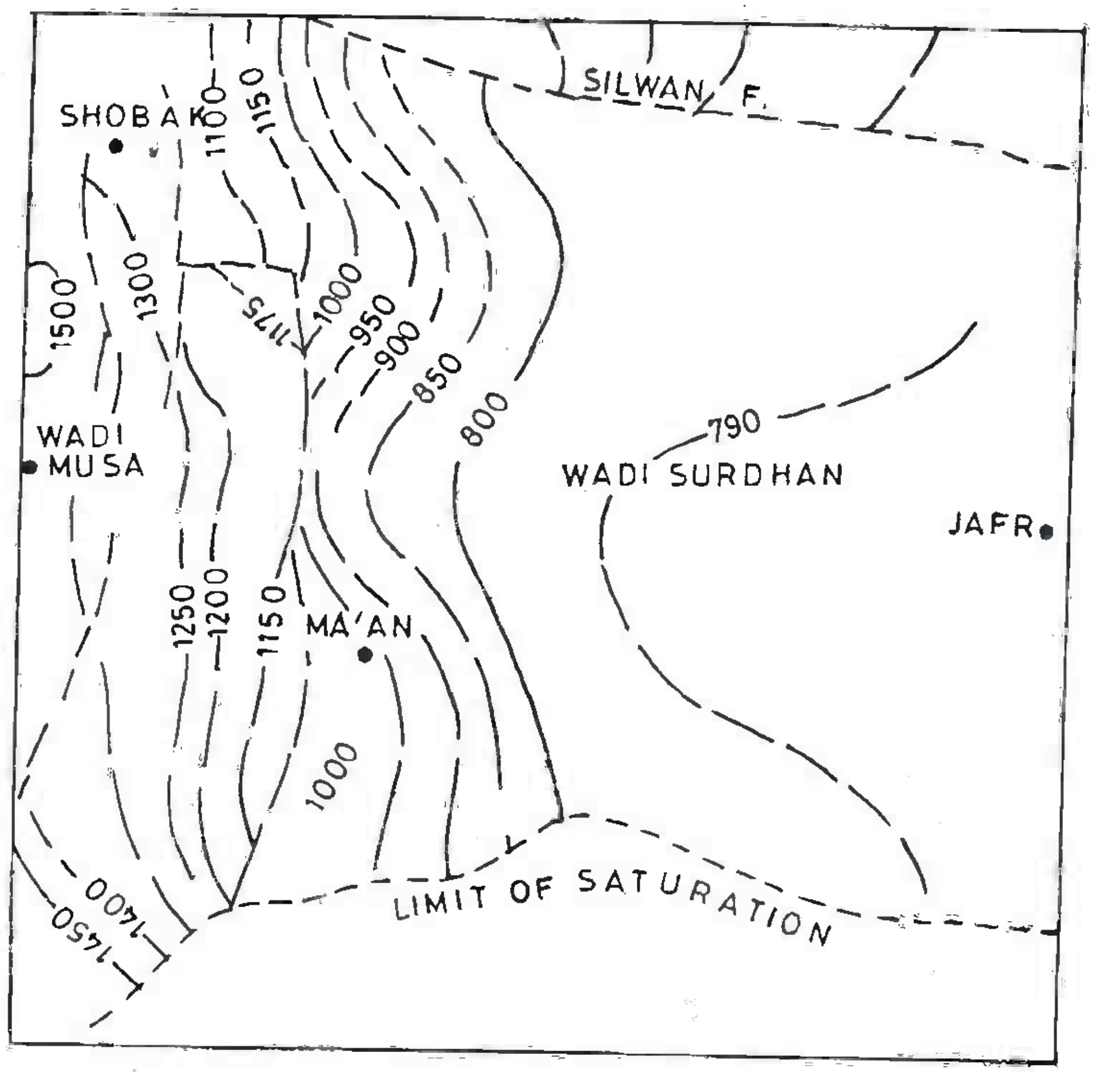
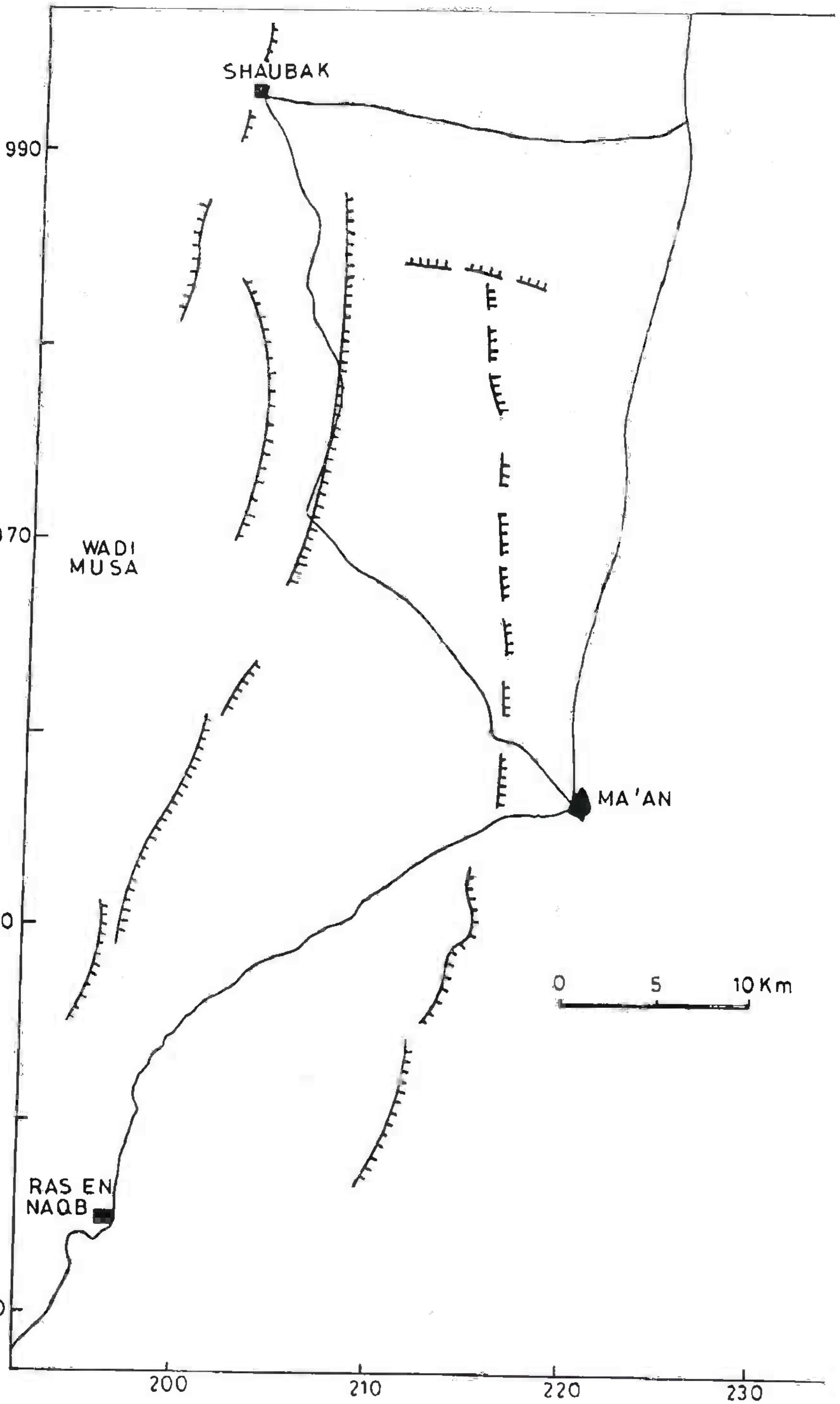

SILWAN F.
SHOBAK
1100
1150
1500
1300
1175
1000
950
900
850
800
790
WADI SURDHAN
JAFR
WADI
MUSA
1250
1200
1150
MA'AN
1000
1400
1450
LIMIT OF SATURATION

FIGURE 3



SHAUBAK
990
970
WADI MUSA
MA'AN
950
0
5
10 Km
RAS EN NAQB
930
200
210
220
230

FIGURE 4

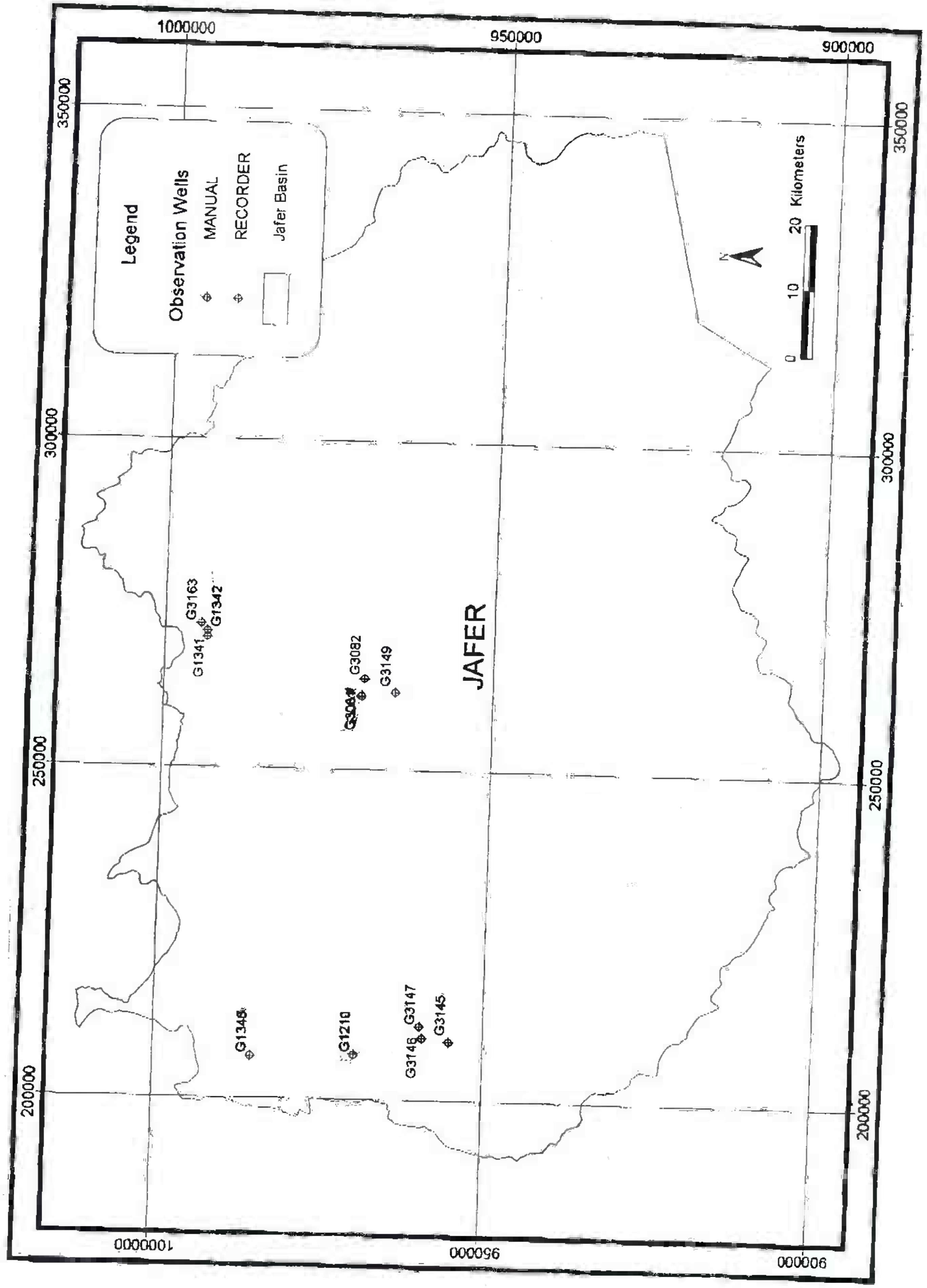

Legend
Observation Wells
MANUAL
RECORDER
Jafer Basin
JAFER
0 10 20 Kilometers
N
1000000
950000
900000
350000
300000
250000
200000
G3163
G1342
G1341
G3082
G3149
G1348
G1210
G3147
G3145
G3146

FIGURE 5

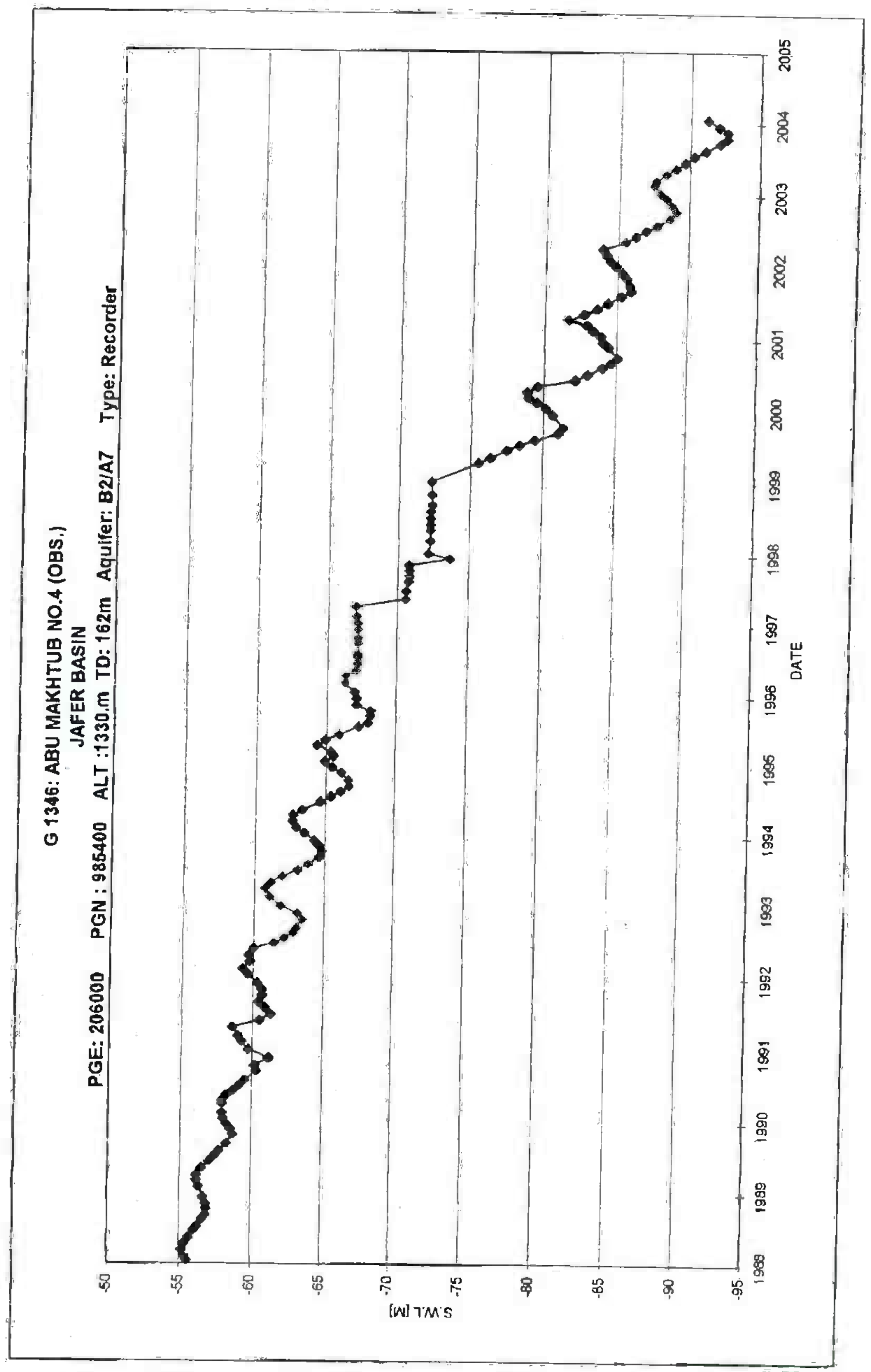

G 1346: ABU MAKHTUB NO.4 (OBS.)
JAFER BASIN
PGE: 206000 PGN : 985400 ALT :1330.m TD: 162m Aquifer: B2/A7 Type: Recorder
S.W.L.[M]
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
DATE

FIGURE 6

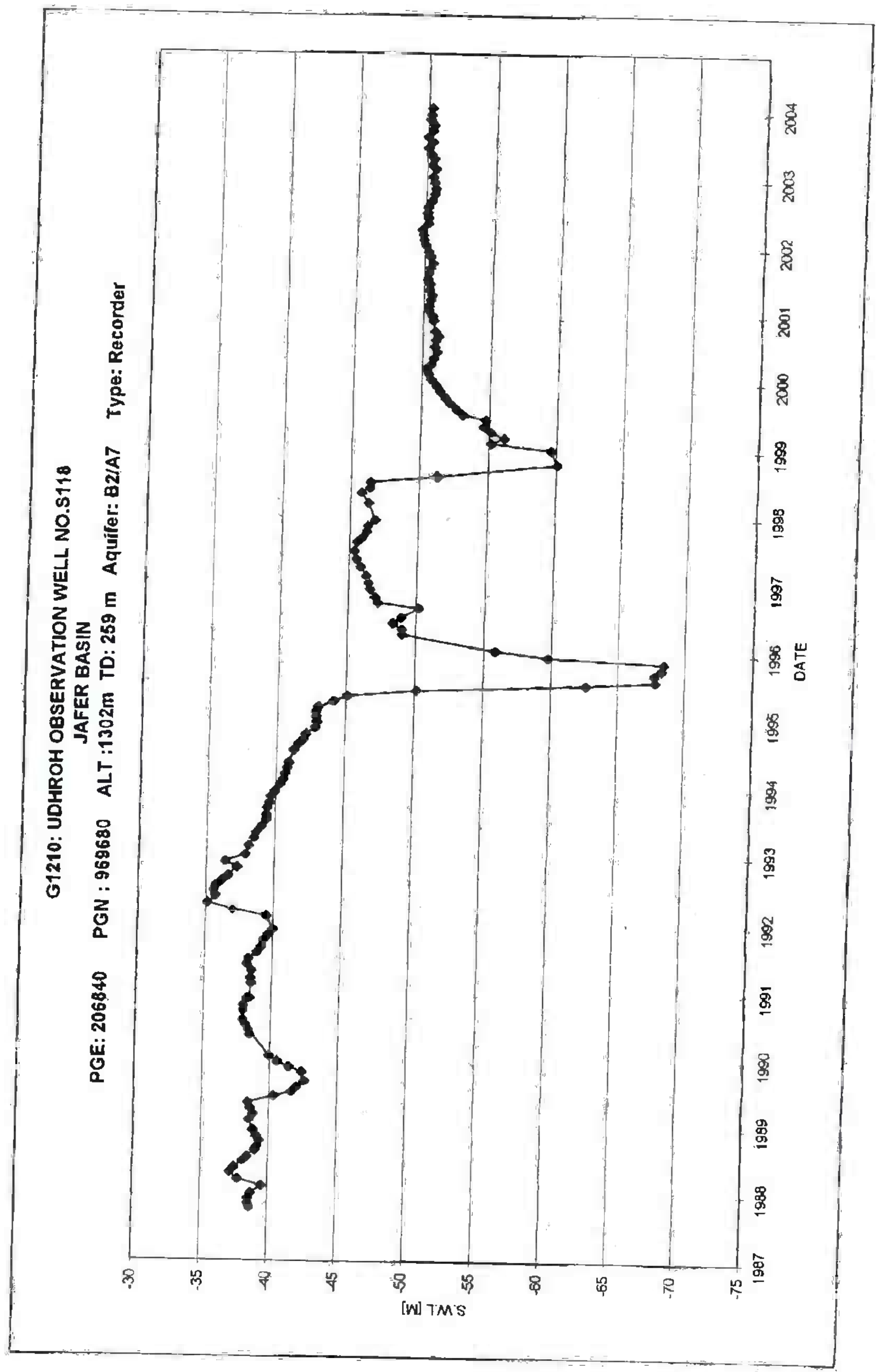

G1210: UDHROH OBSERVATION WELL NO.S118
JAFER BASIN
PGE: 206840 PGN : 969680 ALT :1302m TD: 259 m Aquifer: B2/A7 Type: Recorder
S.WL [M]
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
DATE

FIGURE 7

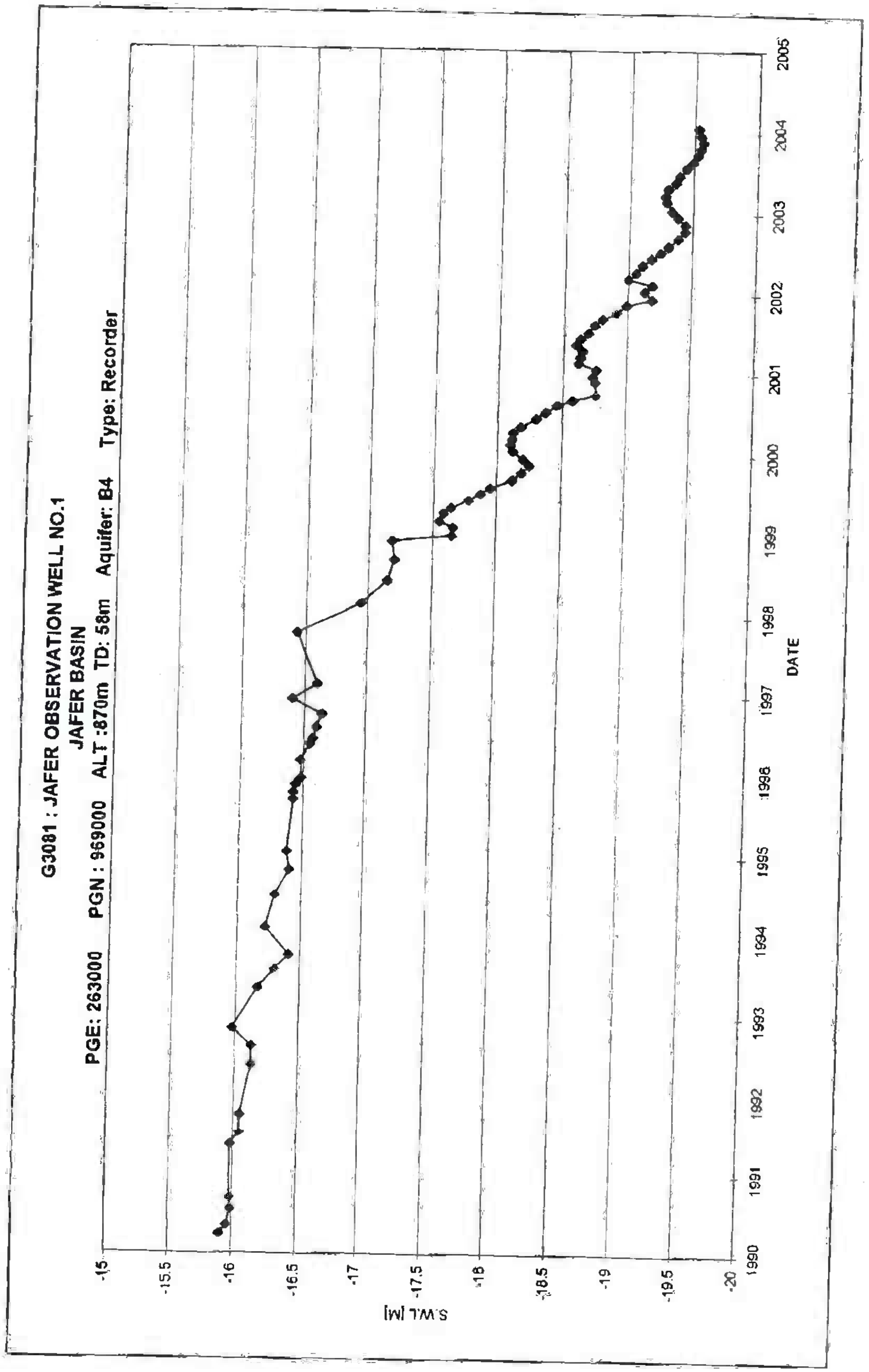

G3081 : JAFER OBSERVATION WELL NO.1
JAFER BASIN
PGE: 263000 PGN : 969000 ALT :870m TD: 58m Aquifer: B4 Type: Recorder
S.W.L [M]
-15
-15.5
-16
-16.5
-17
-17.5
-18
-18.5
-19
-19.5
-20
DATE
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

FIGURE 8

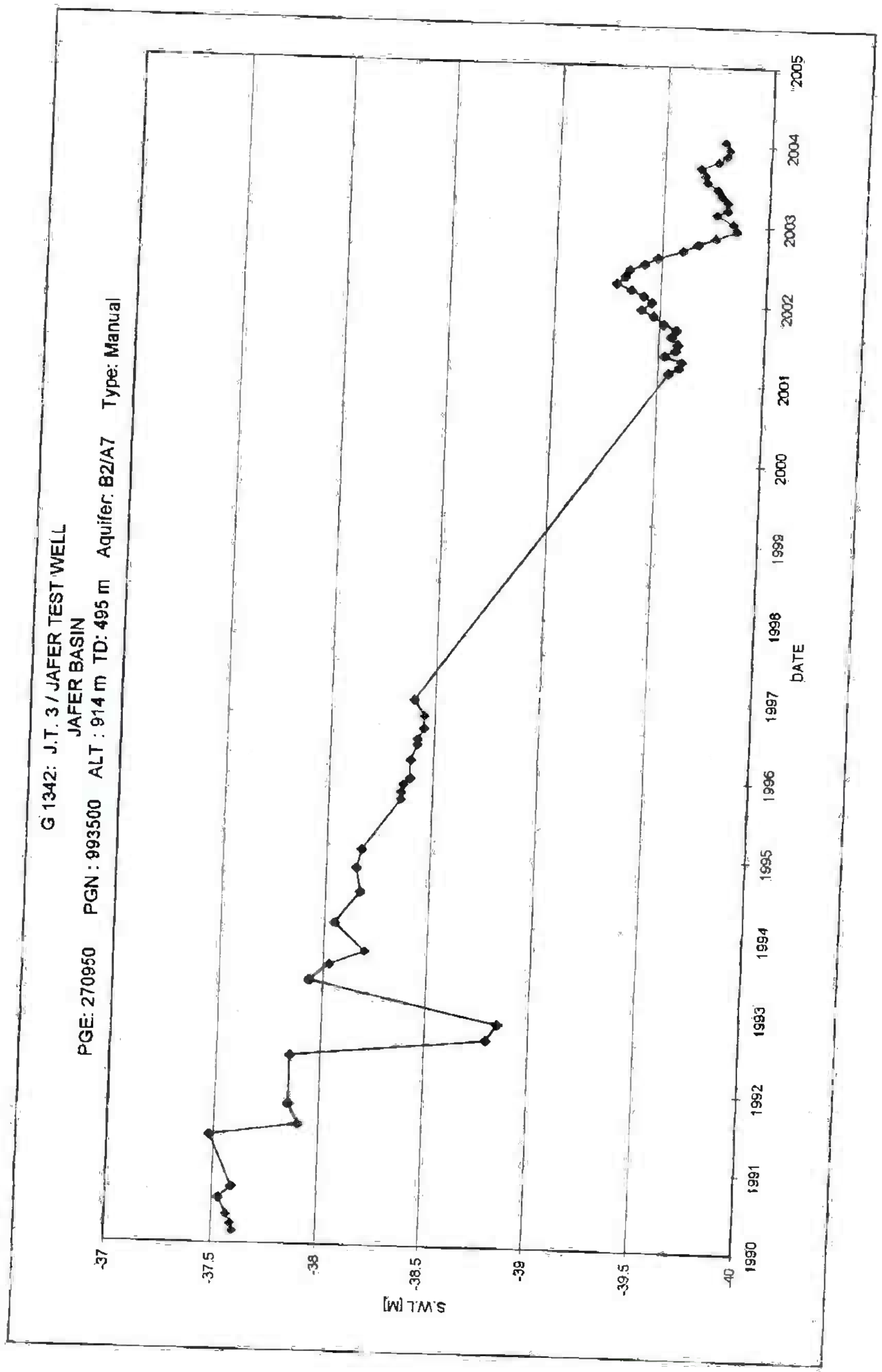

G 1342: J.T. 3 / JAFER TEST WELL
JAFER BASIN
PGE: 270950 PGN : 993500 ALT : 914 m TD: 495 m Aquifer: B2/A7 Type: Manual
S.W.L [M]
-37
-37.5
-38
-38.5
-39
-39.5
-40
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
DATE

FIGURE 9

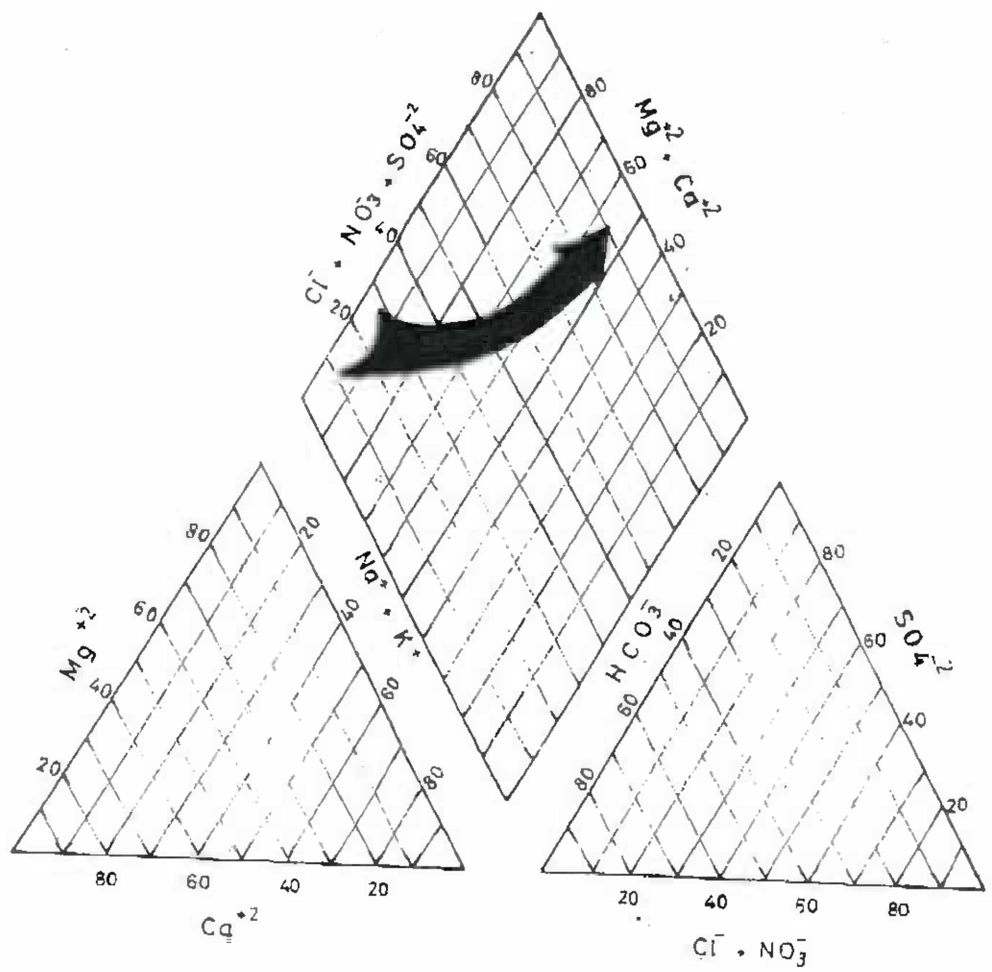


FIGURE 10

REPORT ON CASE STUDIES

ANNEX G WATER POLICY, INSTITUTIONS, LEGISLATION AND REGULATION

CONTENTS

PREFACE

This Document on "Water Policy, Institutions, Legislation and Regulation" forms Annex G of the Report on Case Studies for the DFID funded project No 8332 of the KaR Programme - Water Demand Management in Areas of Groundwater Over-exploitation.

The report comprises a Main Report and the following Annexes:

Annex A – Approach to the Study
Annex B - Water demand management
Annex C – Sustainable livelihoods approach
Annex D – Focus group discussions – Methodology & results
Annex E – Water Resources
Annex F – Economic data
Annex G – Water Policy, Institutions, Legislation and Regulation

Two Case Studies have been undertaken one in Chennai, Tamil Nadu State, India and the other in the Al Jafr-Shoubak region, Hashemite Kingdom of Jordan.

Annex G that follows is presented in three parts.

The first section covers aspects of international approaches to water policy, legislation and regulation. The second section describes the findings on these matters from the case study in Chennai and the third section those related to the studies in Al Jafr-Shoubak.

ANNEX G WATER POLICY, INSTITUTIONS, LEGISLATION AND REGULATION

1. GENERAL

1.1 Water policy

During the 1990s, attempts were made to define a number of over-arching international development principles that should be considered when drafting national water policies. It is now widely recommended that a broad based approach should be adopted in defining development principles. This should ensure that not only technical but also institutional and legal reform, stakeholder participation, devolution, public and private sector management and environmental issues are included in any policy review.

The statements issued in 1992 at the International Conference on Water and the Environment in Dublin (Ref. 1) and the Earth Summit at Rio de Janeiro (Ref. 2) as well as publications such as the FAO Land and Water Bulletin No 3, a joint publication by the FAO/World Bank/UNDP (1995) (Ref. 3) and the UNDP/World Bank Technical Paper, A Guide to the Formulation of Water Resources Strategy (1994) (Ref. 4) on development of the water sector are relevant.

Other forums and documents which have added to the water policy directions include the World Water Forum, The Hague 2000; Earth Summit, Johannesburg, 2002 and the World Water Forum, Kyoto 2003, UN Millennium Development Goals, DFID Strategy for achieving International Development Targets (Ref. 5) and the DFID Sustainable Livelihoods Approach (Ref. 6).

Recently, the World Bank has issued its Water Resources Sector Strategy – Strategic Directions for World Bank Engagement, IBRD/World Bank (2004) (Ref. 7) which reinforces the message that water resources management and development are central to sustainable growth and poverty reduction.

Dublin Conference

The Dublin Conference called for new approaches to the assessment, development and management of freshwater resources and in a statement asserted that "*….it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price*."

The statement suggested four principles should be applied to water resources management:

i.) Water must be managed in a holistic way taking interactions among users and environmental impacts into account.

ii.) Water must be valued as an economic good, managed as a resource necessary to meet basic human rights.

iii.) Institutional arrangements must be reformed so stakeholders are fully involved in all aspects of policy formulation and implementation. This means management should be devolved to the lowest appropriate group, with enhanced roles for non-governmental organisations, community groups and the private sector.

iv.) Women (as well as men) must play a central role in the provision, management and safeguarding of water.

The Earth Summit

The conference confirmed the widespread consensus that the management of water resources needs to be reformed. It concluded that, "*The management of freshwater as a finite and vulnerable resource and the integration of sectoral plans and programs within the framework of national economic and social policy are of paramount importance for actions in the 1990s and beyond. ……. Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good.*"

Since then UNDP, the World Bank and FAO have published a number of papers, bulletins and guidelines defining and discussing water sector objectives, and stating the need for national policy reviews. They have provided general guidance for the development of these within the broad framework of the Dublin and Earth Summit statements.

More recently a number of regional seminars on policy reforms in water resources management have been held throughout the world. Of particular relevance are the MENA/MED water initiatives sponsored by the European Commission, European Investment Bank and World Bank in Cairo (1998), the Second Regional Seminar on Policy Reforms in Water Resources Management, Amman (1999) (Ref. 8).

A number of steps are required to develop an effective national water policy:

- determination of the importance of water in specific regional and national contexts
- a comprehensive water resources assessment which is likely to generate a matrix of problems and critical issues
- definition of development principles
- development of broad options based on these defining principles and evaluation of these thus setting the scene for strategy formulation.

The end point of strategy formulation is the drafting of a programme and an implementation plan which can be incorporated within a Master Plan.

The specific case study reports in Chennai and Al Jafr-Shoubak on water resources development, discussed in Chapters 2 and 3 below, should be seen in this context.

1.2 Institutions, the private sector, NGOs and communities

The implementation of water policy and the management of water depends fundamentally on the institutions, agencies and communities involved. Different situations require different institutional arrangements. The involvement of the private sector in implementing, operating and maintaining infrastructural development is becoming of increasing common. At community level, where public authorities or public-private partnerships fail to deliver the services required, NGOs working with communities may take on a role in the provision and distribution of water.

The importance of ensuring that effective arrangements are in place to deliver and manage water must not be under-rated and the relationships and roles in negotiating outcomes in the water sector through public, private and community participation are important. These are discussed later in this Annex and also in Annex D.

1.3 The need for appropriate water sector legislation and regulations

Water supply and demand management can only be implemented with appropriate legal and regulatory instruments. Governments introducing these measures have an eye to a wide range of aspects including, for instance, abstraction rights and licences, water allocation and conservation, pollution control and tariffs.

Legislation has to be understood and acceptable to water users and stakeholders if it is to be effective. In areas of water scarcity or where demand management measures are being introduced, legislation and regulations may need to be supported with effective monitoring and enforcement.

Outline of the legislation employed within the study areas are discussed briefly below.

2. TAMIL NADU & THE CHENNAI CASE STUDY

2.1 Water Policy

The Ministry of Water Resources, Government of India formulated a “National Water Policy” in September 1987 as a basis for overall planning and development of water resources.

The policy covers such items as:
maximising water availability; social equity, project planning; maintenance and modernisation; safety of structures; groundwater development, the need for assessment and regulation of water use, recharge, integrated use of groundwater with surface water; avoidance of over-exploitation of groundwater (particularly near coastal areas to avoid saline intrusion); water allocation priorities (drinking water, irrigation, hydro-power, industrial and other uses); water rates (to be adequate to cover the annual O&M and part of the fixed costs of supply and of sufficient level to convey the scarcity value of the resource but rationalised with due regard to small and marginal farmers); participation of farmers and voluntary agencies; water quality; water zoning; conservation of water; flood control and management, land erosion by sea and river; drought management; and information systems.

Many of the general policy items of Central Government have been absorbed into the Tamil Nadu State water policy.

In 1993, the Government of Tamil Nadu formed a Water Resources Control and Review Council (WRCRC) to formulate water management strategies and to develop and implement a water policy. The power and functions of the WRCRC are as follows, to:

- establish allocation priority norms for water use for different sectors taken as a given that “the provision for drinking water has the highest priority”;
- formulate water management policy and after acceptance, implement and monitor;
- examine the impact of extraction, utilisation and conservation of water by its users;
- formulate water policies for the state and basin water development, control and management

- establish principles, standards and procedures for allocation of water under licences, preparation of comprehensive regional and river basin plans and for formulation and evaluation of water policy and related land resources projects using technical, economic, social, legal and environmental criteria

- serve as an advisory and co-ordinating body for the State in water and related matters

- review and approve State and river basin master plans; prioritisation of different sectional water needs

- review and approve macro planning, distribution management and water resources taking into account the water needs of different sectors (small schemes of less than 10Ml need not be referred to the Council)

- review and approve for publication an annual assessment of the adequacy of supplies of water necessary to meet the present and the projected State and basin water requirements

- issue orders as may be necessary to carry out its functions

The Water Resources Control and Review Council (WRCRC) is still in existence and is headed by The Honorable Minister, PWD.

Based on the national water policy of the Government of India (1987), the Government of Tamil Nadu formulated the Tamil Nadu Water Policy. The Institute of Water Studies (IWS) drafted the policy in January 1994 and this was approved in July 1994. IWS was appointed to act as the implementing agency for the policy. The ultimate aim of the policy was to develop a State Water Plan which would:

- establish an Management Information System (MIS) for water resources
- ensure preservation and stabilisation of existing water resources
- plan for augmentation of utilisable water resources
- promote research and training facilities for water resources management
- establish allocation priorities for water use by different sectors with provision of drinking water being of highest priority
- maximise the multi-purpose benefit from surface water, groundwater, land and other resources
- provide adequate water for domestic users
- maximise hydropower generation within the constraints imposed by other water users
- provide adequate water for industry
- preserve and enhance the economics of fisheries
- maintain water quality to established standards
- promote equality and social justice

In addition, the water policy encourages participatory approaches to field level problems and training is considered as an integral part of water management. The Government of Tamil Nadu's Water Policy principally accepts that water rates are to be given a purpose; they should be such as to convey the scarcity value of the resource to the users and foster a sense of economy in water use.

Importantly, the river basin is seen to be the unit of water management and for water resources planning. The policy accepts the need for State Frame Work Water Resources Basin Plans. These are being prepared for each of the seventeen river basins (comprising thirty-three main rivers. Four of the basin plans have been prepared (2003). The case study area comes within the Chennai Basin (Araniyar, Kortalaiyar, Cooum, Adayar rivers). The Chennai basin plan is still to be prepared.

2.2 Institutions

(a) Government Institutions

The list below gives the principal organisations involved in the development and management of water resources in the Case Study Area:

Water Resources Organisation, Public Works Department
Tamil Nadu Water Supply and Drainage Board
Agriculture Department
Agricultural Engineering Department
Revenue Department
Chennai Metropolitan Water Supply and Sewerage Board
Rural Development Department
Pollution Control Board
Department of Municipal Administration
Fisheries Department

Descriptions of their principal functions relating to the Case Study area are given below.

Water Resources Organisation (WRO), Public Works Department

The WRO, which is under the control of the Public Works Department is in charge of the water bodies, their maintenance, operation and regulation with regard to irrigation.

The principal officers with responsibilities in the Chennai basin, based in Chennai, are:

Director, Institute of Water Studies, Engineer-in-Chief; Chief Engineer of Chennai region; Chief Engineer (Design, Research and Construction Support); Chief Engineer (Plan formulation), Chief Engineer (State Ground and Surface Water Resources Data Centre), Chief Engineer (Operation and Maintenance); Chief Engineer and Krishna Water Supply project, Circles I & II

Tamil Nadu Water Supply and Drainage Board (TWAD)

The Board has responsibility for developing and implementing programmes for drinking water supplies and drainage facilities throughout Tamil Nadu except in Chennai

Agriculture Department

The Department provides extension services to farmers, soil testing, input on supply of seeds, fertilisers and pesticides and agricultural research

Agricultural Engineering Department (AED)

The AED has responsibilities for Command Area and on farm development including establishing farmers' organisations, catchment stabilisation and soil conservation. These activities also include construction of check-dams for agricultural development, supply of agricultural equipment (e.g. tractors, tillers, drilling rigs on hire basis), subsidies and credit for drip and sprinkler irrigation, the development of wasteland, terracing, ponds, wild-life protection, de-silting of ponds and tanks, fencing, seed and seedlings supply.

Revenue Department

The Department collects water charges and levies from farmers. The Collectors co-ordinate with PWD with respect to water delivery

Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

The Board is responsible for the development, operation and maintenance of water supply and sewerage systems for the city of Chennai and for the preparation of long term plans to meet future water supply and sewerage disposal requirements.

Rural Development Department

Has responsibility for small tanks with command area of less than 100 acres (42 ha) supplying irrigation water

Tamil Nadu Pollution Control Board (TNPCB)

The Board is responsible for prevention and control of water pollution and for restoring water quality to desirable levels

Department of Municipal Administration (DMA)

The Department is responsible for supply of drinking water to several municipalities, sinking borewells, provision of sewerage facilities and for system maintenance. The Department will coordinate activities with TWAD in the provision of drinking water and sewerage facilities and the maintenance of systems in municipalities. Both TWAD and the DMA are under control of the Secretary Municipal Administration and water Supply (MAWS).

Department of Industry and the Electricity Board

Responsible for the promotion of industry, electricity and has involvement in water desalination projects.

Fisheries Department

The Department is involved in the exploration and exploitation of marine resources and for inland and brackish water fish and fish production.

(b) NGOs operating in the water sector in the Study Area

The following is a list of NGOs in the Chennai Metropolitan Area working, although not exclusively in the field of water and sanitation.

1.Asha Nivas
9, Rutland Gate, 5th Street
Nungambakkam, Chennai
600034

2. Anbu Illam, Don Bosco,
33, Malliappan St.

11. Child Relief and You (CRY)
57/2 pP. S. Sivaswamy Salai,
Sullivan Garden Rd.,
Mylapore, Chennai 600004

12. Madras Christian Council of
Social Service MCCSS

20. Guild Plan International.
Guild of Service
81, Venkatesh Nagar
1st Cross St. Vrugambakkam.
Chennai, 600092

21. Presentation Community

Mannadi, Chennai 600001

3. ARUNODAYA
15, Bazar St., Royapuram,
Chennai 600013

4. Indian Council of Child Welfare
5, 3rd Majn Rd, West
Shenoynagar,
Chennai 600030

5. Madras School of Economics
Gandhi Mandapam Road,
Chennai 600025

6.Action Aid India
23, West Park St., Shenoynagar,
Chennai 600030

7. Exnora International,
42, Giriappa St. T'Nagar,
Chennai 600017

8. Human Rights Advocacy and Research Foundation
10, Thomas Nagar, Little Mount, Saidapet, Chennai 600015

9. Don Bosco Social Service Society
Dacosta Rd., Pulianthope,
Chennai 600012

10. CODIAC
280, Khaleel Shirazi Estate, 3rd Floor,
Pantheon Rd., Chennai 600008

21, 6th Main Rd. Jawahar Nagar,
Chennai 600082

13. Developm'nt Promotion Group
2,First St. , Gillnagar,
Choolaimedu,
Chennai 600094

14.M.S. Swaminathan Research Foundation
3rd Cross St., Institutional Area,
Taramani, Chennai 600113

15. World Vision India
8th Floor, Khaleel Shirazi Estate,
344, Pantheon Rd.,
Egmore, Chennai 600008

16. CVG Shelter Trust,
8, Csuarina Drive, Neelankarai,
Chennai 600041

17. JANODAYAM
122, Sterling Rd.,
Nungambakkam,
Chennai 600034
23. NESAKKARAM
16, 1ST Cross St., Lake Area,
Nungambakkam, Chennai 600034

18. The Beatitudes
50 Sundaram St., Vyasarpadi,
Chennai 600039

19. Montford Community
Development Society,
5, 2nd St., Parameshwari Nagar,
Adyar, Chennai 600020

Service Centre
9 General Collins Rd., Choolai,
Chennai 600012

22. CLEAD
1, 3rd Cross St.
United India Nagar, Ayanavaram,
Chennai 600023

23. Ryan Foundation
8, West Mmada St.,Srinagar
Colony,
Saidapet, Chennai 600015

24. TN People's Forum for Social Development,
5/1 Satyapuri St., West
Mamabalamm,
Chennai 600033

25.SEERS
27/531 Sathiamurthinagar,
Vyasarpadi,
Chennai 600039

26. TN Slum Dwellers Federation,
53/2 2nd Floor,
Purasawalkam High Rd.
Chennai 600007

27.Pennurimai Iyakkam,
New 41, old 20, Canal Rd.,
Kilpauk Gd, Colony,
Chennai 600010

2.3 Legislation and regulations

(a) Government of India legislation

The Constitution of India gives exclusive jurisdiction to the Union to regulate and develop inter-State river valleys to the extent Parliament declares it to be in the public interest. It also grants Parliament the right to enact laws for the adjudication of any dispute or complaint regarding the use, distribution or control of waters of any inter-State river or river valley.

The two principal Central Government Acts relating to the Case Study are those listed below:

- Inter-State Water Disputes Act No 33 of 1956, and as Amended
- Rivers Boards Act No 49 of 1956 as Modified [relates to inter-State rivers]

These are relevant in the way that they relate to the supply of water to Tamil Nadu from Andhra Pradesh and in particular to the Krishna river supply which is the subject of an agreement between the State Governments.

(b) Tamil Nadu legislation and regulation

There are a number of State of Tamil Nadu Acts relating to the Water Sector and the Study Area. These are concerned mainly with water abstraction, use of water from government managed schemes and pollution. The key legislation relating to the case study area is as follows:

Chennai Metropolitan Area groundwater (Regulation) Act no 27 of 1987as Amended

The Act authorises the CMWSSB to prohibit drilling new wells in the designated area unless the user first obtains a permit from the Board. It also required the Board to prepare a register of existing wells. Under the Act re-existing users, except agricultural users, must apply for a license within 15 days of the Act. All new users must obtain a license from the Board. This act directs the Government to issue instructions to the Board on the implementation of an artificial recharge scheme. The Act grants the Board power to adopt regulations to prevent seawater intrusion.

(1) The Act envisages control and regulation of abstractions and transportation of Groundwater in the Notified Area through (a) registration of existing wells, (b) regulation of sinking of new wells (c) issue of licences to extract water for non domestic use and (d) issue of licences for transportation through goods vehicles.

The term "Ground Water" mentioned in the Act means the water which exists below the surface of the ground and the term "scheduled area" means the whole of the city of Chennai and the villages specified in the schedule.

(2) The Act which came into force in February '88 exempted wells used for agricultural purposes as on the date of Notification and wells used for purely domestic purposes. Construction of wells for other use was regulated through grant of permission. Abstraction of water was, however, regulated on an annual basis.

The Competent Authorities for the purpose of the Act:

in the City of Chennai is the Board (Metrowater)
in relation to the villages specified in the Schedule, the respective Sub-Collectors of Revenue Divisional Officers of the Taluks in which the villages fall.

In granting or refusing a licence, the competent authority is to have regard to:

(a) The purpose or purposes for which ground water is to be used
(b) The existence of other competitive users
(c) The availability of ground water
(d) The effect on other sources of water supply
(e) The compatability with the existing water supply system
(f) The availability of factors controlling or preventing pollution.

The issue of a licence is to take place after technical clearance and after payment of the prescribed fee. The specified fees are given in the table below :

	Rupees
a) Licence for extraction or use of ground water for agricultural purposes	50
b) Licence for extraction or use of ground water for other purposes using:	
(i) pumps with capacity not exceeding 5 HP	500
(ii) pumps with capacity exceeding 5 HP but not exceeding 10 HP	1,500
(iii) using pumps with capacity exceeding 10 HP	2,000
c) Licence for transport of ground water by lorry, trailer or other goods vehicle	5,000

This Act is important for the reason that it gives CMWSSB the right to control the abstraction of groundwater in the areas from which water for Chennai Metropolitan area may be drawn.

Further details are given in an Appendix at the end of this Section.

Chennai Metropolitan Water Supply and Sewerage Act, Tamilnadu Act No 28 of 1978 as modified 31 August 1981

The CMWSSB has power over construction, drilling and altering of wells, ponds, tanks and cisterns providing drinking water and the power to regulate, control and charge for existing or future use of groundwater for all purposes except irrigation in the CMA.

Tamilnadu Water Supply and Drainage Board Act No 4 of 1971 and as Amended

The Act creates a special Board, The Tamilnadu Water Supply and Drainage Board (TWAD) to address drinking water supply and drainage issues and problems in Tamilnadu. The Board is a corporate body consisting of appointed members of the public and officials from certain State agencies. The Board is charged with developing and executing schemes providing drinking water supplies and drainage facilities.

Tamilnadu Panchayat Act No 35 of 1958 as Amended

The Act provides the purpose and manner of organising village and town Panchayat. It authorises Panchayat to construct and repair various small water related structures. This Act allows the Government to transfer to Panchayats the duty of protecting and maintaining any irrigation works and regulating the distribution of water.

Other relevant legislation includes:

Tamilnadu Land Improvement Schemes Act No 31 of 1959 as Amended

The purpose is to carry out land improvement schemes in declared areas, public and private, other than forest reserves for conservation and improvement of soil and water resources (including groundwater), prevention and mitigation of soil erosion, protection of land against damage from floods or drought, protection of reservoirs from sedimentation and reclamation of waste lands. It provides for establishing Boards at three levels: viz. State, District and River valley catchment areas for carrying out the Act. The Act could be considered as a key law for improving water resources development, utilisation, management and conservation in Tamilnadu.

Tamilnadu Irrigation Tanks (Improvement) Act No19 of 1949 as modified up to 30 April 1949

Under this Act Government has the authority to improve the efficiency and capacity of Government owned or operated tanks regardless of location. The owners of land are subject to pay all or a portion of the costs of improvement.

Tamilnadu Revision of Tariff Rates on Supply of Electrical Energy Act No 1 of 1979

This Act revises the electric rates for users on domestic, public, industrial and agricultural purposes. The act provides for special rates for agricultural users.

Tamilnadu Requisitioning and Acquisition of Immovable Property Act No XLII of 1956 as modified in 1973

This allows the Government to acquire necessary property for construction of structures for water resources development.

Tamil Nadu Irrigation Cess Act No 7 of 1865 as modified 31 October 1980.

This is the fundamental water-cess or fee act for irrigation water use. It provides the policy basis for imposing a water charge. It establishes a policy of recovering a rate of return from beneficiaries of government funded irrigation projects.

Tamilnadu Irrigation, Levy of betterment Contribution Act No 7 of 1955 as modified 31 October 1980.

It provides for betterment assessments to be made against the land which is significantly benefited by the completion of certain improvement works

Tamilnadu Irrigation (Voluntary Cess) Act No 13 of 1942 as modified up to 30 November 1980.

This Act pertains to a special levy against lands for maintenance of certain irrigation and drainage works constructed or maintained by the Government.

Tamilnadu Irrigation Works (Repairs, Improvement and Construction) Act No18 of 1943 as modified up to 30 November 1980

The Act empowers the Government to repair and improve irrigation works, supply water from Government facilities to private irrigation systems, and construct new irrigation works as defined by the Tamilnadu Estates Land Act of 1908. This Act provides for the recovery of costs and fees.

There are a number of existing Regulations and Procedures; the most relevant are:

- Compendium of Rules and Regulations, Part I for Water regulation (1984)
  Relates to regulation of reservoirs gives authority to PWD officers to operate, maintain reservoirs and distribution system.

- Compendium of Rules and Regulations, Part II for Flood Regulation (1984)
  Release rules for reservoirs, list of officers to be notified under prescribed conditions and steps to be taken in disaster situations (cyclones and floods)

- Standing orders of the Board of Revenue
  The Orders establish the rates for assessment of those lands receiving water from a government source. It defines the right to utilise, permissions required, issuance of licenses for diversions from government sources, surface and ground water for purposes other than irrigation.

Appendix

CHENNAI METROPOLITAN AREA GROUNDWATER (REGULATION) ACT 1987

This Act was introduced to regulate and control the extraction, use or transportation of groundwater and to conserve groundwater in and around Chennai City. The necessity of conservation arose for the following reasons.

i. Scarcity of water due to frequent failure of monsoon.

ii. The storage in Poondi, Cholavaram and Red Hills reservoirs, which are the main sources of water supply, is inadequate to meet the requirement of Chennai City.

iii. To control the indiscriminate pumping of groundwater for commercial purposes, in the Arani Koratalaiyar, Cooum and Adayar Basins.

iv. To save the coastal aquifers from over extraction of groundwater and to prevent sea water intrusion.

A key point:

Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) has been vested with the necessary authority to regulate the extraction of ground water in the notified area, by a licensing mechanism. In so far as the city is concerned CMWSSB handles the matters directly. However in the other notified areas (243 villages) within the Chennai Metropolitan Area but falling outside the city limits, the Revenue Authorities of the respective areas are authorised to undertake regulatory functions such as the issue of licenses to extract and transport groundwater through tankers, based on the recommendations of CMWSSB.

Grant of Permit

Any person desiring to sink a well in the notified village has to apply to the concerned Competent Authority in a prescribed form for the grant of a permit for this purpose. The Competent Authority may grant or refuse the permit, by considering the following factors.

i. The purpose or purposes for which the well is to be sunk.

ii. The existence of other competitive users.

iii. The existence of other wells in the locality.

iv. The availability of groundwater.

v. Such other matter as may be prescribed.

Registration of existing wells and use of groundwater in notified area

The existing wells in the notified areas have to be registered under this Act, in a prescribed form, by giving the following details.

i. The type of well and its exact location.

ii. The device used for lifting the groundwater.

iii. The date from which the groundwater is being used.

iv. The purpose or purposes for which the groundwater is being used.

v. The quantity of groundwater utilised.

vi. The extent, location and the survey number of the area, where groundwater is used for agriculture purposes.

vii. Such other matters as may be prescribed.

Licence for extraction, use or transport of groundwater

As per this Act any person wishing to: i) extract or use groundwater, in the scheduled area for any purpose other than domestic purpose and ii) transport groundwater by means of any lorry, trailer or any other goods vehicle, shall make an application to the Competent Authority in a prescribed form. In granting or refusing a license, the Competent Authority shall have regard to

i) The purpose or purposes for which groundwater is to be used.

ii) The existence of other competitive users.

iii) The availability of groundwater.

iv) The effect on other sources of water supply.

v) The availability of factors controlling or preventing pollution.

vi) The compatibility with the existing water supply system.

If the Competent Authority fails to inform the applicant, of its decision on the application within a period of ninety days from the date of receipt of such application, the licence shall be deemed to have been granted to the applicant and such person shall, for the purposes of this Act, be deemed to be a holder of a licence. Whenever the Competent Authority has decided to grant the licence, the applicant is reminded to remit the specified fee. The licence has to the renewed and the licence fee remitted every year.

The Competent Authority is empowered to cancel the sanctioned permit or licence

- if the permit or licence is obtained by fraud or misrepresentation
- if the permit or licence holder has failed to comply with or contravened any of the terms, conditions and restrictions, subject to which the permit or licence has been granted or has contravened any of the provisions of the Act or the rules made under this Act. However the Competent Authority may give an opportunity of showing cause, to such a holder, before canceling the permit or licence. On cancellation of the permit or licence, the Competent Authority by order, will ask the holder to close or seal off the well at his own cost. If the holder of a permit or licence fails to comply with any order, the Competent Authority may, after giving notice to the holder, enter upon the premises where the well is situated and close or seal off the well. The cost incurred thereof shall be recoverable from such holder as an arrears of land revenue.

Exemptions Given in the Act

The following exemptions have been given in the Act for the extraction of groundwater.

i) Without the aid of any pumpset or

ii) With the aid of pumpset of capacity not exceeding 0.5 HP in respect of any one well.

Appeal

Any person aggrieved by an order made under this Act may, within such period and in such manner as may be prescribed, appeal to such authority by notification specify in this behalf.

In deciding the appeal, the authority specified shall follow such procedure as may be prescribed and decision of such authority on such appeal shall be final and shall not be called in question in any court of law.

Offences and Penalties

If any person contravenes or fails to comply with any provisions of this Act or the rules made under this Act, subject to which the permit or licence has been granted, he shall be punished for the first offence with a fine, which may extend to five hundred rupees and for the second or any subsequent offence, with imprisonment for a term which may extend to six months or with a fine which may extend to one thousand rupees or with both.

Any person who after having been convicted of any offence under this Act, continues to commit the same offence shall be punished with a further fine which may extend to one hundred rupees for every day during which he continues so to offend after such conviction. Any offence punishable under this Act shall be a cognizable offence within the meaning of the code of criminal procedure 1973 (Central Act 2 of 1974).

Amendment to this Act

This act was further amended on October 2002 to realise maximum benefits under the Chennai Metropolitan Area Groundwater (Regulation) Amendment Act, 2002. The following are the salient features of the amendment.

- Inclusion of 59 Revenue villages in the taluks of Uthukottai, Ponneri, Tambaram and Sriperumbudur in addition to the existing list of 243 Revenue Villages in Kancheepuram and Thiruvallur Districts
- The Act has been empowered with provisions for confiscating the pumpsets and equipments used for extraction of groundwater and the water tanker used for illegal transpotation of groundwater
- The fine for illegal extraction and transportation of groundwater has been increased up to Rs. 2000 for committing the offence in the first instance. For offences made subsequently, the fine has been increased to Rs. 5000 or an imprisonment of one year or both. If the offence is committed continuously, a fine amount of Rs. 500 will be levied for every day
- The implementation of Rainwater Harvesting in all new and existing buildings is made mandatory
- Industries are required to use recycled water for non-potable purposes
- Use of groundwater for swimming pools, gardening and non-potable use is prohibited
- Water bodies, whether public or private such as lakes, tanks etc. shall be rejuvenated and used only for the purposes defined, in order to make the water bodies fully contribute to groundwater recharge
- The Competent Authority is empowered to restrict the depth of borewells.

3. JORDAN AND THE AL JAFR - SHOUBAK CASE STUDY

3.1 Water strategy, policy and management plans - Jordan

Strategy and policy

The importance of developing an integrated and an effective water strategy and water policies has long been recognised by the Government of Jordan where the demands for water for domestic, industrial and agricultural uses have outstripped the available renewable resource.

In 1997, the Government of Jordan formulated the "Economic & Social Development Plan 1998-2002" on which the Jordan National Water Strategy has been based. The Water Strategy defined the basic concept for development and management as follows:

- sustainable utilisation of the country's water resources and reduction in the abstraction of renewable groundwater
- promotion of the utilisation of treated wastewater and of brackish water for re-use
- strengthening of public awareness of the serious water shortage conditions and of limited water resources
- promotion of participation of the private sector (promotion of privatisation)
- involvement of institutions in order to ensure sustainable water related projects

The basic concept of the Water Strategy is to utilise the limited water resources in Jordan effectively. To rely not only on the development of new water resources but also on: (i) management which aims for sustainable utilisation of the limited water resources through their qualitative and quantitative conservation; (ii) promotion of public awareness; and (iii) the improvement of the existing legislation and institutional systems.

Water policies

Water policy papers were issued in 1997 and 1998 covering water utility policy, groundwater policy, irrigation water policy and wastewater management policy. The principal items covered in these papers were:

Water utility policy

- information systems related to water resources development and management shall be unified under the Ministry of Water & Irrigation
- The retail sectors of the water supply and wastewater treatment of the Water Authority of Jordan shall be separated and privatised

Groundwater policy

- Priority of the groundwater allocation shall be given to municipal, industrial and tourism purposes
- The allocation of groundwater to forestry shall be given high priority within the agricultural sector
- The groundwater monitoring system shall be strengthened to improve conservation of the resource

Irrigation water policy

- Existing water rights for irrigation water shall not be used for other purposes without providing substitute water for agriculture

- Although the extent of the activities and rights of the Jordan Valley Authority (JVA) shall not be changed, emphasis will be shifted towards tourism, industrial and commercial development in the future. In this shift, privatisation of public entities and participation of the private sector shall be promoted
- The tariff for irrigation water (for schemes where water infrastructure is provided by Government) shall be increased to the level which at least enables the recovery of the sustainable maintenance and operation costs of the project.
- Efforts shall be made to change to low water consumption crops
- Where applicable, Participatory Irrigation Management (PIM) systems, in which farmers shall be responsible for water conveyed to their own lands, shall be introduced
- Wastewater shall be regarded not as waste but as an important resource

Wastewater management policy

- For reuse of wastewater, the treatment processes shall be upgraded to comply with WHO and FAO standards
- Wastewater treatment shall be undertaken giving first priority to the protection of water contamination and the health of people
- The public shall be made aware of the principle that the discharging side is responsible for the cost of treatment (the polluter pays)
- The usefulness of treated wastewater shall be advertised through public awareness
- The tariff of the wastewater treatment shall be increased to a level which at least covers the sustainable maintenance and operation cost of the project.

To turn these policies into action plans, the Government commissioned a Study on Water Resources Management and more recently a National Water Master Plan which are described below

Water Resources Management Master Plan

A JICA Study Team undertook and reported on The Study on Water Resources Management in the Hashemite Kingdom of Jordan (Yachiyo Engineering Co.Ltd; 11 Vols) in 2001 (Ref. 9). It took account of the earlier policies and has provided input to the National Water Master Plan (Ref. 10) which is now in preparation.

The study objectives of the JICA study on Water Resources Management (Feb 2000 – Dec 2001) were to:

- formulate a Water Resources Management Plan in Jordan using the tools that have been developed by the GTZ funded Water Sector Planning Support Project.
- undertake a Pre-feasibility study of a priority project based on the findings and results of Master Plan.
- transfer technologies to counterpart personnel in the course of the study.

The main features of the Plan, taken from the Final Summary Report (2001), are given below.

The Water Resources Management Master Plan covers the period to 2020, and is aimed at “unified, comprehensive and sustainable management of the water resources” and “strategic development of remaining scarce water resources” while keeping in mind a future goal of a “shift to a water recycling society”.

Concepts like "global climate change" (specific to the arid region) and "cooperation for regional peace water development" have been incorporated in the formulation of the Master Plan for the country's twelve governorates. Furthermore, the system and database of the "Digital Master Plan", which was prepared by MWI with the technical cooperation of GTZ, was utilized in the formulation of the Master Plan. The area studied included all Jordan and the twelve Governorates. The planning horizons were: short-term 2000 to 2005; mid-term 2006 to 2010 and long-term 2011 to 2020.

The Plan was developed on the basis of the "water strategy" and "water policies" described above.

The water resources examined included desalinated brackish groundwater, desalinated sea water and treated wastewater, in addition to the conventional sources such as surface water, peace water (water released on the basis of agreements with Israel), renewable and fossil groundwater.

For the formulation of the Water Resources Management Master Plan, both conventional and non-conventional water resources were examined. In addition, qualitative and quantitative issues were examined and institutional and legislative issues were considered in the context of Jordan's Water Strategy and Water Policies. Within the restricted water availability, the allocations for Municipal/Industrial/Touristic (MIT) demand and agricultural demand were considered taking account of the study results of USAID and GTZ projects.

After balancing water demand and supply for the whole of Jordan, the water resources development and water resources management plans (including inter-Governorate water allocation and water conveyance plans) were formulated for twelve Governorates.

The Study has provided data to support The National Water Master Plan which is now in preparation by the Ministry of Water and Irrigation (MWI). This is also backed by inputs from the Water Sector Planning Support Project (GTZ funded). Under this project, the Water Information System (WIS) database and associated planning tools provide support to water sector decision makers. The WIS makes use of data from the Water Sector Support Project and the MWI database which was established with support from USAID.

The National Water Master Plan has been prepared as a digital planning document so that it can provide maximum flexibility. Elements of the Plan can be updated using the latest data, the results of which feed into the Plan as a whole. Water balances are performed for different spatial layers: natural regions (surface water basins); administrative regions (Governorates) and water-use related regions or socio-economic zones.

Policies adopted in the Water resources Management Master Plan

The following basic policies were adopted:

- surface water, renewable groundwater and fossil (fresh) groundwater are considered as conventional sources of water. Surface water should be used to its maximum potential; control on the abstraction of groundwater should be introduced to reduce the overdraft on renewable resources; for fossil (fresh) groundwater the development period should be restricted to fifty years; for peace water the amount supplied from Israel would be in accordance with the peace treaty (currently 33 M m^3/annum increasing to 60 Mm^3/annum by 2005 and finally to 90 Mm^3/annum by 2010 after storage on the Jordan River and side wadis has been developed)

- desalinated brackish groundwater, desalinated seawater and treated wastewater are considered as non-conventional type water resources. The potential for desalinated brackish groundwater was considered to be large along the east bank of the Dead Sea and Southern Jordan Valley. Its full scale development would be implemented after 2020 or preserved for emergency cases in future (because desalination costs are still high). For sea water desalination, this would only be used for Municipal, Industry and Tourism (MIT) purposes in Aqaba as conveyance costs are high. For treated wastewater, its re-use would be limited to the vicinities of the treatment plants and in the Jordan valley as it would not be economically feasible for uplands in view of the high cost of conveyance.

Strict demand control policies were chosen for municipal, touristic, industrial and irrigation water as follows:

- Municipal water: The increasing demand for municipal water is anticipated to grow by 3.03% per year but the consumption rate per capita would be maintained at the present level of about 100-150 l/c/d excluding physical losses). The differences of per capita consumption among the twelve Governorates would be balanced by 2020.

- Industrial and touristic water: These sectors account for 10% and 13% of the GNP (1998) respectively. The minimum possible demand for them would be secured. In demand projection, the major tourist and industrial development will be considered (these include the Dead Sea Touristic Development, special economic districts, industrial development districts and oil shale developments).

- Irrigation water: Water for agriculture would be reduced in the future (in line with the Irrigation Water Policy of 1998). Irrigation water could not be increased because of increasing MIT demands. The abstraction of renewable groundwater would be reduced in the Upland Area where the groundwater level and water quality are declining. A shift of agricultural activities from the Upland to the Jordan Valley would be considered together with the use of treated wastewater in the Upland areas as a supplementary source for irrigation.

Other policy objectives include:

- Improvement plan for Unaccounted for Water (UFW). The aim is to reduce physical losses from 25-30% to 15% by 2010

- Existing agriculture using surface water for irrigation would be maintained in the future but agriculture using groundwater would be controlled in terms of quantity of use in accordance with the groundwater reduction plan. Water available from new surface water developments would be allocated primarily to municipal water use with priority; the remaining quantity would be allocated to irrigation. The quantity of treated wastewater would, as far as possible, be used for irrigation and industrial uses.

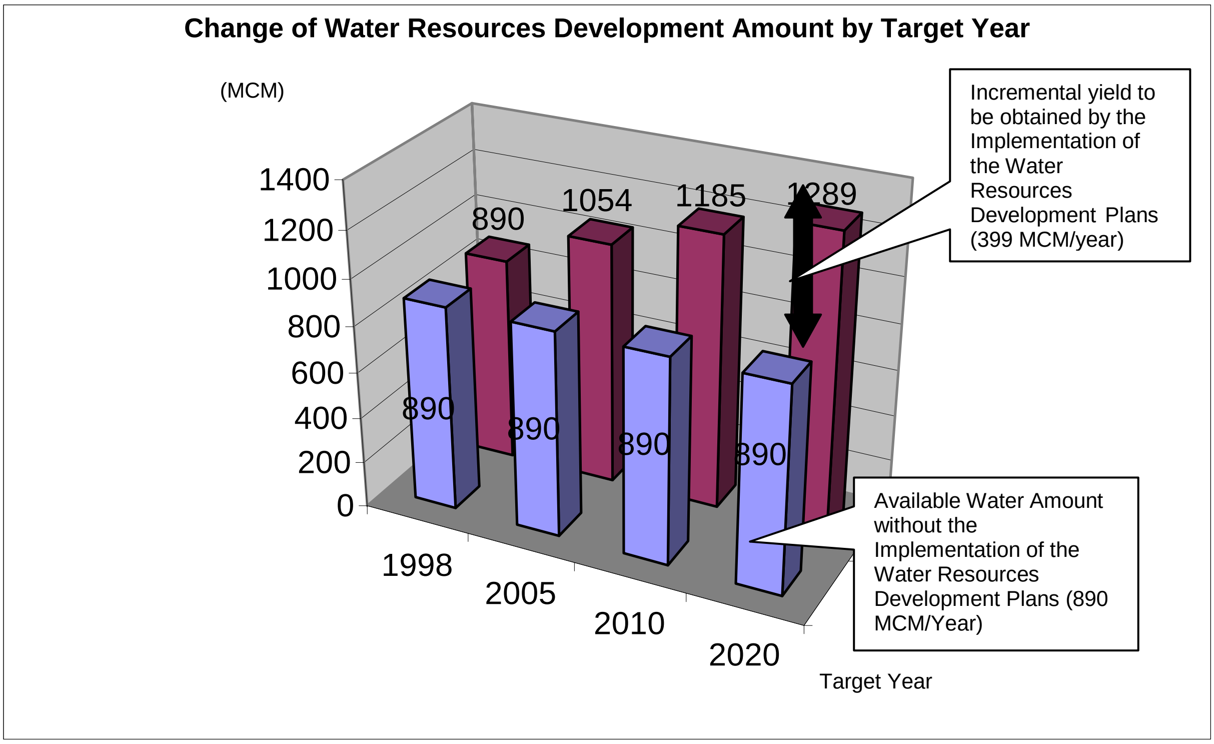
- There would be a reduction plan for renewable groundwater abstraction. The safe sustainable yield of the renewable groundwater would be examined and evaluated based on existing data and studies. The reduction plan would be formulated in each Governorate based on the sustainable yield. The plan would cover not only abstraction for irrigation but also abstraction for MIT. The reduction plan in the Amman/Zarqa basin, recommended by USAID, would be taken into account.

- A water quality conservation plan would be developed making use of the national monitoring system for surface water and groundwater recommended by the USAID Study (WQICP)

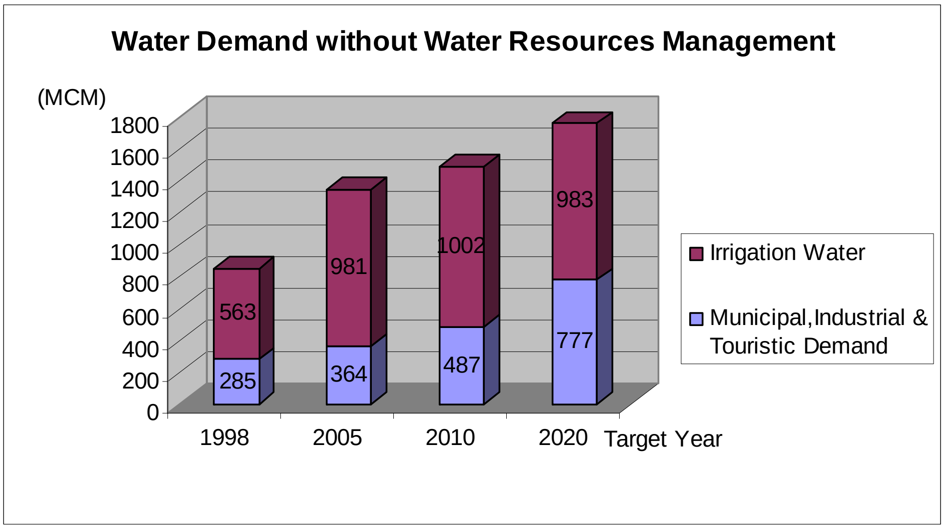
- Institutional and legislative requirements would be reviewed in the light of the Water Resources Management Master Plan.

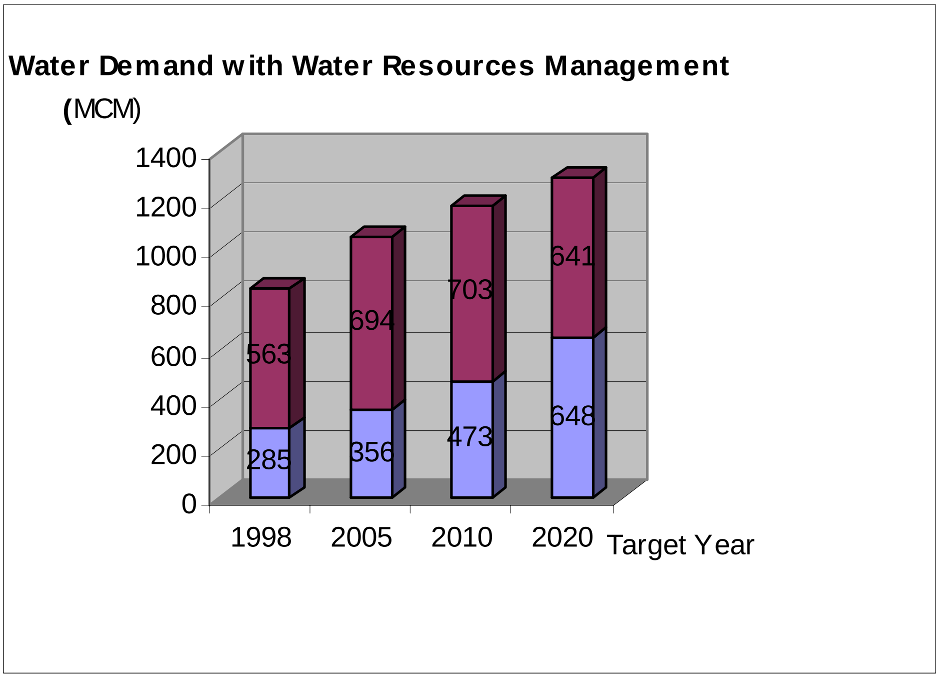
Water resources management plan

A number of scenarios were examined for future development and management of resources. Figure 3.1 below shows the preferred scenario and the estimated increase in water resources available in the period to 2020. These would arise from developing a number of conventional and non-conventional water resources.



Figures 3.2A and 3.2B show how water demand will have to be limited in the irrigated agriculture sector to ensure that, even with the increased development of resources, the demand does not exceed the available supplies.





3.2 Water policy and management plans: Shoubak - Al Jafr

The Study on Water Resources Management examined both national priorities and the broad water balances for individual Governorates.

The Shoubak - Al Jafr area is within the Governorate of Ma'an. The Plan envisages a national growth of the water allocation for irrigation in Jordan up to the year 2010 (to 703Mm^3/a) followed by a reduction to 641 Mm^3/a to below present levels by 2020.

The plan indicates that allocation for irrigated agriculture in Ma'an Governorate should be reduced from 46.4 Mm^3/a in 2005 to 13.4Mm3/a in 2020.

(The plan also considers an alternative target demand which would fulfil the maximum agricultural development of schemes envisaged. This is considered as a "target demand for irrigation water" although in practice it looks unachievable. Under this scenario irrigation water demand for all Jordan would grow from 551Mm^3/a to 960Mm^3/a in 2020. the Ma'an demand would rise from 46.4 Mm^3/a to 84 Mm^3/a by 2020).

Reduction plans for renewable groundwater abstraction

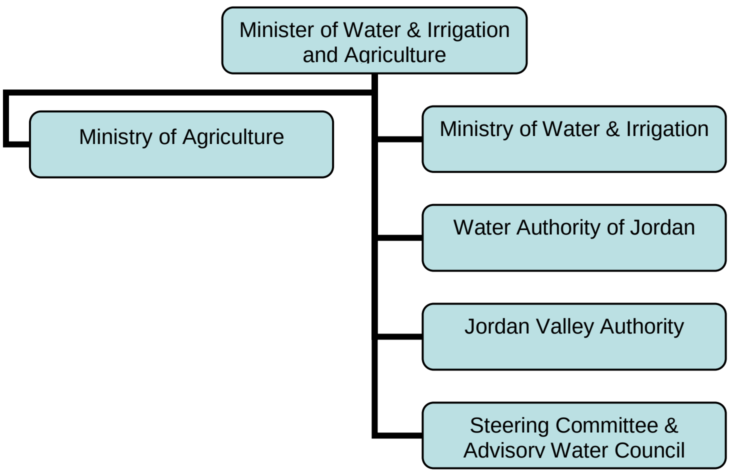
The reduction in the renewable groundwater abstraction is discussed as an imperative in any future plan if the resources are not to become exhausted. In the Water Resources Planning Study by USAID (2001) on the Amman/Zarqa basin (Ref. 11) a number of possible reduction measures are discussed. These include:

- Well buy-outs
- Enforcing abstraction limits
- Exchange of groundwater to recycled water
- Developing irrigation advisory services

The study suggests that the expected possible reduction rates for these measures could be as follows: well buy-outs (25-33%); enforcing abstraction limits (25-33%); exchange of groundwater to recycled water (17-25%) and irrigation advisory services (8%).
The cost of well buy-outs (2001) was estimated on the basis of the annual production of wells and the unit cost of buy-out as between 0.5 – 1.1 JD/m^3 (0.7 – 1.6 US$/m^3)

3.3 Institutions

The organisational structure of the Water Sector is given below:



The Ministry of Water and Irrigation was formed in 1992, under Law No 54/1992. Its main objective was to centralise the national management of water resources which were previously regulated by multiple agencies (WAJ, JVA, Ministry of Agriculture and Ministry of Health). The MWI was given the responsibility of distributing and regulating the water resources in Jordan and for settling disputes between agriculturalists and water supply authorities.

The Water Authority of Jordan (WAJ) is responsible for construction, operation and maintenance of water supply and sewage facilities and for national water resources management plans.

The Jordan Valley Authority from 1977 has been the prime authority for planning and implementing water supply services in the Jordan Valley. Subsequently, JVA extended its role to infrastructure development in the Valley (to include water electricity, land and municipalities).

3.4 Legislation and regulations

The principal. Laws, ordinances and regulations related to the abstraction, use and conservation of water in Jordan are:

- Water Authority Law No 18 of 1988 and Amendments thereof, Law No 62 of 2001
- Municipal Wastewater Law No 12 of 1977
- Underground water control By-Law No 26 of 1977

The most recent legislation relating to the abstraction of groundwater in Jordan is By- Law No. (85) of 2002: Underground water Control By- Law, (Ref. 12) issued in pursuance of Articles 6 and 32 Of the Water Authority Law No. 18 of 1988. The key articles and clauses of this legislation are as follows:

General Provisions

Article 3:

1. The underground water is owned and controlled by the State. Extraction or utilization thereof is prohibited except by license issued under this By-Law prescribing therein the usage, the extraction quantity and any other condition.
2. Ownership of the land does not include ownership of underground water therein. The license to extract water issued to the landowner is considered merely as a permit to utilize it within the license conditions.

Article 4:

1. The Ministry performs the technical studies, the discovery of water resources, the monitoring of the quality and quantity thereof, the identification of these resources and the utilization thereof. .
2. The Board on the submission of the Minister determines the maximum quantity of the underground water permitted to be extracted annually from each ground water basin within the limits of safe yield.
3. The regulatory measures for ensuring safe extracting from any water basin shall be determined by the Board in coordination with the Ministry of Agriculture, which defines the arable area of the land from which the water is extracted and the quantities of water needed for its irrigation in the light of the sort of the crops and the irrigation methods used for this purpose.

Article 5:

The competent officials nominated by the Minister or the Secretary General, shall have the right to enter any land for conducting studies or investigation or collection of information related to underground water or for carrying out any measures required by this By-Law.

Article 6:

1. The areas where drilling of wells is prohibited shall be defined by a resolution of the Council of Ministries upon recommendation by the Board, provided such resolutions shall be published in the Official Gazette and in two local daily news papers.
2. As an exception to the provisions of clause "A" of this article, in the case where the Ministries, Governmental Departments, Official Institutes, Universities, and industry and tourism sector find it impossible to secure their water needs from the public water supply network the Board may grant any of them a license to drill wells in the prohibited areas pursuant to the provisions of this By-Law.
3. If the person to whom the drilling license was issued failed to commence drilling or to complete same, or to do the pumping test in an area banned after the issuance of the license thereto, the said license shall be deemed ipso-facto cancelled. The Authority shall publish this cancellation by the methods it deems fit.

Article 7:

Without violation of the provisions of The Jordan Valley Development Law in force, the rules governing the construction of public and private water wells, the methods of using the underground water extracted therefrom, and the quantities thereof shall be determined by regulatory decisions issued by the Board upon the submission of the Minister.

The licensing of wells drilling and water extraction

Article 8:
Everybody is hereby prohibited to commence drilling a well or extracting underground water, or changing the specifications of an existing well or drilling a substitute well unless a license to this effect in accordance with the provisions of this By-Law has been obtained.

Article 9:
The license to drill a well should carry out under the supervision of the Authority a pumping test before commencement of the utilization thereof, so that the well production capacity and the water quality may be determined, and an extraction license may be issued in which the allowed pumping quantity annually and the rates thereof is defined. This function should be completed within a period not exceeding six months from the date of the drilling completion. This period may be extended for justifying reasons by a decision of the Board on the submission of the Secretary General.

Article 10:

Any one who is granted a license to extract underground water is hereby obligated to refrain from causing any water pollution or depletion, and to comply strictly with the conditions of the license.

Article 11:

The owner or the possessor of a private well is hereby prohibited to do the following:

1. To irrigate any land other than that specified in the water extraction license or to sell this for irrigation purposes.

2. To sell the water extracted from the well by water-tankers for drinking purposes or any other purpose without obtaining a prior written approval from the Secretary General, or his delegate, and according to conditions outlined for this purpose.

Article 12:

If the ownership of the land where the well is located, is transferred to a new owner, it is not permitted to transfer the drilling or water extraction license to the name of the new owner unless any sums due for the Authority are paid. The new owner shall comply with the license conditions or any additional conditions imposed by the Authority thereon.

Article 13:

The Authority shall have the right-by virtue of Board decision and in pursuance of the legislation in force to take over by acquisition- any public or private well together with an appropriate access thereto, to enable the Authority to utilize same.

Article 14:

The Authority is not entitled to sell, rent or assign any of its wells unless by virtue of a decision by the Council of Ministers on the submission of the Board.

Article 16:

If any areas were found to be polluted or depleted, the Board shall take a decision to set the appropriate measures that will put an end to such pollution or depletion including the rationalization or reduction of the extraction rate, to an extent that would allow the halt of pollution or depletion, and the restoration of the natural balance to the aquifer or to the underground water basin.

Article 17:

On the submission of the Secretary General, the Board may take a decision to the following effect:

1. The cancellation of a drilling or an extraction license, if the license violates any of the conditions therein, and the shutting down of the well until the breach is rectified.
2. The cancellation or amendment of the license condition if the public interest so requires.

Article 18:

1. The Secretary General may take any of the following measures:
   (a) Backfill any well drilled without a license in pursuance of the provisions of this By-Law.
   (b) Backfill any well whose owner did not abide with the conditions of the license granted thereto.

2. The offender shall bear the costs of rectifying the violations specified by clause (A) of this article.

3. If the offender does not rectify the offence set out under clause (A) of this article, the licenses granted thereto shall be cancelled.

Article 19:

1. If any one was caught performing drilling, deepening, cleaning, maintaining or testing any well or extracting water therefrom, or operating or possessing a drilling rig in contradiction to the provisions of this By- Law, a restraint report against him should be made, and the drilling rig and other equipment shall be seized. The offender shall be referred to the competent court to inflict upon him the punishment provided for under this By-Law.
2. The provisions of paragraph (A) of this article cover the owner or possessor of the land where the breach took place. The offender shall bear the costs of the seizure act until a decision by the court is made there upon, without affecting the right of the Authority to remove the offence by administrative means in accordance with of the law.

Article 20:

To enable the Authority to collect its dues by virtue of this By- Law, coordination should be made by the Authority with both the Land and Survey Department and the income Tax Department to make use of the process of transactions through these two departments, by their ascertainment that the transactions submitted to either department by owners of lands with ground water wells, have fulfilled their obligations to pay the amounts due from them to the Authority, in the light of lists containing the names of these persons presented to the said Department from time to time by the Authority.

Article 22:

1. It is hereby prohibited to grant a license for drilling a well for irrigation purposes in a land of an area of less than one hundred dunums provided that the applicant proves his ownership of the land on the date of submitting his application through presenting a real estate registration deed issued by the competent authorities and provided that the provisions of the Jordan Valley Development Law in force are abided with. No drilling licenses may be granted in the Jordan Valley areas unless after consultation with the Jordan Valley Authority.

It is thereby prohibited to grant a drilling license to any person to drill a well on lands owned by the State unless after the approval of the Council of Ministers on the submission of the Board, based on the recommendation of the Minister.

Article 24:

No license for drilling a well for industrial or touristic purposes of for universities use may be granted, unless the applications enclose supporting documents from the competent official bodies within the conditions requested by the Authority. It is prohibited to extract water therefrom except for the purposes for which it was licensed. However, in case either the project or the license thereof is cancelled, the drilling and extraction licenses shall be deemed ipso facto repealed and the license must shut down the well or backfill what was drilled thereof. If the license fails to comply within the time limit fixed by the Authority, the Authority shall have the right to implement the said measures and to go back on the license for the costs plus 25% as administrative expenses.

Article 25:

The distance between a well and another shall be decided by a decision of the Board upon a submission of the Secretary General provided that such distance shall not be in any case less than one kilometer. Provided in this respect the rules in force governing the agriculture units in the Jordan Valley area are complied with.

Article 26:

It is hereby prohibited to issue a license to drill a new or a substitute well, or to deepen an existing well in spring areas unless the drilling site is not less than three km far from the nearest spring, provided that the applicant submits a written undertaking that the extracted water will not have an effect in any way on the average output of the spring. If it was proved that the average output of the spring has been affected or its natural flow has been halted, then the license shall be cancelled by a decision of the Board on the submission of the Secretary General who shall take the necessary measures to backfill the said well.

Article 27:

1. A license for a substitute well shall be granted by a Board's decision on the submission of the Secretary General in accordance with the following conditions:
   (a) The well should be existent and licensed.
   (b) The new license should contain the rules relating to drilling wells in the region and the distances fixed between them.
2. There should be technical and mechanical reasons but not reasons of water scarcity in the first well.
3. The distance between the substitute well and the old well should not exceed 50 meters provided that the distances between the wells in the region are complied with, and that the drilling depth should not exceed the depth of the first well.
4. A license for a substitute well shall not be granted if the preceding well was located in the banned area and was not utilized or was back filled, or the drilling therein did not penetrate the underground water layer. In all instances, the first well shall be deemed as if non-existent.
5. The license for water extraction shall not be granted and shall not be utilized unless the preceding well has been back-filled. If the license does not abide with this condition, the Authority shall have the right by a decision of the Minister to repeal the original and the substitute licenses, and to back-fill the well by administrative measures without the need for the issue of a notice or warning.

Article 28:

Licenses for deepening, cleaning or maintaining an existing well shall be granted by a Board decision in accordance with the following conditions:

1. The existence of technical justifications confirmed by a report from a specialized and authorized engineering or geological office if the need arises.
2. The well depth should be fixed in the license provided it does not exceed the level of the water-layer where the well is drilled, and provided that the drilling does not affect the water layer utilized by the Authority for the drinking purposes.

Article 29:

1. Every owner of a well drilled and tested in accordance with the provisions of this By-Law should obtain before commencement of utilization thereof a license for water extraction issued by the Secretary or delegate containing the conditions that the license should comply with, including the following:

The maximum amount of water that may be extracted from the well within a fixed period of time.
The purpose of water use.
The maximum area that may be irrigated from the water of the well licensed for agricultural purposes.
The installation, at the expense of the owner of the well, of a water – meter after it has been approved and stamped by the Authority. This condition should be complied with prior to the issuance of water extraction license.
Notification of the Authority within a period not exceeding 48 hours in case of non-function of the water-meter. The owner of the well shall reimburse the Authority for the fixed maintenance expenses. Of the water-meter.
Refrainment from taking any measures that impedes the flow of water from the well to water-meter directly for the measurement thereof.
Obligation by the license to pay to the Authority in time the prices fixed for the extracted water.
The keeping by the license of a register-approved by the Authority where all data relating to the well, and extraction process shall be registered regularly in accordance with instructions issued by the Authority the competent Authority officials have the right to inspect this register.

2. The water-meter referred to in paragraph "A" of this article shall be considered sufficient evidence on the extracted amount of water from time-to-time, unless the Authority finds the meter non-operative or has been manipulated with. In such cases, the water quantity shall be calculated in the light of the irrigated area, type of crop, or consumed electricity power and in accordance with rules adopted by the Board for this purpose in coordination with Ministry of Agriculture.

Article 30:

1. It is hereby prohibited to grant more than one drilling or extraction license for one plot of land.
2. No drilling or extraction license may be granted to any person who has been previously given a valid drilling license unless he had commenced drilling work and completed same in accordance with of the previous license.

The licensing of drilling Rigs and Drillers

Article 32:

1. Every person is hereby prohibited to process or use directly or indirectly a drilling rig unless he has obtained a license from the Authority in pursuance of the provisions of this By-Law.

Article 34:

The owners of drilling rigs that are used for petroleum exploration, soil tests or mining are hereby prohibited to perform drilling thereby for the purpose of extracting water, unless after the obtainment of a license to that effect in accordance with the provisions of this By-Law.

Licenses fees, water prices and services charges.

Article 37:

The following fees shall be levied by the Authority for issuance of licenses:

Drilling license	JD (1000) one thousand Jordan Dinars
Renewal of drilling license	JD (500) five hundred Jordan Dinars
Water extraction license	JD (100) one hundred Jordan Dinars
Renewal of extraction license	JD (50) fifty Jordan Dinars
Substitute drilling license	JD (750) seven hundred and fifty Jordan Dinars
Well Deepening license	JD (500) five hundred Jordan Dinars
Well maintenance or cleaning license	JD (300) three hundred Jordan Dinars
Possession or use of a drilling rig license	JD (500) five hundred Jordan Dinars
Renewal of possession or use of a drilling rig license	JD (100) one hundred Jordan Dinars
Driller license	JD (50) fifty Jordan Dinars
Renewal of driller license	JD (10) ten Jordan Dinars

Water prices

Article 38:

Subject to the conditions of the water license and the quantities specified therein for permitted extraction, the prices levied by the Authority for the water extracted annually are fixed as follows:

1. Agricultural water wells

(1) Licensed agricultural wells

No.	Water quantity	Water price
1-	Zero-150 thousand cubic meters.	Free
2-	151-200 thousand cubic meters.	25 Fils per cubic meter
3-	More than 200 thousand cubic meters	60 Fils per cubic meter

(2) The quantities of water that are extracted in Al-Azraq area from wells licensed with specified quantities shall be gratis. The quantities exceeding that up to (100,000 cubic meter), shall be charged 20 Fils per cubic meter, and what exceeds that shall be charged of 60 (sixty) Fils per cubic meter.

(3) The prices of water extracted annually from active unlicensed agricultural wells whose status will be rectified in pursuance of article (41) of this By-Law, shall be as follows:

No.	Water quantity	Water price
1-	Zero-150 thousand cubic meters.	25 Fils per cubic meter
2-	101-150 thousand cubic meters	25 Fils per cubic meter
3-	151-200 thousand cubic meters.	35 Fils per cubic meter
4-	More than 200 thousand cubic meters	70 Fils per cubic meter

1. Wells, which belong to Government Departments, official public institutions, public institutions and municipalities:

a. Twenty-five Fils per cubic meter of water used for agriculture.
b. One hundred Fils per cubic meter of water used for drinking or any other Purposes.
c. One hundred Fils per cubic meter if the water well was designated for drinking purposes and was partly used for any other purposes.

2. 250 Fils per cubic meter of water from wells for industry, production, tourism or university purposes.
3. 250 Fils per cubic meter for the price of the sale of water extracted from wells designated for drinkable water.
4. One hundred Fils for each cubic meter for the price of the sale of water extracted from wells of non-drinkable water.

Service Charges

Article 39:

The Board shall fix the charges to be levied by the Authority for any services rendered to the well owners including the following:

1st- Technical field inspection.
2nd- Supervision of pumping test.
3rd- Monitoring of drilling, cleaning, deepening and maintenance works.
4th- Electrical probing of the well (geophysical logging).
5th- Testing of rock samples extracted from the well.
6th- Testing of well water samples and lab assessment thereof.

Closing and transitional provisions

Article 41:

1st- (1)- the owners of wells, active prior to the coming into effect of this By-Law, whether licensed or unlicensed must adapt their status in compliance therewith within a period not exceeding six months from its coming into effect in order to avoid the responsibility of legal measures taken against them, including the backfilling of these wells by administrative measures.
(2)- the above- mentioned period under item (1) of this clause may be extended for a similar period by decision of the Council of Ministers on the submission of the Minister.

2nd- Notwithstanding the provision of clause “A” of this article if there are economic or social factors justifying continuation of water extraction out of unlicensed wells prior to the coming into effect of this By-Law, the Board, on the basis of principles approved by the Council of Ministers, may approve the extraction of water from these wells for limited periods and on the condition, set out thereby in return for the payment of a sum of one hundred and fifty Dinars for each meter length of the well depth, provided no losses are inflicted on the interest of the neighboring licensed well owners, and provided also that the well owner shall bear any claim for compensation for loss sustained by a third party.

3rd- The approval to extract water granted in accordance with the provisions of clause B of this article shall not be deemed as a drilling license issued under the provisions of this By-Law.

Article 42:

1st- The owner of unactive wells licensed prior to the coming into effect of this By-Law must notify the Authority of their wish not to utilize the well so that the license issued thereto shall be repealed and they shall be obligated to backfill the wells within a period fixed by the Board. Otherwise the Authority shall backfill the well at their expense.

2nd- The owner of unactive, unlicensed and existing wells at the coming into effect of this By-Law, must take the necessary measures to backfill these wells under the supervision of the Authority and at their own expense within a period to be fixed by the Board by an advertisement published for this purpose. Otherwise they shall be subjected to the legal responsibility resulting therefrom.

Article 43:

The Underground Water Control By-Law No. 26 of 1977 is hereby repealed, provided that any instructions issued thereunder shall remain in force until they are submitted.

Glossary of terms

General

Cess	Tax or Rate
Stakeholder	An individual or a governmental, non-governmental or private organisation who has an interest in, would participate in or be affected by the implementation of measures (relating to water resources development)

India

A-K aquifer	Aquifer underlying the Araniyar, Kortalaiyar river basins
Chennai basin	River basin comprising Araniyar, Kortalaiyar, Cooum and Adaiyar rivers
Panchayat	Council of five; village committee (Government system in India)
Taluk	Revenue subdivision comprising several villages; an estate.

Jordan

Dunum	0.1 hectare (1,000 m^2)

Abbreviations and acronyms

General

DFID	Department for International Development, UK
FAO	Food and Agriculture Organisation, Rome
ha	hectare (10,000 m^2)
HP	Horse-power
JICA	Japanese International Cooperation Agency
MENA/MED	Middle East North Africa/Mediterranean
NGO	Non-governmental Organisation
PIM	Participatory Irrigation Management
UFW	Unaccounted for Water
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WHO	World Health Organisation

India

A-K aquifer	Araniyar-Kortalaiyar aquifer
AED	Agricultural Engineering Department (Tamil Nadu)
CMA	Chennai Metropolitan Area
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board (also referred to as Metrowater)
IWS	Institute of Water Studies (Tamil Nadu)
TWAD	Tamil Nadu water Supply and Drainage Board
WRCRC	Water Resources Control and Review Council (Tamil Nadu)
WRO	Water Resources Organisation, Public Works Department (Tamil Nadu)

Jordan

JD	Jordanian Dinar
JVA	Jordan Valley Authority

MIT	Municipal/Industrial/Touristic (sectoral water demand in Jordan)
MWI	Ministry of water and Irrigation (Jordan)
JVA	Jordan Valley Authority
MIT	Municipal/Industrial/Touristic (sectoral water demand in Jordan)
MWI	Ministry of Water and Irrigation (Jordan)
WAJ	Water Authority of Jordan
WIS	Water Information System

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