Proceedings of the National Seminar on Groundwater Governance in Sri Lanka

International Water Management Institute, Colombo, Sri Lanka,
August 15, 2013

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Organized by

International Water Management Institute

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Cover photo by Ranjith Ariyaratna showing extraction of groundwater and irrigating cropland.

Due to time constraints we were unable to contact authors to clarify some sources, acronyms, etc.: Organizer and Coordinator. In addition to the standard request given at the end of this page, if clarifications are needed please contact h.manthri@cgiar.org

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Abbreviations and Acronyms

ADB	-	Asian Development Bank
AUSAID	-	Australian Agency for International Development
Bm^3	-	Billion cubic meters
bgl	-	below ground level
CBO	-	Community base organization
CEA	-	Central Environmental Authority
CKD	-	Chronic kidney diseases
DANIDA	-	Danish International Development Agency
FINNIDA	-	Ministry of Foreign Affairs - Development Cooperation
DSD	-	Divisional Secretary Division
DSWRPP	-	Dam Safety and Water Resources Planning Project
GDP	-	Gross Domestic Product
GIZ	-	The German Society for International Cooperation
GW	-	Groundwater
IFS	-	Institute of Fundamental Studies
IIMI	-	International Irrigation Management Institute
IPL		Intense pulse light
IRDP	-	Integrated rural development project
IWMI	-	International Water Management Institute
I&WRM	-	Irrigation and water resources management
JICA	-	Japanese International Corporation Agency
JKWSSP	-	Jaffna Kilinochchi Water Supply and Sanitation Project
JMC	-	Jaffna Municipal Council
JWRMC	-	Jaffna Water Resources Management Committee
LAA	-	Legal Aid Agency
NGO	-	Nongovernmental Organizations
NORAD	-	Norwegian Agency for Development
NWS&DB	-	National Water Supply & Drainage Board
SIDA	-	Swedish International Development Agency
SW	-	Surface water
SWL	-	Static water level
UN	-	United Nations
UNICEF	-	United Nations Children's Education Fund
WB	-	World Bank
WRB	-	Water Resources Board

Contents

1. Objectives

The objective of this seminar is to take concrete steps towards the development of practical policy and management options to govern groundwater management in Sri Lanka in order to protect vulnerable and valuable groundwater resources from over-exploitation and contamination, and to sustain groundwater resources for drinking, health, agriculture and other economic activities.

Sri Lanka is considered as a country rich in water resources. It receives rains from both the northeast monsoon (September to January) and the southwest monsoon (February to June). People in most parts of the country depend mainly on surface water for their entire water requirements. Areas like Jaffna, Mannar, Dambulla, Matale and Kalpitiya are dependent on groundwater mainly for agricultural requirements and partly for other requirements. However, surface water helps recharge of groundwater and its availability reduces surface water usage. Hence, managing groundwater needs to be done in conjunction with surface water as these two are interdependent.

During the last two to three decades groundwater development has increased rapidly. That it was available in abundance is a false assumption. Research studies have revealed that groundwater is faced with the threat of diminishing and polluting due to over-extraction and untreated waste being disposed of by householders, industries and hotels.

Over-extraction of groundwater encourages intrusion of seawater creating the problem of rising salinity. Levels of nitrates and other hazardous minerals are also of concern, threatening human health and endangering fauna and flora. These contaminants could even have a negative effect on agricultural production by bringing about plant diseases and reducing yields.

The situation at present is serious, but far from hopeless. Sound and sustainable groundwater management could guarantee supplies for generations. But key stakeholders need to act now. There is a real need for more sustainable utilization of groundwater in Sri Lanka, guided by suitable regulations and operational plans based on the hydrogeological and geochemical situation. In order to fulfill these requirements it is necessary to establish a groundwater monitoring network, develop a groundwater model for the region, study the spatial variation of water quality of the area and prepare groundwater vulnerability maps and reports incorporating information on land use and land management practices.

To support this process IWMI planned to conduct two meetings: one in Jaffna, held on 1 May, 2013, and the other in Colombo on 15 August 2013. The objectives of the meetings were:

- To highlight the importance of current groundwater utilization trends and the related issue of pollution and the need to address such issues with firm evidence.
- To explore potential options for more sustainable use and management of groundwater in the country with decision makers in all stakeholder sectors.

2. Summary

The seminar was graced by Hon. Minister Nimal Siripala de Silva, Minister for Irrigation and Water Resources Management and Hon. Minister Mahinda Yapa Abeywardena, Minister for Agriculture with the participation of a large number of key stakeholders representing the government institutions, the private sector, universities, international nongovernment organizations (INGOs), nongovernment organizations (NGOs) and funding agencies. All of them agreed that groundwater in the country should be protected and preserved by implementing a sustainable management program. This is an encouraging sign of their recognition of the need for groundwater management.

The theme of the seminar was groundwater governance with due consideration to health aspects as polluted groundwater is suspected to have contributed to some diseases prevailing in the areas where groundwater is widely used for drinking.

All the presentations made including the keynote address were based on recent research, and the presenters were keen to share their findings, find solutions to problems and implement them in

partnership with others to help resolve the problems of groundwater in the country. The National Water Supply & Drainage Board (NWS&DB), Water Resources Board (WRB), International Water Management Institute (IWMI) and the Institute of Fundamental Studies (IFS) had conducted extensive research studies. Some serious health problems were suspected due to the consumption of polluted groundwater; hence, immediate remedial actions are required before this situation gets worse and irreversible. Therefore, establishing governance for groundwater in the country facilitated by the local political authority as well as by all the stakeholders has become essential.

Considering the situation prevailing in Jaffna Peninsula, pipe-borne water for the people there is an urgent need. Implementing the North Central Canal Project, which will bring Mahaweli River water to Iranamadu tank to replace the piped water to Jaffna through the Jaffna-Kilinochchi Water Supply and Sanitation Project (JKWSSP), was heartening news for all. Expanding industries while preserving groundwater was stressed at the seminar held there. The immediate attention of the Central Environmental Authority (CEA) and other relevant organizations was earnestly requested in this regard.

With a view to achieving the final objective of establishing governance for groundwater, discussions involving all stakeholders were conducted on the following three topics:

- Legal, institutional and policy links.
- Monitoring, research and training.
- Public awareness and participation.

Thus the outcome of the seminar can be said to fairly represent the opinions of all stakeholders. Both Dam Safety and Water Resources Planning Project (DSWRPP) and JKWSSP have recognized the need for improved regulation for groundwater. Efforts being made by the WRB and NWS&DB through the above two projects with the facilitation of IWMI will help ensure successful and sustainable groundwater governance. The active participation of all important stakeholders was a promising sign of the successful implementation of the intended program.

Two seminars were conducted at IWMI on this topic prior to the one held in Jaffna. All three seminars were well attended and the facilitation process to be played by IWMI was welcomed by all. It was reinforced at this seminar.

3. Outcomes of the Meeting

1. The groundwater management committees established by the WRB throughout the country, which are already functioning under the Chair of each Divisional Secretary, are to continue as they are, facilitated by IWMI.
2. The Jaffna Water Resources Management Committee (JWRMC) established under the JKWSSP and under the Chair of the Government Agent (Jaffna) is to continue with frequent meetings with the addition of some other important stakeholders, facilitated by IWMI.
3. Further discussions to be held on the experiences of others managing scarce water resources in the global context, whilst recognizing the uniqueness of groundwater resource in Sri Lanka.
4. Agreed-upon rules to be followed for sustainable and equitable groundwater management to suit the current situation and mitigation of pollution threats.
5. Reducing demand on aquifers by making the most of other water sources such as rainwater, water reuse, plowing before rains, wastewater for irrigation, etc.
6. Informing, educating, training and collaborating with the public and all other stakeholders. Encouraging further research and continuing to have regular meetings with all stakeholders to present research findings.

Areas recognized for research are:

- Areas where artificial recharge of groundwater is possible/required.
- Areas of high groundwater potential.
- Areas with chronic kidney diseases (CKD) and nitrates, and salinized areas.
- Effects on groundwater due to climate changes.
- Identifying sensitive and vulnerable areas of groundwater pollution due to natural and anthropogenic reasons.

Areas recognized for training are:

- Capacity-building of institutions as well as human resources.
- Applications of software for groundwater management such as groundwater modeling, Geographic Information Systems (GIS) and hydrogeological modeling.
- Investigations for groundwater aquifers through geophysics.
- Training for all officials in order to keep everyone informed of what is happening.

7. Proposal to form a National Projects Overseeing Committee to govern groundwater. The position of Secretary to the Treasurer has been proposed as the Secretary to the Committee. All other secretaries are at the second level. The third level occupies representatives from Chief Secretary, CEA, WRB, NWS&DB, Geological Surveys & Mines Bureau, Divisional Secretaries, and the Local Government. The Agrarian Development Department will participate at the regional level.
8. In order to implement the management system it is necessary to have a legal framework. It is proposed to review the present system and a suitable one with improvements suggested in order to implement it easily.

4. Agenda

Inaugural session:

8.30 a.m. - 9.00 a.m.	Registration
9.00 a.m. - 9.10 a.m.	National anthem and lighting of traditional oil lamp
9.10 a.m. - 9.15 a.m.	Objective of the seminar
9.15 a.m. - 9.25 a.m.	Welcome speech by Dr. Peter McCornick, Deputy Director General-Research, IWMI
9.25 a.m. - 9.35 a.m.	Address by Eng. Upali Wickramarathne, Additional Secretary, Ministry of I&WRM
9.35 a.m. - 10.05 a.m.	Keynote address by Dr. Tushaar Shah, Senior Fellow, IWMI, India
10.05 a.m. - 10.20 a.m.	Refreshment/Tea break

Session I: Getting prepared to meet challenges of groundwater in Sri Lanka

Chaired by Dr. Peter McCornick, Deputy Director General (Research), IWMI

10.20 a.m. - 10.40 a.m.	Overview of Efforts of Water Resources Board by Mr. G.R.R. Karunaratne Assistant General Manager, Hydrogeology, WRB.
10.40 a.m. - 11.00 a.m.	Groundwater Development for Potable Water Supply by Eng. D.N.J. Ferdinando, Additional General Manager and Mr. M. Premathilake, Manager - Groundwater Studies, Hydrogeologist, NWS&DB.
11.00 a.m. - 11.20 a.m.	Managing Aquifers of Jaffna by Mr. S.M. Croos, Consultant, JKWSSP.
11.20 a.m. - 11.40 a.m.	Agro-wells for Ending Rural Poverty - Dr. Madar Samad, Theme Leader, Theme IV (Water & Society), IWMI, Colombo.
11.40 a.m. -12.00 noon	Fluoride and Hardness by Mr. J.P. Padmasiri, Consultant, IFS, Kandy.
12.00 noon - 12.20 p.m.	Challenges of Groundwater Management in Sri Lanka - Dr. Karen G. Villholth, Senior Researcher, IWMI, South Africa.

12.20 p.m. - 12.30 p.m. Discussion
12.30 p.m. - 12.40 p.m. To be graced by Hon. Minister Mahinda Yapa Abeywardena, Ministry of Agriculture
12.40 p.m. - 12.50 p.m. To be graced by Hon. Minister Dinesh Gunawardana, Ministry of Water Supply and Drainage
12.50 p.m.- 13.00 p.m. To be graced by Hon. Minister Nimal Siripala de Silva, Ministry of I & WRM
13.00 p.m. - 13.40 p.m. Lunch break

Session II: Learning from International Experience
Chaired by Dr. Tushaar Shah, Senior Fellow, IWMI, India
13.40 p.m. - 14.00 p.m. Developing and Managing Groundwater under Challenging Conditions: The Case of Lao PDR by Dr. Paul Pavelic, Principal Researcher, IWMI, Lao PDR
14.00 p.m. - 14.20 p.m. Technical Challenges and Solutions for Sustainable Groundwater Management – An International Perspective by Dr. S.A. Prathapar, Principal Researcher, IWMI, India
14.20 p.m. - 14.40 p.m. Prepaid Meters in Irrigation Management Systems, especially for Sustainable Groundwater Management by Dr. Asaduz Zaman, Consultant, Asian Development Board (ADB), Bangladesh
14.40 p.m. - 15.00 p.m. Discussion
15.00 p.m. - 15.15 p.m. Refreshment/Tea break

Session III: The Way Forward
Chaired by Eng. Upali Wickramaratne, Additional Secretary, Ministry of I & WRM
15.15 p.m. - 15.20 p.m. Introduction on the Session by Dr. H. Manthrithilake, Head, Sri Lanka Development Initiative, IWMI.
15.20 p.m. - 15.50 p.m.Group Discussion facilitated by Elizabeth Weight, Global Science Uptake Coordinator, IWMI, Colombo
15.50 p.m. - 16.05 p.m. Presentation by Group 1 (Legal, Institutional and Policy Frameworks)
16.05 p.m. - 16.20 p.m. Presentation by Group 2 (Monitoring, Research and Training)
16.20 p.m. – 16.35 p.m.Presentation by Group 3 (Public Awareness and Participation)
16.35 p.m. - 16.50 p.m. Summing-up by Chairperson
16.50 p.m. - 16.55 p.m. Closing
17.00 p.m. - 19.00 p.m. Further Refreshments

5. Introduction to the seminar by Dr. Manthrithilake Herath, Head, Sri Lanka Development Initiative, IWMI

Good morning!

I thank you all for accepting our invitation at short notice and joining us here today. We have a wide range of participants representing different, but all, sectors of society. Some participants have come all the way from Jaffna, and others have come from Kandy and other places as well. All of them are very senior-level personalities. We welcome all of you to this National Seminar on Groundwater Management.

We had a similar seminar on groundwater in Jaffna as well. You can see behind me some photographs of that very successful seminar we had in Jaffna. We focused on groundwater management in the Peninsula. We had studied the groundwater situation and agro-well developments in Jaffna, Kalpitiya and Medawachchiya areas.

Often, we talk on the management of surface water but we have paid very little attention to groundwater. There are many issues coming up like abandoned wells due to lack of water, contamination,

over-extraction and saltwater intrusion, health impacts (Blue babies, kidney diseases and stomach cancers are reported), etc., with regard to the use of groundwater.

In the global context there is plenty of groundwater. But its availability in Sri Lanka is about 5% of usable water. Groundwater is being used mainly for domestic purposes, but largely used for agriculture and other purposes. Hence, it is essential to protect and manage groundwater properly, especially to face drought periods. Line agencies are working hard to manage it sustainably. WRB is fully focused on investigations and establishing a monitoring system and NWS&DB is using groundwater for rural water supply. Other uses are private in nature. However, there are limitations with regard to funds, recruitment, and trained staff, etc., for these organizations to achieve their targets. That is why we have initiated a support scheme to them and are working as a team to improve, with the help of any funder, the governance of groundwater.

Today, we will hear what our neighboring countries India, Bangladesh and Lao PDR are doing along with our own two agencies so that we can learn from them about managing groundwater as some of them are ahead of us. Today, the first session shall deal with managing groundwater. Then we will think together about how we can go about helping national agencies, ministries, etc., for them to become better and stronger.

I need to tell you that we expect four ministers to attend this meeting. They promised to come here after the Cabinet meeting. They are, the Hon. Minister of Irrigation and Water Resources Management, Hon. Minister of Water Supply and Drainage, Hon. Minister of Agriculture and Hon. Minister of Health. They may come in the middle of our sessions. So, there may be a few interruptions in the proceedings, in order to receive them. With this short speech I hand over the Chair to the Deputy Director General of IWMI. Wish you all a very fruitful day!

6. Welcome speech by Dr. Peter McCornick, Deputy Director General-Research, IWMI

Good morning, distinguished guests, ladies and gentlemen, colleagues and friends!

On behalf of the International Water Management Institute, it gives me great pleasure to welcome you all to IWMI's international headquarters, and particularly to this workshop on groundwater governance in Sri Lanka.

As many of you are aware, IWMI was established in 1985 by an act of the Sri Lankan Parliament. We are one of 15 international agricultural research institutes of the Consultative Group on International Agricultural Research (CGIAR), but the only international organization headquartered here in Sri Lanka. Our mission is to improve the management of water and land in developing countries. We are affiliated with the Ministry of Irrigation and Water Resources Management in Colombo, and also work with a number of other agencies in the country, many of which are represented here today. We primarily work in Asia and Africa, with considerable experience in groundwater management and governance, most notably in India, and more recently in South East Asia, sub-Saharan Africa and Central Asia.

In many key food producing areas of the world, intensive groundwater use has been, and continues to be, a dominant factor in increasing production. Through the development of groundwater, the livelihoods and food security of millions of farm families in Asia and Africa have been improved. In Asia, groundwater development for agriculture has occurred with greater social and spatial equity than investments in large-scale irrigation. However, this development, which has largely been unplanned, is faced with a number of challenges, and the longer-term sustainability of the resource is difficult to determine. Despite these concerns, the pressure on groundwater continues to rise.

Sri Lanka has a very long history in managing water, with water systems dating back to more than 2,000 years, some of the earliest developments and innovations on small tank systems, and the more recent large-scale developments in irrigation and hydropower of the Mahaweli system. Now, with access to new technologies and growing markets for food and agricultural products, and other demands placed on the resources from other sectors in a growing economy, water management in Sri Lanka is going through yet another transformation.

In many ways, Sri Lanka is experiencing challenges similar to those the world at large is experiencing in sustainably managing its natural resources. If anything, the drivers of change, including economic growth, effects of climate change and the demand for more food are occurring faster than experienced elsewhere. This offers an important opportunity for Sri Lanka to learn from the difficulties experienced by other countries, avoid their mistakes, and develop solutions that meet the needs of Sri Lanka. Drawing on lessons from the past and experiences elsewhere, how does Sri Lanka address the challenges ahead, to grow its economy and ensure equitable access to water and development opportunities for its people?

As I suggested above and as we will hear during this workshop, groundwater has been a particularly important resource in reducing the uncertainty in enhancing agricultural productivity and in providing rural livelihoods for the poor. However, it is widely taken for granted, and the development of this resource has raised new challenges, especially with regard to its sustainability.

Sri Lanka recognizes these challenges. The President's Vision, or Mahinda Chintana, identifies research needs with an emphasis on cooperation with support to "*development and exploitation of surface and groundwater, maintenance of the water quality and supply of water for social, economic and environmental needs on a sustainable basis.*" The country has already achieved the 2015 Millennium Development Goal targets for water and sanitation, and has already established goals to reduce the portion of water diverted to agriculture.

From IWMI's earlier work here in Sri Lanka on improving the management of irrigation systems, we now have a growing program focused on critical challenges in managing water resources. Working closely with a number of partners within the country, our present program focuses on four main areas:

- Improving agricultural water use and productivity.
- Helping to better manage floods, droughts and climate change impacts.
- The sustainable management of natural resources and ecosystems. Capacity development for management and sharing of knowledge.

Within this Sri Lankan program we are establishing a common information system on water for Sri Lanka, improving the management of human waste with improved policies on wastewater and sludge management and, especially relevant to you all today, promoting the sustainable governance of groundwater resources.

In Sri Lanka we have focused our research on groundwater use in response not only to the significant opportunities that it provides but also to the risks that need to be mitigated – risks of over-abstraction or unsustainable 'water mining', and of pollution, whether by intrusion of saline water or contamination from industrial, urban or agricultural sources. In May of this year I had the pleasure of participating in a workshop in Jaffna, where IWMI and partners explored issues and opportunities to manage the particularly fragile groundwater resources in that area.

As I mentioned above, groundwater governance has been an important part of IWMI's global research program for over a decade. In addition to our Sri Lankan-based researchers, we also have a number of our key groundwater experts present here today, including Dr. Tushaar Shah who has pioneered our work in India, Dr. Karen Vilholth from our southern Africa office, Dr. Paul Pavelic from our South East Asia team, and Dr. Prathapar, who is presently based in India but moving here next month. Drawing on this expertise and of others in this workshop, we look forward to strengthening existing partnerships and developing new linkages with the Government of Sri Lanka, other national and international organizations, universities and community organizations to develop solutions to effectively govern the groundwater resources.

Again, welcome all to IWMI-HQ and this workshop, and thank you.

7. Address by Eng. Upali Wickramaratne, Additional Secretary, Ministry of I&WRM

Good morning. Dr. Peter McCornick, Deputy Director General of IWMI, Dr. Manthrithilake, distinguished invitees, ladies and gentlemen. I am representing Eng. Ivan de Silva, Secretary of I&WRM who is unable to participate at this seminar due to an important and urgent undertaking at the ministry. First of all, I would like to thank IWMI for inviting me to this seminar on behalf of the Secretary, I&WRM.

You may be aware that we have inherited a long hydraulic civilization which goes back to 2,500 years. All our ancient projects were developed for harnessing surface water resources, but very little has been mentioned about the development of groundwater. Although groundwater has been used for generations in the Jaffna Peninsula nothing much has been done for its real exploration. In the early 1990s, the first assessment of groundwater was done in the hard rock region of the Vavunia District. In the early 1950s, the Irrigation Department started a groundwater project in Vanathavillu mainly for cashew cultivation. WRB, one of the institutions under our ministry has done many studies on groundwater.

We have already completed feasibility studies to develop and utilize all possible surface water resources. So what is the next option available for the country to meet the increasing demand of water? Our ministry has to prepare the water resources plan for the country to realize our millennium development goal to provide access to safe drinking water for all by 2025. Now we are working together with NWS&DB to reach that goal. The other millennium development goal is alleviating poverty. To realize this we need to use surface water and groundwater potential as much as possible and perhaps rainwater harvesting to increase the production of the available lands as we have problems of developing new lands. As Dr. Manthrithilake said in his speech we have a good groundwater source for meeting our water needs. We receive 1,900 mm of average rainfall per year. So the total rainwater that falls over the island is 120,000 million cubic meters (Mm^3). Of this, 45,000 Mm^3 account for surface runoff, and 12,000-15,000 Mm^3 are used for irrigation and other purposes. The estimated groundwater recharge is about 7,000-8, 000 Mm^3 per year. So there is a big potential, but we need more information to plan to achieve our goal. We are progressing well compared to some other countries in achieving the millennium development goals.

We need a good monitoring system for the development of the groundwater management system. As I mentioned earlier, we have done many studies on groundwater. Yet we are lacking real-time data for managing it. Hence, WRB is planning to implement a project to collect these data using a groundwater network in Sri Lanka by establishing 1,300 data loggers covering 103 river basins including Jaffna Peninsula. These collected data will be on the quality and quantity of groundwater. To carry out this work we are discussing with a funding agency to obtain funds through a project. The government has already given the green light to go ahead with the work. When this project is implemented we will have all the information necessary for governance of groundwater. Then we will have data to manage and monitor groundwater resources including addressing problems like contamination, over-extraction, etc. WRB, established in 1966, has been authorized by a parliamentary act to carry out the above work. But it is unable to implement the work without this information on groundwater. However, now we are treading the correct path.

With this, I am concluding my speech without taking your time further.

Thank you very much.

8. Address by Hon. Mahinda Yapa, Minister of Agriculture

The Hon. Minister thanked IWMI for extending him the invitation. He acknowledged that IWMI is the only international organization headquartered in Sri Lanka and praised the Institute for its good work.

He said that though Sri Lanka is blessed with water and has a long history of water management, currently, the country is facing a new problem of clean water for drinking purposes. He referred to

bottled water as a new phenomenon. He invited IWMI to do in-depth studies on this matter, bring in experience from the rest of the world and help manage pollution of drinking water sources.

He explained how farmers are addicted to the use of agrochemicals as fertilizers and the rampant pollution taking place countryside resulting in the fast spreading of kidney diseases around the country. He referred to the observation in a few countries where families were suffering seriously from similar health problems. He has requested IWMI to step in and help in this case.

Finally, he expressed his appreciation to IWMI for inviting him for this important seminar.

9. Address by Hon. Nimal Siripala de Silva, Minister of Irrigation and Water Resources Management (I&WRM)

The Hon. Minister greeted the audience. He welcomed the National Seminar on Groundwater Governance and regretted that he had missed most of the deliberation during the technical session. He said that groundwater is an area which has had no attention whatsoever. This was because the country has been developing mostly surface water for irrigation and drinking purposes. He doubted that there is any drinking water system supplied with substantial amounts of groundwater. Tube wells were popular at one time. But these too had run dry and created environmental problems. In certain areas, farmers were helped with subsidies to construct agro-wells in order to ensure the availability of sufficient water for agricultural needs.

He added that though IWMI had been here for quite some time and the Ministry officials were involved with it, there has been no impact on the Ministry or the Government on groundwater, or on any other topic for that matter, from the research IWMI does. “The overall result in the world from organizations like yours is that only 1-2% of the research benefits the poor and the peasants in the world, and the rest goes for the maintenance of the organizations and research groups. There is very little help for the day-to-day activities and the economy of the people.”

“In any case, with the World Bank-funded DSWRP project, we are able to map where the groundwater is and what its quality is. Yet the project is not well developed.

“In a part of the last presentation, I heard about the challenges of groundwater management. It is good that these experts meet and discuss these issues. However, I am not convinced how that will be translated into action. What is their use for the ordinary farmer? Your assessments have no use unless a vibrant program is developed to attract farmers and groundwater users on how to use the groundwater. We should also come up with a program to recharge groundwater, without sending it over the surface to the sea, so that it can be used for drinking, agriculture and industry. Another problem we face is the kidney diseases. To what extent the polluted water is contributing to this problem is not known. I managed to bring in the WHO to study this. They too, could not find reasons. However, we take care of drinking water supplies assuming polluted water is the cause.

“I also heard that you talk about climate change. This is important. All of your earlier reports and data become useless in this new context. You cannot rely on statistics and predictions based on those statistics. What is the methodology we are going to use? Innovative thinking is needed to supply water for the community.

“I would urge you to do more work like in India and make the community benefit from it. I find that you do not do it here in Sri Lanka. My perceptions do not permit me to praise you. Curtail the scholarships! Curtail the trips aboard! Syphon that money to the periphery! Syphon that money to the people of this country who need it! Have seminars for farmers! A few experts and officials getting together has no meaning if they forget what they talked when they get back to their desks! I observe many officials travel abroad to gain experience, which is not applied in Sri Lanka. Therefore, I urge you to learn here! Gain more experience! Share with others at the periphery! Talk to the press and sensitize all! Because, their participation in this matter is very important! This is something as the Minister I must say to guide you as to what has to be done.

"Your Indian experience is very valid for us. I have studied your work. It has benefited a large number of people. Please collaborate with work which we started in DSWRP project. Publish in all three local languages and tell the world that we are not building only surface water storages.

"We have a dearth of trained irrigation engineers, unlike in Thailand where university education is reformed to suit the needs of the country. We need similar changes here, too. How can we add value to agricultural products? I am not an expert on this. These are a few thoughts that flashed through my mind. I am a lawyer and hope you will take my remarks seriously.

"Thank you!"

10. Keynote address by Dr. Tushaar Shah, Senior Fellow, IWMI, India, on "Groundwater Governance in Sri Lanka: Lessons from Around the World"

Good morning! All the secretaries of ministries of the Government of Sri Lanka, distinguished guests, ladies and gentlemen, I am delighted to be here. I want to congratulate Manthri and IWMI for finally initiating some work on groundwater in Sri Lanka. I have been a groundwater watcher for about 30 years. When I first came to Sri Lanka from India to work as a researcher at IWMI I went around talking to see what work was being done about groundwater. I represented South Asia. Groundwater had come to play a very important role in the agricultural life of this country. But whom should I ask about groundwater in Sri Lanka? Those whom I met said groundwater is not important to Sri Lanka. They have here a hydraulic civilization and large tank and irrigation systems which are thousands of years old.

There was a colleague, Hilmy Sally in the Colombo IWMI office; he and I took off to meet farmers who used hand pumps. But there had to be some lifting of water. At the end of the day Hilmy and I came back and we presumed that about 500 pumps were selling in Colombo around the year 2000. And we gathered that there was a great deal of activities going on. Shop dealers also told us pumps, particularly small pumps, were used to lift groundwater. There was also a good deal of groundwater being lifted from shallow wells. In 2003, we carried out a more systematic study in Sri Lanka. We came with this startling conclusion; there were about 50-55 thousand agro-wells in operation there, of course with variations across regions. So I knew there was a very active groundwater irrigation economy already in place in Sri Lanka. Then we needed to understand how this would work in order for us to manage it. So, I am very glad that we are talking about it today. And I hope it is not only in Jaffna Peninsula but also in other parts of Sri Lanka including in command areas of canal irrigation systems that there is a good deal of groundwater irrigation going on.

When we talk about groundwater governance we need to take necessary steps not only to maximize the benefit of groundwater use but also to minimize the use of harmful attacks on groundwater use. For doing it effectively people should understand not only about the resources or the supply side but also about the demand side. In India and other parts of the world I find too much attention given to it. It is important for us to understand the resources, also who is drawing groundwater, why, in what type, by how many numbers, and the drivers of groundwater demand.

In the next few minutes I will focus only on the demand side of groundwater. I will go into the global picture of the problems we have encountered, and the attempts made to fix them. I hope my discussion would be a kind of complement to what we will be talking today. What is important is the explosive growth of groundwater use and groundwater drought prevailing worldwide over the past 50-60 years. We have no estimate as such but groundwater is mostly used for domestic, agricultural and drinking purposes. Figure 10.1 shows the natural rates of groundwater recharge developed by some international researchers.

Highlights

- Explosive growth in groundwater use today from less than 100 billion cubic meters (Bm^3) in 1950 to more than 1,050 Bm^3 per year.
- Groundwater meets more than 70% of the rural and urban drinking water requirements; "strategic resource."
- Groundwater use in irrigation has grown from less than 50 Bm^3 to 750 Bm^3.
- South Asia is at the forefront of using groundwater irrigation.
- Low-yielding hard-rock aquifers are unfit and not suitable for intensive groundwater use but in 1970 Peninsular India developed these. Now, northern and eastern provinces of Sri Lanka too are witnessing the growing groundwater use in agriculture.
- Since groundwater irrigation expands quietly by private initiative, it is called a "silent revolution."

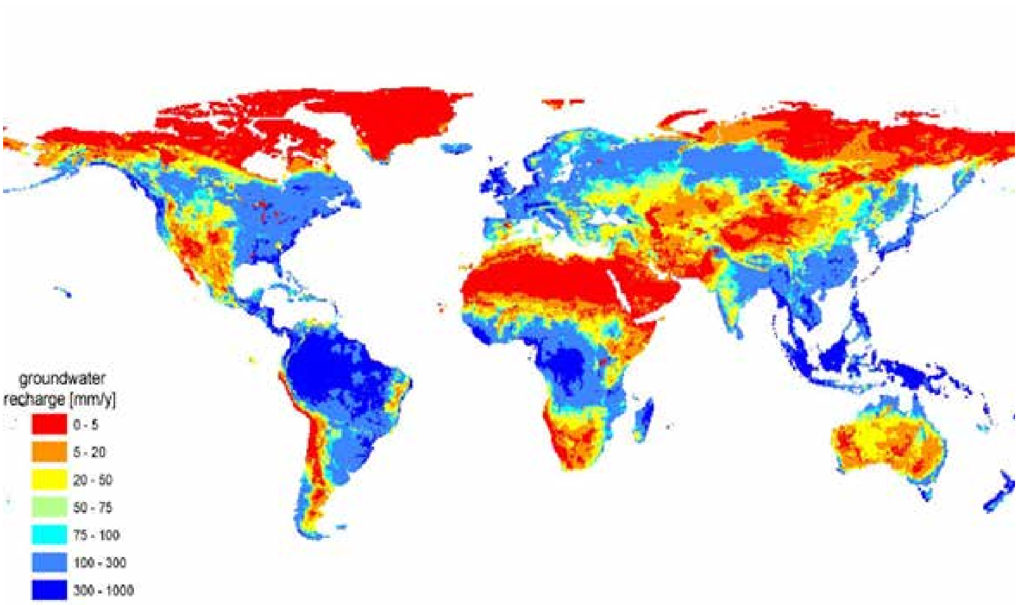


Figure 10.1. Natural rates of groundwater recharge developed by some international researchers.

- Groundwater governance is a "wicked problem." By the time we are ready to do something about groundwater everything that needs to happen has already happened. By the time we understand what is happening there is very little we could do to change it. I think Sri Lanka is in a favorable situation: it is catching up with the revolution.

Groundwater recharge is high in humid areas and low in arid areas. What is important is that intensive groundwater development has occurred around the world. Figure 10.2 shows the long-term average groundwater recharge.

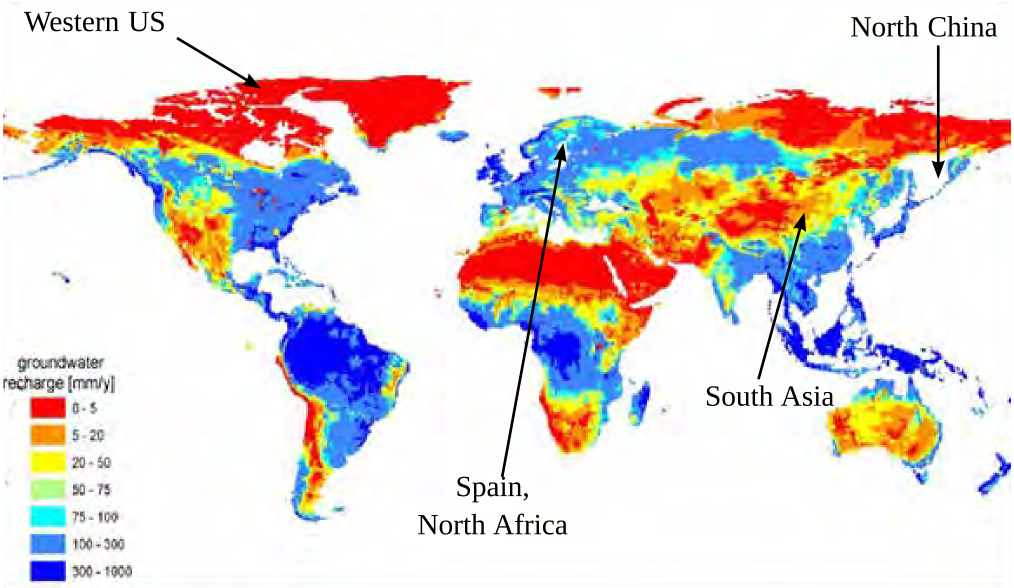


Figure 10.2. Long-term average groundwater recharge.

For decades, groundwater use for agriculture seems to have moved inversely with natural recharge. Eastern India, Bangladesh and Nepal terai have jumped this bandwagon and, now in South Asia, Sri Lanka is following suit.

There are four contexts of agricultural groundwater use: Arid agrarian, industrial agricultural, smallholder intensive farming and extensive agro-pastoral systems (Table 10.1 and Figure 10.3).

Table 10.1. Four contexts of agricultural groundwater use.

	Arid agrarian systems	Industrial agricultural systems	Smallholder intensive farming systems	Extensive agro-pastoral systems
Examples	Jordan, Iran, Saudi Arabia	California, Australia, Spain, Mexico	South Asia, North China	Sub-Saharan Africa, South America
Groundwater use	Mostly nonrenewable	Managed depletion	Unsustainable use	Under-developed resource
Driver	Only source of water	Wealth creation	Intensive diversification	Stock watering
Contribution of groundwater to poverty alleviation	Low	Very low	Very high	High

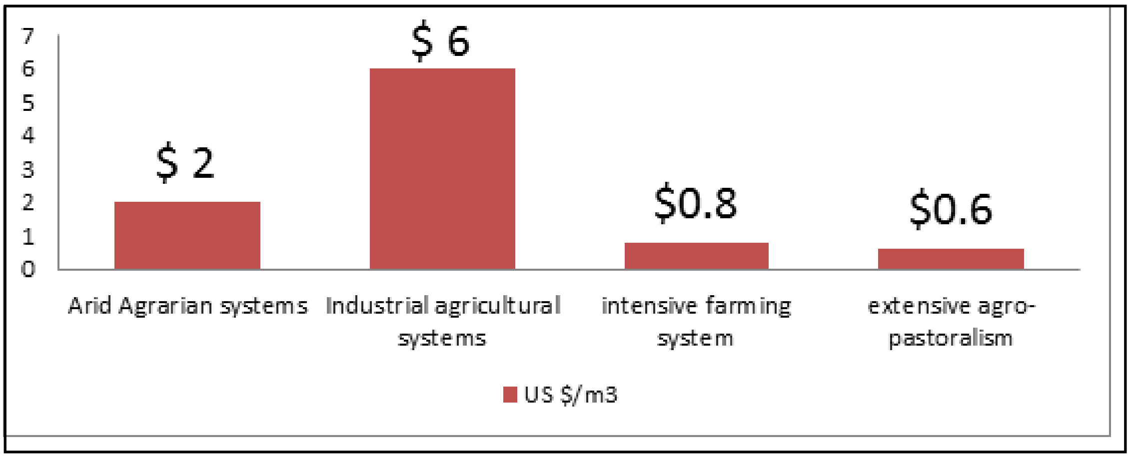


Figure 10.3. Four contexts of agricultural groundwater use.

Groundwater productivity is very high in the US, Australia and Spain, that is in commercialized agriculture. When it comes to South Asia and sub-Saharan Africa it is limited. The groundwater development drive is a consequence of the demographic expansion in the world.

Groundwater population density in 1700 was 5 persons per square kilometer (Figure 10.4), but in 2000 it was about 500 persons. Around 2000 the croplands expanded worldwide to provide food and livelihoods for the people. Basically, expansion of croplands is essentially linked with the demographic expansion ratio and crop limit function (Figure 10.5). Figure 10.6 shows the drivers of groundwater intensive use.

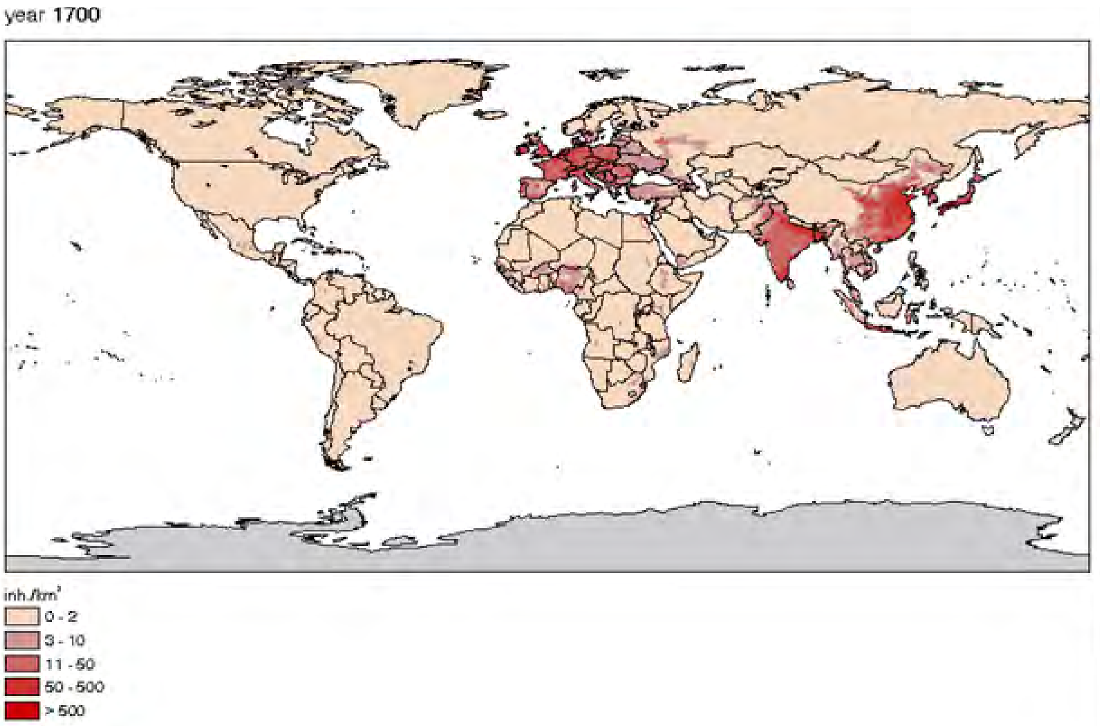


Figure 10.4. Growth in population density around the world (persons/km^2), (year 1700).

Note: inh/km^2 = inhabitants/km^2.

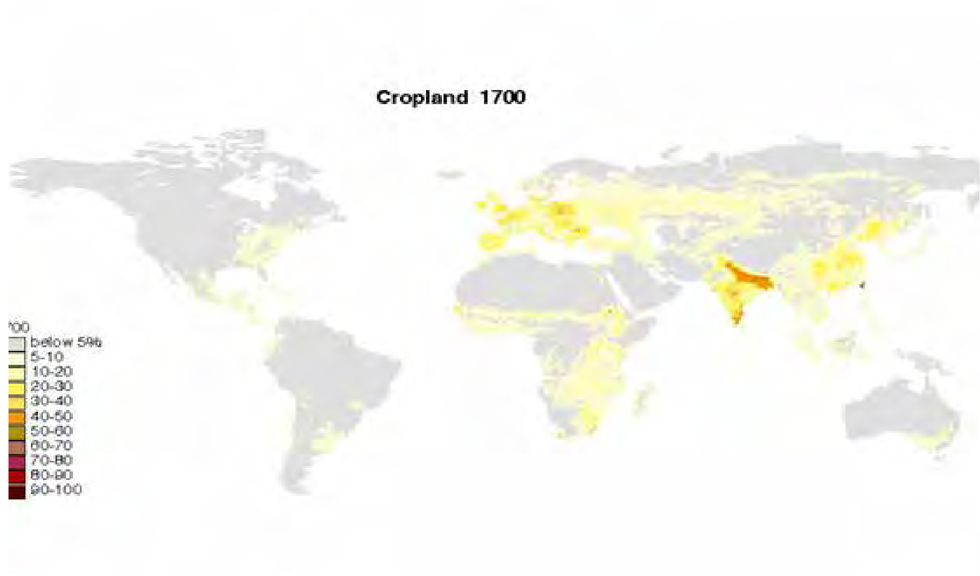


Figure 10.5. Expanding cropland 1700-1990 - Fraction of grid cell in croplands.

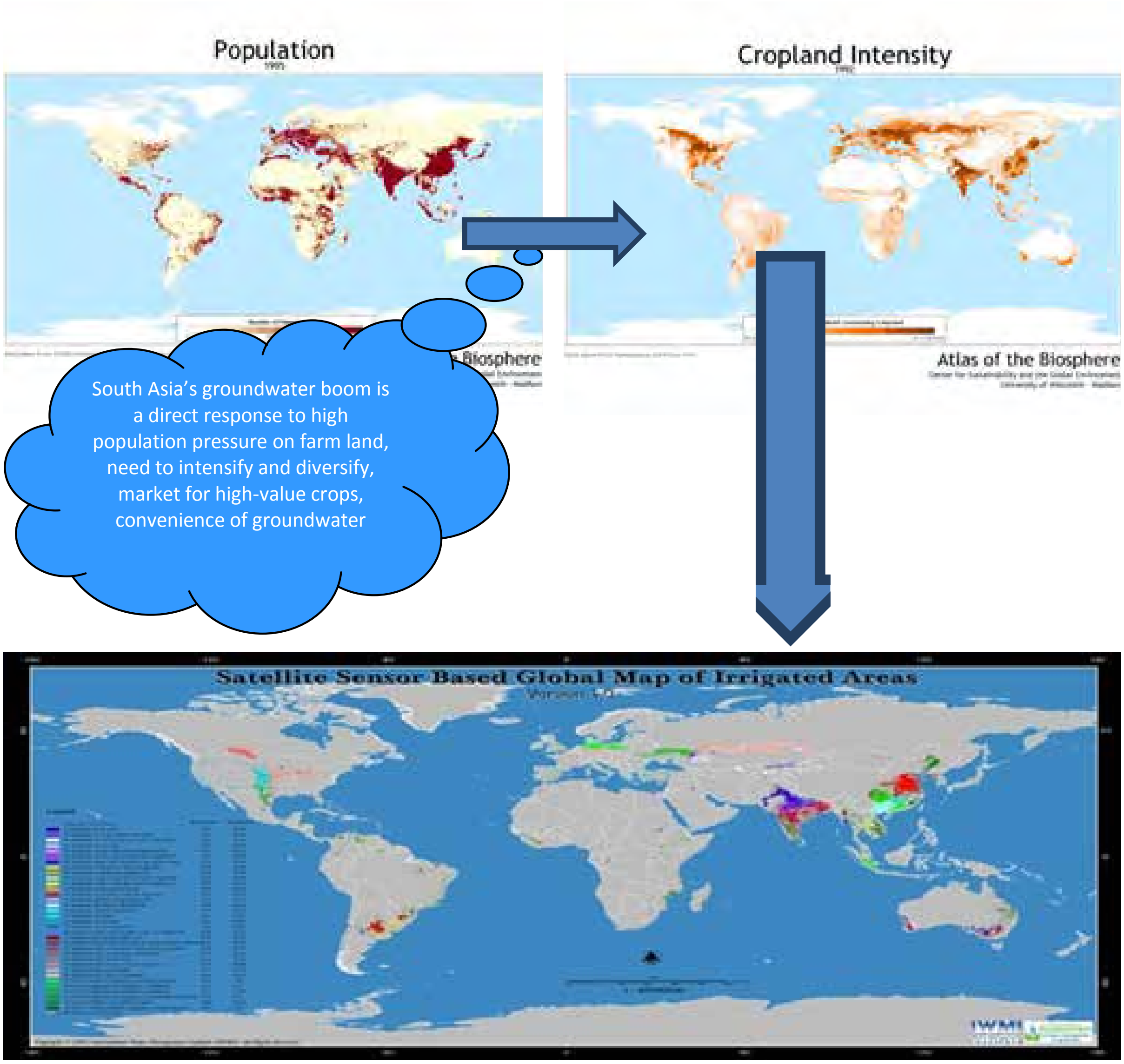


Figure 10.6. Drivers of groundwater intensive use.

Like Sri Lanka, India and Pakistan too invested mainly in surface irrigation. Yet, today, groundwater irrigation has emerged as the mainstay of agriculture in these countries.

In 1960, US and India were the biggest groundwater withdrawers at 100 Bm^3/year and about 20 Mm^3/year, respectively. But today India is withdrawing about 250 Mm^3/year. In 1970, groundwater development was intensive and largely done by private investors. Today, groundwater irrigation has transformed Bangladesh to a rice exporter from a rice importer. Sri Lanka is a rainfall-rich country and the recharge rate of groundwater is high. So no one thought Sri Lanka would develop so much of groundwater for agriculture. In Sri Lanka, highland cultivation in *maha* (during the northeast monsoon) and lowland cultivation in *yala* (during the southeast monsoon) were done with groundwater for high economic crops. The income is 4-5 times in Sri Lanka groundwater farming compared to other South-Asian countries. But India and Pakistan grow rice with groundwater which has no economic sense at all. Figure 10. 7 shows the groundwater use in ten countries.

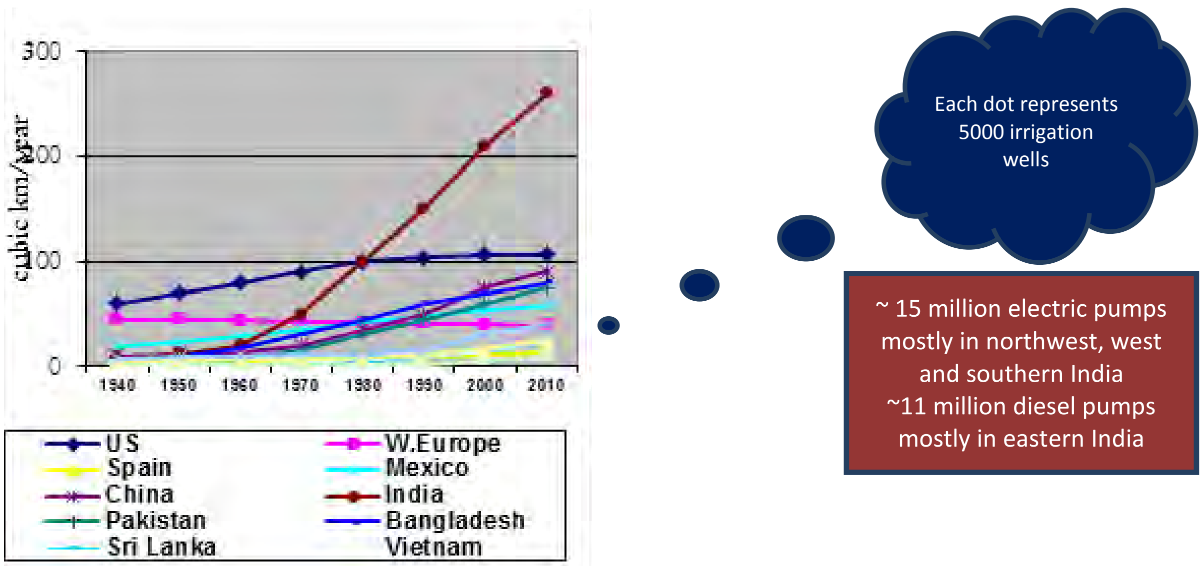


Figure 10.7. Groundwater uses.

Acceleration in agro-well irrigation in dry zones of Sri Lanka

- In an IWMI study Kikuchi et al. (2003) estimated that Sri Lankan farmers had invested Rs 0.8 billion in digging 50,000 agro-wells by 2000. The number of wells is likely 200,000-250,000 by now.
- Agro-wells have transformed highland agriculture and made yala cultivation more lucrative than maha cultivation. A typical agro-well irrigates 0.2- 0.8 hectares (ha).
- In Anuradhapura, agro-wells in one acre of land have irrigated 5-15 acres of irrigated paddy in terms of net farming income.
- The number of agro-wells per 100 ha varied from 2.7 in Ratnapura to 31.2 in Anuradhapura in 2000.

From 1965 to 2000, there has been a meteoric rise in private agro-wells and farmers' investments in agro-wells in Sri Lanka (Kikuchi et al. 2003). Figure 10. 8 shows the groundwater use from 1965 to 2000 while Figure 10. 9 shows the income from groundwater cultivation during the same period.

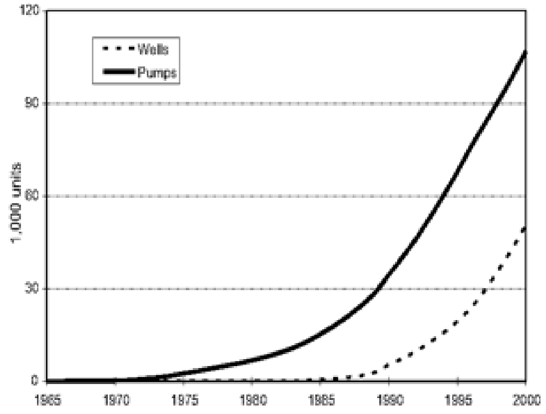


Figure 10.8. Groundwater use.

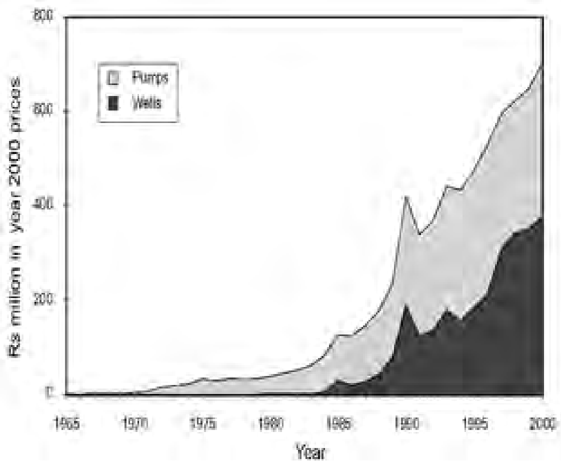


Figure 10.9. Income from groundwater cultivation.

Table 10.2. Agro-ecological transformation of Galenbindunuwewa in Sri Lanka after the boom in agro-wells.

	Before the boom in agro-wells	Now
Lowland maha season paddy cultivation	+++++	+++++
Lowland yala paddy cultivation	+++++	+++++
Supplemental irrigation to rice	++	+++
Mung bean and cowpea cultivation in chena (slash-and-burn) land	+++++	++
Vegetable cultivation	++ only for home consumption	+++++ for market
Other market crops	+	+++++
Cattle	++	+++++
Focus of cattle husbandry	Milk for home consumption; work animals	Milk production for the market
Approach to cattle husbandry	Extensive, based on grazing	Intensive based on stall-feeding
Green fodder cultivation as mulch for cattle	+	+++++
Tree crops	+++	++++

Sri Lanka and Kerala are the only countries that use groundwater for high-value garden cultivation with less environmental impact. But in India groundwater has been depleted creating a groundwater drought. So farmers are deepening the boreholes every year due to lowering of the groundwater level. And this is where groundwater governance is necessary – to manage the demand with its availability.

Everywhere in the world various systems are used to manage groundwater. There had been attempts to price groundwater. In Jordan, Israel and Iran wells are metered and abstraction of groundwater is being closely monitored and farmers have to pay a price. In a pilot project, China had recently introduced a progressive price regime where a farmer has to pay a price if he abstracts more than his entitlement and after that the rate increases (if he abstracts more). Groundwater governance is a very logical tool to achieve a balance between abstraction and availability. It works only where the governments are very persistent. Another method tried is stable groundwater entitlement in the US (in Kansas and Colorado), Australia and Mexico for larger farms. After exceeding one's entitlement he or she has to pay a thinner price, or abstraction from the well will be stopped. This is being monitored using computer systems.

Table 10.3. Four groundwater and livelihoods scenarios in South Asia.

E-I-L Zones of South Asia	Energy footprint	Groundwater structures	Type of agriculture	Net income /ha (US$)	Groundwater externality
Kerala, Dry Zone of Sri Lanka (mostly humid and hard rock)	Very small (500-700 kWh/ha)	Shallow, open wells, 1-2 horse power pumps in millions	Garden cultivation of high-value market crops	US$ 2,000-3,500/ha	Nil or insignificant
Eastern India, Bangladesh, Nepal (humid and alluvial)	Small (800-1,100 kWh/ha)	Shallow tube wells with 5-7 horse power diesel pumps	Mostly rice-wheat; some market vegetables	US$500-1,000/ha	Nil, barring arsenic; opportunity lost
Indian Punjab, Haryana, west Rajasthan (alluvial) Gujarat, Pakistan Punjab and Sind (arid and alluvial)	Very high (5,000-7,500 kWh/ha)	Deep tube wells; 10-120 horse power electric pumps	Mostly wheat-rice; average-value farming	US$800-1,000/ha	Depletion; fluoride and other geogenic contaminants
Hard rock peninsular India (semiarid and hard rock)	Quite high (3,500-5,000 kWh/ha)	Dug-cum-bore/ bore wells with 5-12 horse power electric pumps	Mostly grains and Bt cotton; average-value farming	US $800-1,200/ha	Huge negative

Groundwater-stressed blocks of India

Groundwater-level recovery is tried without harassing individual farmers. A large number of open wells were constructed to collect monsoonal rainwater but farmers were allowed to abstract water only during daytime.

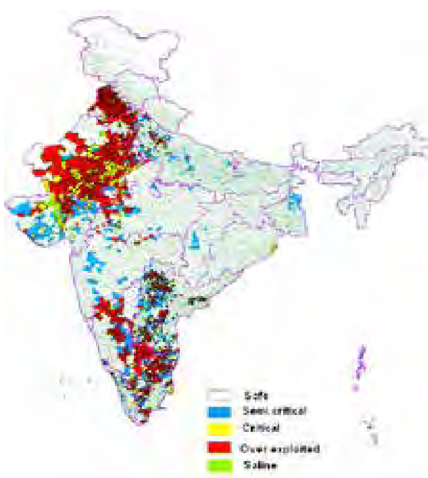
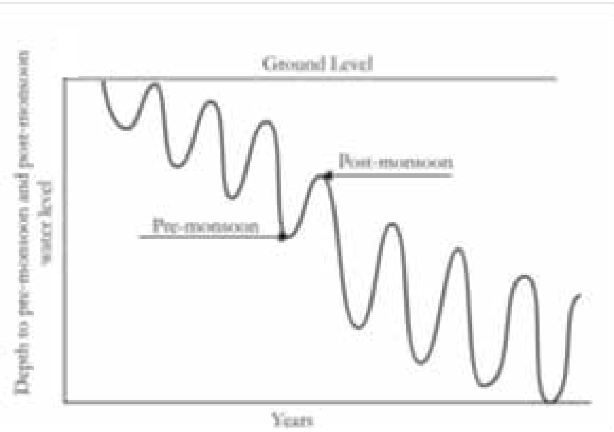


Figure 10.10. Groundwater-stressed blocks of India.

Table 10.4. Groundwater governance experience around the world.

	Instrument	Where tried	Challenge
1	Pricing groundwater abstracted	Jordan, Israel, Iran, China pilot projects in Shaanxi and Hebei	Monitoring groundwater withdrawals by numerous dispersed pumpers
2	Tradable groundwater entitlements	Kansas, Colorado, Australia, Mexico	Works with large abstractors; high transaction costs; have to exclude small users; scope for malpractices
3	Community aquifer management	Mexico, Spain, Andhra Pradesh	Strong authority needed for sustained enforcement of norms (China's state-di rected community aquifer management)
4	Legal and administrative regulation	Yemen, China, India, Spain, Mexico, Morocco	Success depends on enforcement; difficult with numerous, small, dispersed abstractors; political costs
5.	Indirect instruments	Energy policies; output and input subsidies; conjunctive management of surface water, groundwater and rainwater	Has been tried in India with variable success

1. In monsoonal Asia, groundwater development first amplifies intra-year fluctuations in static groundwater levels (Figure 10.11).
2. Sustained overdraft over natural recharge results in secular decline in water levels.
3. Managed aquifer recharge can ensure monsoonal recovery of water-levels to near pre-development levels.
4. Sri Lankan dry zones ensure precisely this.



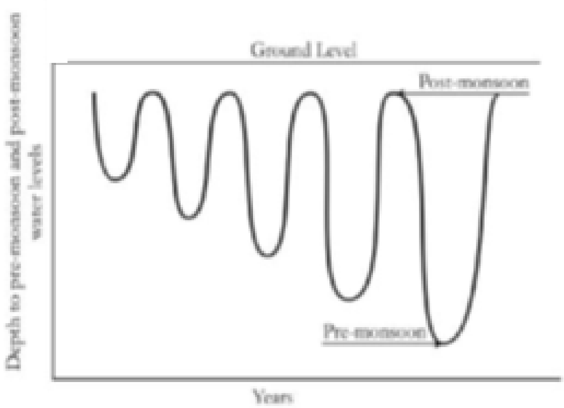


Figure 10.11. Groundwater development first amplifies intra-year fluctuations in static groundwater levels.

Saurashtra Region of Gujarat in western India has experienced a mass-movement in decentralized managed aquifer recharge (MAR) since 1990. Farmers, with support from religious leaders, diamond merchants, cement companies and government have modified 400,000 open wells for monsoonal recharge and constructed more than 300,000 check dams, percolation ponds, and other recharge structures. A few examples are given below (Figures 10.12 to 10.14):

Figure 10.12. Dudhara Village in Saurashtra. Photo credit: Tushaar Shah.

Figure 10.13. Gadh Village in Banaskantha.

Saurashtra receives some 700 mm of rainfall in 60 hours of torrential downpour. Profusion of small dams and ponds impound the monsoonal floodwater and fills up the dewatered Vadose zone of limestone and basalt aquifers. Sri Lanka's dry zones already have such profusion of recharge structures in the form of tanks.

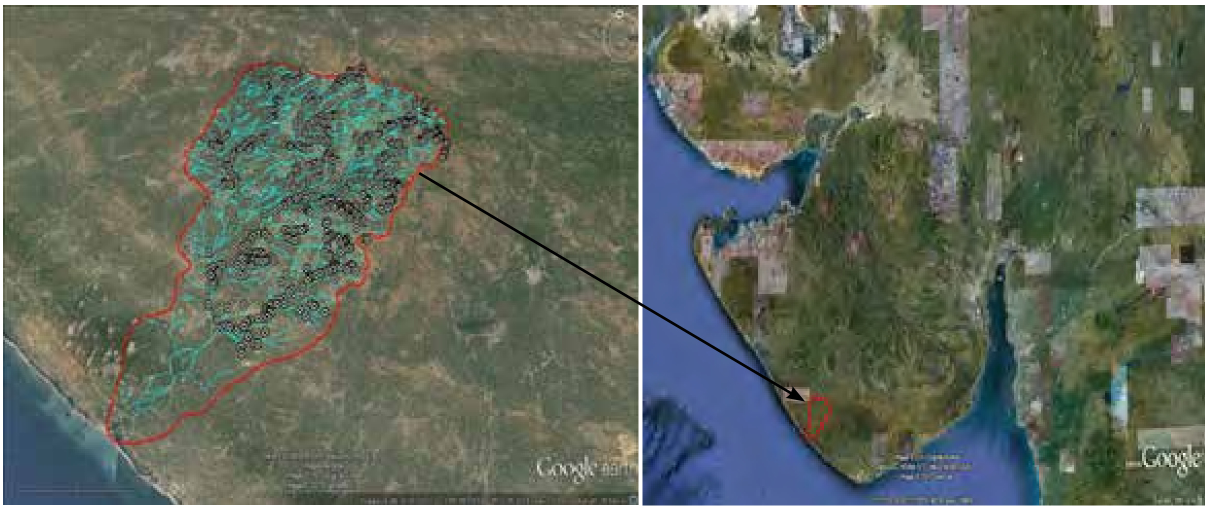
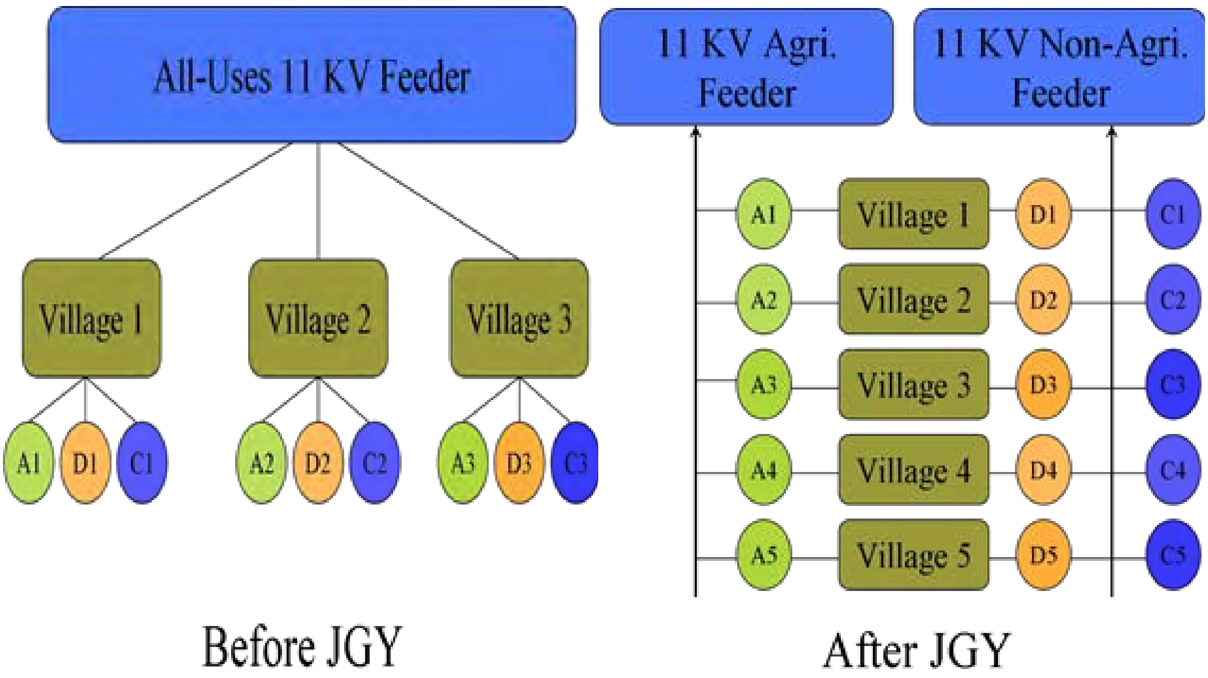


Figure 10.14. Map of Saurashtra.

Photo credit: Tuhsaar Shah.

To manage demand for groundwater, Government of India invested US$250 million in separating 800,000 tube wells from other rural connections and imposed a power ration of 8 hours per day but of top quality and full voltage. This reduced aggregate groundwater draft. Figure 10.15 shows the electricity networks before and after GJY.



Electricity network before Electricity network after

A – Agriculture, D – Domestic, C – Other, JGY – Jothi Gram Yojana

Figure 10.15. Electricity networks before and after GJY.

Gujarat is the only state in India where growing areas are witnessing monsoonal recovery in groundwater levels.

Figure 10.16. shows monsoonal changes in groundwater level in 2000 while Figure 10.17 shows the same in 2008. Figure 10.1.18 shows the mean MAI for South Asia for June, 1999.

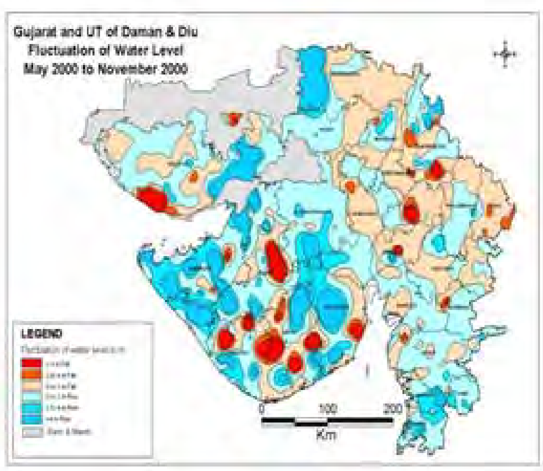


Figure 10.16. Monsoonal changes in groundwater level: 2000.

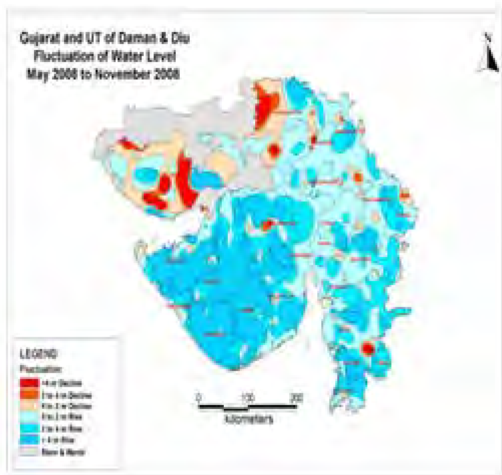


Figure 10.17. Monsoonal changes in groundwater level: 2008.

Groundwater governance in Sri Lanka

- Tank irrigation is central to sustainable groundwater use in Sri Lanka.
- Managing the dynamic balance between tank irrigation of paddy fields and agro-well irrigation

in uplands can enhance sustainability of groundwater.

- Manage the impact of perverse subsidies; impact of fertilizer subsidy policy on agro-well irrigation needs to be closely monitored.
- Focus on supply as well as demand side.
- Farmer organizations to manage both surface water and groundwater? Need more thinking.
- Distinguish between island-wise generic issues versus location-specific groundwater stress.

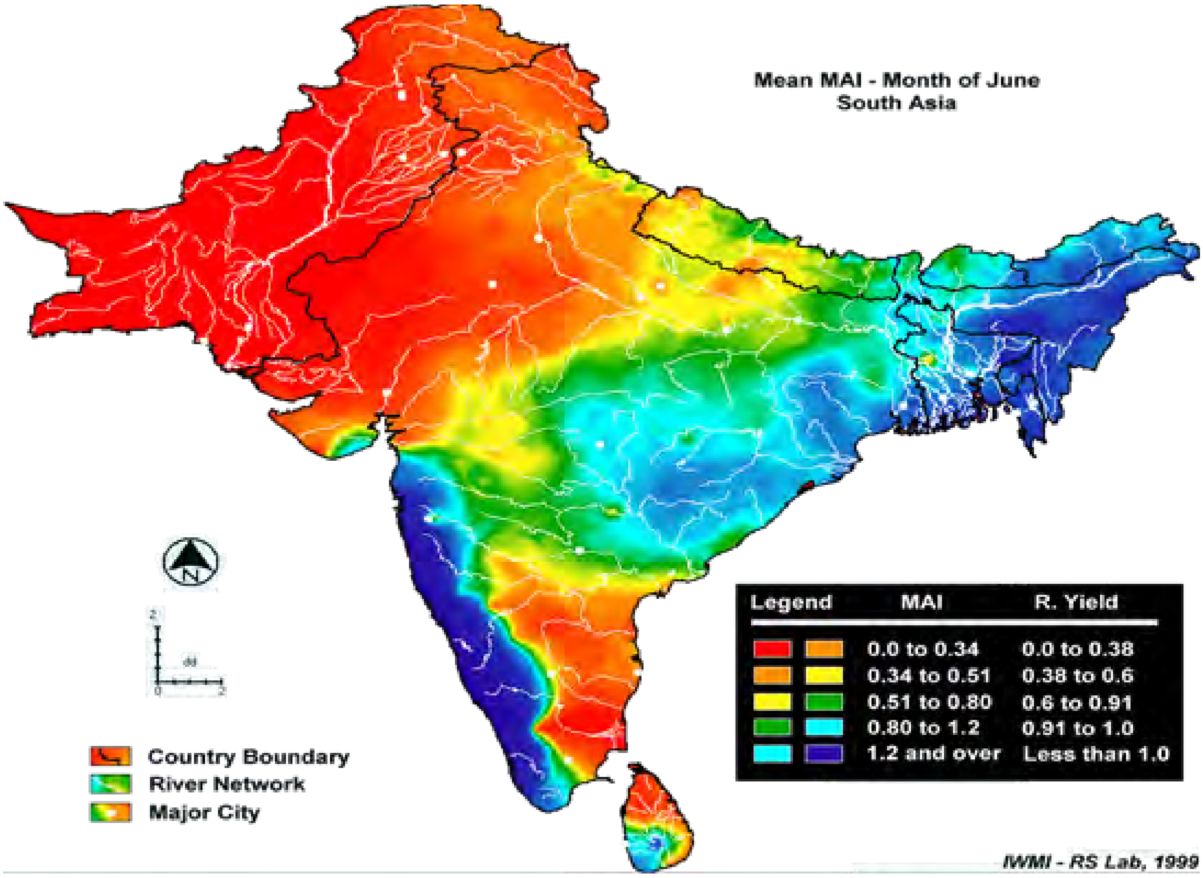


Figure 10.18. Mean MAI for June (1999), South Asia.

Groundwater contribution to poverty alleviation in South Asia and sub-Saharan Africa is very high. So we need to protect groundwater for today and tomorrow.

Sri Lanka has strong farmer organizations to manage surface water and we have to find out whether we can use them to manage groundwater too. We need to identify groundwater resources islandwide.

11. Presentations

First Presentation of Session 1

11.1 Overview of Efforts of Water Resources Board by Mr. G.R.R. Karunaratne, Additional General Manager-Hydrogeology, WRB.

Good morning everyone! First, I am going to list out the key themes of my presentation.

Key Themes

- Background of WRB
- Historical efforts made by the WRB
- Present activities of the WRB
- Future plans of the WRB towards groundwater management

Historical Background

WRB was established in 1966 under Act No. 29 of 1964, as an advisory body to the Minister of Irrigation on all matters concerning the control and utilization of the water resources in Sri Lanka. Subsequently, the act was amended and passed by Parliament in 1999 to enable the Water Resources Board to pay more emphasis on matters pertaining to groundwater resources in Sri Lanka under the Ministry of Irrigation and Water Resources Management.

Vision

Adequate access to clean and safe water for all.

Mission

To advise the government and the people on assessing, conserving, harnessing, developing and frugally utilizing particularly the finite water resources in the country, working in close collaboration with the rural society, relevant central and local government departments/divisions/authorities/institutions, national and international organizations and scientific communities here and aboard.

Institutional background and key operational divisions of the WRB

a. Hydrogeology Division

- Hydrogeologists
- Geophysicists
- Geochemists

b. Provincial officials and water resources research and training center

c. Tube Well Drilling Division

- Number of multipurpose truck-mounted heavy duty drilling rigs 08. Backed by a heavy machinery maintenance service unit

d. Operations Division

Geophysical laboratory

e. Geographic information system and database unit

f. Water analytical laboratories

g. Library

Human resources of the Water Resources Board (2013)

Hydrogeologists	20
Engineers	01
Chemists	03
Water analysts	04
Drilling officers	14
Administration and support	55
Security guards	16
Laborers	100
Drivers	35
	248

Before discussing our historical efforts I will explain the general hydrogeological setup of the country.

In the northwestern dry zone coastal part of the country we have a Miocene limestone aquifer; a deep confined aquifer system is present underneath.

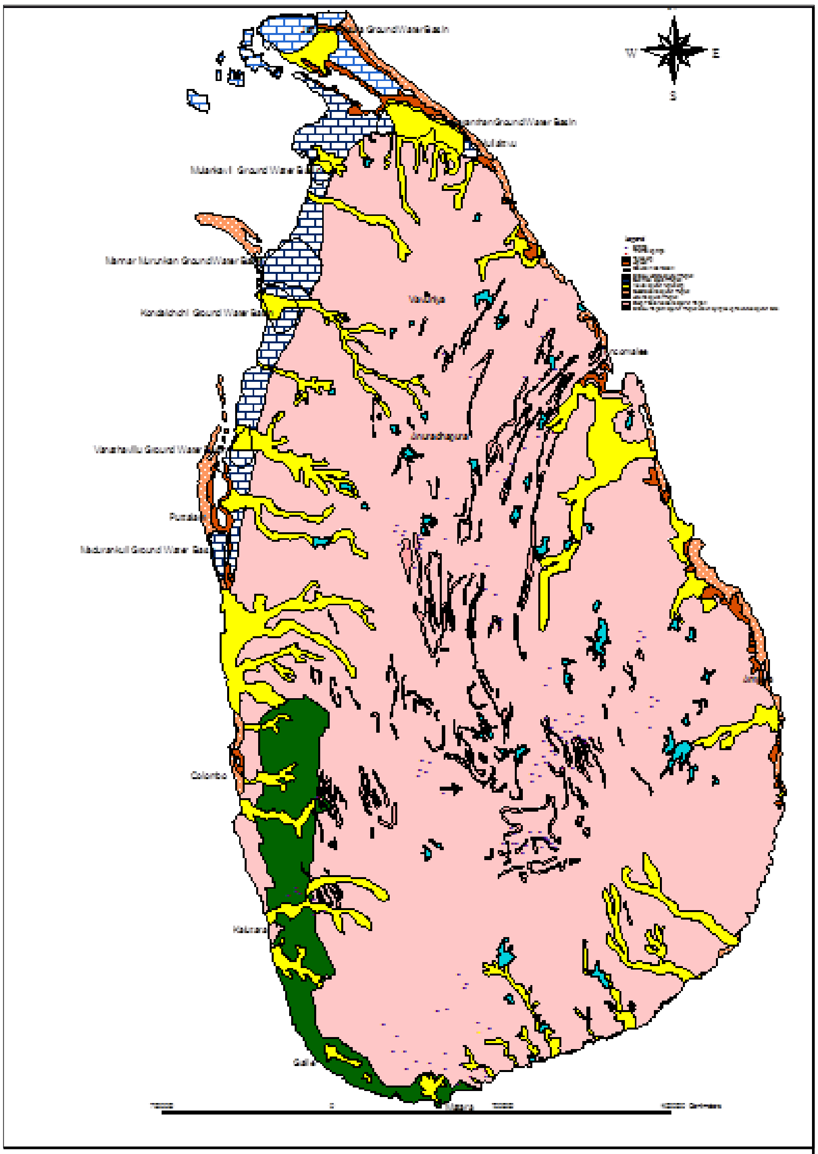
The shallow Regolith aquifer is in the weathered fractured hard rock region in the inland areas.

Sand aquifer is present in the coastal belt round the island.

Laterite (*kaboc*) is present mainly in the southwestern part. A shallow karstic sedimentary aquifer is present in the Jaffna Peninsula.

The above details are given in Figure 11.1.1 below.

Figure 11.1.2 shows the study area and its hydrogeology while figure 11.1.3 shows rural and urban water supply wells developed by the WRB.



- Shallow Karstic Aquifer of Jaffna Peninsular
- Deep Confined Aquifers
- Coastal Sand Aquifers
- Alluvial Aquifers
- Shallow Regolith Aquifer of the Hard Rock Region
- South Western Lateritic

Figure 11.1.1. General aquifer classification of Sri Lanka: Aquifers delineation.

In 1966, the Board was established with the Department of Irrigation and the very first effort made by the WRB was abstracting groundwater by means of boreholes. The past work done is listed below.

Groundwater development projects completed by the WRB up to 2010

1. It is significant that deep groundwater was raised by means of tube wells for the first time in 1966 with the assistance of Israeli experts in the Vanathavillu groundwater basin in the Puttalam area. The location is given in the map.
2. The systematic study of groundwater development potentialities of the Miocene karstic limestone sedimentary aquifer basins in the north and northwestern coastal belt (Jaffna to Puttalam) under the North West Dry Zone Latesol Development Project (NWDZLDP) component was assisted by the Overseas Development Agency (ODA) of the United Kingdom from 1980 to 1983. It is a very good groundwater basin covering Vanathavillu, Murunkan, Bulankavil, Poonarin and Mulathiv. This was the very first groundwater assessment done in our country. The map below shows the location.

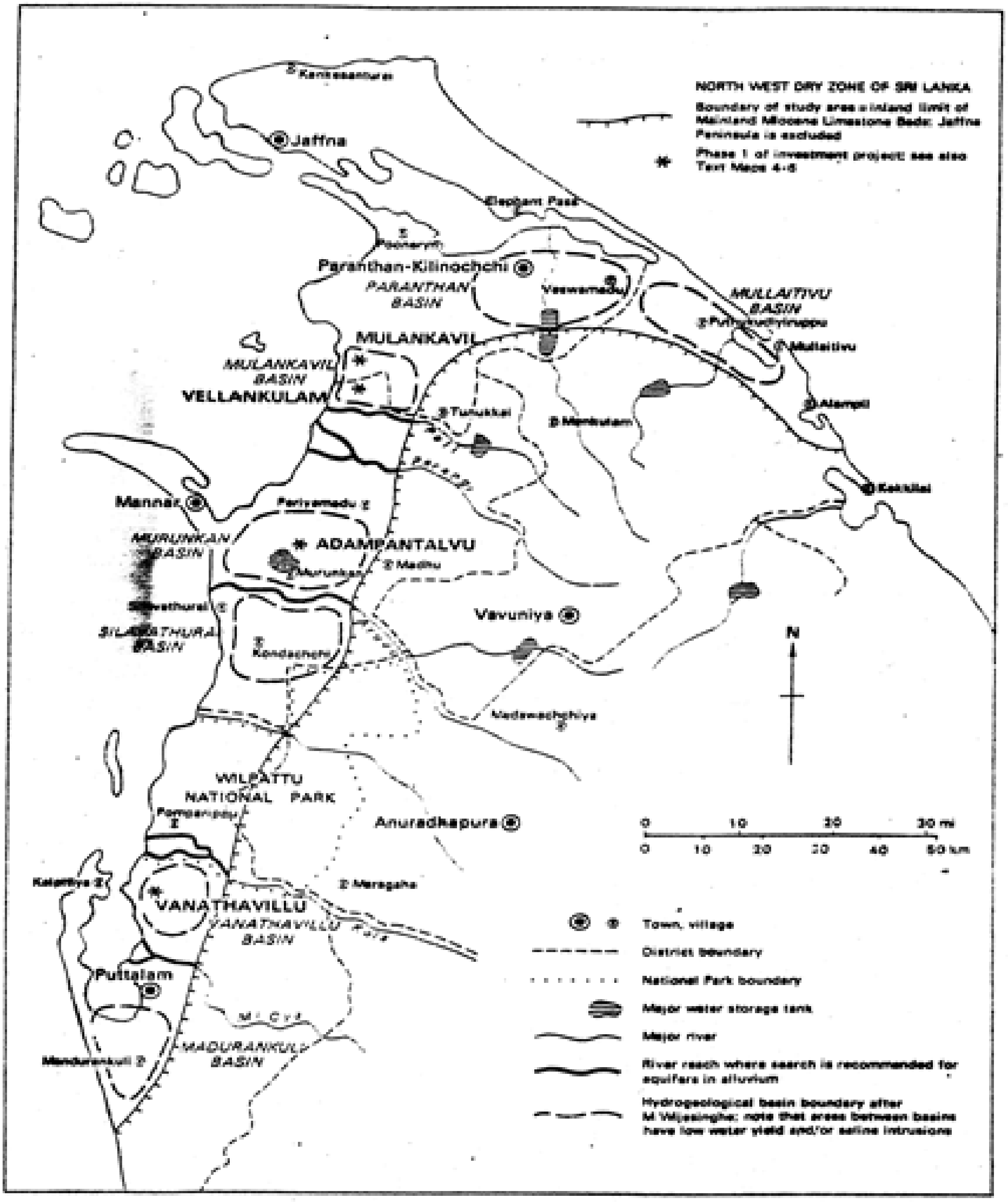


Figure 11.1.2. Study area and its hydrogeology.

3. Groundwater exploration work to supply over 1,000 m^3 of water per day. A supply source network was developed to meet the initial demand of the very first industrial export promotion zone at Katunayake in1980 after opening up of the market economy in the country.
4. A supply of over 500 m^3 of water per day from the coastal sand aquifer areas was developed urgently to realize the second export promotion zone at Koggala in the Galle District in 1991.

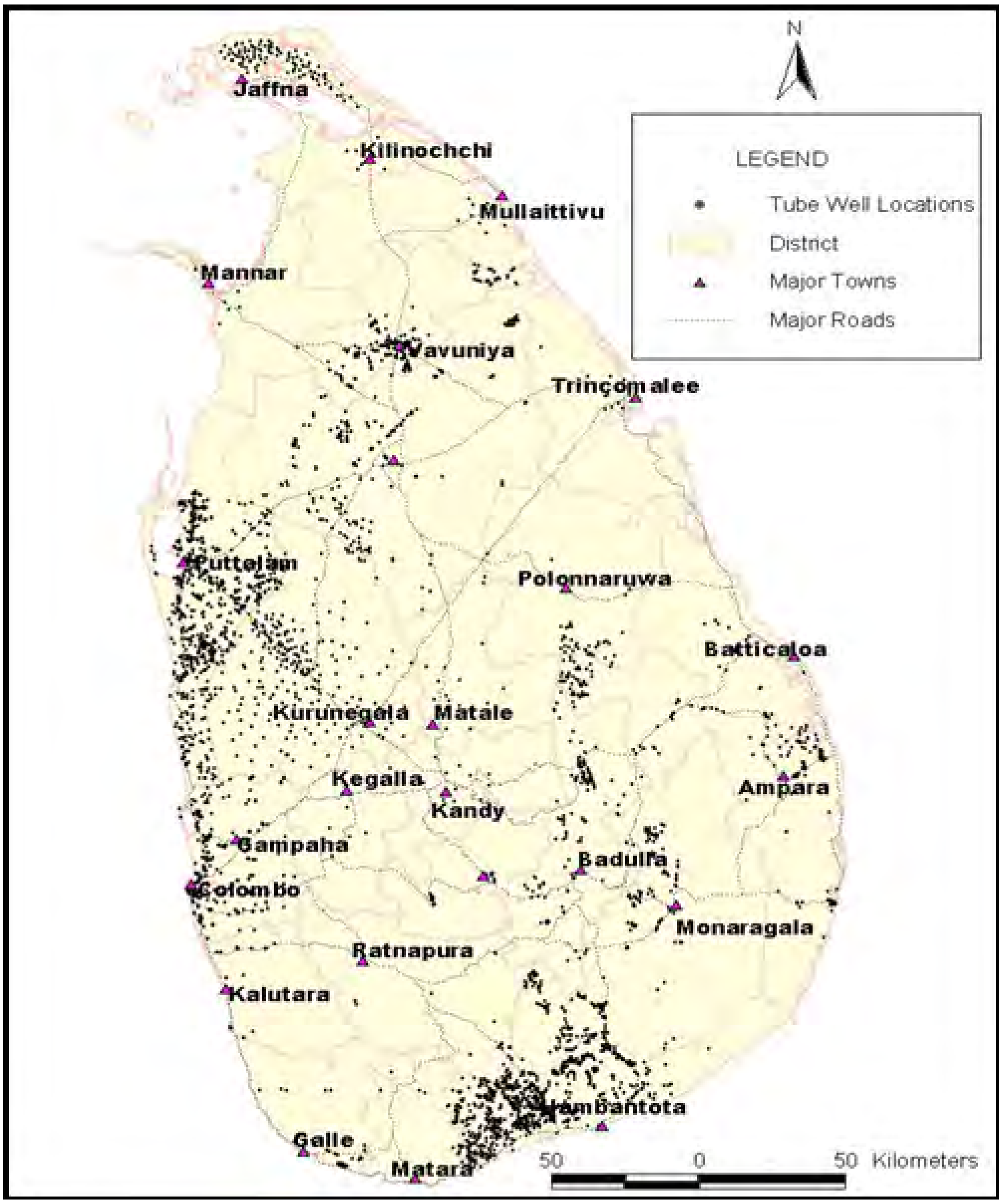


Figure 11.1.3. Rural and urban water supply wells developed by the WRB.

During the two decades from 1980 to 2000, WRB, together with the NWS&DB, developed rural and urban water supply wells covering the whole country, particularly in the dry-zone areas. Work on 8,700 wells was completed. Density of wells is shown in the map. Given below are the number of wells constructed by the WRB alone. One can imagine the number of wells operating in the country and constructed by both the NWS&DB and private parties.

Table 11.5. No. of tube wells constructed by WRB.

Province	District	No.of Tubewells with Geographical Coordinates	No.of Tubewells without Geographical Coordinates
Central	Kandy	52	39
	Matale	147	60
	Nuwaraeliya	37	14
East	Ampara	258	102
	Batticaloa	39	125
	Trincomalee	61	24
North	Jaffna	46	167
	Kilinochchi	12	21
	Mannar	90	122
	Mullaitivu	52	35
	Vavuniya	454	704
North Central	Anuradhapura	452	120
	Polonnaruwa	204	102
North Western	Kurunegala	248	235
	Puttalam	1171	638
Sabaragamuwa	Kegalle	4	7
	Ratnapura	80	32
Southern	Galle	124	52
	Hambantota	899	102
	Matara	19	10
Uva	Badulla	204	39
	Monaragala	373	126
Western	Colombo	233	22
	Gampaha	461	70
	Kalutara	78	10
		5798	2978
		Total	8776

Currently important projects

Figure 11.1.4. Dam safety and water resource.

DSWRPP under groundwater component 11

Initiated under the project and during a 2- year period a groundwater monitoring network had been established for the selected DSDs of Jaffna, Puttalam, Gampaha, Anuradhapura, Matale and Ampara districts with the objective to identify long-term changes in both water quality and groundwater level of the pilot areas marked in the map to identify impact on groundwater quality and quantity due to various natural occurrences and human activities (anthropogenic, etc.).

These pilot areas were selected considering prevailing groundwater issues.

Groundwater protection plan being implemented to achieve the above targets (for a 2-year period)

This groundwater plan is the result of participatory work done along with NWS&DB and other stakeholders. In this work, people too were involved as the intended results of monitoring being done at the national, regional and grassroots levels cannot be achieved without their involvement.

Table 11. 6. Groundwater protection program – Activity plan.

																			2014	2015	
			Jul	Au	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Se	Oc	No	Dec	Jan	
Item	Activity																					
1	Awareness																					
		Institutions	■																			
		Public																				
		Farmer community																				
2	Formation		■	■																		
	of action																					
	committees	District secretary																				
		Divisional secretaries																				
		Environmental and planning officers																				
		Grama niladari																				
		Farmer organizations																				
		Water resources Board																				
		Agriculture and agrarian																				
3	Monitoring	WRB		■						■						■					■	
	program																					
4	Reporting	Committee			■						■						■					■
	and																					
	Progress																					

2. Hydrogeological study on the coastal sandy aquifer extending from Colombo to Negombo (most industrialized and urbanized area of the country) with the following objectives:

- To identify aquifer geometry, aquifer properties, groundwater potential, recharge and discharge areas, etc., and finally to develop a groundwater model (studies we undertook previously were not done systematically).
- To identify locations (favorable aquifer units) suitable for artificial recharge to groundwater system. Boreholes numbering 60 had been drilled up to August 2012 (only for monitoring purposes).

Hydrogeological studies will be very important for the management of groundwater of our country.

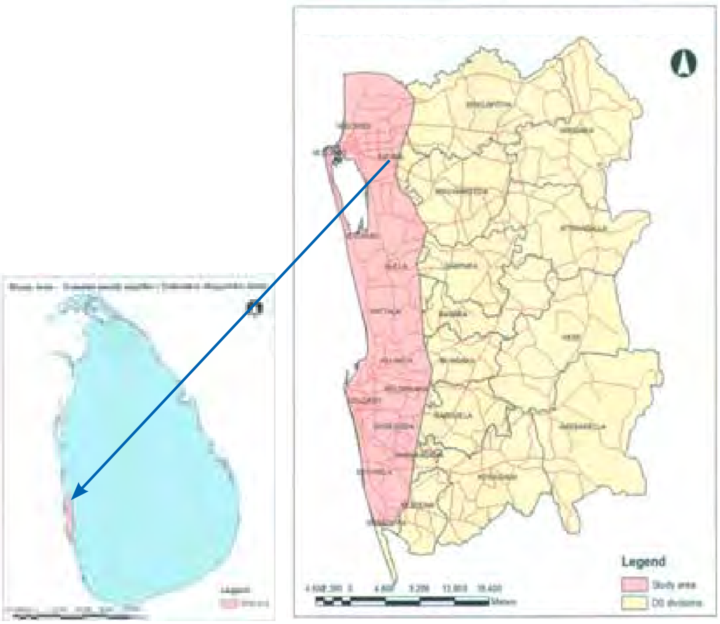


Figure 11.1.5. Coastal sandy aquifer extending from Colombo to Negombo area.

Figure 11.1.6. Hydrogeological study from Colombo to Negombo area.

BOI Zone Katunayake

- To identify locations suitable for artificial recharge to groundwater system.

Figure 11.1.7. Artificial recharge.

Figure 11.1.8. Artificial recharge.

BOI Zone Katunayake – Identification of locations for artificial recharge

Photo credit: G.R.R. Karunaratne.

3. Water quality study in Anuradhapura District (area with the problem of CKD prevalence) with the following objective:

- To identify different kinds of water quality parameters including heavy metals like arsenic in the water resources of Modaragama Aru, Malwatu Oya, Yan Oya, Kala Oya and Ma Oya basins.

4. Water quality study at CKD-prevalent areas of Medawachchiya DSD.

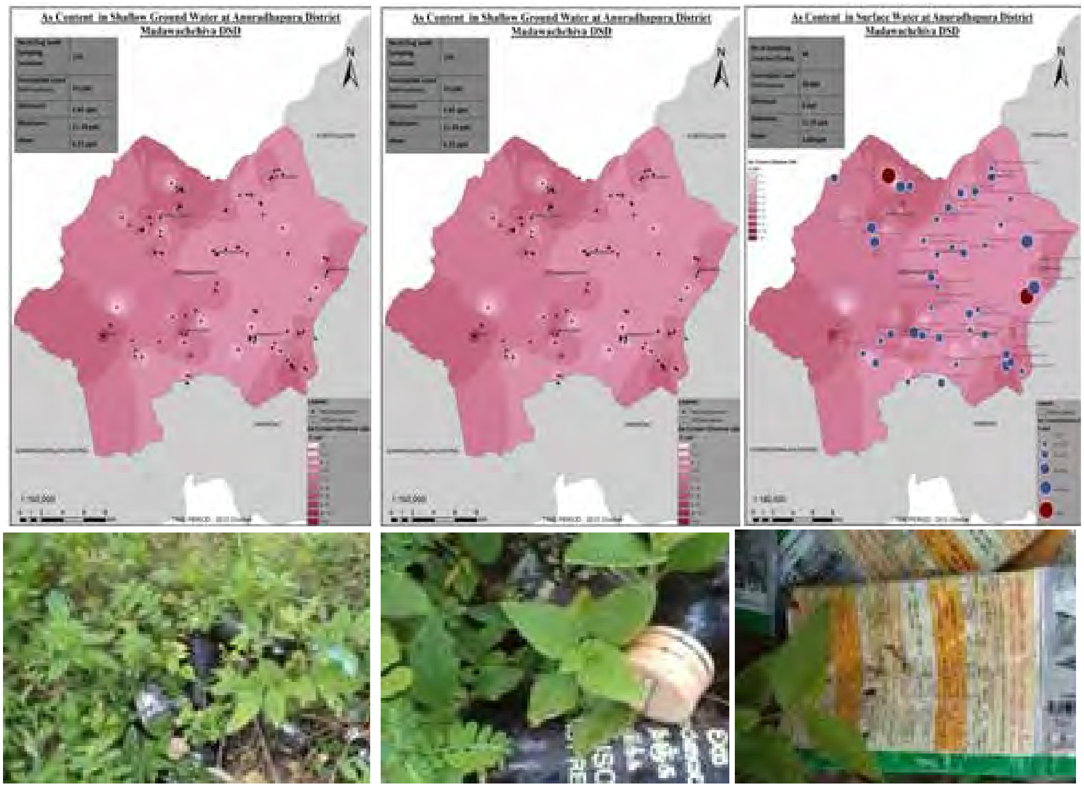


Figure 11.1.9. CKD study results.

Photo credit: G.R.R. Karunaratne.

5. Recommendations

6. WRB recomments the following:

- The presence of arsenic in groundwater ranges from 2.67 to 11.28 ppb. It is obvious that arsenic is added to the water from agrochemicals.
- The arsenic level of groundwater of 76 out of 128 samples (shallow dug wells and tube wells) was reported within the range of 5-10 ppb.
- Make people aware of the abovementioned facts and reduce usage of agrochemicals and fertilizer in agricultural practices.
- The safe and environmental-friendly agrochemicals should be listed and farmers should not be allowed to purchase low-quality agrochemicals directly from the dealers.
- Use of carbonic fertilizer and heavy metal-free high-quality agrochemicals should be encouraged and the supply of agrochemicals should be done through the Department of Agriculture or Department of Agrarian Services.
- Encourage farmers to apply traditional methods to control pests by minimizing the application of agrochemicals. A similar study was started at Padaviya DSD too.

7. Awareness programs on all water resources was found very important. Three-day residential awareness programs and water clinics were conducted by the Training Centre at Anuradhapura (2008 -2012).

Participants were middle-level officials who are directly involved: public health inspectors, *grama niladharis* (government officers with the lowest-level administrative powers at the village level) midwives, *samurdhi* officers, school teachers, agrarian development officers and community health development officers. We made use of mobile laboratories supplied by the DSWRP to carry out water clinics where *in situ* tests of water quality were done in the villages.

8. Development of natural springs - No. of springs developed were 20

There is a very good *ulpotha* (spring) system present in the Anuradapura District where the water quality is very good. We have developed the springs mentioned below for the benefit of the people.

Dambagaha ulpotha	:	Benefited 200 families, 30,000-40,000 liters/day (l/d)
Singhaya ulpotha	:	Benefited 300 families, 45,000-50,000 l/d
Yakalla ulpotha	:	Benefited 50 families, 12,000-15,000 l/d
Gonamariyawa ulpotha	:	Benefited 200 families, 30,000-40,000 l/d
Theladinnanwewa ulpotha	:	Benefited 20 families, 10,000-15,000 l/d
Garinda ulpotha	:	Benefited 100 families, 20,000-25,000 l/d

Figure 11.1.10. Dambagaha ulpotha before development.

Figure 11.1.11. Dambagaha ulpotha after development.

Photo credit: G.R.R. Karunaratne.

9. WRB conducted the groundwater assessment study at Thirappane cascade with the objective to:

Identify the groundwater recharge mechanism in the area with special reference to the contribution from the tank system to groundwater. The previous speaker explained how the ancient cascade systems contributed to recharge groundwater. It will be very important in the future, especially with the expansion of groundwater use. The density of agro-wells is very high in this area. Work connected to this area has already been started.

10. Hydrogeological study and establishment of two monitoring networks in Jaffna Peninsula conducted as pilot areas under DSWRPP with the objective to:

Assess groundwater potential of the entire peninsula and to study groundwater quality and water-level changes along with NWS&DB and other stakeholders, which are very important for the management of groundwater. Agro-well density is very high in this area. Work in three DSDs have already been completed. In some areas we found water quality to be very good while some areas have high storages.

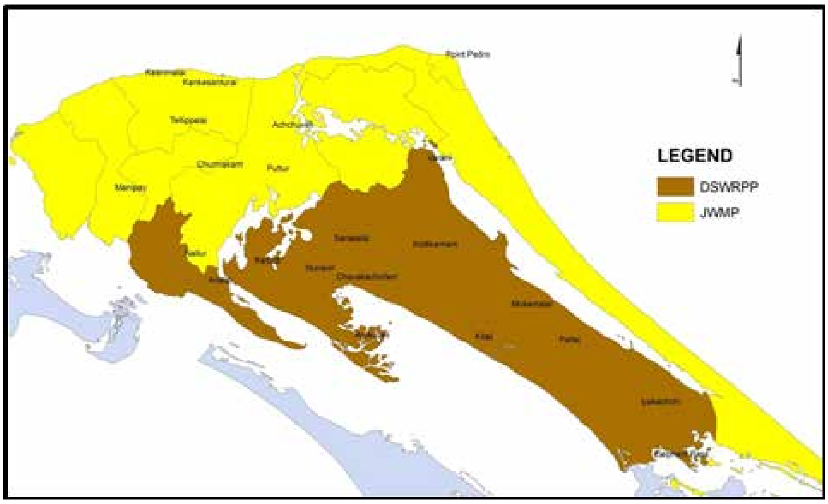


Figure 11.1.12. Monitoring network to cover the DSD.

11. WRB conducted hydrogeological studies at Vavuniya and Kilinochchi districts too.

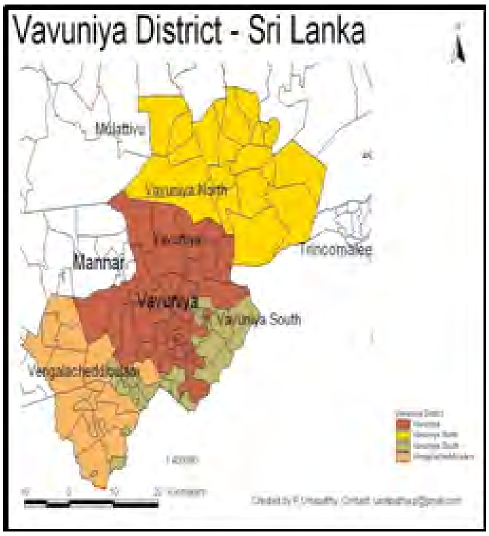


Figure 11.1.13. Areas in Vavunia where hydrogeological studies were conducted.

Figure 11.1.14. Areas in Kilinochchi where hydrogeological studies were conducted.

Objective to assess ground-water availability of the two districts

12. Other work being conducted by the WRB are:

- Groundwater assessment in the resettlement areas and the model farm at Guruwela under Moragahakanda Project with the objective to identify groundwater sources for drinking and agricultural purposes: Capacity of the well – 800 l/m.
- Geophysical surveys carried out at Moragahakanda.
- Construction of agro wells is in progress at Moragahakanda resettlement area.
- A hydrogeological study was conducted with the objective to determine the aquifer parameters and groundwater potential zones in the limestone aquifer at Mannar District to develop a groundwater model.

Future plans of WRB on development and management of groundwater

- Establishment of a groundwater monitoring network
- Development of a national groundwater database
- Preparation of groundwater vulnerability maps
- Groundwater modeling with various scenarios
- Hydrogeochemical modeling
- Optimization modeling
- Community participation and awareness programs

Proposed other projects of the WRB

Establishment of a national-level groundwater monitoring network for Sri Lanka (2014-2016), with the objective to collect comprehensive and accurate real-time data on:

- Groundwater level.
- Water quality.

Role of the WRB in monitoring data in water management

(Why we need data, how we collect them and how we utilize the collected data)

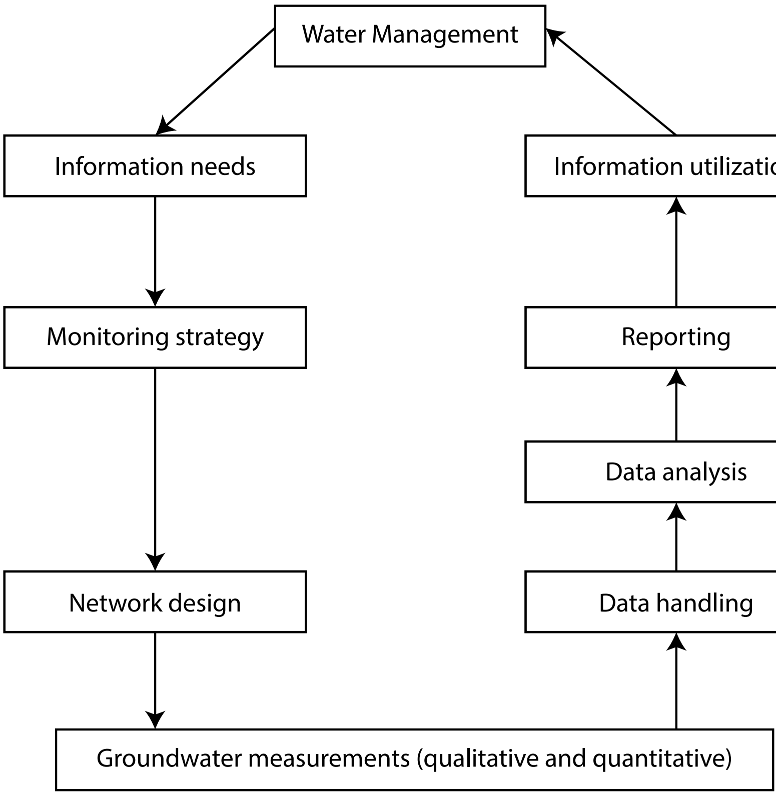


Figure 11.1.15. Role of the WRB in monitoring data in water management.

1,310 data loggers will be installed by WRB covering the whole country. Locations are given in the figures below.

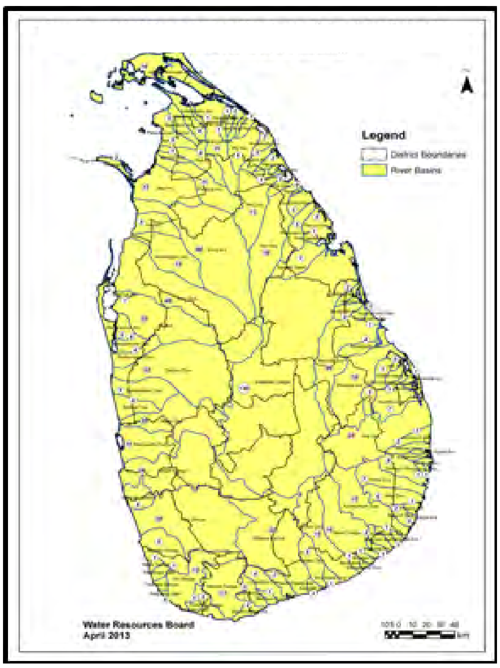


Figure 11.1.16. Development of groundwater monitoring network.

Figure 11.1.17. Groundwater monitoring network for Sri Lanka.

Target areas where data loggers are to be installed for receiving real-time data.

- Community water supply schemes
- Aquifers used to extract groundwater for industries and industrial zones (mineral water industry, beverage industry)
- Intensive agricultural areas (areas subjected to groundwater pollution)
- Areas subjected to groundwater pollution
- Coastal aquifers
- At least 10 locations within one river basin covering 103 basins
- 280 locations in selected areas in some coastal belts and Jaffna Peninsula

Expected outcomes of the project

- Develop a real-time groundwater database for Sri Lanka.
- Maintain a proper groundwater management system.
- Provide data for decision makers, researchers, stakeholders and the general public.
- Quick action to the groundwater-related issues in the country.

13. Forecast groundwater-related issues

Figures 11.1.18 a and b show the installation of data loggers at Katunayake Economic Promotion Zone.

Figures 11.1.18 a and b. Installation of data loggers at Katunayake Economic Promotion Zone.

Photo credit: G.R.R. Karunaratne.

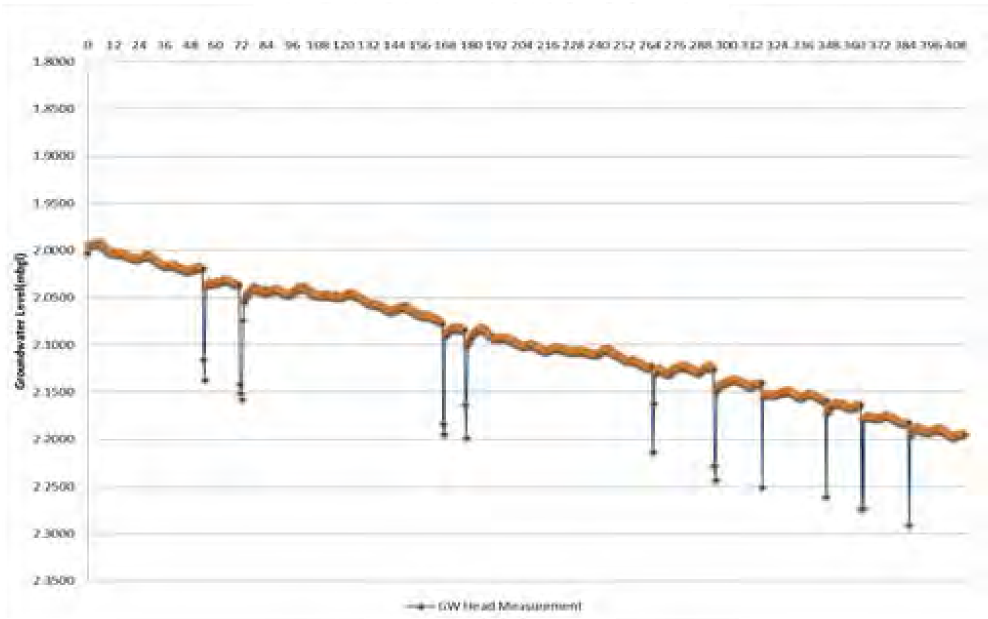


Figure 11.1.19. Groundwater head fluctuation in sand aquifer at KEPZ from 26.02.2013 to 15.03.2013.

The data logger recorded that the groundwater level has declined by 20 cm within 17 days in February and March this year. The anomaly shown is due to water drawn from the nearby wells.

I very much like to thank IWMI for inviting me to make a presentation at this seminar and everybody present here for listening to my presentation. The General Manager, other officials present here or I will answer any questions.

Q. Is arsenic in groundwater a serious problem? What are the areas where it is found in large quantities?

A. Yes, but we have to conduct long-term analytical studies in a systematic way to make recommendations.

11.2 Second Presentation of Session 1

Eng. D.N.J. Ferdinando, Additional General Manager (Policy & Planning) and Mr. K.M. Premathilake, Manager (Groundwater studies), NWS&DB on **Groundwater development for potable water supply**

Good morning! I will present a sort of general things in part A of my presentation.

Part A of the presentation covers the following:

- Country perspective.
- Technical interventions.
- Organizational interventions.
- Financial interventions.
- Managerial issues and strategy for poor groundwater-quality areas.

Country perspectives

- Population - 20.4 million, rural 70%; safe drinking water coverage 83%.
- Government target of 100% safe drinking water by 2020. It requires an urban growth of 6% and a rural growth of 14% to attain this target.

- Rural water supplies largely depend on groundwater. Hence *accelerated groundwater development is essential to achieve expected targets. Although some work has been done we have not been developing groundwater systematically in the past several decades.*

For this purpose we have taken the following steps:

Technical Interventions

- Rectifying of non-operational hand pumps (50% non-operational hand pumps due to various reasons like quantity, quality issues, etc.); dysfunctions of approximately 1,000 out of 10,000 pumps rectified. Scientific investigation of groundwater undertaken.

  (*Funds are provided by the Government of Sri Lanka, UNICEF, WB, ADB, AUSAID*).

  - Matale District (Central Province).
  - Mannar, Jaffna, Mullaithivu (Northern Province).
  - Trincomalee (Eastern Province).

Organizational Interventions

Table 11.2.1-The three-tier maintenance system introduced for sustainability of the hand pumps.

Level	Organisation	Maintenance role	Shortcomings
Tier 3	NWS&DB	Major hand pump repairs, hand pump replacement, flushing of wells	Inability to support due to shortage of local funds, etc.*
Tier 2	Local Authority	Minor hand pump repairs; Local Authority is supposed to have technicians	Not so effective in most places
Tier 1	CBO	Upkeep of basin, local drainage	Cannot bear full cost**

* NWS&DB is working on establishing a system to find funds for this purpose.

** NWS&DB has decentralized its functions. It has small rural water supply units in 18 districts. An additional unit is to be established shortly.

The annual budget of NWS&DB is Rs35 billion mainly donor-funded. We focus more on mega projects because of commercial interests, interested contractors and so on. Hence, it is very easy to continue developing large projects, and by now, most of the urban areas are covered; of course, we have to do some augmentations and expansions. If rural areas are to be covered under the mega projects their capital investments will go up since we are lagging behind scientific groundwater developments. These capital investments have gone up over Rs300,000 and sometimes to Rs350, 000 per beneficiary householder. Hence, mega projects were pruned down and rural areas are taken up separately. They need to be developed under rural concepts with some organizational changes to attract officials of all categories for those projects as some are unwilling to work in these projects.

Organizational changes

- Prepare district development plans (select areas to be developed, how to develop them).
- Already established in all provinces except in the North and East.
- Some development plans are already prepared.
- Groundwater development working groups established including even main donors UNICEF, JICA, WB and ADB at national level at the Head Office of NWS&DB.
- Active NGOs will also be invited.

Financial Interventions

Maintenance cost - rural water supply schemes/hand pump

- Often CBOs cannot bear the full cost so that the government/NWS&DB should provide bridging funds. General investment for rural water supply schemes.
- Uneconomical to cover remote rural areas under large integrated water supplies.
- Need for well-planned cost-effective systems.
- Strategic decisions taken to allocate 5% of investments on major water supply projects.

Contractors are not willing but NWS&DB is going to be very strict on this issue to get it institutionalized (sanitation and catchment conservation, etc., included).

Poor groundwater quality areas

Issues to be considered are salinity, hardness, iron, manganese, fluoride and agricultural pollution of groundwater.

- We apply a new strategy for CKD areas
- Provide advanced treated groundwater for drinking and cooking (5 l/day/person-well water for washing vegetables and rice). Water tankers used to fill community tanks (one tanker per three houses)
- Capital cost of US$135 per household. Operational cost US$2.4 per household/month
- Pilot scheme implemented in Billewa, North Central Province (since 2011 March, there have been 34 CKD persons; out of 10 in the 3rd stage two have improved to stage 2 and the other 8 have remained for 1½ years. There are 104 persons in the village of whom two died and 30 have survived with pure drinking water).
- Program to be expanded to other areas.

Part B of the presentation covers the following:

- Status of groundwater development.
- Case study.
- Conclusion.

Essential components of any groundwater development program

- Investigation activities.
- Well design and construction of wells.
- Assessment of aquifers and wells.
- Groundwater quality and risk assessment.
- Monitoring exercise.
- Protection of groundwater aquifers and wells.
- Enhancing of groundwater (artificial recharge).

In Sri Lanka, more attention is paid to the first three components and less to the last three. Due to this, most of the groundwater systems are faced with problems such as quality, quantity, performance,

etc., resulting in aquifer drain and quality and quantity problems which are very common. The following system was used to resolve it.

Table 11.2.2. Summary of groundwater development.

Type of water supply	Number of units	Remarks
Crises management	Completed 500	Temporary resettlement programs: deep hand pump wells
Pipe-borne water for towns and community-based water supplies	Completed 2,500	Construction of productive boreholes (deep and shallow), lateral wells, and dug-wells of large diameters
Rural water supply by hand pumps	Provided 25,000	Gam Udawa, Danida, Finnida, GTZ, IRDP, capital budget, NORAD, ADB, WB
Water supply for institutes (factories, schools/health centers)	Done 234 solar type + 1,000 wells with submersible pumps	Deep tube wells with solar and electric pumps. Garment factories and other private institutes numbering 200.
Groundwater development DSD/District/Provincial /river-basin-wise	A few completed	Awaiting the agreement prepared for groundwater development of the Moneragala District.

Table 11.2.3. Summary of groundwater extraction schemes completed.

Groundwater extraction (m3/d)	Number of water supply schemes	Aquifer type
More than 5,000	5	Alluvial/sedimentary rock formations
1,000-5,000	22	Alluvial/ sedimentary/metamorphic rock formations
Less than 1,000	2,473	Alluvial/ regolith/sedimentary/metamorphic rock formations

Case study: Groundwater development program - Point Pedro water supply scheme

This is a critical area because water is floating over saline water. Aquifer thickness is small with a maximum of 20 m. Our problem was how to extract this water. First we thought the most viable solution was boreholes. Later we found that two lateral wells for each well was a better solution. The Report of the SMEC International Pvt Ltd. with Ceywater Consultants Pvt Ltd. (2006) says groundwater potential here is 4,000 m^3/day.

- Present demand - 1,000 m^3
- Demand (2025) - 4,000 m^3 proposed area - Point Pedro DSD
- Available water sources - Groundwater, seawater

Figure 11.2.1. Land use pattern of the Point Pedro area.

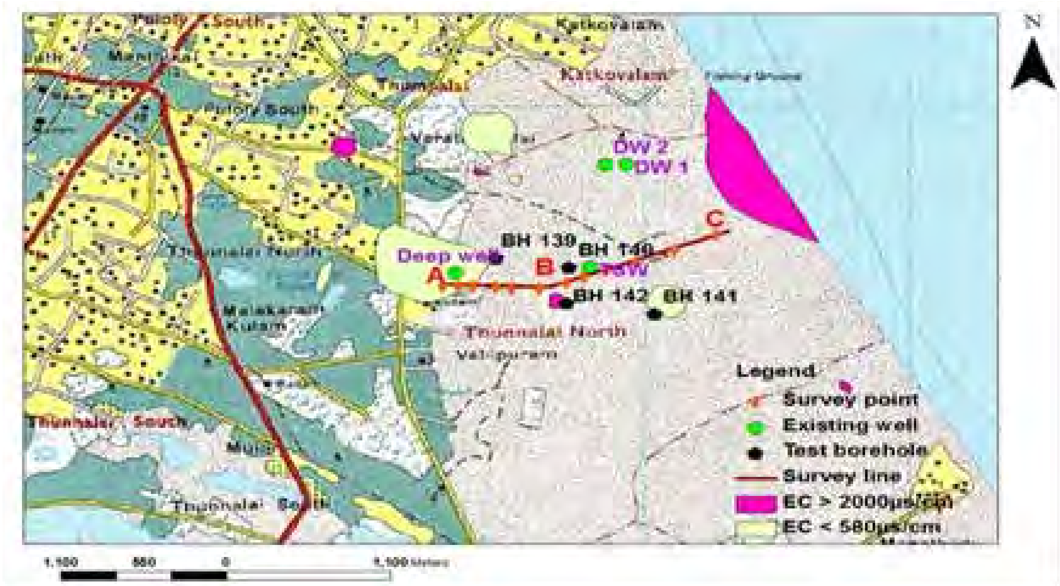


Figure 11.2.2. Field observation of EC and resistivity survey.

Results of investigated points

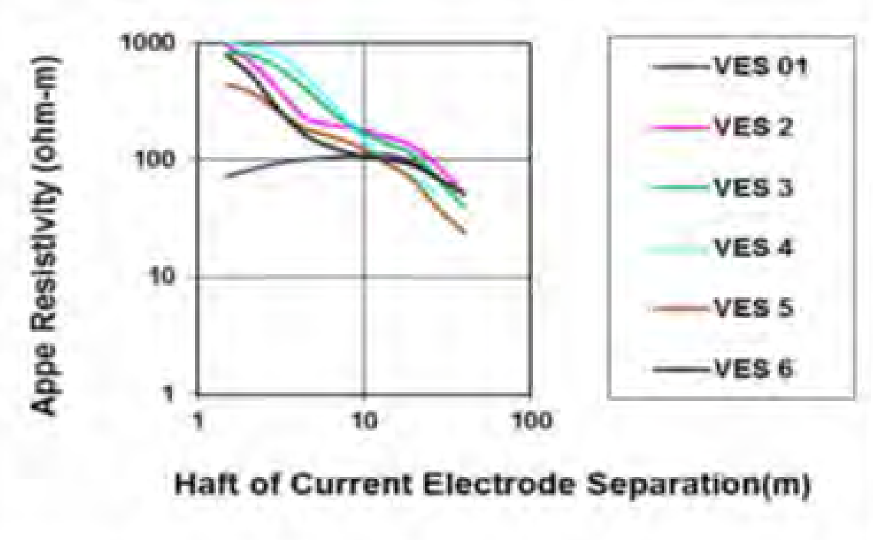


Figure 11.2.3. Field resistivity curves (VES 01-VES 6).

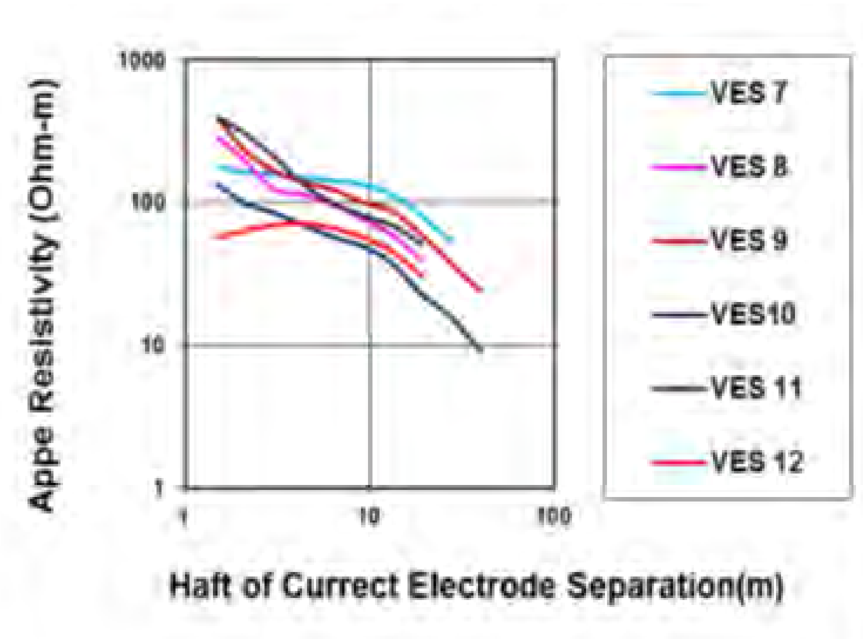


Figure 11.2.4. Field resistivity curves (VES 7-VES 12).

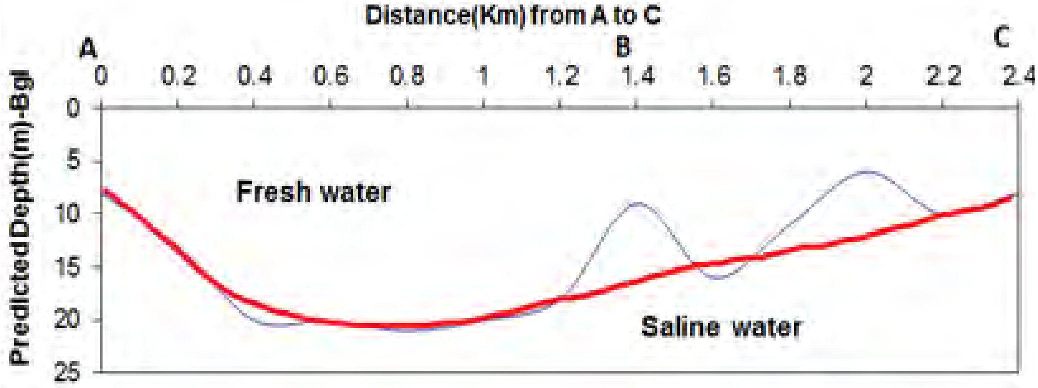


Figure 11.2.5. Interpretation of freshwater-saline water interface.

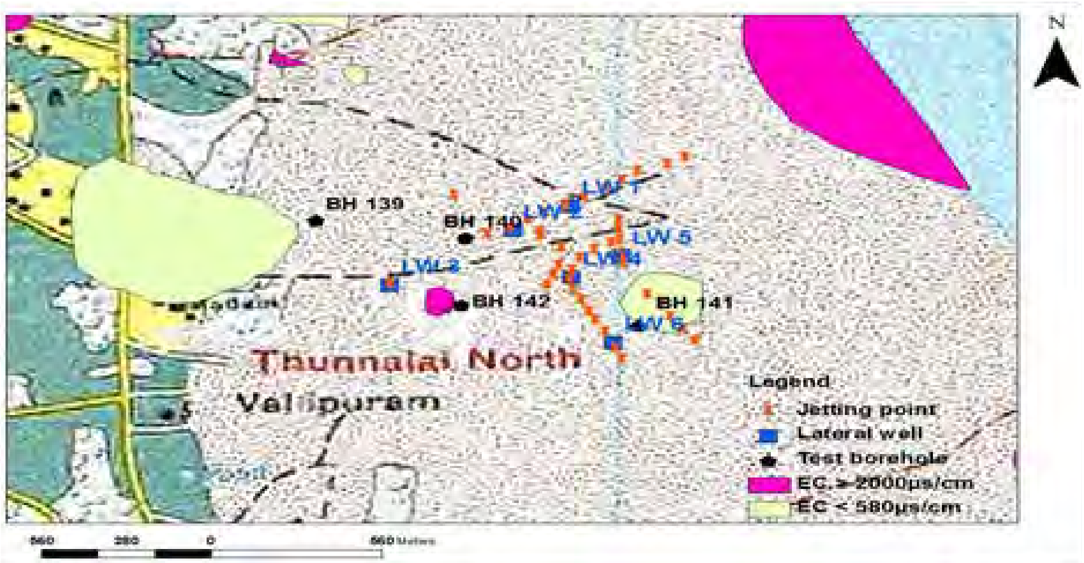


Figure 11.2.6. Proposed lateral wells with jetting points.

Table 11.2.4. Details of test wells.

Test well number	Flushing yield(l/m)	EC (µs/cm)	Total depth (m)-bgl	Screen length(m)	SWL(m)-bgl (2010/2014)	Diameter of casing (mm)
BH/139	250	410	6	5.5	1	280
BH/140	300	330	7	5.4	1	280
BH/141	300	220	10.5	8	0.7	280
BH/142	300	665	10.6	8	1.2	225

Table 11.2.5. Pumping test details.

Test well Number	Tested Rates (l/m)	Duration (minutes)	SWL(m)- bgl (2010/10)	EC (μs/cm)	Drawdown (m)-bgl	Recovery 90% min.	Transmissivity m^2/day
BH/139	150	2,880	1.4	429-465	1.64	105	188
BH/140	150	2,880	1.3	560-782	1	340	123
BH/141	175	2,880	1.1	205-419	1.8	550	200

Table 11.2.6. Variation in chemical quality.

Date	Well no.	Color	Turbidity	pH	EC	Cl	F	Hardness	Iron	Phosphate	Sulfate	Alkalinity	TDS
2010.9.27	I/B/BH/141	10	0.37	7.83	205	58	0.17	136	0.22	0.08	4	265	123
2010.9.28	I/B/BH/141	10	0.57	8.89	213	61	0.21	140	-	0.03	2	224	128
201.10.14	I/B/BH/141	10	0.27	7.45	215	60	0.17	206	0.06	0.37	1	440	251
2010.9.29	I/B/BH/141	10	0.59	7.99	419	62	0.17	136	-	0.11	2	260	135
2010.10.12	I/B/BH/139	10	0.41	8.04	429	57	0.23	232	-	0.43	-	440	257
2010.10.13	I/B/BH/139	10	0.34	7.86	465	77	0.15	242	0.05	0.37	2	412	279
2010.10.20	I/B/BH/142	10	0.35	7.94	782	119	0.24	184	-	0.22	-	176	469

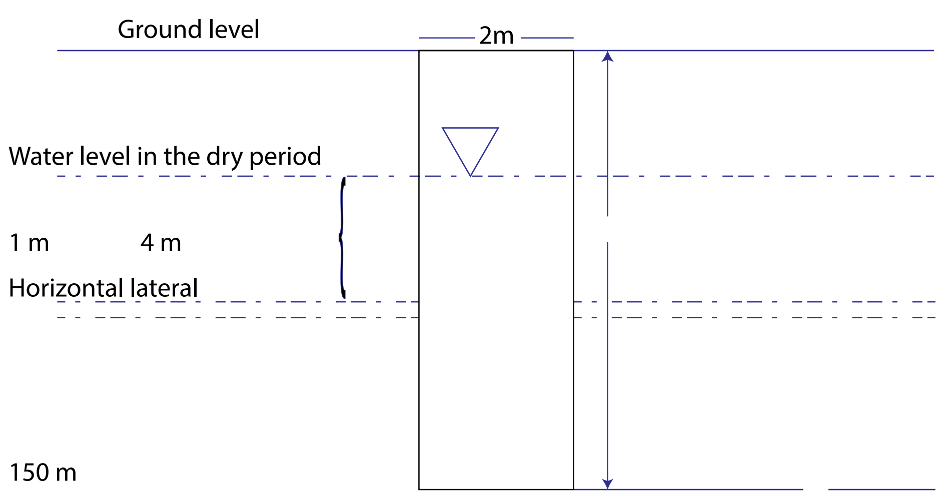


Figure 11.2.7. Design of dug-wells with laterals.

Figure 11.2.8. Installation of laterals (Elongated parallel to the beach line).

Photo credit: K.M. Premathilake.

Figure 11.2.9. Gravel pack and installation.

Photo credit: K.M. Premathilake.

Figures 11.2.10 a and b. Construction in progress (Intake well 1).

Photo credit: K.M. Premathilake.

Testing of intake well 1
Step test (2012/10/06)

- Rates (300, 500, 700 l/m).
- SWL (static water level) -0.71 m (bgl) and drawdown - 0.16 m.
- Recovered up to - 0.74 m (bgl) for 3 hours.
- Electrical Conductivity (217 to 243 µs/cm).

Long duration test (2012/10/07-2012/10/10)

- Rate-500 l/m for 2,880 minutes.
- SWL-0.74 and drawdown-0.25 m.
- Recovery-3,300 minutes.
- Electrical Conductivity (215 to 470 µs/cm).

Four wells will be completed in Point Pedro and work already completed on two wells.

Activities to be concerned in terms of water quality and quantity

- Sand mining.
- Solid waste disposal site (800 m away towards NW).
- Movement of cattle.

Figures 11.2.11 a and b. Improper garbage disposal.

Photo credit: K.M. Premathilake.

Activities and test to be completed for protection of well fields

- Land requirement for protection and development of well-field area - 3 km^2 but authorities had allocated an area of 56 ha (0.56 km^2).
- Combined test for well field should be conducted after completion of all intake wells.
- Demarcation of protection area for well field.
- Monitoring strategies should be developed.

Conclusive Remarks

General problems in groundwater development

- Low attention to the groundwater monitoring, management of aquifers and pumping wells (attention leading to corrective and preventive action not taken).
- Lack of sufficient knowledge of groundwater dynamics in operation level (e.g., over-extraction, sometimes 24 hours, causing quality changes and finally well failure).
- Difficulties in controlling of interfering with other pumping well/wells and other borehole construction in the same aquifer (same/different institutions drill wells in the same aquifer).
- Lowering of general groundwater table (aquifer drainage) due to sand mining along the rivers.
- Decreasing recharge related to aquifer drainage.
- Pollution (mainly these wells are close to paddy fields and cause agricultural pollution).

Finally, some institutional provisions are needed to manage groundwater and, if not, there is no meaning in talking of governance for groundwater.

Thank you very much.

Good presentation, which led to asking a very pertinent question: what organization has the power to monitor conjunctive water uses (surface water and groundwater)

A: At the moment we do not have such an organization. Irrigation Department and Mahaweli Authority use surface water. WRB has been given authority to pay more emphasis on matters pertaining to groundwater by a parliamentary act and NWS&DB deals with groundwater for rural water supplies. Some years back, an agency called National Water Resource Agency (NWRA) was formed to monitor water resources in the country but it could not survive due to political and social issues.

Q: In the northern and eastern provinces there are lots of issues to be considered. What is the arrangement made by your organization?

A: Our regional group established for that area takes actions to solve problems in the area. At these offices we are short of staff but we are trying get enough staff now.

11.3. Third Presentation of Session 1

Mr. S. Croos, Consultant to the JKWSSP on **Managing aquifers in Jaffna Peninsula and providing safe drinking water**.

Good morning ladies and gentlemen! I will explain about managing aquifers in the Jaffna Peninsula which has a unique geography considering the other parts of Sri Lanka. It has no rivers and is a flat land underlined with Miocine limestone. The annual evaporation is more than annual rainfall in the area. The present population of Jaffna Peninsula is around 650,000. The people there depend for their livelihood, food production and drinking, I would say, on groundwater. But unfortunately it is very badly contaminated and affect people's health. The aquifers are shown below.

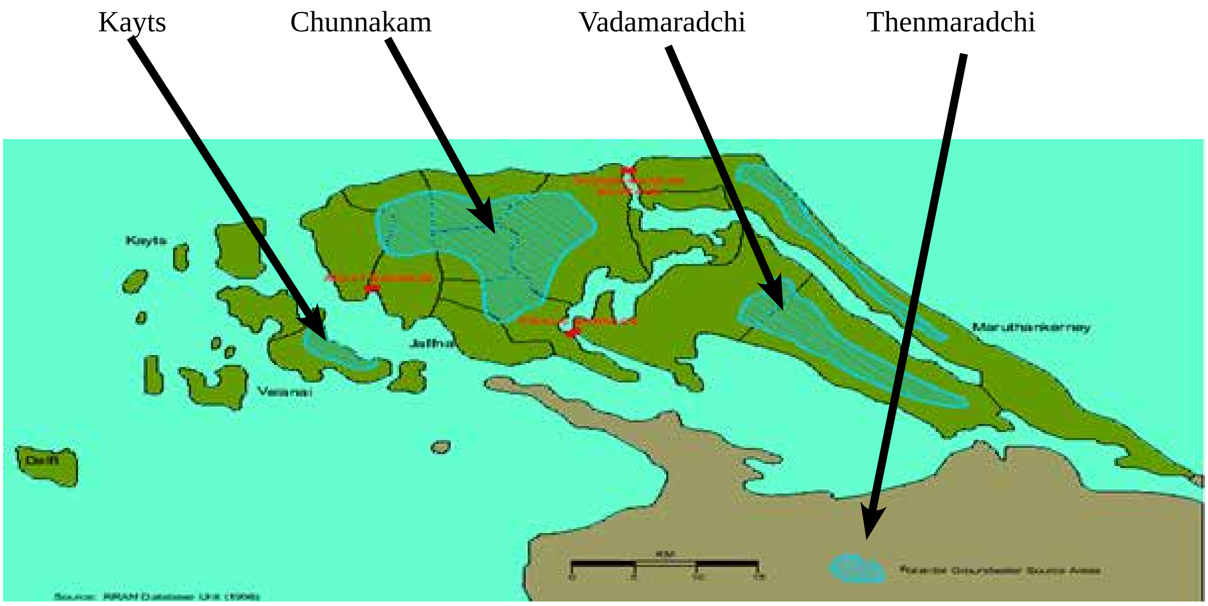


Figure 11.3.1. Major aquifers in the Jaffna Peninsula.

Major problems in the Jaffna Peninsula

- Inadequate water sources within Jaffna Peninsula to provide pure and clean drinking water.
- Existing underground water resources are contaminated (bacteriological and chemical contamination and intrusion of seawater).
- About 30% of typhoid cases in Sri Lanka are from Jaffna Peninsula while cancer cases are increasing. Farmers are losing their income due to saline paddy fields.
- Water supply available in the Peninsula is at a minimum where people have to spend long hours at stand pipes.

Kayts Jaffna town

Figure 11.3.2. Examples of need for sustainable water supply for people in the Jaffna Peninsula.

Photo credits: S. Croos.

Major objectives of initiating JKWSSP

Component 1

A. Providing safe drinking water to Jaffna and Kilinochchi districts with a population of 300,000.
B. Providing a sewerage system within the Jaffna Municipal Council area for controlling bacteriological contamination and reuse of wastewater, to a population of 80,000.

Component 2

Strengthening the Jaffna water resources management committee for improving groundwater.

Component 1A

Providing surface water for a population of 300,000 in the following areas:

Jaffna	Kodikamam	Nallur
Moolai	Araly	Vaddukkodai
Karaveddy	Chavakachcheri	NavatkuliKopay
Atchuvely	Sandilipay	Kaddudai
Navaly	Chankanai	Karainagar
Kayts	Analaithivu	Eluvaithivu
Punguduthivu	Velanai	Mandaithivu
Poonakery	Palai	

Water from Iranamadu tank in Kilinochchi District will be diverted for the use of the rest of the population of 300,000.

Providing underground water for a population of 350,000

- Water supply schemes operated by NWS&DB and local authorities which draw water from aquifers.
- Small-scale community water supply projects also being implemented under the project.

Component 2

Strengthening the existing Jaffna water resources management committee (JWRMC)

The need for a regulatory body was felt for controlling water pollution. Figures 11.3.3 and 11.3.4 show pollution from a) garbage dumping and b) oil and grease.

Figure 11.3.3. Garbage dumping pollution.

Figure 11.3.4. Oil and grease pollution.

Photo credit: S. Croos.

Figure 11.3.5. Black water pollution.

Figure 11.3.6. Solid waste disposal pollution.

Photo credits: S. Croos.

Figure 11.3.7. Over-extraction.

Figure 11.3.8. Chemical pollution.

Photo credits: S. Croos.

Table 11.3.1. Common pollutant sources and extent of pollution.

	Pollutant	Source of the pollutant	Measuring unit, mg/l	Maximum concentration registered	Location of test source	Standard maximum permitted
1	Salinity	Seawater under aquifer	As chloride	>2,000	See map	1,200 mg/l
2	Nitrites	Fertilizers, human waste	As No_2	0.263 mg/l	Kondavil	0.1 mg/l
3	Nitrates	Agro-chemicals, fertilizers, human waste	As No_3	149 mg/l	Kondavil	45 mg/l
4	Organic leachate (Ammonia)	Solid waste from urban areas	Ammonia	0.36 mg/l	Kondavil	0.06 mg/l
5						
6	C_aCO_3 or M_gCO_3	Limestone or dolomite	Total carbonate	48%	Standby round	600 mg/l
7	Iron	Topsoil/ Fertilizer	Total (Fe)			240 mg/l

Assistance provided to JWRMC from JKWSSP

- Assisting existing committee in designing a policy and institutional framework for Integrated Water Resources Management (IWRM), by developing a water resources management plan.
- Support NWS&DB, WRB and other institutions in developing a monitoring system on groundwater quantity and quality.
- Support Legal Aid Agency (LAA) in monitoring and managing groundwater resources by helping it to design effective laws, rules and regulations.
- Conduct public water conservation, environmental protection, and hygienic awareness campaigns, and a program for community monitoring.

Members of the JWRMC under the chairmanship of Government Agent, Jaffna

- Director/Deputy Provincial Secretary - Kachcheri.
- Project Director - JKWSSP.
- Team Leader/Consultant - JKWSSP.
- Regional Manager/Junior Research Officer - NWS&DB.
- Area Officer - WRB.
- Divisional secretaries.
- Deputy Director - Department of Agriculture.
- Assistant Commissioner of Agrarian Development Department.
- Director, Department of Irrigation.
- Deputy Provincial Director of Health Services.
- Assistant Director - CEA.

- Representative from the University of Jaffna.
- Assistant Commissioner of Local Government.
- Hon. Mayor - JMC.
- Chairmen of Local Authorities.
- Representative from the Chamber of Commerce.
- Farmer Organizations.

Table 11.3.2. JWRMC- Action plan (tentative).

Problems	Actions undertaken
▶ Bacteriological contamination	▶ Implementing solid waste management - Constructing sewage system in JMC area to control chemical contamination.
▶ Chemical contamination	▶ Improved agricultural practices. - Encouraging organic farming. - Reducing fertilizer usage.
▶ Salinization	▶ Improving water management in farming practices. - Promoting drip and sprinkler irrigation. - Regulating agricultural groundwater usage.
▶ Depletion of aquifer	▶ Improving the recharge system. - Maintaining minor tanks (900 tanks). - Converting saltwater lagoons into freshwater lagoons. - Promoting rainwater harvesting. - Controlling sand mining.

As the JKWSSP will end by 2016 we need to look for a way to sustain the committee.

Construction of barrages is necessary for converting saltwater lagoons to freshwater bodies

Figure 11.3.9. Location of barrages.

Source: Provincial Irrigation Department.

For the sustainability of the committee

- ► Support from the center.
- ► Empowering regulatory bodies.
- ► Continuous assistance from funding agencies and institutions like IWMI is necessary.
- ► Capacity-building of stakeholders (officials in NWS&DB, WRB, CEA, and LAA) is necessary.

11.4 Fourth Presentation of Session 1

Dr. Madar Samad, Acting Theme Leader -Water and Society, IWMI, Sri Lanka on **Wells and Welfare: The Sri Lankan Case.**

I had been working at IWMI for the last 20 years on welfare implications of the agro-wells. As Thushaar rightly pointed out there has being a groundwater boom in Sri Lanka, which is a silent revolution. It has escaped not only the private eye but also the public eye, and it has not been reflected in any lateral statistics either. We talk about minor irrigation, major irrigation and rain-fed irrigation but there is no statistics at all for the groundwater sector. We also know that, fortunately or otherwise groundwater development has escaped from the eye of the politicians. Up to now, we do not see politicians inaugurating a tube well or a public well; that has not been done so far. We also do not see bureaucrats around that. It is purely only farmers' incentive, farmers' initiative, and farmers' capital. And we also do not hear groundwater farmers protesting in front of the ministries or the Mahaweli Authority or Irrigation Department asking for more water. There is no water diverted for hydropower or electricity or urban water supply. So it is quite rightly a kind of silent revolution. I am going to talk about what this revolution has done in Sri Lanka from a welfare point of view based on some fieldwork study I have done. In doing so, first I will give an overview of my presentation.

The groundwater (agro-well) boom since mid -1980s "The silent revolution".

Figure 11.4.1. Dug agro-well.

Photo credit: IWMI.

Overview of the presentation

- Trends in agro-well development.
- Tank-agro-well interrelationship.
- Changes and results in agrarian systems development.
- Outcomes of the change.
- What the future scenario looks like.

In the early 1980s Kikuchi, Debagae and myself did a study on groundwater development in Sri Lanka but there were no statistics at all. So Kikuchi, Parakrama, another colleague of mine, and I went to the field to derive some statistics from what was available, do a rapid appraisal, and meeting DSDs of various divisions to look at the trend in 1985. That was the time when Agricultural Development Authority (ADA) was involved in promoting and funding groundwater development.

Diffusion of agro-wells

There has been a remarkable increase in developing agro-wells in the last three decades.

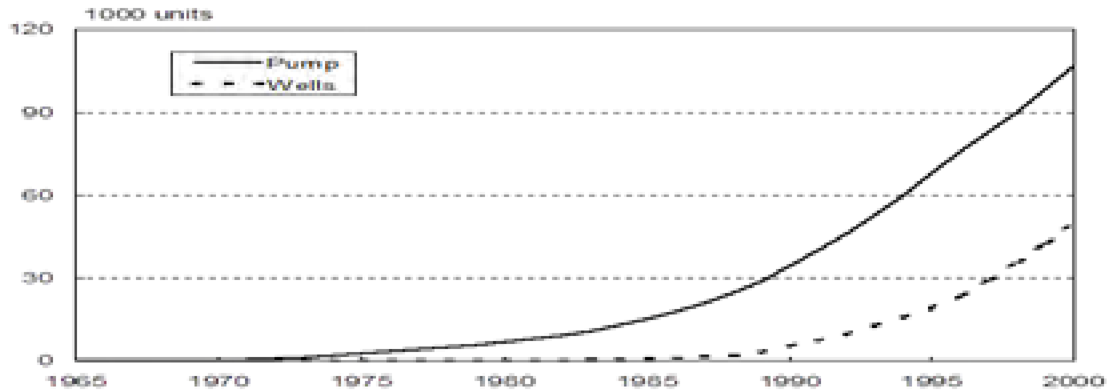


Figure 11.4.2. Diffusion of agro-wells and irrigation pumps in the command and highland areas of irrigation schemes in the dry zone of Sri Lanka, 1965-2000.

Source: Kikuchi et al. 2003.

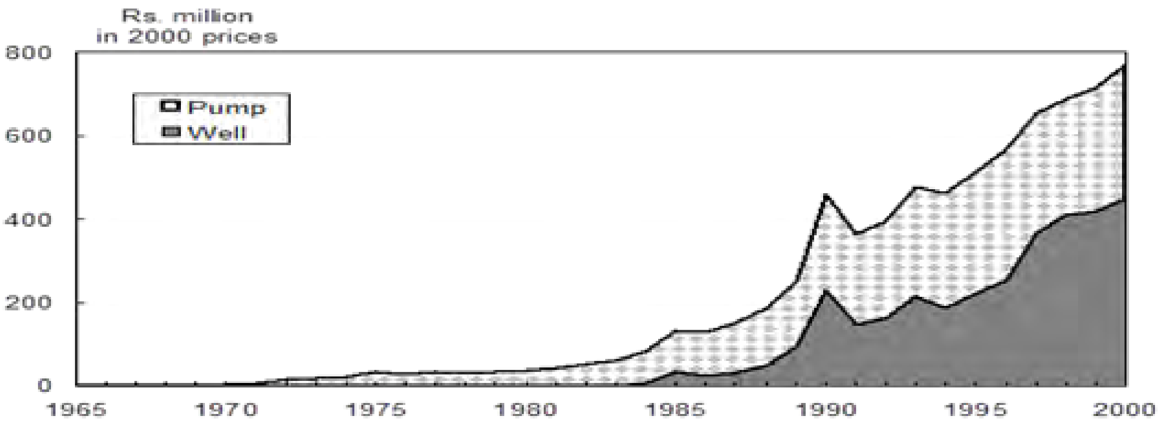


Figure 11.4.3. Private investment on agro-wells and irrigation pumps in irrigation schemes in the dry zone of Sri Lanka, in 2000 prices.

- Investment in agro-wells and pumps by farmers is estimated to be about Rs0.8 billion in 2000 in current prices. Now it may be more with the easy availability of pumps and opening up of the North and East.
- By the late 1990s, private investments in agro-wells and pumps exceeded the total public expenditure for the operation and maintenance (O&M) of the entire major irrigation schemes in the country.
- In 2000, private investment on agro-wells and pumps was as much as 20% of the total investment and expenditure in the irrigation sector.
- The diffusion of wells has been very rapid and pervasive in minor irrigation schemes in North Western Zone and the North Central Dry Zone. This is still more in the Northern and Eastern areas.
- The difference in agro-wells in Sri Lanka as compared to other South Asian countries is their shallowness. As a result, the pumps are small and the sizes of irrigable areas are small. In India, Pakistan and in other parts of South-East Asia groundwater is used for cereal cultivation in the low valleys. In Sri Lanka, groundwater is used to cultivate high economic value crops while tank water is used to cultivate cereals and rice. Most of the agro-wells are located in the highlands and form a component of the small tank farming system.
- For analytical and resource management purposes groundwater irrigation from agro-wells should not be considered as a separate entity but considered in conjunction with surface water irrigation from tanks.

Impact of small tank farming systems

This is a very sustainable system which had been in use for more than 2000 years. But the farmer income has been low. Studies were carried out on small tank irrigation systems.

Figure 11.4.4. Production conditions under small tanks were embedded in a low equilibrium trap.

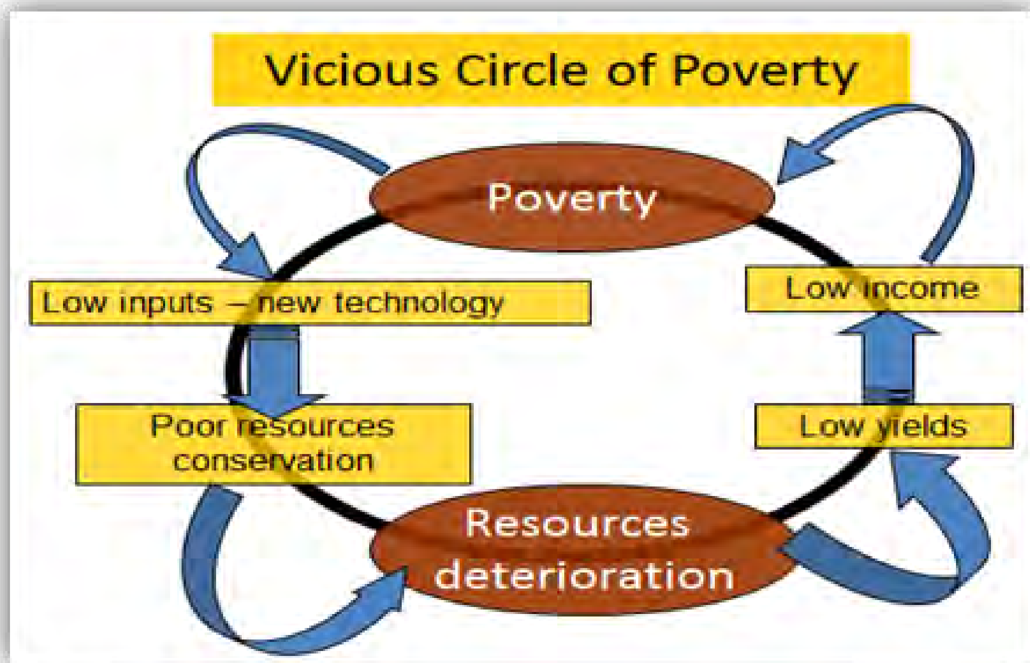


Figure 11.4.5. Rapid rural appraisal (RRA) to assess the impact of agro-wells on the small tank economy.
Source: Samad et al. 2011-2012; Shah et al. 2012.

People depending on small tank systems had no escape mechanism. They were stuck in the small tank system due to constraints imposed by the hydrology of the system, institutional constraints and, most importantly, the land tenure system that was evolved due to intense demographic pressure, e.g., distribution of family-owned land among their children. So, over time, it was all embedded in a vicious circle of poverty.

Study Objective

To document the dynamics of agrarian changes in four small tanks systems in Sri Lanka due to technological innovations, especially groundwater irrigation, mobile phone communication and market linkages.

The escape route came to the people who depended on small tank systems through groundwater. The kind of dynamism that was taking place in the upland areas with the use of groundwater made a revolution. They cultivated high-value crops there, and the cropping intensity too had increased against lowland cultivation; linked to that the mobile phone revolution took place. People started using cell phones to get information on the prices in the markets. It was noticed that three things were happening: groundwater irrigation, markets and commercialization. This was the trend in those villages.

- Since 2000, the construction of agro-wells has intensified.
- The numbers of agro-wells in each sample village (they did not have agro-wells before 2000) are given below.

Table 11.4.1. Location of wells.

Location	Galkandegama	Moragoda	Gallallegama	Galenbindunuwewa
Purana Wela	0	0	0	0
Akkarawela	3	12	5	6
Goda idam	48	124	100	78
Home gardens	8	11	12	9
Chena	0	1	0	0

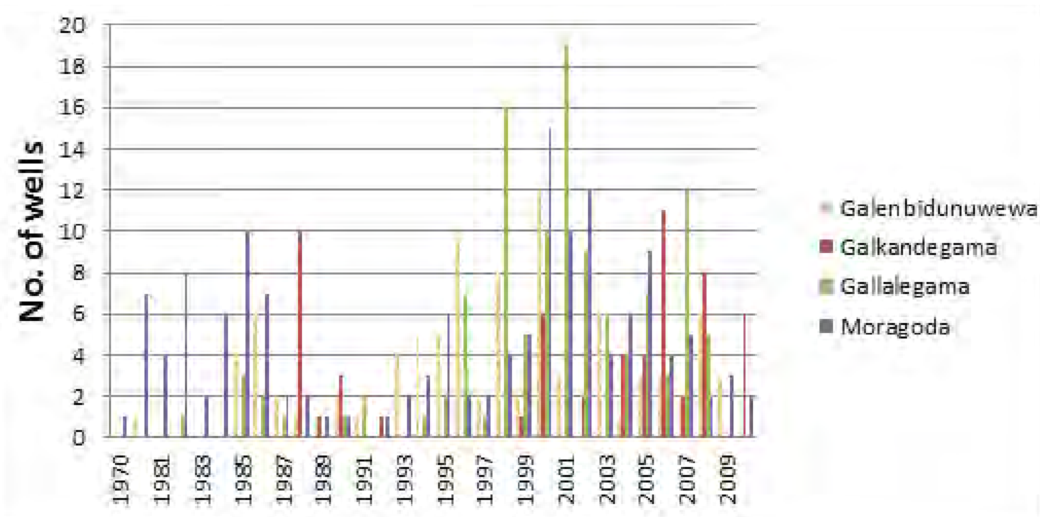
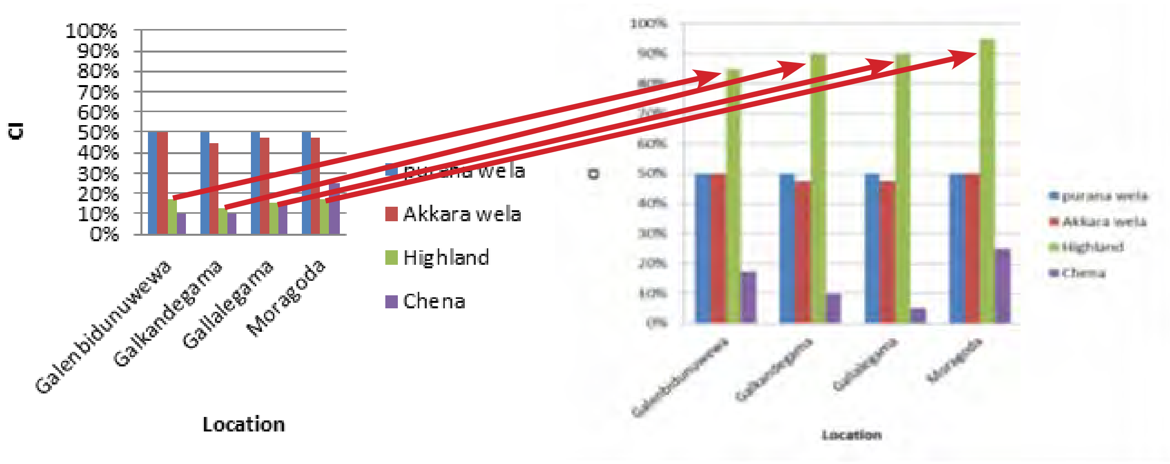


Figure 11.4.6. Trend in establishment of agro-wells at Galenbindunuwewa, Gallallegama, Galkandegama, Moragoda (n=151).

Figure 11.4.7. Current well density in the study sites: Galenbindunuwewa, Gallallegama, Galkandegama, Moragoda.

Table 11.4.2.Agro-wells and agro-ecological transformation in Galenbindunuwewa (Shah et al. 2012).

	Before the agro-well boom	Now
Lowland maha season paddy cultivation	+++++	+++++
Lowland yala paddy cultivation	+++++	+++++
Supplemental irrigation to rice	++	+++
Mung bean and cowpea cultivation in chena land	+++++	++
Vegetable cultivation	++ (for home consumption)	+++++ (for market)
Other market crops	+	+++++
Cattle	++	+++++
Focus of dairy farming	Milk for home consumption; work animals	Milk production for the market
Approach to dairy farming	Extensive, based on grazing	Intensive based on stall-feeding
Green fodder cultivation as mulch for cattle	+	+++++
Tree crops	+++	++++



Before

After

Figure 11.4.8. Cropping intensity before and after agro-well construction.

Market information via mobile phones

Figure 11.4.9. Market calls; market sources.

Figure 11.4.10. Daily prices received via SMS/voice.

Photo credits: IWMI.

Marketing Channels

Table 11.4.3. Before agro-well.

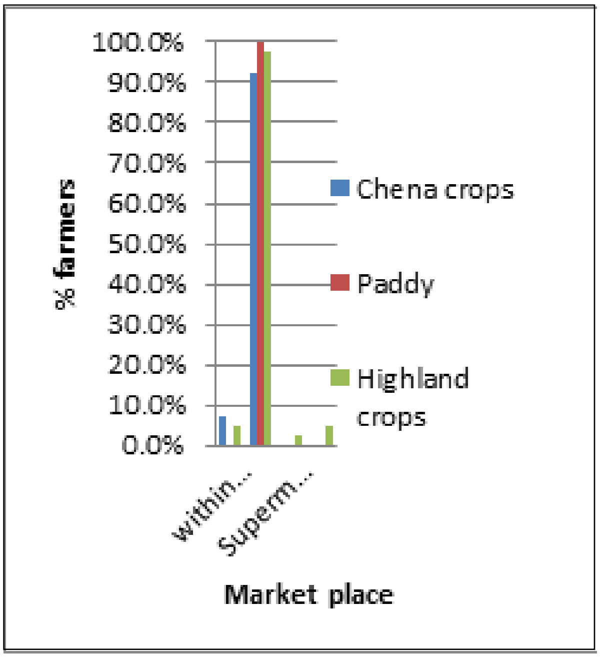
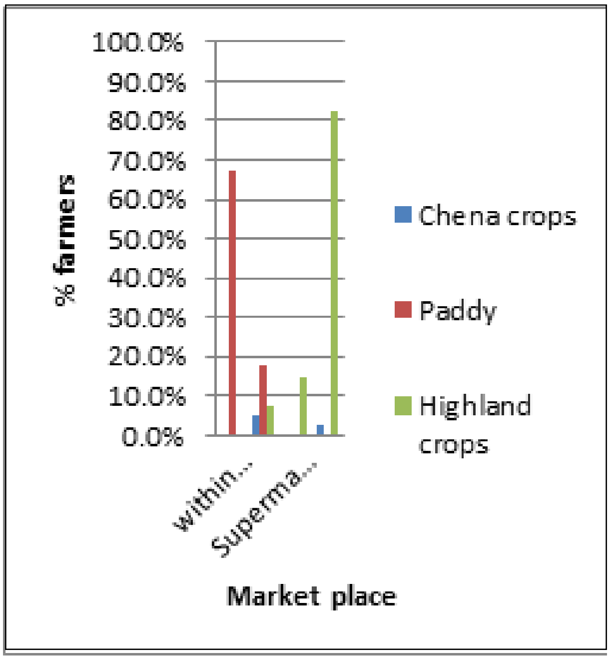


Table 11.4.4. After agro-well.



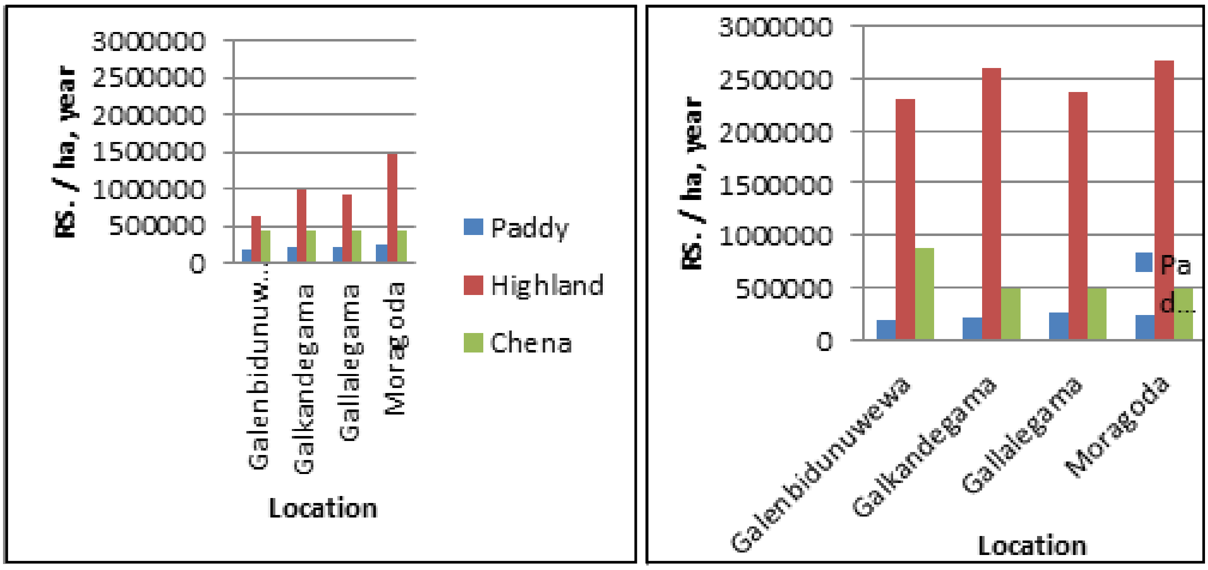


Figure 11.4.11. Gross income before and after agro-well construction.

Impacts

- Visible improvements in housing and living standards, school enrollments, health and the status of women. Social and cultural bonds persist but to a lesser extent.
- No threat to the major GW resource base - seasonally recharged with monsoonal rains.

Wells and Ill-fare: Some negative externalities

- Most of the benefits have gone to more well-off households who had the capital to invest in the necessary equipment and farm inputs.
- Increased encroachment on state land and private enclosures of common property.
- The poor and landless are increasingly marginalized raising questions of social and economic equity, and growing concerns about the environment.
- Groundwater quality – increased pesticide use, Chronic Kidney Disease?

Future Scenarios (Based on: Shah et al. 2012)

- Given the high returns it is very likely that agro-well irrigation will soon spread widely including in the wet zone
- Electricity use in agro-well irrigation in Sri Lanka at present is insignificant, but it is likely to grow rapidly because irrigating with kerosene/diesel pumps is progressively becoming more expensive:

Amount required to irrigate 1 acre of Bombay onions at 425 liters per acre = Rs. 425 x 120= Rs51,000. Electricity cost for irrigating 1 acre of onion = Rs. 15,000.
Source: A farmer in Pul Eliya.

- With rising energy costs there would be a strong demand for micro-irrigation for energy efficiency more than for water use efficiency.
- Sri Lanka's electricity pricing policies need to recognize growing electricity use in agriculture.

- There is a case for treating agro-well owners as a distinct category with a distinct pattern of electricity use.
- Rational electricity pricing and supply policies can be a powerful tool for pro-poor agricultural growth based on groundwater irrigation.
- High time a national policy on groundwater use was formulated.


Figure 11.4.12. Production gluts.


Figure 11.4.13. Storing onions.

Photo credits: IWMI

It is best to remember King Parakramabahu's words for economical use of water.

King Parakramabahu (1153-1186 AD):
"Let not a drop of water that falls from the sky reach the ocean without being of use to human beings."


Figure 11.4.14. Parakrama Samudraya.


Figure 11.4.15. Potgul statue (generally believed to be that of King Parakramabahau).

Photo credits: IWMI.

11.5 Fifth Presentation of Session 1

Mr. J.P. Padmasiri, Scientist, IFS on **-- Removal of hardness and fluoride from groundwater**

Good morning everybody! The Government had developed rural water supplies in Anuradhapura District by means of limited water tanks. Over the years we had been testing their water quality and found that 20% of these schemes have run into problems. We have conducted similar tests in Kurunegala Districts too.

Table 11.5.1. High hardness and fluoride in CBO areas in Anuradhapura.

Community-based rural water supply schemes	Conductivity μS/cm	Total hardness, mg/l (C_aCO_3)	Fluoride, mg/l
614:1983 Desirable level	750	250	0.6
Murungahiti Kanda, Madatugama	870	420	1.33
Hunuvilagama, Nochchiyagama	820	358	1.52
Udunuwara, Nochchiyagama	560	280	1.90
Kudawewa, Pinidiya, Nochchiyagama	810	375.	1.90
Padavi, Prakramapura, Padaviya	680	275	1.19
Medavachchiya	790	310	2.15
Ambagahawewa Praja Moola Nochchiyagama	590	300	1.40
Sahana Priaja Moola, Pemaduwa	1,250	370	1.63
Bandaragama Praja Moola, Athdathkalla	1,160	688	1.62
Bhagya Praja Moola, Kirilketiya, Mahavilachchiya	2,330	420	0.83

Table 11.5.2. Problematic rural water supply schemes in Kobeigane and Nikaweratiya DSDs in Kurunegala.

Community-based RWSS	Conductivity, μS/cm	Fluoride, mg/l
Desirable levels as per SLS 614:1983-	750	0.60
Nirmala Diyadahara, Pannawa, Kobeigane	2,300	0.39
Sri Sumangala 2, Kobeigane	790	1.30
91 km post, Nikaweratiya	1,550	0.40
80 km post, Hewanpallessa, Nikaweratiya	870	2.70
Lee kola wewa, Nelson well, Kobeigane	1,280	2.01
Pattiyadaluwa, Kobeigane	860	2.00
Prashakthi, Hathalawa, Kobeigane	680	1.97

In these areas water is hard, and our dental researchers found 55% of schoolchildren have dental problems (typical cases of dental fluorosis) and 50% of the wells have fluoride > 1 mg/l.

Figure 11.5.1. Dental fluorosis.

Photo credit: J. P. Padmasiri.

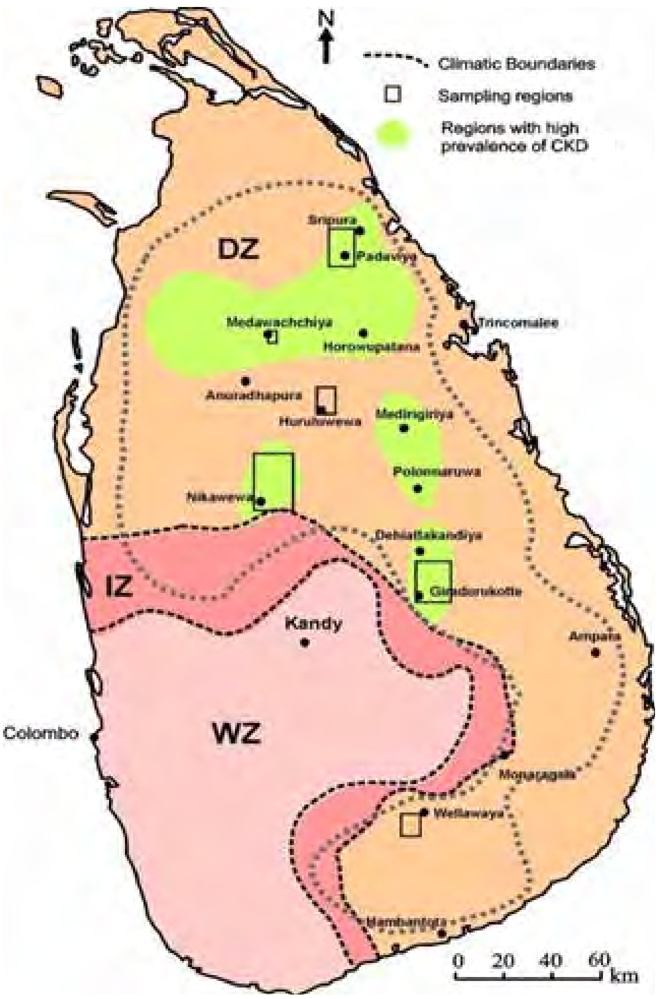


Figure 11.5.2. CKD area map of Sri Lanka.

CKD areas are marked in green. Almost all identified CKD areas fall into the high fluoride zone. Therefore, we believe that fluoride plays some role in CKD.

About 5% of hardness is removed by boiling the water. Hotels use geezers and hot water to reduce hardness.

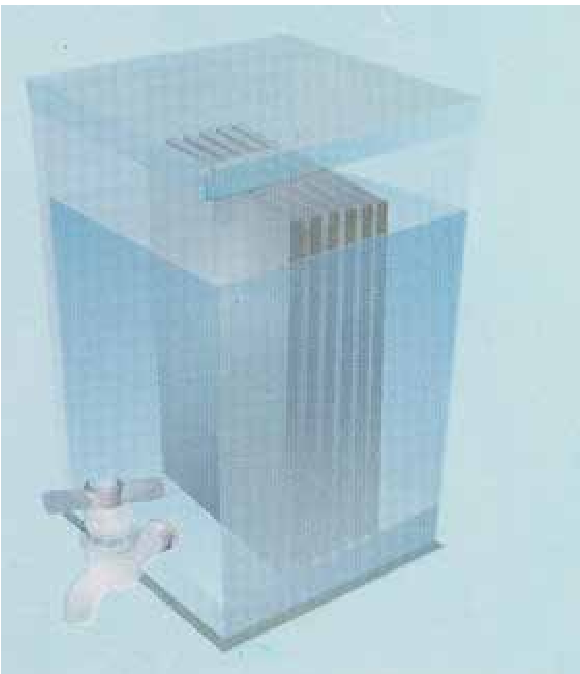
Having identified this problem we thought of finding a solution to it. I mention here about Eng. W.H. Jayawardane who was a member of our team. He had developed a filter for removing hardness of water.

Figure 11.5.3. Hardness – scaling.

Photo credit: J.P. Padmasiri.

Bench-scale unit

It has an anode and a cathode. We pass a 2 ampere current from the anode to the cathode. The reaction shown below takes place and finally Aluminum Hydroxy Fluoirde complex is formed and it comes as sludge in this system.



At the Anode

$$Al \qquad Al^{+3} + 3e$$

$$2H_2O \qquad O_2 + 4H^{+} + 4e$$

At the Cathode

$$2H_2O + 2e \qquad H_2 + 2OH^-$$

$$HCO_3^- + OH^- \qquad CO_3^{--} + H_2O$$

$$CO_3^{--} + Ca^{++} \longrightarrow CaCO_3$$

$Al(OH)_{3-x}F_x$ - Aluminium Hydroxy Fluoirde

Figure 11.5.4. Bench-scale unit.

Figure 11.5.5. Tube reactors. Figure 11.5.6. Ten sets of tube reactors.

Photo credit: J.P. Padmasiri.

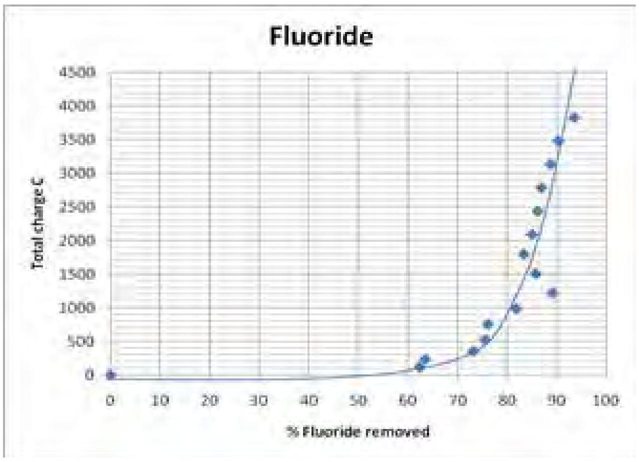


Figure 11.5.7. Total charge vs. removal of fluoride.

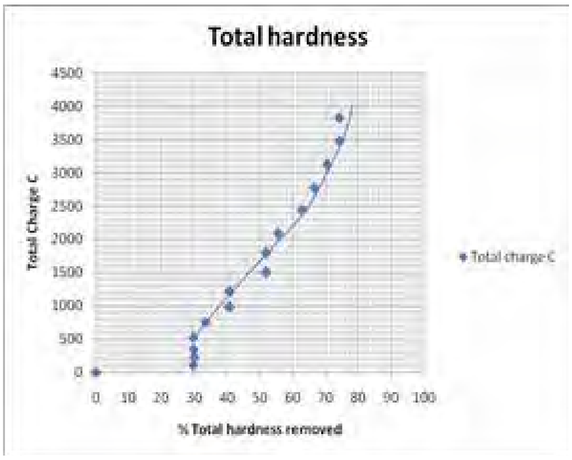
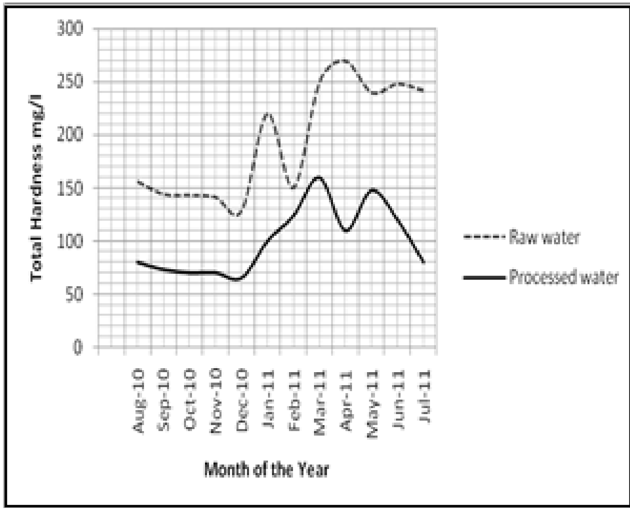


Figure 11.5.8. Total charge vs. total hardness.

Trial at Asokamalgama reactor – Flow rate 100 l/h.

With two celoms, 80% fluoride could be removed. By increasing the charge we can remove up to 90% and this method could be applied to remove hardness too. Both plate reactors and tube reactors could be used. Hardness of 350 mg/l has been brought down to 50 mg/l and fluoride of 1.4 mg/l has been brought down to 0.1 mg/l. These plants have a capacity of 200 l/hour. A plant can produce 1,000 l of drinking water/day. The cost of this complete plant is Rs. 2 million now. We got support from the private sector as well as from the government sector. We were able to establish 15 plants over this area. They were installed 1 year back and we need to see how far we could go with these plants. They are still in the operational condition.



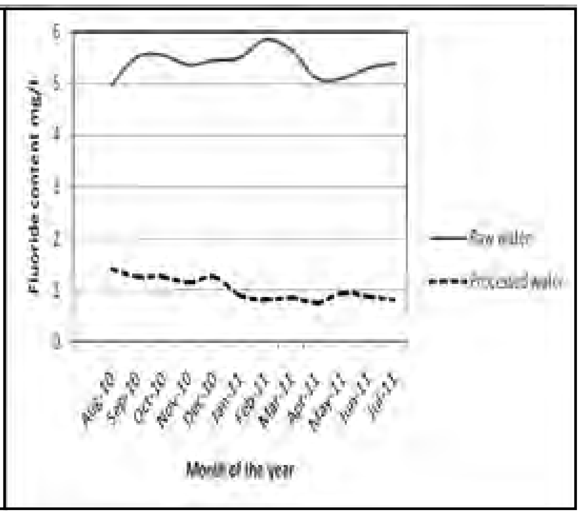


Figure 11.5.9. Hardness of water.

Figure 11.5.10. Fluoride content of water.

Residual Aluminum

Also we are keeping an eye on the aluminum residue. We were able to keep it below 0.2 mg/l.

Figure 11.5.11. Aluminium residues.

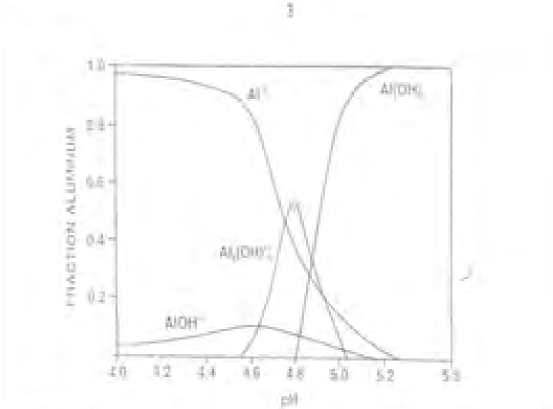


Figure 11.5.12. Distribution of hydrolyzed aluminium (III) as a function of pH, redrawn to concentrate on lower pH values, from Batten.

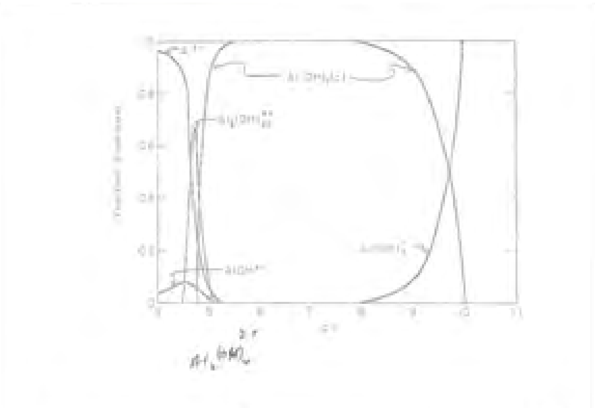


Figure 11.5.13. Distribution of 5.0x10-4 M hydrolyzed aluminium (III) as a function of pH, from Hayden and Rubin.

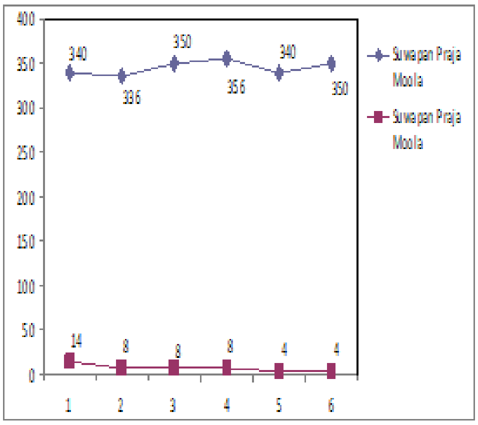


Figure 11.5.14. Aluminum Vs pH.

Fluoride

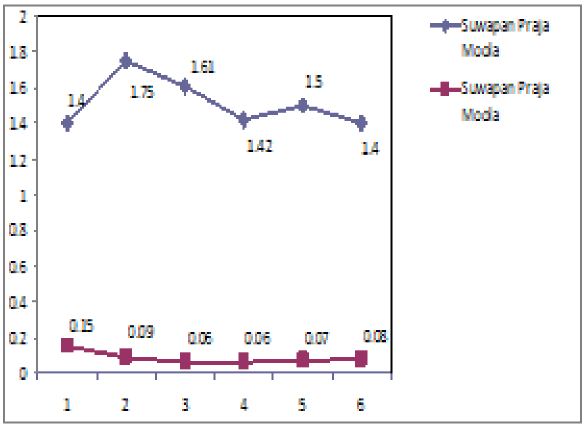


Figure 11.5.15. Aluminum Vs Fluoride.

Suwapan Praja Moola - Hardness and Fluoride

(a) Electro-coagulation reactor.

(b) Plate reactor.

(c) Sludge drying beds.

(d) Sand filter.

(e) Sludge recovery tank.

Figure 11.5.16. EC unit comprising (a), (b), (c), (d) and (e).

Photo credit: J.P. Padmasiri.

The plate reactor was preferred for its easiness in setting in under village conditions.

Figure 11.5.17. Distribution of water treatment plants.

Funds from the private sector

A	Asokamalagama, Nochchiyagama
B	Nikawewa, Kurunegala
C	Giribawa, Kurunegala
D	2-acre farm, Cheddikulam
E	400-acre farm, Ulukkulama
F	Thattawa, Cheddikulam

Funds from Ministry of Technology & Research

1	Sisilasa Praja Moola, Mahavillachchiya
2	Suwapan Praja Moola, Nochchiyagama
3	Randiya Praja Moola, Nochchiyagama
4	Ekamuthu Praja Moola, Galadivulwewa
5	Mahasen Praja Moola, Mihinthale
6	Arunalu Praja Moola, Galnewa
7	Isuru Praja Moola, Medawachchiya
8	Sahana Praja Moola, Pemaduwa

Response of the community

- No aches and pains in the body.
- No burning sensation while urinating.
- Improvement in preparation and preservation of rice.
- Cheaper than buying bottled water.
- Regular use of the processed water.
- Lack of awareness among the community has been improved.

But I feel it is still too early to comment about the response of the community. We have to get medical advice regarding these ailments.

We charge about Rs2 per liter of water. It is with that money that we pay operators and use the balance to maintain the plant.

I would like to thank Eng. Jayawardena.

- IFS.
- NWS&DB.
- Link Natural Products (Pvt) Ltd., Kapugoda.
- Spectra Industries Lanka (Pvt) Ltd., Kurunegala.
- Atlas Machine Components (Pvt) Ltd., Dompe, for the assistance given for implementing the work.

Sixth Presentation of Session 1

Karen G. Villholth, Senior Researcher - Groundwater Management, IWMI, Pretoria, South Africa on **Challenges of Groundwater Management in Sri Lanka**

I have been working for IWMI for almost 5 years on two occasions. I was working here in Sri Lanka from 2004 to 2007 and it was during the tsunami in which I was very much involved. I think that was a very big eye opener for me as well as for other people regarding groundwater, generally speaking, in Sri Lanka. I also want to acknowledge counterparts, the WRB and the Eastern University; we worked together at the time. Knowing the conditions about the groundwater resources at such a disastrous situation was quite a critical time to understand what it takes to enhance the drinking water situation in the coastal line where salinity had increased with the tsunami. That was the major problem we faced.

I was going to talk about the challenges in managing groundwater. But I do not want to repeat what has already been said because we have already discussed many issues on challenges of management. The following areas would cover my presentation.

Groundwater resources of Sri Lanka.

Groundwater research and management development.

Comments on present progress.

Recommendations focusing on the management aspects.

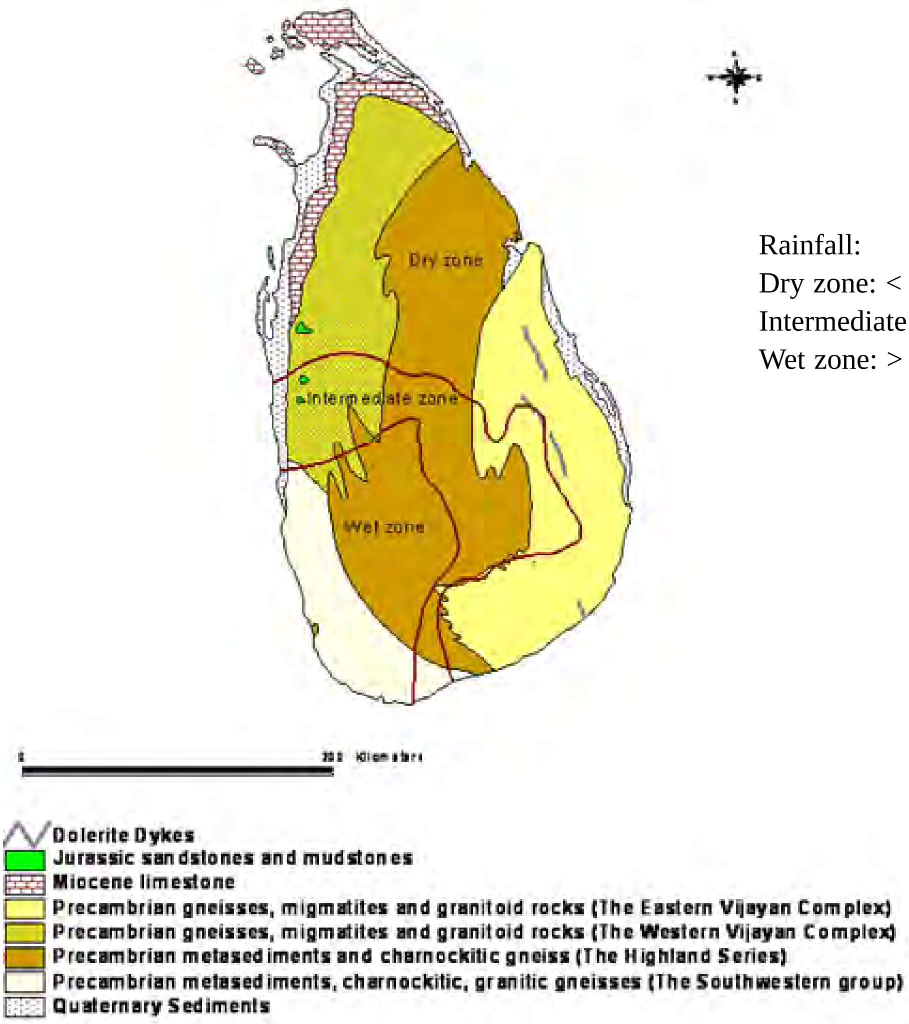
Major geological formations of Sri Lanka

Figure 11.6.1. below shows major geological formations of Sri Lanka.

Figure 11.6.2. below shows the five different aquifers in the country.

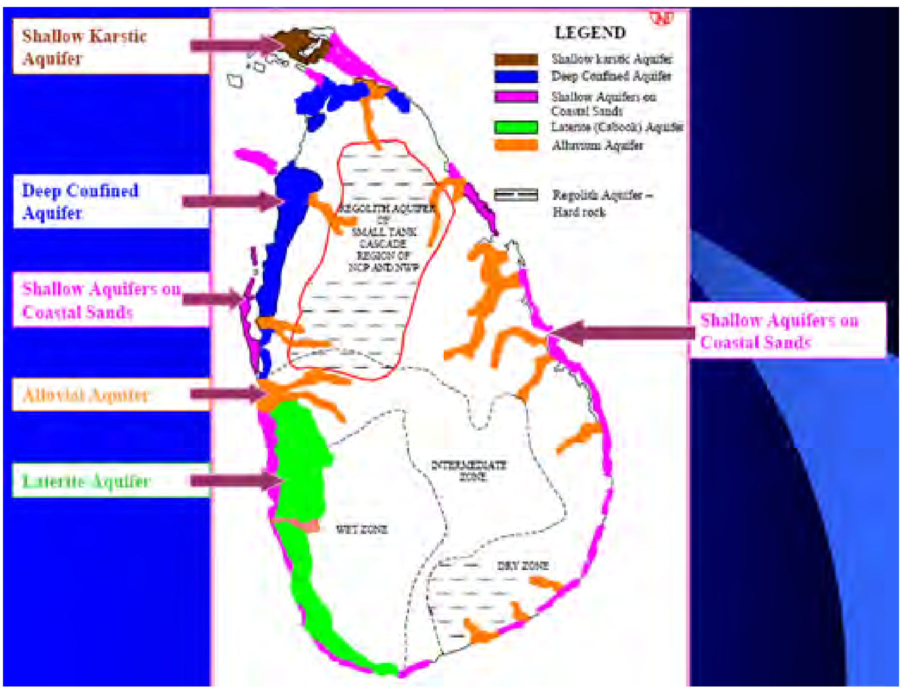
In Figure 11.6.3. the groundwater resources with geological conditions are superimposed with river basins in Sri Lanka. So you can see how these two overlap. There is not much good correspondence between where you have aquifer systems and where you have river basins. There is very low rainfall with poor aquifers in the dry zone and in the southern part and that is why it is running out of groundwater. Otherwise, Sri Lanka would probably be considered quite rich in groundwater resources. So that automatically gives some challenges in terms of managing groundwater. Because these are the two units you have to look at when you want to manage groundwater; you have to look at groundwater and surface water in combination.

In water management you have to look for optimizing these resources: where to use groundwater and where to use surface water. When you want to use groundwater well you have to look at surface water systems as these two have a very important interaction. That has to be looked into more in the future in terms of groundwater and overall water management in Sri Lanka.



Rainfall:
Dry zone: < 1,500 mm
Intermediate zone: 1,500 - 2,500 mm
Wet zone: > 2,500 mm

Figure 11.6.1. Major geological formation of Sri Lanka.



90% of area underlain by hard rock formations at shallow depth

Groundwater available: 7,250 million m^3/yr (Fernando 1985)

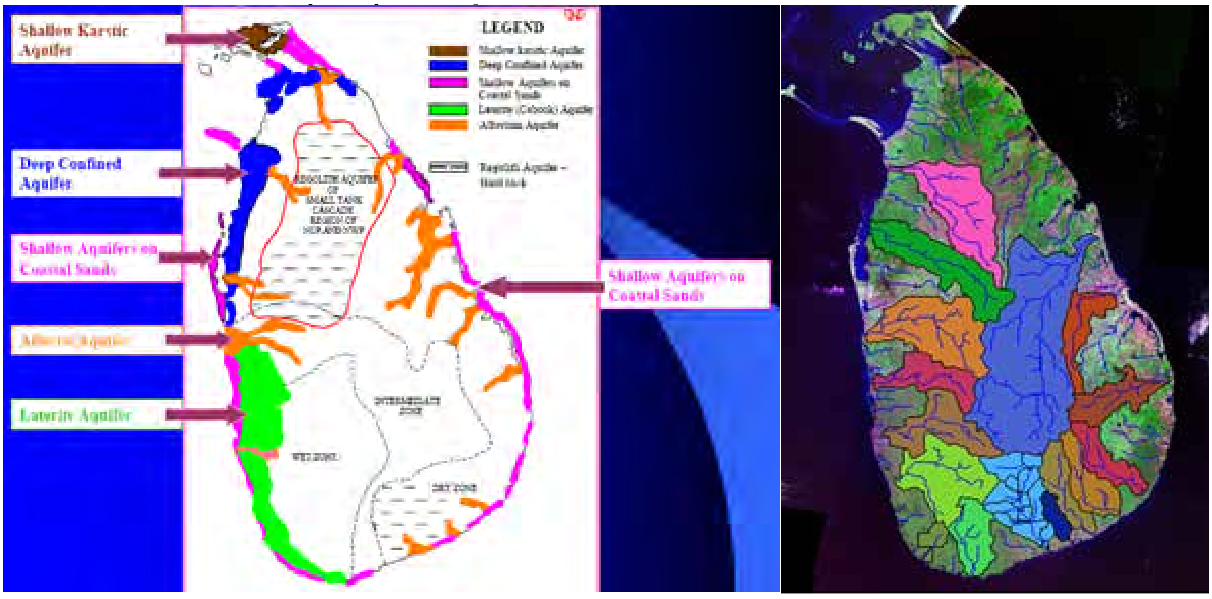


Figure 11.6.3. Surface vs. subsurface systems.

Groundwater is invisible

Groundwater is invisible; we cannot easily see and access it. We all know that. So that costs us a lot of challenges managing it. You have to dig into the groundwater to get data which cost us a lot. Also it is very costly to remedy any kind of damage caused to groundwater resources. And this is one of the fundamental problems in groundwater management.

Figure 11.6.4. Groundwater is present underneath.

Photo credit: Karen G. Villholth.

Threats to groundwater degradation are many

This one is closely related to the volume of groundwater. So over-extraction, leaking seawater, subsidance, failure of wells when the groundwater level drops and then you can see here all the sources of pollution. Manay of these are present here in Sri Lanka, and that is something we have to

pay attention to. In many cases, contamination problems are catching up with water quantity problems, and for groundwater this is very critical because it is very difficult to remedy it once it is polluted. So we have to see ways of prevention of groundwater pollution. We have to really protect this precious resource from the outset. If you do it later it would be costlier.

Figure 11.6.5. Groundwaer threats from groundwater use or decreasing storage.

Figure 11.6.6. Groundwater pollution threats.

Surface water and groundwater relationship

Surface water is an expression of groundwater

Also I have to tell you that surface water is a reflection of groundwater. We try to think of groundwater and surface water as two separate resources. But especially in Sri Lanka you have many river systems. Many of them are fed by groundwater. Part of the river flow is actually coming from groundwater. So if the groundwater is polluted surface water will be polluted. The above picture shows that flows of the rivers are very much reflections of the groundwater levels. So there is a very close relationship between groundwater and surface water. So you cannot separate the management of these two resources.

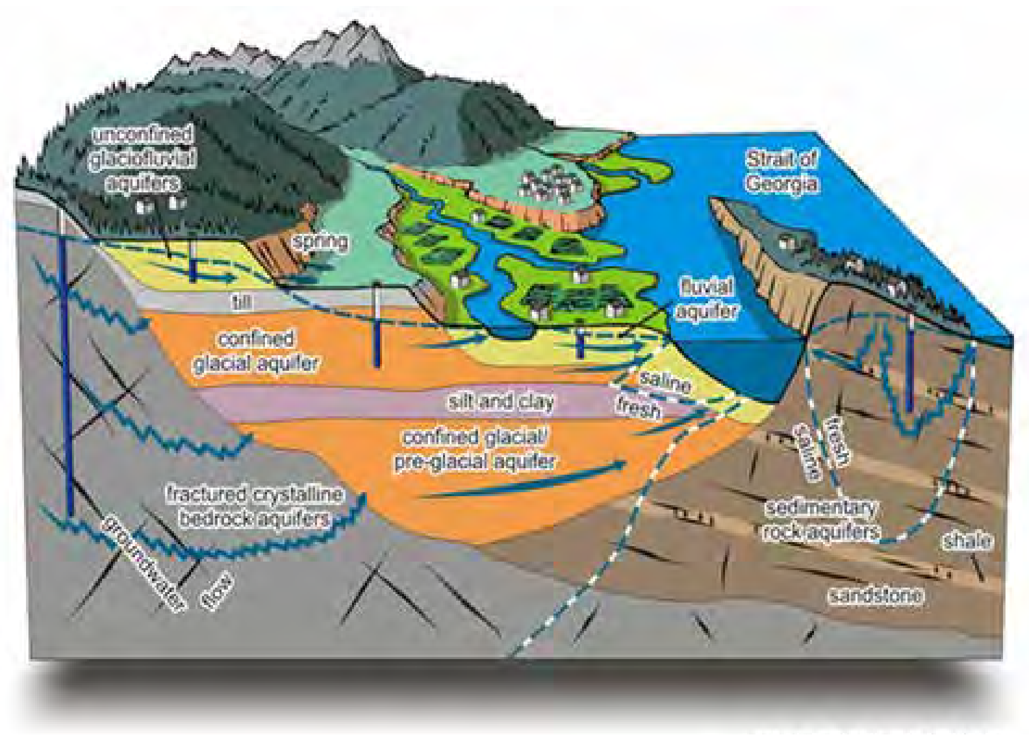


Figure 11.6.7. Surface water is an expression of groundwater.

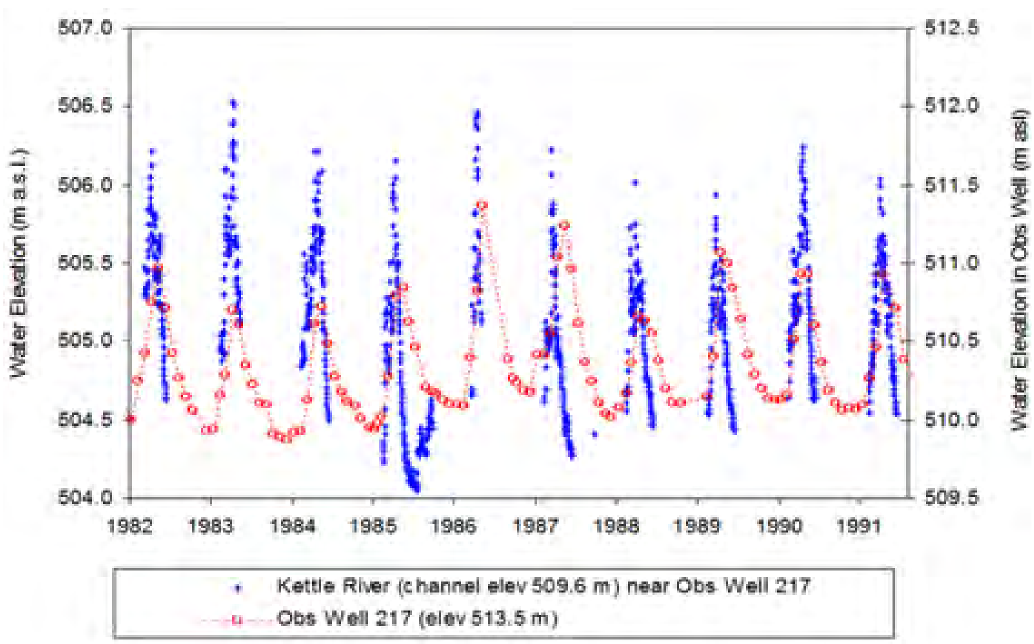


Figure 11.6.8. Surface water is an expression of groundwater.

Note: elev = elevation; Obs = observation.

Drivers for groundwater management

We have to do something about the first three figures out of the six given below because now we have problems. We also have long-term drivers: population growth, urbanization and food security imperatives that are more challenging. On top of that there are more incidental kind of problems so

that we have to address these situations facing us today.

ure 11.6.10. Drought 2012.

Drivers for groundwater management

- Drought of 2012.
- Tsunami of 2004.
- Contamination incidences.
- Population growth.
- Urbanisation.
- Food security imperatives.

Figure 11.6.11. Population growth.

Photo credit: Karen G. Villholth.

IWMI involvement in groundwater research in Sri Lanka

- Groundwater conditions in Sri Lanka (Panabokke, WRB 2007) – some early works.
- Agro-wells in the dry zone Kikuchi et al. 1996.
- Coastal sand and limestone aquifers in Jaffna and Kalpitya.
- Tsunami impacts on the east coast.

Conclusion in early 2007

- "Groundwater management in Sri Lanka is in its early stages"

When I did some assessment of management of groundwater resources in 2007 my conclusion was that groundwater management was in its infant stages. And when I was requested to make this kind

Figure 11.6.12. Laborataries.

Photo credit: Karen G. Villholth.

We heard from the previous speaker that a lot of work is being done under the DSWRPP and they are introducing new laboratories. They are doing a lot of awareness-raising on groundwater and they are setting up a big monitoring system in the country, trying to understand resources and going forward on the basis of knowledge and doing it in a systematic way and trying to understand critical areas where groundwater is used and where there is a lot of human pollution. We are happy to see all these developments. And also we see increased applications of groundwater modeling systems in trying to understand this resource and we see a lot of dialogue between the institutions involved in groundwater management. I think this is really the breaking point; that is trying to get all the institutions together to see problems, how we can collaborate to take this forward. I think this is something very critical.

Figure 11.6.13. Conducting awareness-raising programs.

Photo credit: Karen G. Villholth.

Groundwater monitoring

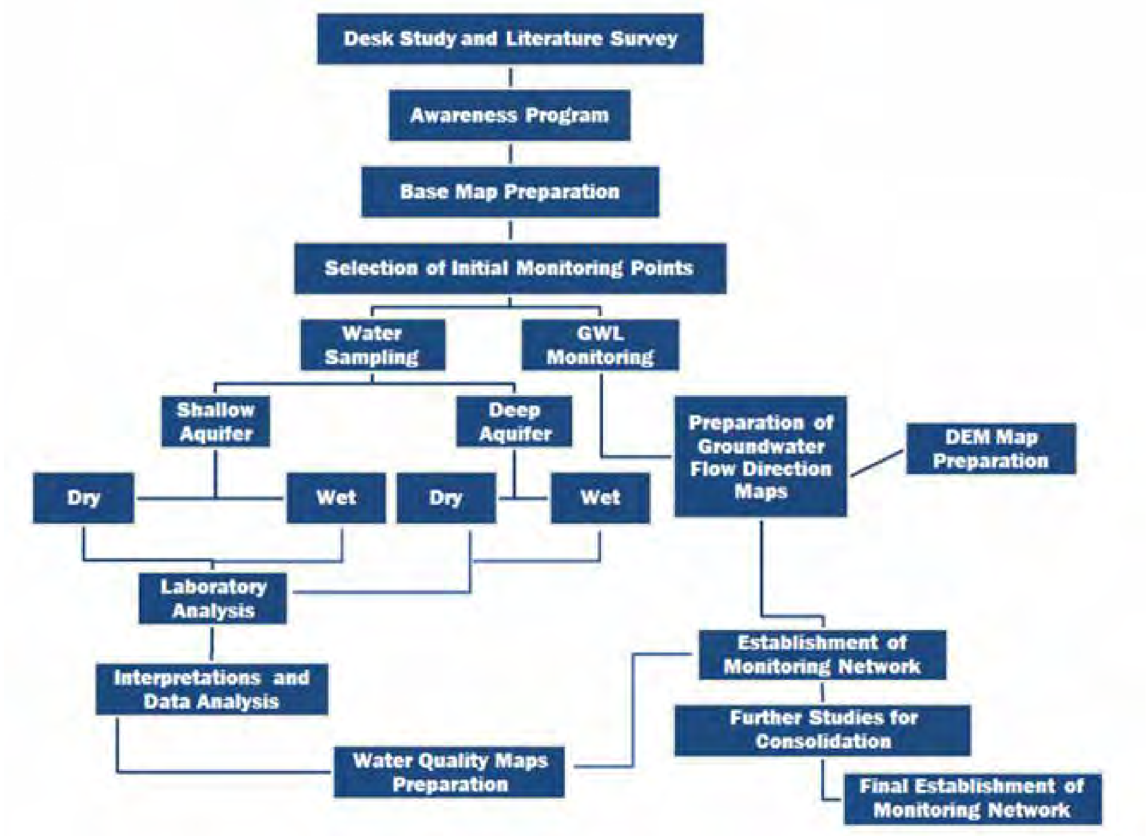


Figure 11.6.14. Flow chart for groundwater monitoring process.

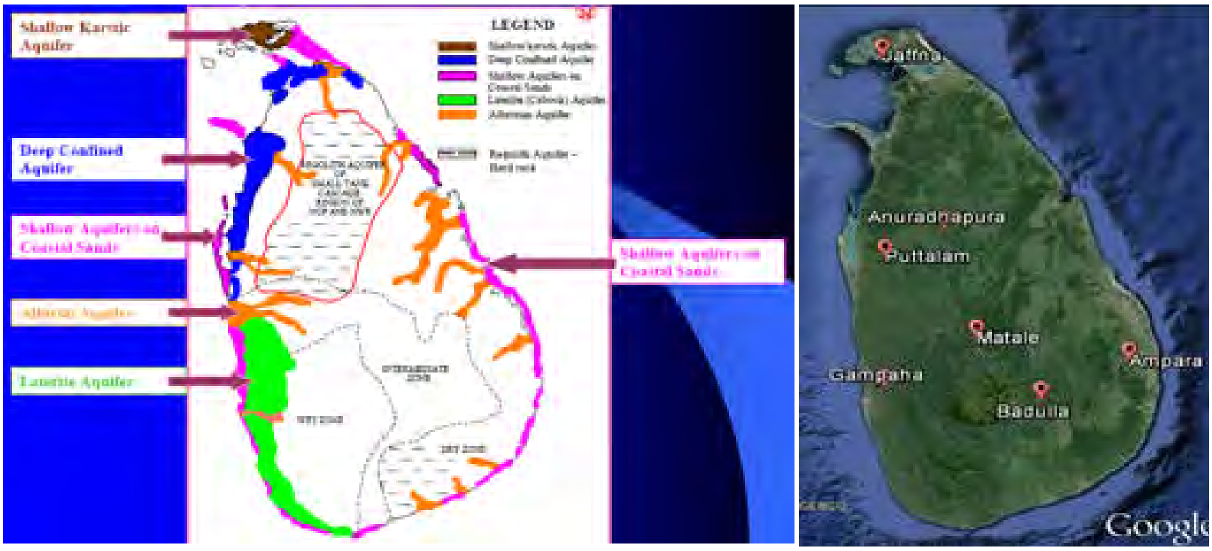


Figure 11.6.15. Map showing pilot sites selected for monitoring.

Table 11.6.1. Surface water and groundwater in various districts.

District	Total supply of SW and GW resources (m^3/day)	Supply of GW resources (m^3/day)	Percentage of GW supply (%)	Percentage of SW supply (%)
1.Ampara	12,457.0	329.0	2.6	97.4
2.Anuradhapura	20,965.0	3,285.0	15.7	84.3
3.Badulla	22,223.0	0.0	0.0	100.0
4.Baticaloa	1,449.0	1,449.0	100.0	0.0
5.Colombo	561,889.0	0.0	0.0	100.0
6.Galle	26,247.0	987.0	3.8	96.2
7.Gampaha	51,374.0	4,859.0	9.4	90.6
8.Hambanthota	27,176.0	1,021.0	3.8	96.2
9.Jaffna	209.0	209.0	100.0	0.0
10.Kegalle	15,887.0	0.0	0.0	100.0
11.Kaluthara	30,604.0	555.0	1.8	98.2
12.Kandy	44,075.0	13,233.0	30.0	70.0
13.Kurunegala	11,483.0	1,800.0	15.6	84.4
14.Mannar	550.0	550.0	100.0	0.0
15.Monaragala	4,228.0	12.0	0.3	99.7
16.Matale	13,113.0	714.0	5.4	94.6
17.Matara	77,482.0	1,311.0	1.7	98.3
18.Nuwaraeliya	8,724.0	4,500.0	51.6	48.4
19.Polonnaruwa	7,655.0	355.0	4.6	95.4
20.Puttlam	8 694.0	8,424.0	96.8	3.2
21.Rathnapura	19 650.0	0.0	0.0	100.0
22.Trincomalle	1 433.0	9.0	0.6	99.4
23.Vavuniya	776.0	776.0	100.0	0.0

Note: SW = surface water; GW = Groundwater.
Groundwater use for water supply
Increasing model applications

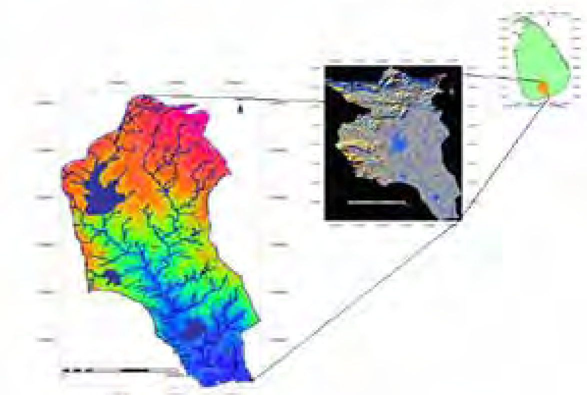
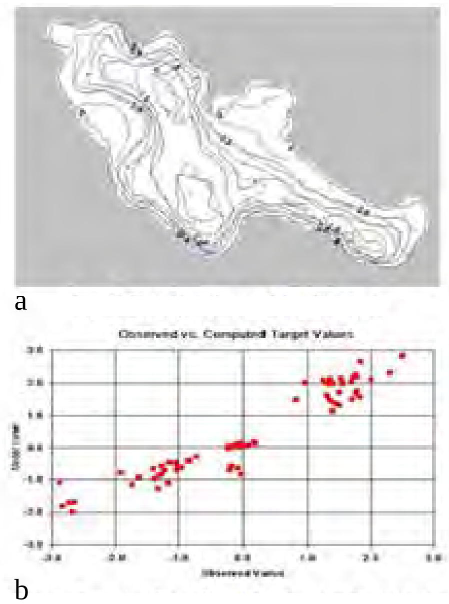


Figure 11.6.16. Walawa.



Figures 11.6.17 a and b. Kayts.

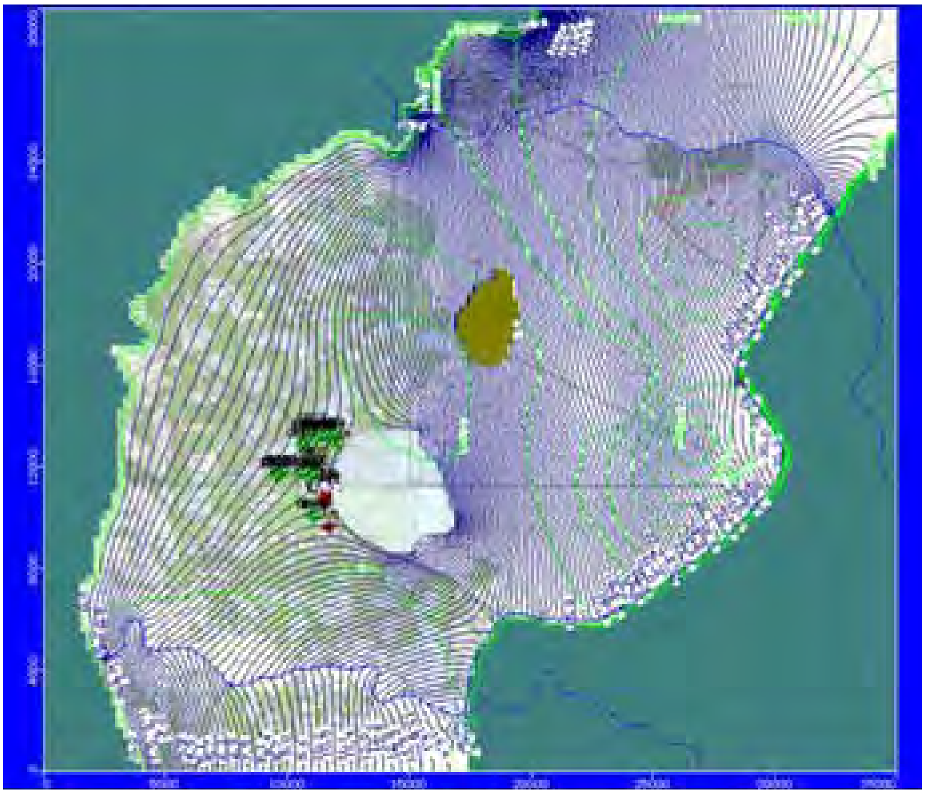


Figure 11.6.18. Mannar.

Figure 11.6.19. Increasing dialogue by having meetings.

Photo credit: Karen G. Villholth.

Pillars of groundwater management

We have to build a very fundamental knowledge base on groundwater conditions. We need to know the users as well as the institutions that are trying to manage this resource. This is the very basis of groundwater management. Once you have the knowledge you go on getting more knowledge. You try to control what is related to groundwater abstractions, pollutions as well as the land use. I think the last one is important to keep in mind. It is not like surface water. It is basically what happens to that water. Groundwater is very much related to what is going on in the ground; so it is very important.

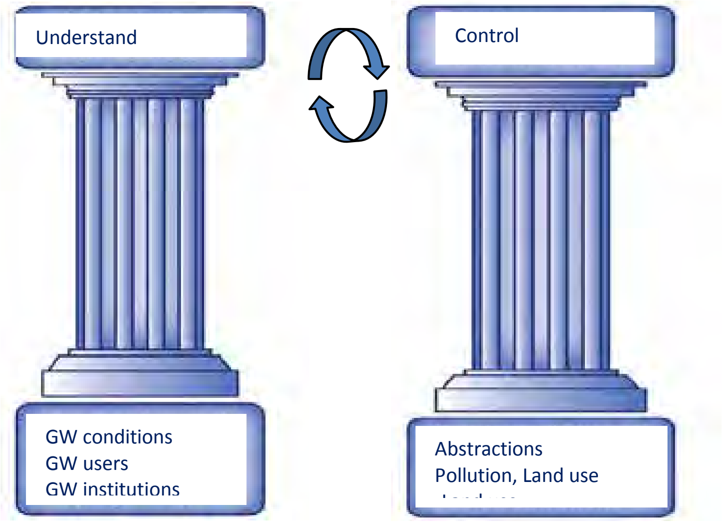


Figure 11.6.20. Pillars of groundwater management.

Note: GW = Groundwater.

Table 11.6.2. Special considerations/provisions needed in aquifer management

Groundwater distinct characteristic	Joint user/use registration, regulation, monitoring, and enforcement	Prior notification of development plans to other party	Precautionary principle	Conflict resolution	Stakeholder engagement	Long-term monitoring of resource	Flexibility in conceptual model and clear data sharing arrangements	Land use and waste regulations	Prioritized protection
Open source	xx								
Invisible and heterogeneous		x					x		
Vulnerable to land use impacts									
Slow reacting/delay in response		x							
Recharge/discharge is distributed and uneven									
Boundaries uncertain							xx		
Climate change impacts uncertain							xx		
Blurred up- and down-stream relations							xx		

Relationship between groundwater properties and what that means to groundwater management

Basically, groundwater has specific properties like groundwater vulnerability. We have to use precautionary principles.

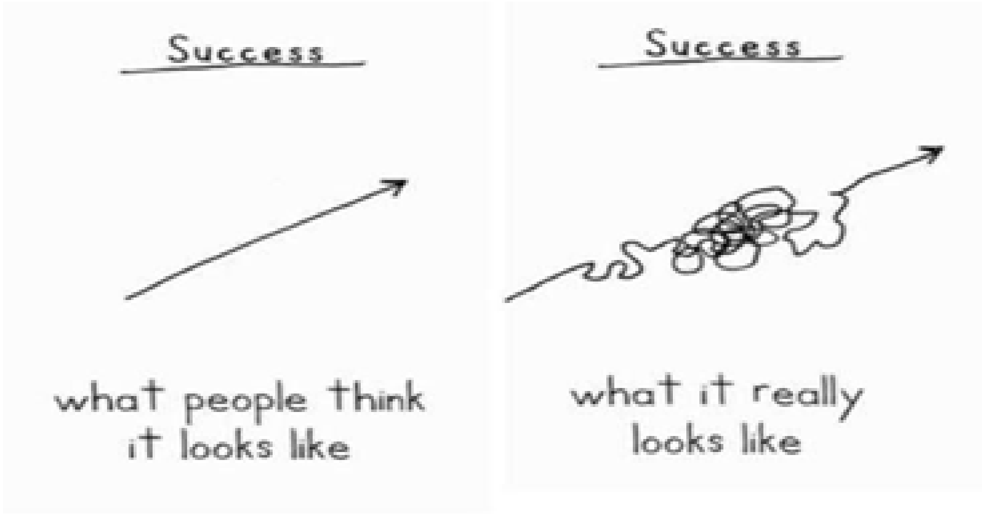


Figure 11.5.21. Success in groundwater management.

Groundwater management is not a straight line and it is a composite process that will take a long time to get a good system and we have to keep trying and go forward.

Research needs

- Monitoring should be coupled with better conceptual understanding of flow and transport processes and chemical processes in the aquifer systems.
- Understand the socioeconomic implications of groundwater use and threats.
- Understand the recharge mechanisms, recharge levels and impacts of climate change.
- Monitoring to include groundwater abstractions (not being done at the moment).
- Understand groundwater resources and groundwater installation failure (need to know whether it is failure of groundwater or of pumps).

Management needs

- Policies and regulations to be formulated explicitly.
- Roles and responsibilities of various groundwater-related organizations to be clarified and coordinated.
- Integrate groundwater management with environmental protection.
- We have to intensify research.
- Supplant IWRM with various nexuses:
  - Water(ground) – food.
  - Water(ground) – energy.
  - Water(ground) – waste/sanitation/urban growth.
  - Water (ground)– land use.
  - Water(ground) – climate change.

Incentive researchers needed

- Increase funding for earmarked groundwater research.
- Implement awards for best groundwater research.
- Collaborate internationally.

Private sector

- Coorporate social and environmental responsibility.
- Green economy.
- Awards to green producers.

Conclusions

- We cannot afford to lose any aquifers because of groundwater degradation – simply too costly and it has too many implications in the long term so we have to protect and prevent any major problems.
- Groundwater management in Sri Lanka has received increased attention and resources over the last decade.
- Explicit policies and regulations are still lagging behind, with unclear mandates for various constituencies of the public sector – we are still lagging behind.
- Increasing dialogue and partnerships for research and management on groundwater issues that are developing.
- The knowledge base for groundwater management is increasing.
- Recommend to establish an ad-hoc national-level interdisciplinary working group on groundwater management under the aegis of the WRB and try to define the roles of each agency.

I think that is what I wanted to say. Thank you very much.

References

Villholth, K.G. 2013. Integrated groundwater use and management in vulnerable coastal zones of Asia-Pacific.In: *Water use and management in vulnerable coastal zones of Asia-Pacific.* Protect and prevent any major problems, ed., Wetzelhd, M.C.#2.

Villholth, K.G.; Neupane, B.2011.Tsunamis as long-term hazards to coastal groundwater resources and associated water supplies. In: *Tsunami - A growing disaster,* ed., Mokhtari, M. In Tech. ISBN 978-953-307-431-3, pp. 87-104.

Jayasekera, D.L.; Kaluarachchi, J.J.; Villholth, K.G. 2010. Groundwater stress and vulnerability in rural coastal aquifers under competing demands: A case study from Sri Lanka. *Environ. Monit. Assess*. 176 (1-4), 13-30. DOI: 10.1007/s10661-010-1563-8.

Villholth, K.G.; Rajasooriyar, L.D. 2009. *Groundwater resources and management challenges in Sri Lanka - An overview. water resources management*, DOI 10.1007/s11269-009-9510-6.

Illangasekare, T.; Tyler, S.W.; Clement, T.P.; Villholth, K.G.; Perera, A.P.G.R.L.; Obeysekera, J.; Gunatilaka, A.; Panabokke, C.R.; Hyndman, D.W.; Cunningham, K.J.; Kaluarachchi, J.J.; Yeh, W. W-G.; Van Genuchten, M-R; Jensen, K.H. 2006. Impacts of the 2004 Tsunami on Groundwater Resources in Sri Lanka. *Water Resources Research* 42, W05201.

Villholth K.G.; Manamperi, A.S.P.; Buergi, N. 2006. Chemical characteristics of tsunami-affected groundwater and lagoon on the East Coast of Sri Lanka. Paper submitted to the 32nd WEDC International Conference. Sustainable Development of Water Resources, Water Supply and Environmental Sanitation. Colombo, Sri Lanka, Nov. 13-17, 2006.

Villholth, K.G.; Amerasinghe, P.H.; Jeyakumar, P.; Panabokke, C.R.; Woolley, O.; Weerasinghe, M.D.; Amalraj, N.; Prathepaan, S.; Btion, N. 2006. W*ater vulnerability. We have tsunami impacts on shallow groundwater and associated water supply on the East Coast of Sri Lanka*. Colombo, Sri Lanka: International Water Management Institute (IWMI), 68 p. ISBN 92-9090-622-7.

12.1 First Presentation of Session II

Dr. Paul Pavelic, Principal Researcher - Hydrogeology, IWMI, on Practical Efforts to Improve Groundwater Governance in the Challenging Context of Lao PDR

Figure 12.1.1. Water uses in a village.

Thank you very much. Hon. Minister, Chairman, colleagues and friends. Thanks for giving me this opportunity.

Manthri invited me to talk on groundwater governance in Lao PDR because the situation in Sri Lanka might be as bad, I think, as some areas in Lao PDR but at a worse level. We talk about very different kinds of reasons in comparison to the two countries. This is an IWMI-led project, which is 1-year old. The only opportunity in expanding groundwater use in Lao PDR is for agriculture in the country. Only a few people with skills in groundwater aspects were called upon to advise and get involved in other activities of groundwater. Having been in Lao PDR for just 1 year, let us talk about its groundwater use for agriculture there.

Overview of the performance development review of Lao PDR

- Small country in South East Asia but larger in comparison to Sri Lanka, which is called the "landlocked developing country in Asia".
- Population: 6.5 million (population density very much lower than in Sri Lanka).
- Geographical area: 237,000 km^2.
- Rainfall: 1,300 to 3,700 mm/year (wet country).
- Forest cover: ~50%.
- Main industries: Mining, hydropower, timber, tourism.
- Low-middle income bracket.
- Ranked 22nd most land developing country.
- Gross Domestic Product per capita ~ US$1,300/year (production not sufficient, so that there is a lot more to be done).
- 33% below the International Poverty Line of <US$1.25/day (poverty areas are marked in red in the map (Figure 12.1.3), major economic activities going on in the North and the highland areas).

There are three major millennium development goals. Lao PDR has to do a lot more work on food security.

Figure 12.1.2. Lao PDR.

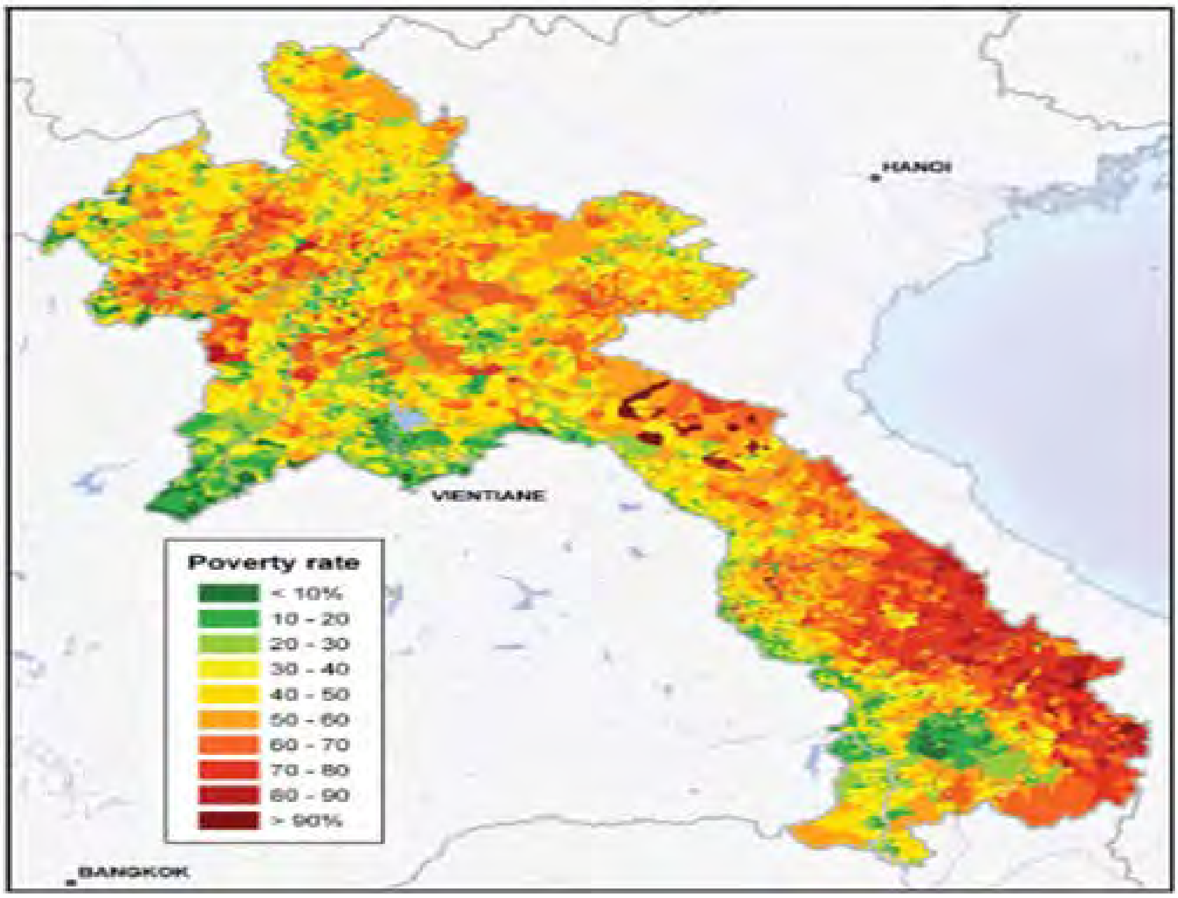


Figure 12.1.3. Map showing poverty areas.

Millennium development goals and challenges

- ► Medium-term goals, short-term goals.
    - Improved water supplies (75% in rural areas by 2015).
    - Food and nutritional security (a lot more to do – more intensified agriculture needed).
- ► Longer-term national development goals.

- Expanding irrigation development is important in contributing to poverty alleviation. and livelihood improvements.

► Climate change and climate adaptation.

- Enhanced water storage, resilience, adaption (storages will be very important for groundwater as in Sri Lanka and anywhere else).

Figure 12.1.4. Improved access to water supply.

Photo credit: Paul Pavelic.

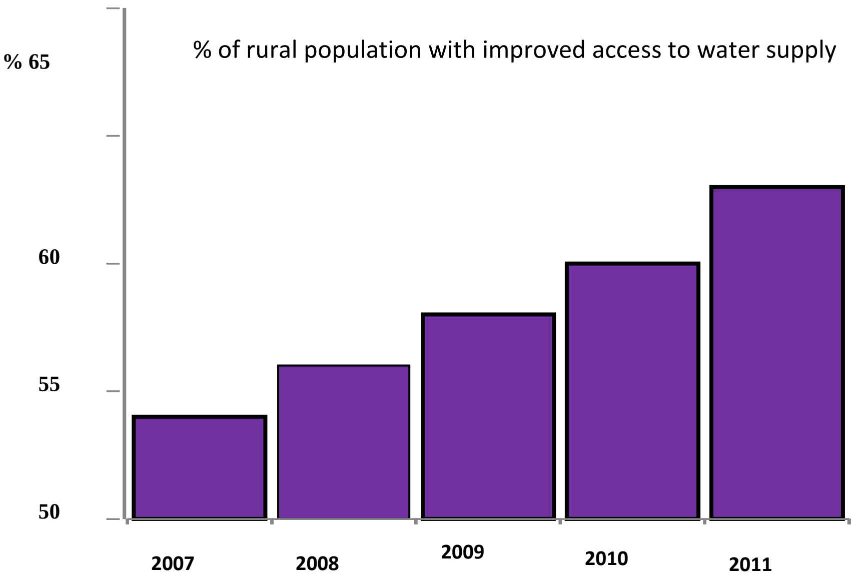


Figure 12.1.5. Improved access to water supply.

Table 12.1.1. Irrigated agriculture in Lao PDR – Countrywise statistics on groundwater irrigation.

Country	GW irrigated area (ha)	Total irrigated area (ha)	Total GW-irrigated area (%)
Cambodia	0	241,823	0.0
Lao PDR	200	271,703	0.1
Myanmar	100,000	2,073,000	4.8
Thailand	481,063	5,279,860	9.1
Viet Nam	32,000	3,200,000	1.0

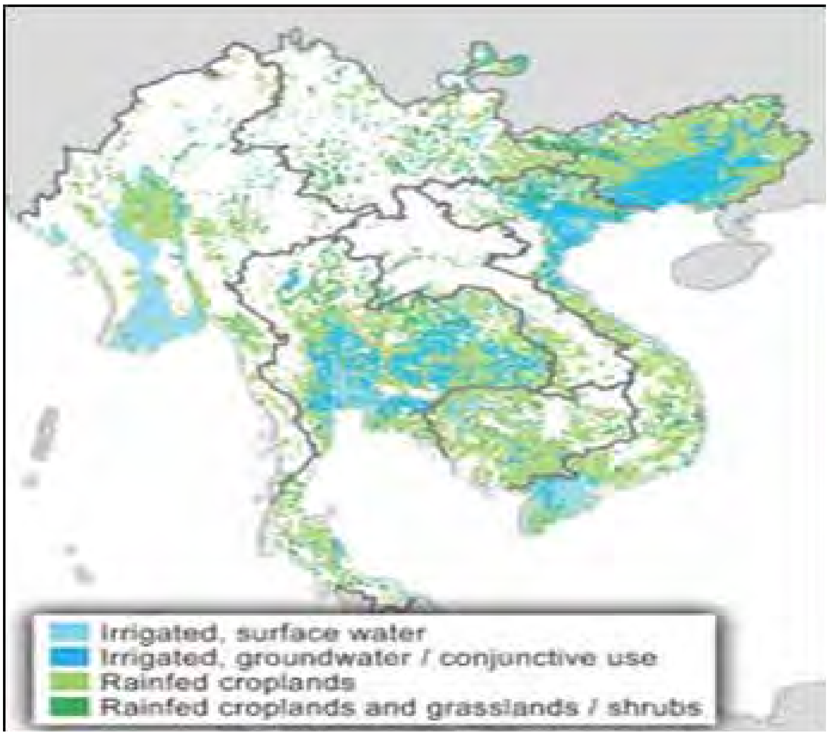


Figure 12.1.6. Irrigated area map.

Groundwater irrigation is very minimal. Government is very keen to boost areas under groundwater irrigation in Lao PDR to 100,000 ha in the coming years. It will depend on research and activities going on now in the country.

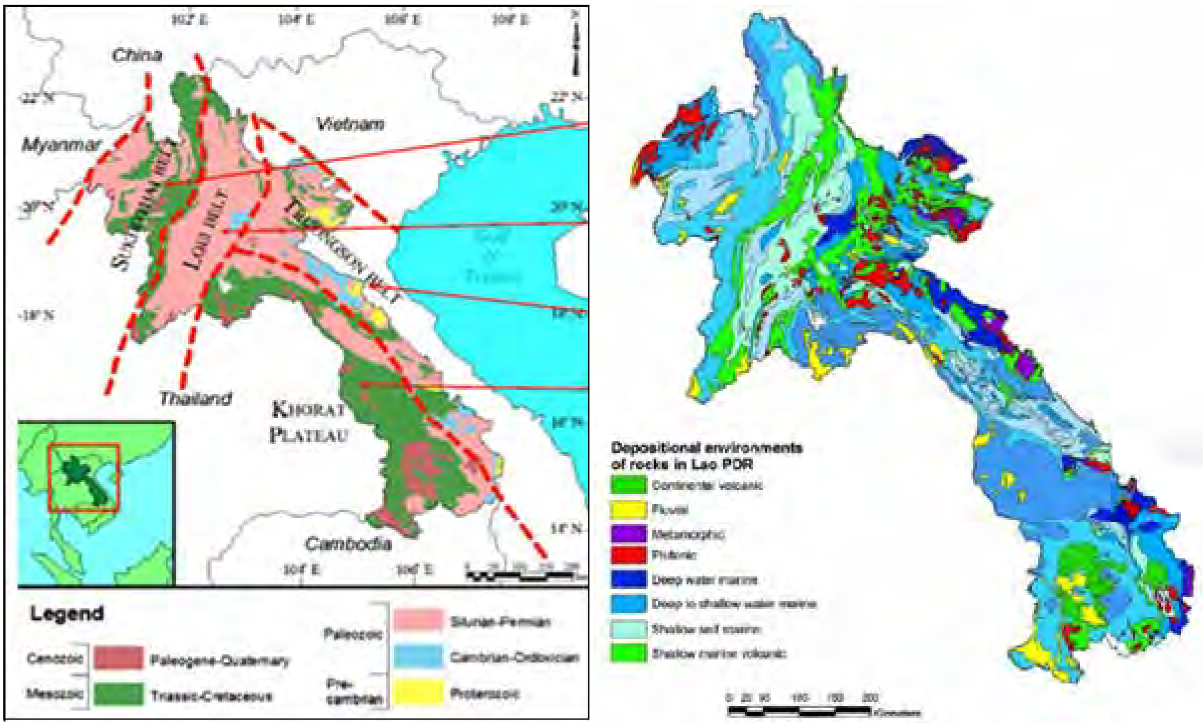


Figure 12.1.7. Geology of Lao PDR.

Hydrogeology of Lao PDR is much more complicated than in Sri Lanka. It is highly variable and highly complex. There are various types of topographic sequences and geological activities there. Crystalline rock formation and consolidated volcanic ashes are present there. So there are four ranges of different types of aquifer possibilities in the country.

The role of groundwater (in a rich country)

Figure 12.1.8. Rural supplies.

Figure 12.1.9. Urban supplies

Figure 12.1.10. Rural freshwater industries.

Photo credit: Paul Pavelic.

In rural areas rural water supplies need to be developed by the use of new boreholes or existing shallow wells. Government and NGOs are involved in the protection of these from contamination. In cities, groundwater is not used for drinking because of the perception of the public. In some smaller cities and towns where surface water is in short supply groundwater is used for water supplies. But most of the industries rely on groundwater as soft drinks, etc. Saline groundwater is productively used for some industries.

There are more activities going on in the field, which are not reflected in the statistics. Some areas (60-70%) have access to groundwater. This is used for domestic purposes, livestock and homeland cultivation. It is being extensively used at the subsistence level. Also, there are more prospective uses of high economic-value, e.g., export agriculture of coffee cultivation.

Figure 12.1.11. Eco system services.

Photo credit: Paul Pavelic.

Figure 12.1.12. Agriculture.

Figure 12.1.13. Saltwater industries.

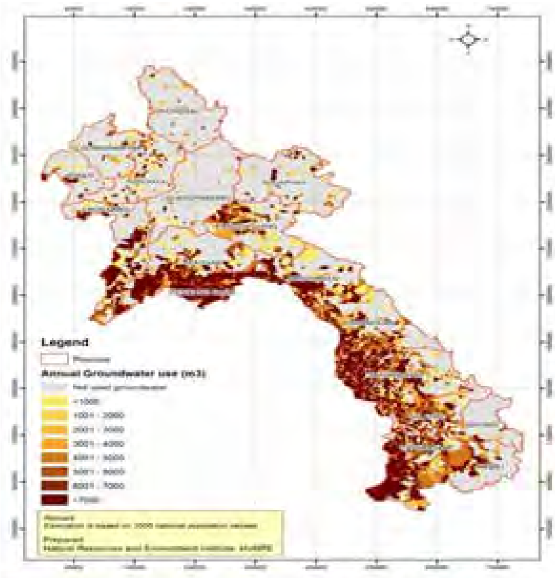


Figure 12.1.14 Extent of groundwater–Spatially.

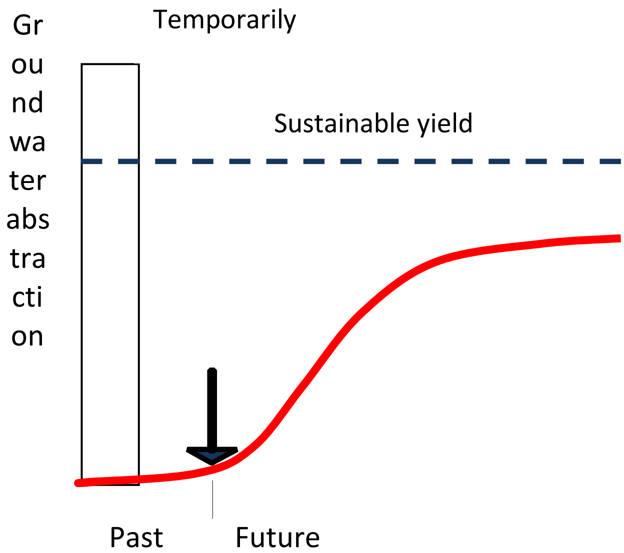


Figure 12.1.15. Pattern of groundwater abstraction.

Table 12.1.2. Participating actors involved.

Role / Institution	Development	Research /Investigations	Management
Public	Nam Saat, DHUP	NREI, DOI, DWR, DGM, NAFRI	DWR, RBOs, NREI, PAFOs
International donors	ADB, WB, JICA, UNICEF, SIDA, World Vision, AusAid, SNV, WHO	ADB, ACIAR, Crawford foundation, ICE-Warm, MRC	WB, IFC, ADB
NGOs	DIC, CDEA, ADRA, Save the children, world education		
Academic / Research		NUOL, IWMI, KKU-GWRC, IGES	
Private	HP companies, Mining companies, LB companies, farmers, rural households	THPC, GHD, Nor-Consult, Hydrogeology	

Some of the perceived issues for groundwater development and management

- Limited capacity at central and field level to plan, implement, operate and manage groundwater projects effectively.
- Lack of coordination amongst agencies involved.
- Level of skepticism about groundwater development for rural water supplies.
- Poor water quality in some areas due to natural or human-related pollution (salt, arsenic, microbes) due to poor-yielding, saline or abandoned wells.

The present state of affairs: governance checklist (pragmatic model)

Technical	• Existence of basic hydrogeological maps	N
	• Groundwater body/aquifer delineation	L
	• Groundwater level/quality monitoring network	L
	• Groundwater pollution hazard assessment	N
	• Availability of aquifer numerical models	N
Legal and institutional	• Water well drilling permits and groundwater use rights	N
	• Instruments to reduce over-abstraction of groundwater	N
	• Sanction for operation of illegal water well	N
	• Groundwater abstraction and use charging	N
	• Land-use control/levies on potentially polluting activities	N
	• Government agency as "Groundwater Resource Guardian	Y
	• Community Aquifer Management Organizations	
Cross-sector policy coordination	• Coordination with agricultural development	N
	• Groundwater-based urban industrial planning	N
	• Compensation for protection of groundwater	N
Operational	• Public participation in groundwater management	L
	• Existence of groundwater management action plan	N

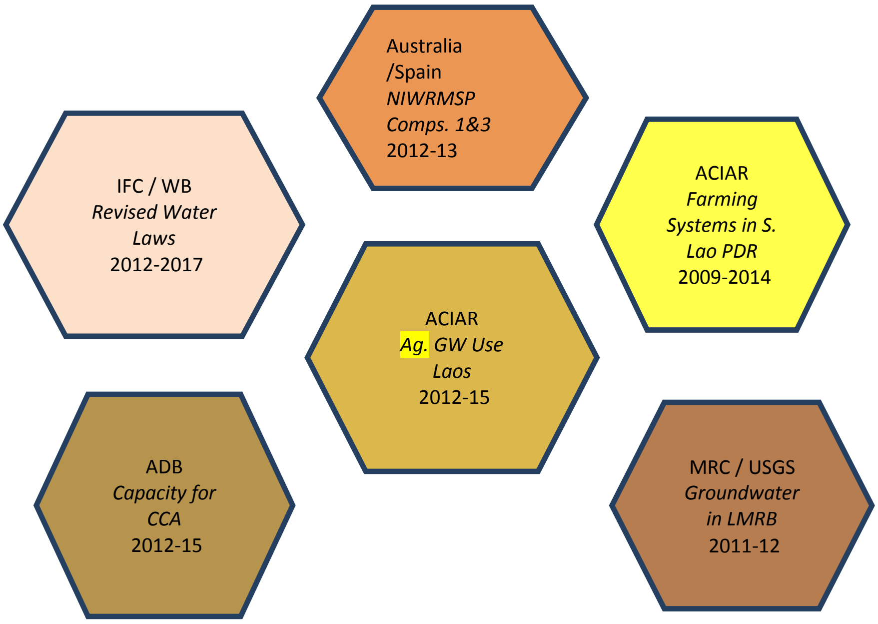


Figure 12.1.16. Critical mass of current activities.

Some important research and development questions

In the context where greater groundwater utilization is necessary and certain:

- How can use be encouraged without unduly compromising long-term sustainability and environmental services?
- Can the level of risk/failure associated with new development be reduced?
- Does significant and irreversible groundwater exploitation pose an imminent threat for a country characterized by high rainfall and low population density?
- What is the right level of knowledge and governance sufficient to sustainably manage the resource?

Improving the Understanding of the Resource

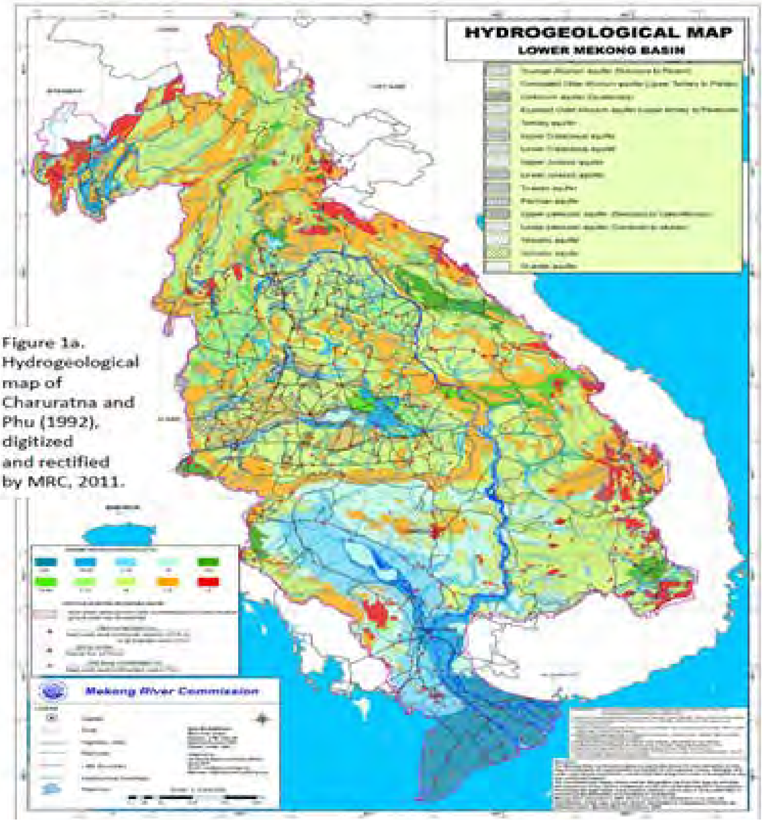


Figure 12.1.17. Hydrological map of Charuratna and Phu (1992)

Source: Digitized by Mekong River Commission, 2011.

- Acquire data from relevant agencies (government, NGOs, private sector, etc.)
- Construct a database and information system
- Assess existing groundwater potential maps against independent data in focal areas
- Develop methodology for assessing groundwater potential and generate final groundwater potential maps for focal areas

Limited monitoring of the resources

- No regional/ongoing monitoring of groundwater.
- Existing monitoring at the research project level.
- Opportunities to build groundwater into existing hydro-meteorological network.

Figure 12.1.18. Groundwater monitoring network.

Source: Mekong Committee 1993

Capacity building was done extensively locally and also with assistance of Australia.

Postgraduate scholarship support

UNIVERSITY OF TECHNOLOGY SYDNEY

Figure 12.1.19. Capacity-building assisted by Australia.

Photo credit: Paul Pavelic.

Figure 12.1.20. Capacity-building.

Photo credit: Paul Pavelic.

Figure 12.1.21. Capacity-building.

Photo credit: Paul Pavelic.

Institutional Changes

New division of groundwater management formed in 2012 under the Division of Water Resources (DWR)

- Mandate is clear but operationalization is starting slowly.

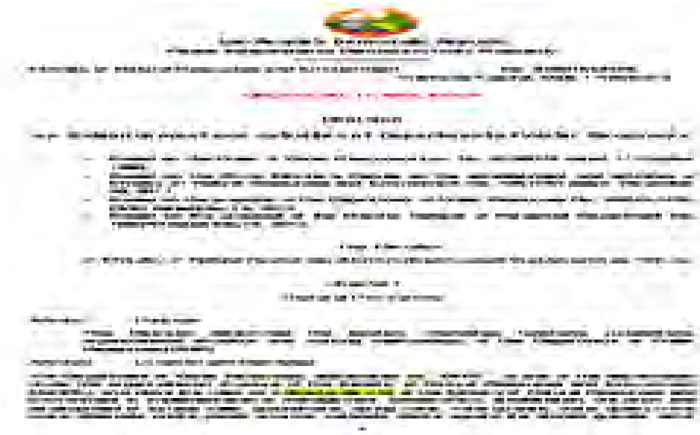


Figure 12.1.22. New division of groundwater management was formed.

Photo credit: Paul Pavelic.

Figure 12.1.23. National water laws under revision with stronger emphasis on groundwater.

Photo credit: Paul Pavelic.

Main messages

- Groundwater is vitally important even in a water-rich country such as Lao PDR.
- The major challenge for groundwater governance is to build the necessary human and institutional capacity which requires concerted efforts and extended time frames.
- Groundwater governance is very much in its infancy in Lao PDR but efforts to improve it are underway.

Figure 12.1.24. Making communications and linkages.

Photo credit: Paul Pavelic.

Communications and linkages

- Stakeholder consultation.
- National groundwater orientation workshop (shortly).
- Working with industry.
- Project brochure (Lao and English).
- Project website (shortly).
- Media release.
- Radio interviews.

12.2 Second Presentation of Session II

Dr. S.A. Prathapar, Theme Leader - Productive Water Use, IWMI, on Technical Challenges and Solutions for Sustainable Groundwater Management – An International Perspective.

Good afternoon. Thank you for giving me an opportunity to speak about groundwater, which is my specialization. Previous presenters spoke about groundwater governance, and I heard about issues faced in groundwater in Sri Lanka and also about programs currently under way. The solution to a problem is awareness. Problem is already here. We are halfway through. I was paying a lot of attention to the speech of the Chairman of WRB, Mr. Premarathne. He identified a broader framework, where the issues are coming up and what they are trying to do; starting from measuring to monitoring, modeling, and forecasting. They continue to manage groundwater not only on the institutional side of it but also on the technical side of it. I will talk about challenges raised by various speakers and see what people have done outside.

Technical challenges?

- Where is groundwater?
- How much is there?
- Is it enough?
- How do we share it equitably?
- How do we use aquifers to hedge against variability? That in the context of climate change.
- Problems other than groundwater depletion! (water quality and other challenges)

From time to time you have to check whether the stethoscope is working right and also add piezometers where changes in groundwater level are more than desirable for which you need an additional budget.

Talking and worrying about the quality were going down. And there are other challenges also. I will talk about a few of those things.

Where is Groundwater?

Rationalization of groundwater monitoring network

To find where the groundwater is we need to have a network of piezometers. In the morning we heard a monitoring network has been planned with 103 piezometers. These are like stethoscopes measuring the health of groundwater. So, if we want to monitor groundwater we need to have a network rightly designed, rightly placed and righty monitored. Groundwater monitoring is a very expensive business. Another piece of information we heard was that 9,700 wells are monitored with 1,300 monitoring points. How do we know that we are monitoring the right way, at right locations and at the right frequency? These have to be answered. So one of the studies I was involved with were similar but done in a much smaller scale in Oman where 200 different wells were monitored. The water levels were monitored daily and the water quality, once a year. These are not transmitted automatically. Somebody has to drive these distances, bring data to the laboratory, enter the results, and process and analyze them. These constitute very expensive work. Also from time to time you have to check whether the stethoscope is working right.

There are new techniques that eliminate unnecessary piezometers. You can have the desired number of piezometers using this method. You are not only looking at water levels going up or down and whether water quality is good or bad but whether you are using the right kind of piezometer network. This was first used in gold mining industry and is now widely used in the groundwater sector. If you want to perceive this kind of analyses sometimes IWMI would be able to provide assistance.

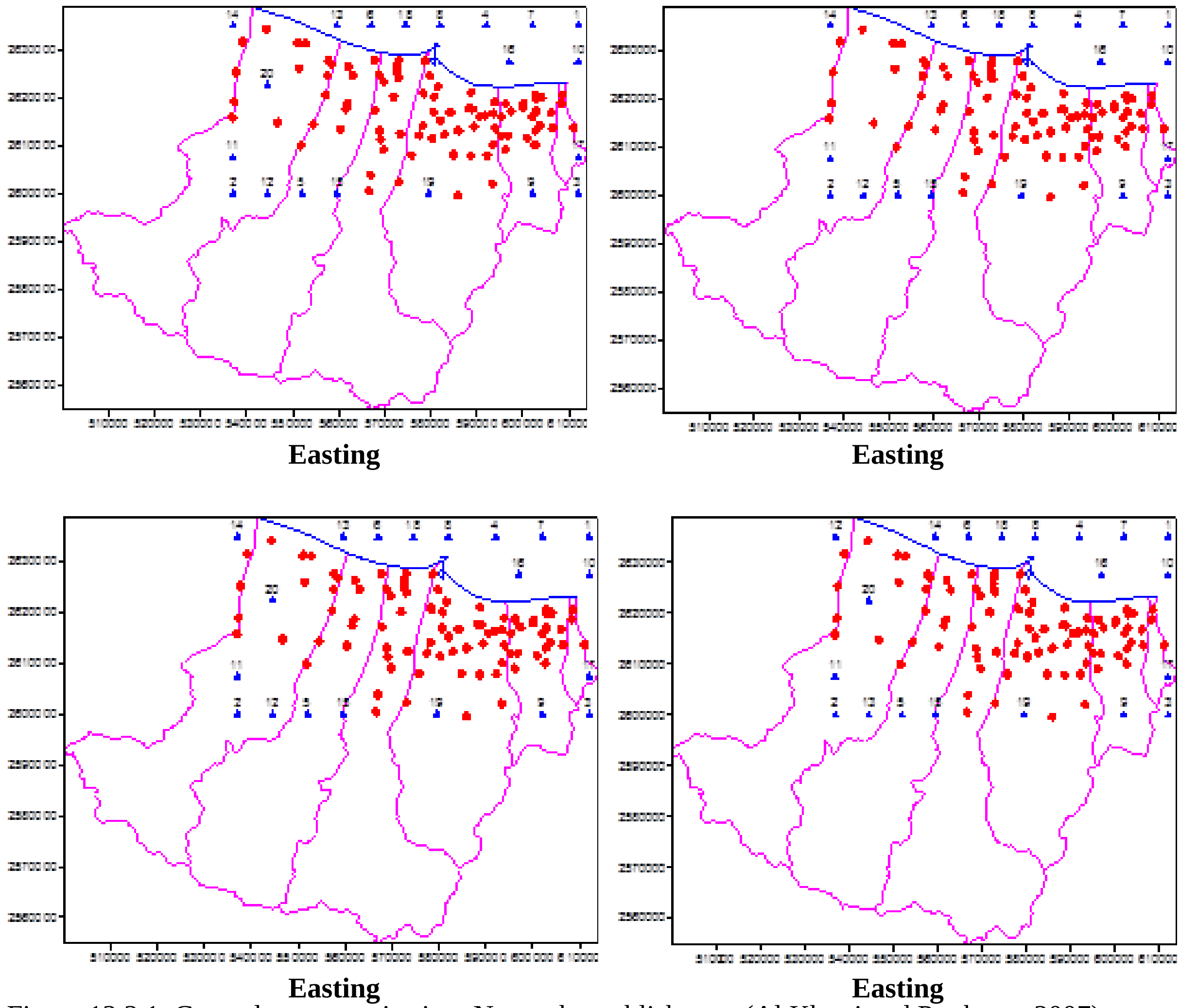


Figure 12.2.1. Groundwater monitoring: Network establishment (Al Khatri and Prathapar 2007).

Locations where bores need to be eliminated.

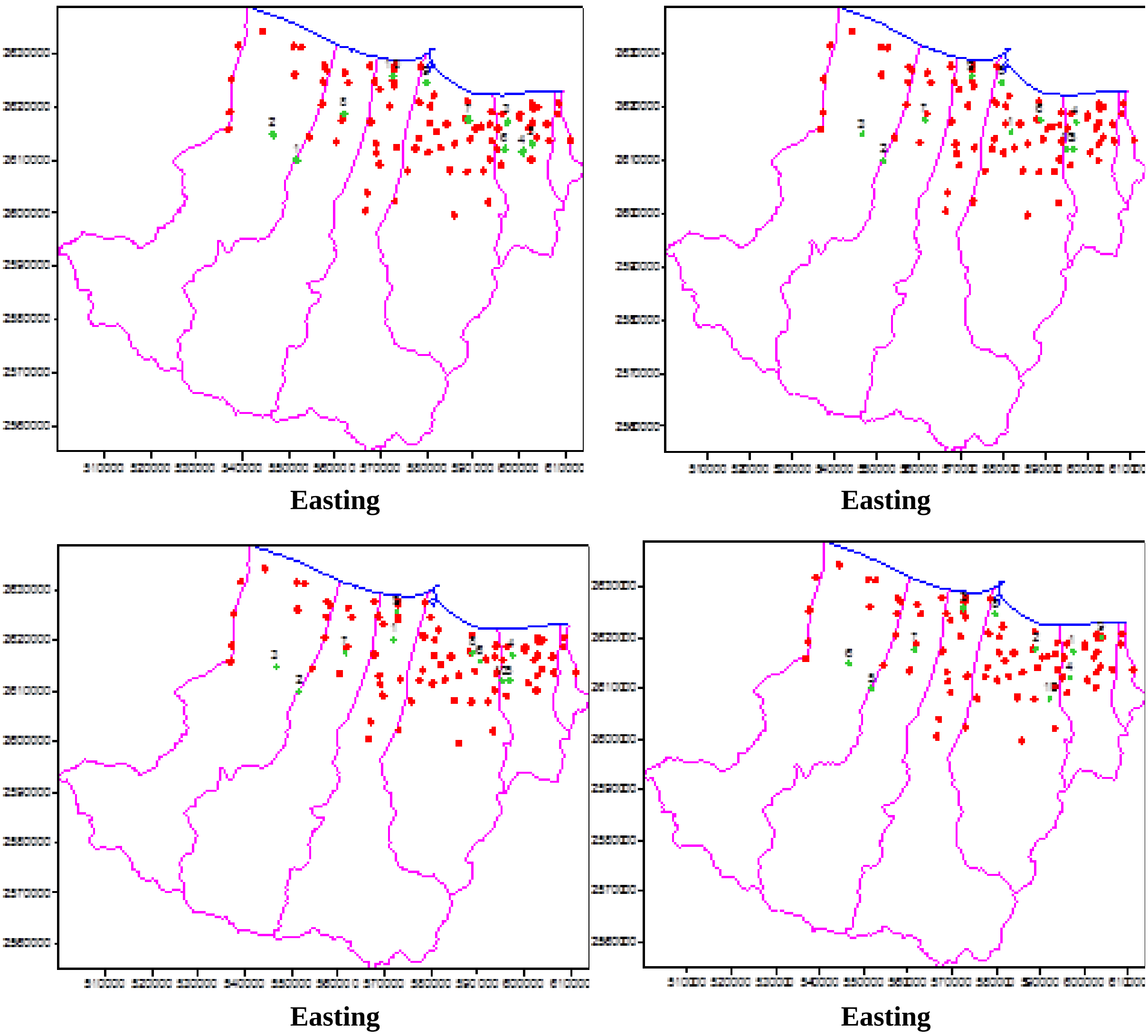


Figure 12.2.2. Groundwater monitoring: Network establishment (Al Khatri and Prathapar 2007).

Locations where bores need to be eliminated.

How much is there?

Estimating sustainable yields and groundwater assessment.

How much can I pump, where, for what, for how long, and so forth? There are techniques available; starting from simple tilt pot type based on piezometer data monitored over a year or going into some detailed levels of modeling to decide where the recharge is taking place, and how it is moving through the aquifer system. The mountainous area may be getting recharged and the recharge gradually moving to its dry zone part. There are techniques to do these. This particular study was done for the groundwater basin called Murrumbidgee Leaky Aquifer in Australia. It is very complicated and has multi-layers of hydrogeological formations. Certain aquifers are pumpable and others are not. For the leaky aquifer we developed a three-dimensional model. We calibrated it and started doing some numerical simulations. At one particular point there is a crossover and allocations are done based on that. This number is used to decide the land entitlement. It is part of the groundwater plan.

Table 12.2.1. Groundwater assessment: Estimating safe yields (Prathapar et al. 2002):

Estimating sustainable yields

Lower Murrumbidgee Leaky Aquifer

Three stratified aquifers.

MODFLOW model calibrated.

Numerical simulations to determine aquifer response to pumping.

Safe yield is when pumping equals leakage.

Methodology applied to others.

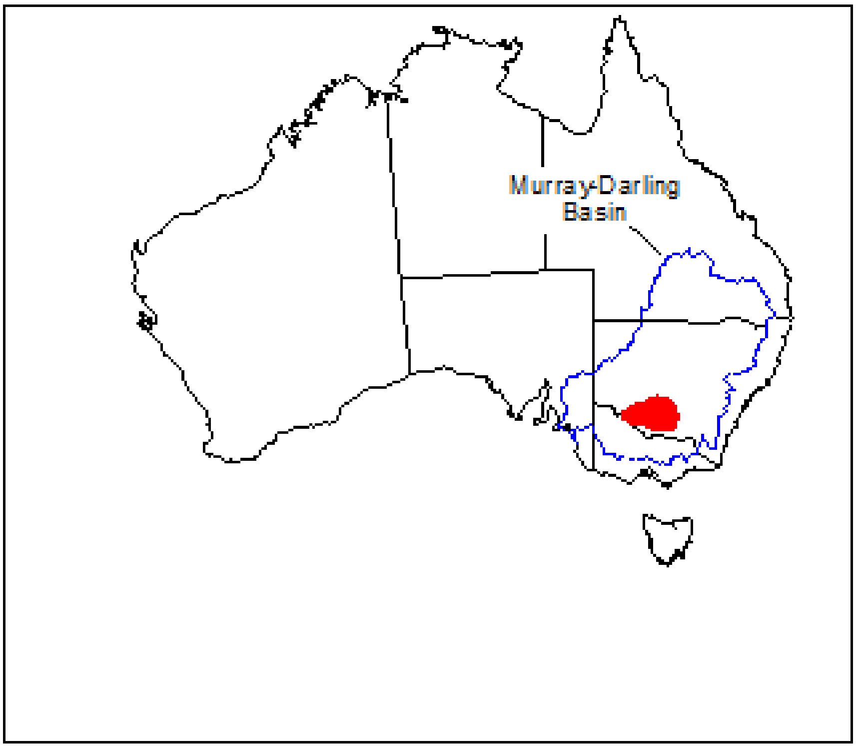


Figure 12.2.3. Lower Murrumbidgee Leaky Aquifer (Marked in red)

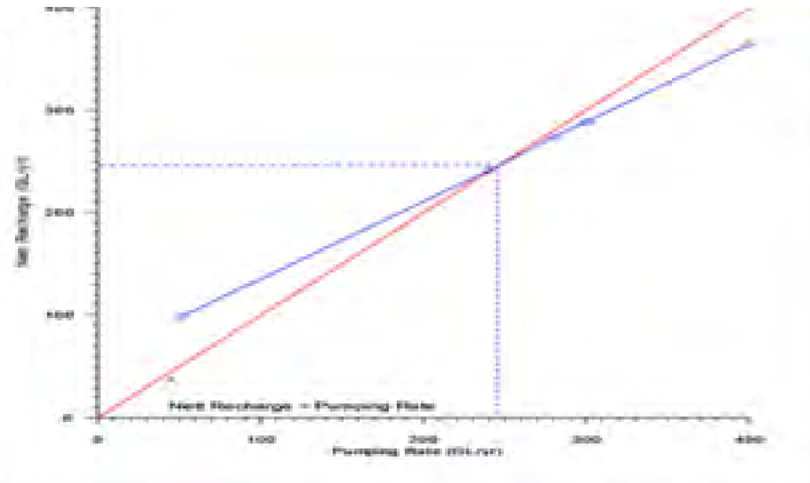


Figure 12.2.4. Safe yield is when pumping equals leakage.

Is it enough?

Land and water use optimization - Matching land use – Swagman options – Prathapar et al. 1997.

This is matching lands to water availability. If the evaporated demand created by a crop matches with the available water, that is an optimum situation. The problems come in the areas where the land use and the water availability and the water use patterns are not optimized or matched. In Punjab and also in Gujarat the groundwater levels are going down. Their land use is more than water availability; their goals are larger like food security, income generation, etc. This is not sustainability.

Example of sustainability in Australia -

It was planned for 500,000 ha of land

- Simultaneous profitability and sustainability.
- Hierarchical dual criteria optimisation model.
  - Maximize profits – gross margins.
  - Minimise recharge.
- Physical constraints.
  - Land and water availability.
  - Land suitability.
  - Hydrogeology.
  - Recharge.
  - Salinization.
- Non-physical constraints.
  - Farmer preferences.
  - Permanent plantings.

Figure 12.2.5. Sustainability in Australia.

Photo credit: S. A. Prathapar Shanmugam.

How do we share it equitably?

Groundwater sharing and allocation

Water interference is a serious issue in managing a limited resource, e.g., different organizations install groundwater pumps independently. Now I am talking about interactions and interferences with each other. WRB has developed a simple tool which they can show the farmers when new requests come for drilling wells. WRB can explain how these interfere/interact with nearby wells as in the picture below (Figure 12.2.6 Groundwater allocation - Prathapar and Piscopo 2002 - Well interference and drawdown evaluation).

Managed aquifer recharge (MAR)

How do we use aquifers to hedge against variability?

As the graph below shows no rains come for 7 months and then it rains cats and dogs. Will it recharge? If there is storage capacity we store it. Otherwise it is stored in the ground; that is recharge.

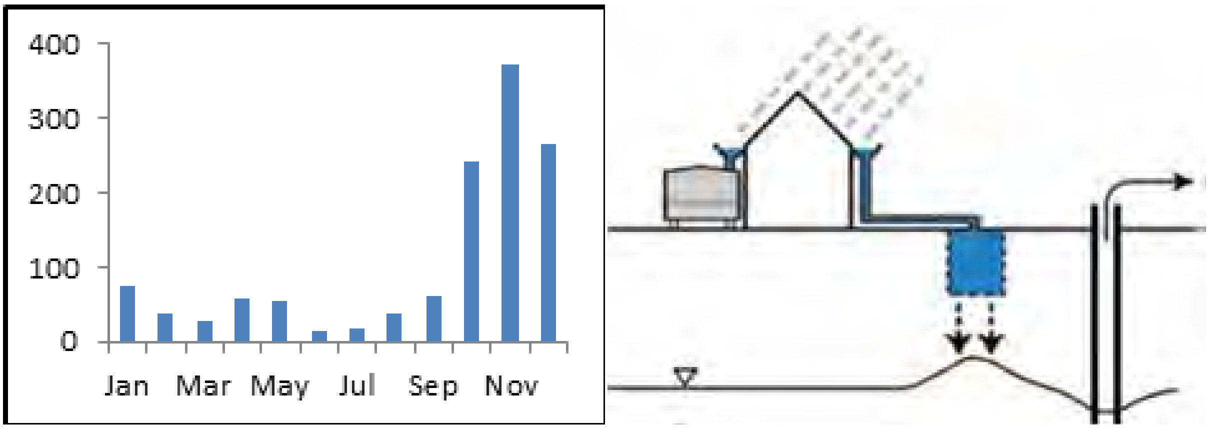


Figure 12.2.6. Rooftop rainwater harvesting and managed aquifer recharge (MAR).

In rainwater harvesting rainwater goes to a recharge pit from gutters and is then released to the ground for recharging. In the eastern and the northern parts of Sri Lanka we have a karstic sand aquifer which is permeable. If you pump out this recharge from your garden the water level of the garden belonging to the next house goes down. This is called a social aquifer. Imagine every house has a recharging pond. It would be a very good system. WRB could design a program for collecting rainwater from all existing houses with some financial assistance from banks. In India, programs of this type are implemented on government subsidized systems. IWMI too may help.

In coastal regions, aquifers are very shallow so people have to wait a long time to get water from wells. If rainwater from each house is collected into an individual tank it will benefit the people a lot.

Other groundwater-related challenges

Contribution of shallow water table to evaporation and transpiration of winter wheat in silt loam soils in the Ferghana Valley.

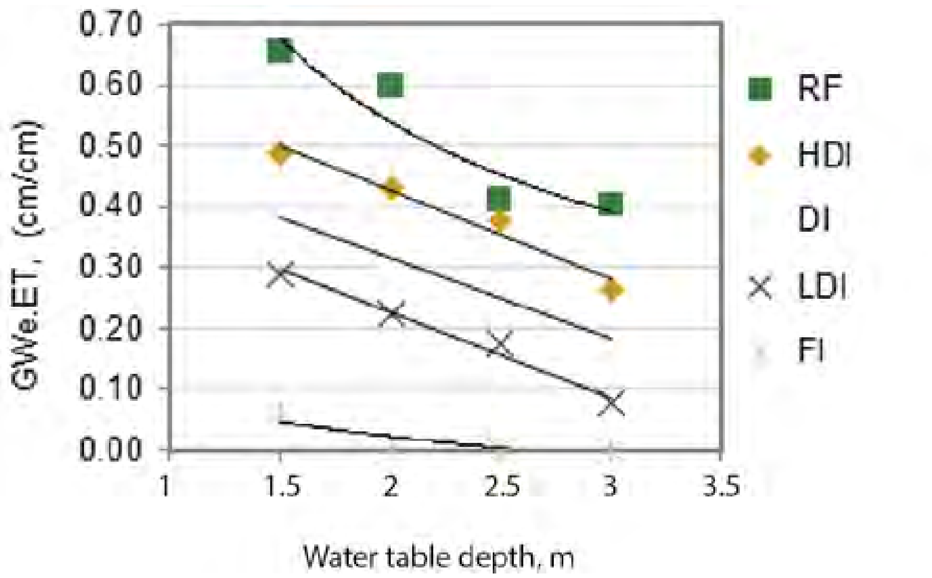


Figure 12.2.7. Contribution to evaporation and transpiration in silt loam soils in the Ferghana Valley.

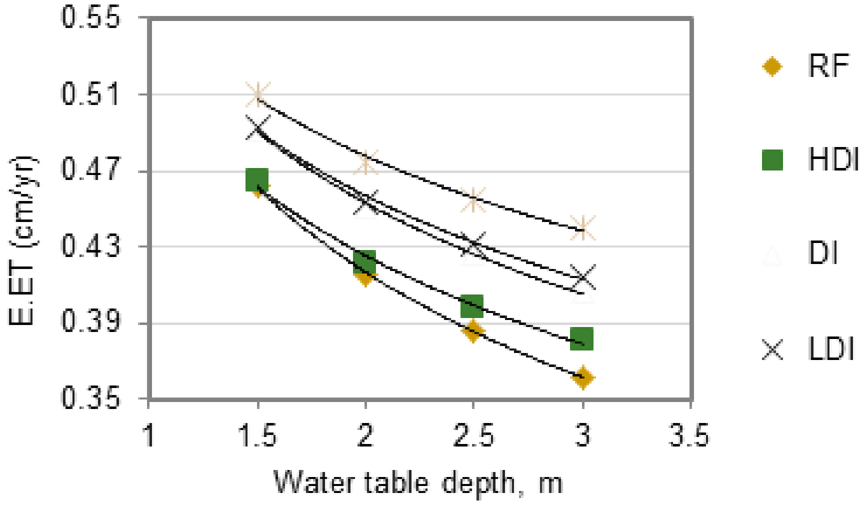
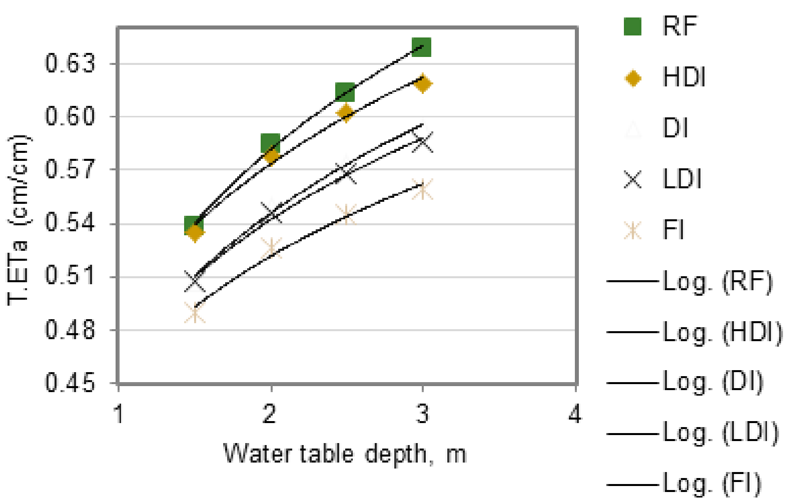


Figure 12.2.8. Contribution to evaporation and transpiration in silt loam soils in the Ferghana Valley.



Modeling scenarios:

RF – Rain-fed winter wheat

HDI – High deficit irrigation

LDI – Low deficit irrigation

Figure 12.2.9. Contribution to evaporation and transpiration in silt loam soils in the Ferghana Valley.

We talk widely about the groundwater level going down but if it comes up there will be waterlogging which will creates problems. We did some studies in Central Asia to find how irrigation water is managed there. It maximizes water use by pumping out water from the water table when roots get near it. In areas like System H in the North Central Province, Sri Lanka, the groundwater level is very shallow. We have to rethink about how we should manage these areas.

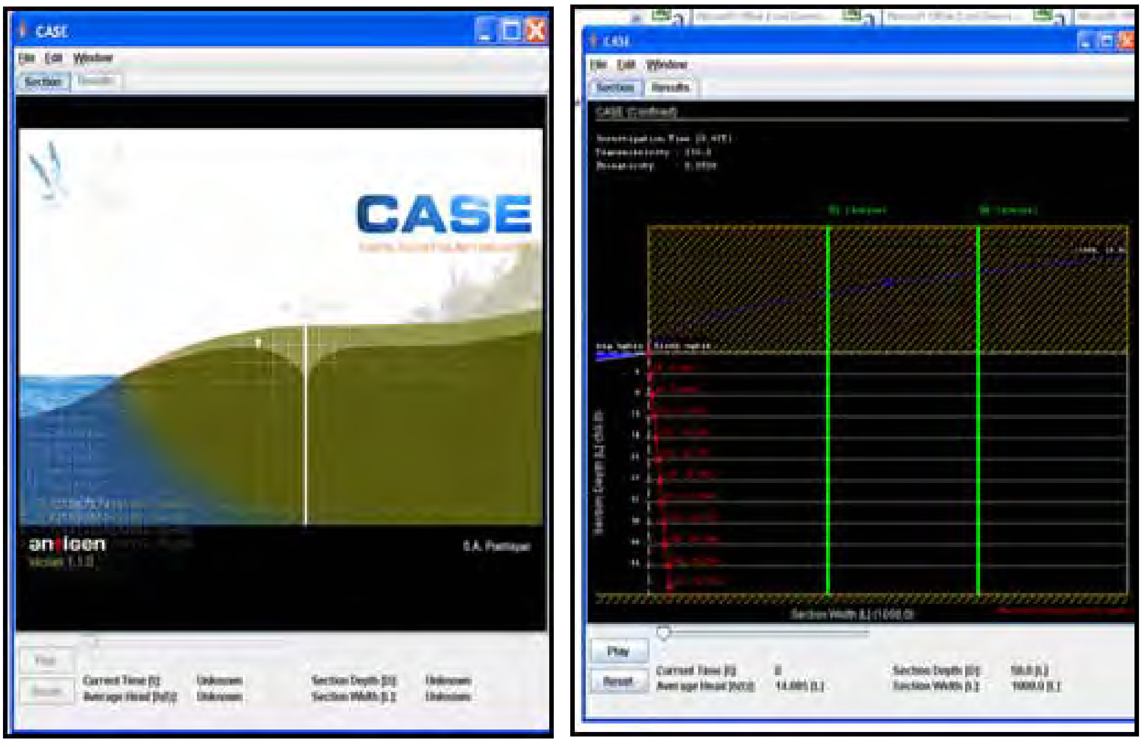


Figure 12.2.10. Groundwater protection - Coastal aquifer salinity evaluation: Prathapar (2002).

Groundwater protection: Seawater intrusion, non-point pollution, Upcoming of inland aquifers –

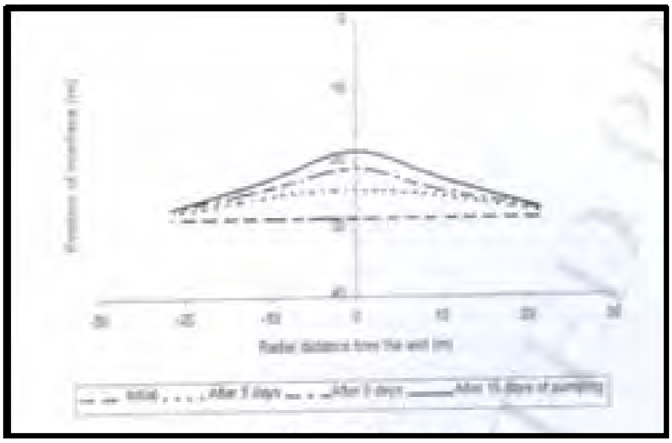


Figure 12.2.11. Interface movement during pumping

- Common problem in South Asia
- MODFLOW MT3D
- Guidelines to design skimming wells proposed

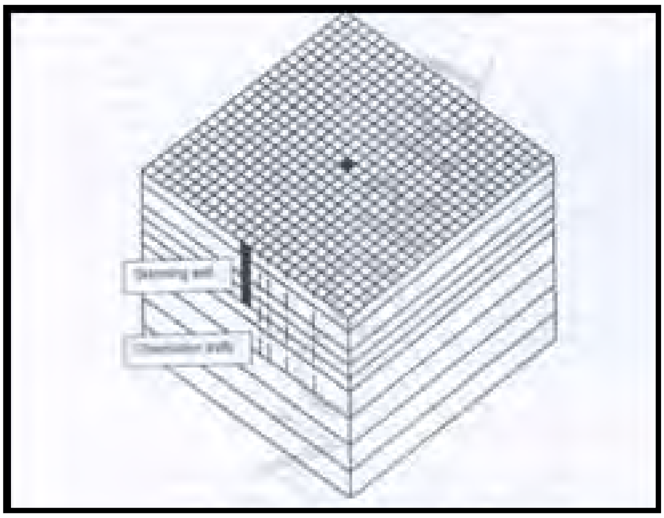


Figure 12.2.13. Schematic configuration of simulation setup: Asghar et al. (2001).

There is an interface between saltwater and freshwater. So when you pump out water the salt interface may go up. This action could be simulated for preventing saltwater intrusion. The application is called the provision of skimming a well. Similarly, water could be collected through lateral pipes or radial pipes. For this, we can prepare guidelines and find solutions. So I have touched upon some technical problems of groundwater to share with you. Allowing for questions I conclude.

Thank you very much!

Dr. Asaduz Zaman, Consultant, ADB – Bangladesh on Prepaid Meter and Smart Cards in Irrigation Management Systems. Why, where and how?

Figure 12.3.1. Barind before 1985.

Controversial comments on groundwater of Barind area

This area is in the northwest part of Bangladesh. Before 1985 it grew one crop per year and whatever the rainfall it received it flooded. Paddy was cultivated in the monsoon and received an excellent yield. During the rest of the year (8-9 months) cattle find their food in the fallow fields. In 1971, when it was East Pakistan there was an agreement with Yugoslavia to set up 1,000 deep tube wells in this district covering 750 square miles excluding the hatched area which is Barind. Barind area consisted of a little of laterite soil and red alluvial soil. Up to 980 feet there is no aquifer. So, the Bangladesh Water Board advised only to have domestic tube wells. That time the area was under the Ministry of Agriculture.

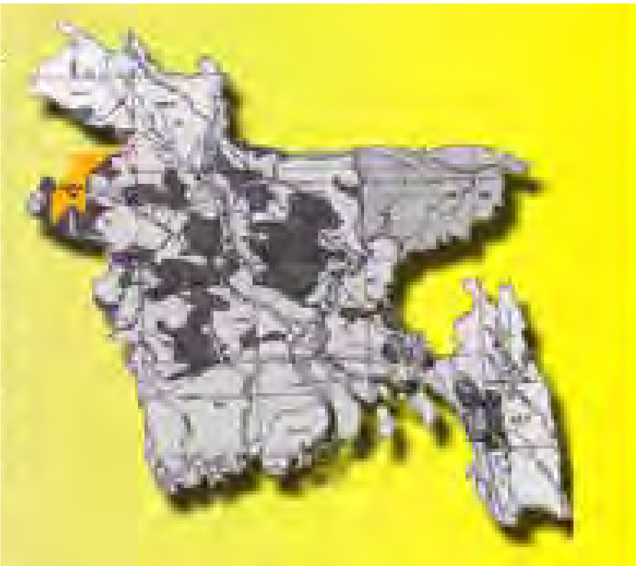


Figure 12.3.2. Barind tract.

Zone ‘O’ lies in the western Rajshahi District and consists of older alluvial deposits known as the Barind tract. The existence of thick clay deposits has been tested by test-drilling, indicating that the main aquifer does not occur in the upper 300 m (980 ft.). The groundwater is relatively thin. Fine-grained sand zones occur within the clay sequence. The aquifer is capable of supporting only small domestic needs. (UNDP, New York, 1982).

Controversial comments on groundwater of Barind area

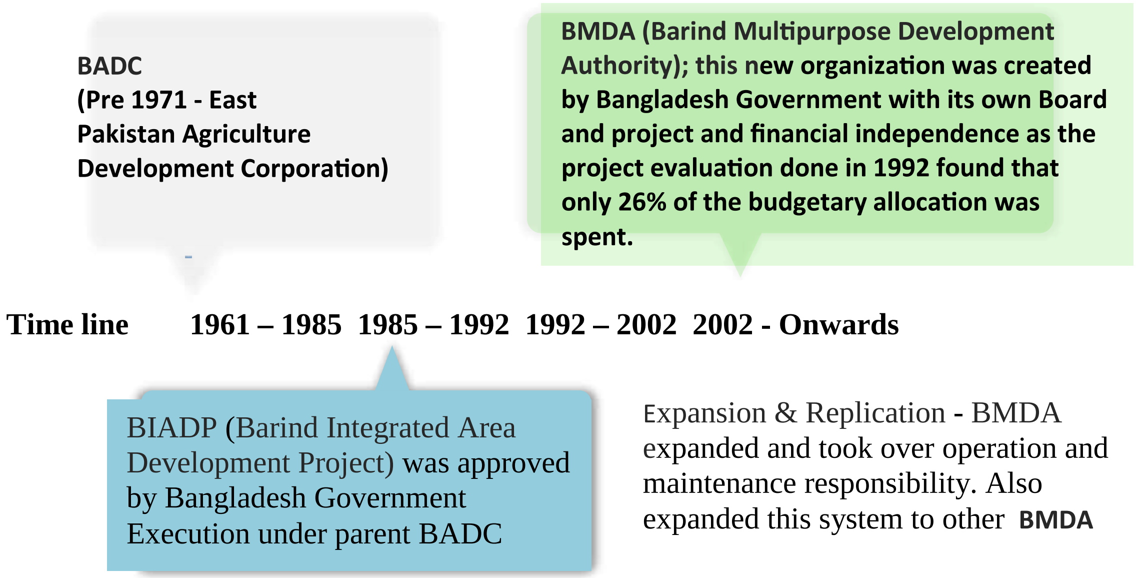
The construction and installation of all necessary materials and equipment for 1,000 tube wells in the Rajshahi district covering approximately an area of 750 square miles excluding Barind area are complete. As present prospects for further development are nil, only deep-set hand tube wells for domestic purpose are advised. “Not suitable for development.”

In 1982-83, Government decided to change institutional, financial and technical aspects.

Table 12.3.1. Challenges faced by BADC (Bangladesh Agriculture Development Corporation).

Institutional	Financial	Technical
• Closed-fertilizer wing	• Government-imposed debt service liability	• Lack of expert technicians
• Irrigation wing down-sized	• Insufficient funds for new project	• Lack of sincerity among senior policymakers
• Government jobs cut from 27,000 to 9,000		
• Farmers lost faith	• Struggle with employee salary	• Unguided field officers

History of Barind



Government replicated this model even in the Bangladesh Water Development Board which was instrumental especially for the operation of tube wells. Then the Barind area was brought under irrigation introducing different types of wells, called inverted wells. A conventional well is around 300 feet deep but the inverted well goes down only up to 100 feet and there is no aquifer after 100 feet.

Actions taken

- Adopting appropriate localized policies to meet the needs of the project.
- Development of innovative “inverted wells” and surface water supply.
- Underground plastic pipe water distribution system for surface channel.
- Replacement of cash transaction to “prepaid meter with SIM card.”
- Provision of best possible services for most reasonable and affordable fees.
- Introduction of crop credit.

These actions have changed the whole scenario of irrigation management not only in Barind but in other irrigation sectors in Bangladesh. But these actions were taken mostly in the public sector and not in the private sector. The private sector can sell water at various prices.

In 1985, an irrigation charge was imposed for water use for different crops. Irrigation Department collects it. But there were a lot of loop holes such as the staff not correctly recording the amount of fees received, etc. We thought of making this feasible and sustainable. The Government pays for development but the authority has to fully maintain it. So we changed the system. Coupons, which could be used only for irrigation water, were introduced.

One portion of the coupon remains in the office and two portions are given to the farmer who gives one portion to the operator to get water. Around the year 2000 we had some bad experience regarding the security of printing of the coupons. As an incentive, at the end of the financial year (July 15) there was a lottery draw for designing the coupons.

In 2006, a groundwater study was done by the Institute of Water Modeling. In Bangladesh there are 40,000 deep tube wells in the field but only 18,000 are in operation and the situation in other developing countries may be similar. Reasons for this were the lowering of the water level, nonavailkability of spare parts, group conflicts, lack of farmers’ interest, fraud, power interruption, etc. So inverted wells were introduced to the Briand areas.

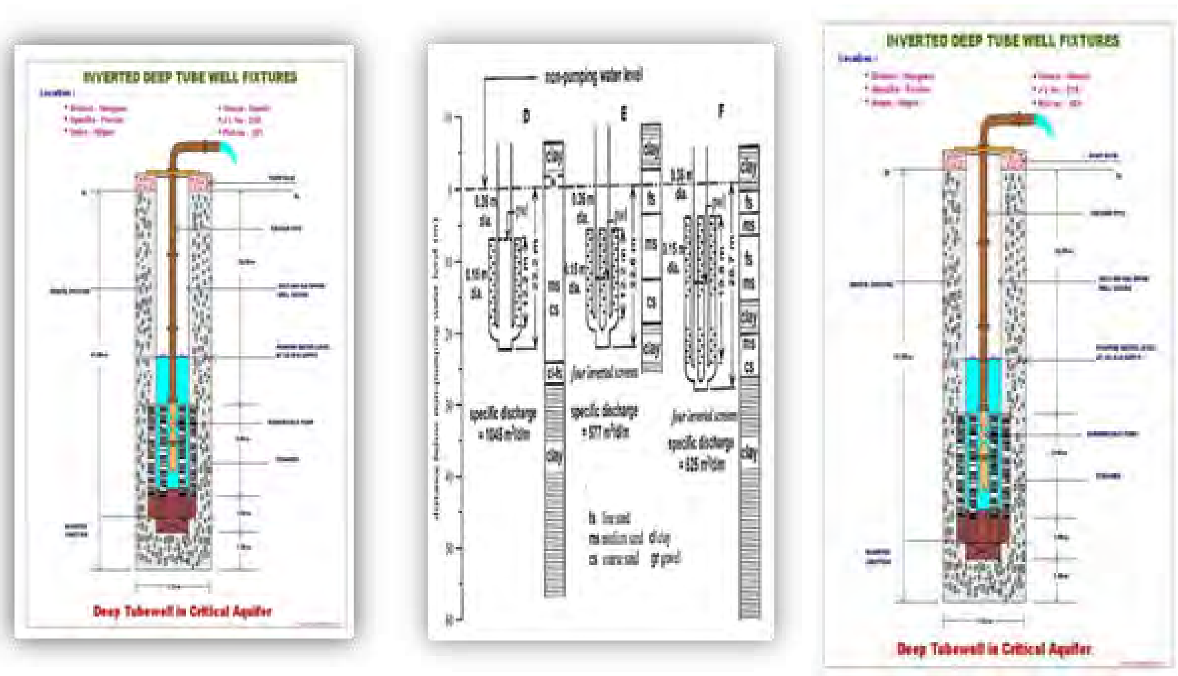


Figure 12.3.3. Design of the inverted well.

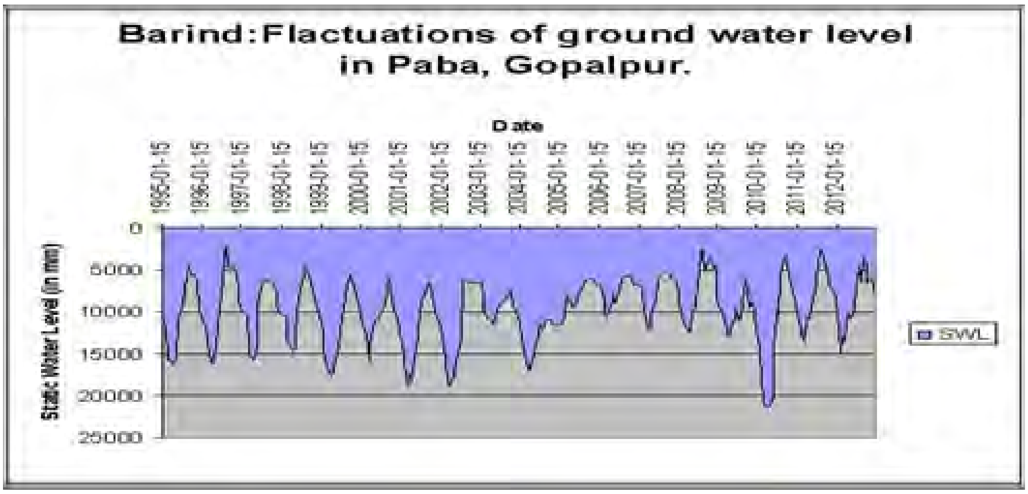


Figure 12.3.4. Fluctuations of groundwater in Paba, Gopalpur.

In 2004, we thought of modernizing the system. We called for quotations for what to do and how to do. We received joint quotations from India – Bangladesh, Malaysia – Bangladesh and China – Bangladesh. The Malaysian one takes a longer time to respond to the system of using SIM cards. The Indian one was not demonstrated and they asked for a longer period for demonstration. The Chinese did not speak or understand English; with body language they explained and, surprisingly, it worked. The quotation was for 500 tube wells with prepaid meters, installed closer to the head office after successfully explaining the mechanism to the politicians who opposed the system.

SIM cards can be bought from the Barind office. When a card is inserted into the machine it starts to run indicating how much money is left and for how many hours he can get water but the machine runs only 20 seconds after withdrawal of the card. So he loses 20 seconds of his irrigation time. The same procedure is followed for the other uses too. At the end of the week an electrician will go and punch a card and collect data for the whole of the previous week. A farmer can recharge his card from the prepaid vending machine where he has to pay a commission. Also he has to pay the electricity bill for pumping water.

Farmers' net earning has increased. There is retirement benefit to the farmers (200,000 are working). The field staff of the Irrigation Department is paid incentives depending on the increase of command area. If a 100% target is achieved a 10% incentive is paid. Up to 60% they can get 1%. If less than 60% there is a penalty like withholding their traveling expenses until they achieve at least the lowest target.

Comments on groundwater potential of Barind

- Hydrographs also show that even for large abstractions, the groundwater table regains its original peak position every year in the monsoonal period.
- This indicates that aquifers in those locations have potential for groundwater recharge and there is scope for further development. [Groundwater Model Study by the Institute of Water Modeling (IWM 2006)]

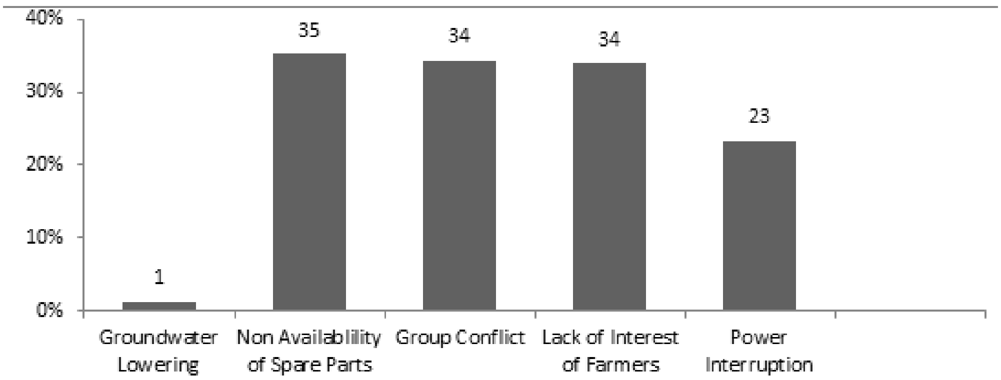


Figure 12.3.5. Conflict percentile BADC before introducing new systems.

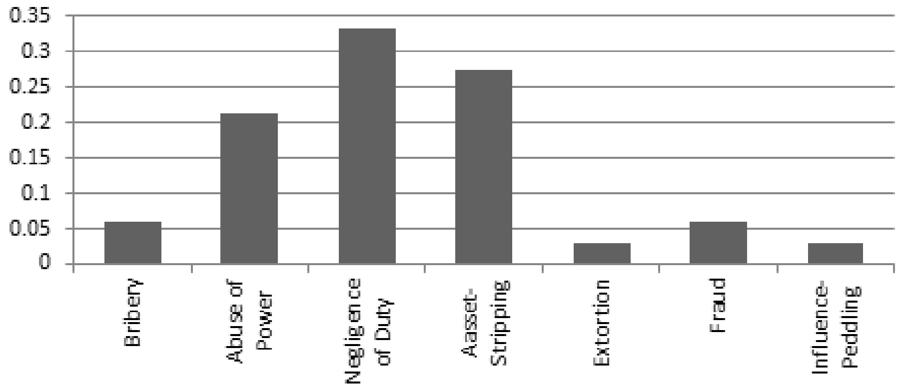


Figure 12.3.6. Corruption percentile TIB before introducing new system.

“Poor collection rates are more a function of Irrigation Departments’ unwillingness to collect than of farmers’ unwillingness to pay.” Mark Svendsen.

Table 12.3,2. Irrigation charges 1985 - Irrigation charge by seasons/crops.

Name of crops	Irrigated area under each tube well (acre)	Irrigation charge (per acre in Taka)	Yearly irrigation charge per well (in Taka)
Boro/irrigated	33	105.00	3,500.00
Aus	50	90.00	4,500.00
Wheat/potato	67	60.00	4,000.00
Transplanted almond	100	30.00	3,000.00
Total	250		15,000.00

Table 12.3.3. Without water distribution system.

Discharge of the well (cusec)	Minimum command area (acre)	Applicable irrigation charge (Taka)	Applicable irrigation charge up to 31 January including a 20% rebate	Applicable irrigation charge up to 15 February including a 10% rebate	Remarks
1	2	3	4	5	6
1.20-1.50	45	10,135	8.100	9,121	
1.51-1.75	54	12,150	9,720	10,935	
1.76-2.0	60	13,500	10,800	12,150	

Table 12.3.4. With water distribution system.

1.20-1.50	60	13,500	10,800	12,150	At the rate of Taka225 per acre
1.51-1.75	80	18,000	14,400	16,200	
1.76-2.00	100	22,500	18,000	20,250	

Irrigation coupons were introduced in 1992 to this area.

Figure 12.3.7. Irrgation coupons.

Table 12.3.5. Prizes of coupons lottery.

Serial no.	Value of coupon (Taka)	1st prize (Taka)	2nd prize (Taka)	3rd prize (Taka)
1	10	3,000	1,500	750
2	20	4,000	2,000	1,000
3	50	6,000	3,000	1,500
4	60	7,000	3,500	1,750
5	75	8,000	4,000	2,000
6	100	9,000	4,500	2,250
7	500	10,000	5,000	2,500
Total		47,000	23,500	11,750

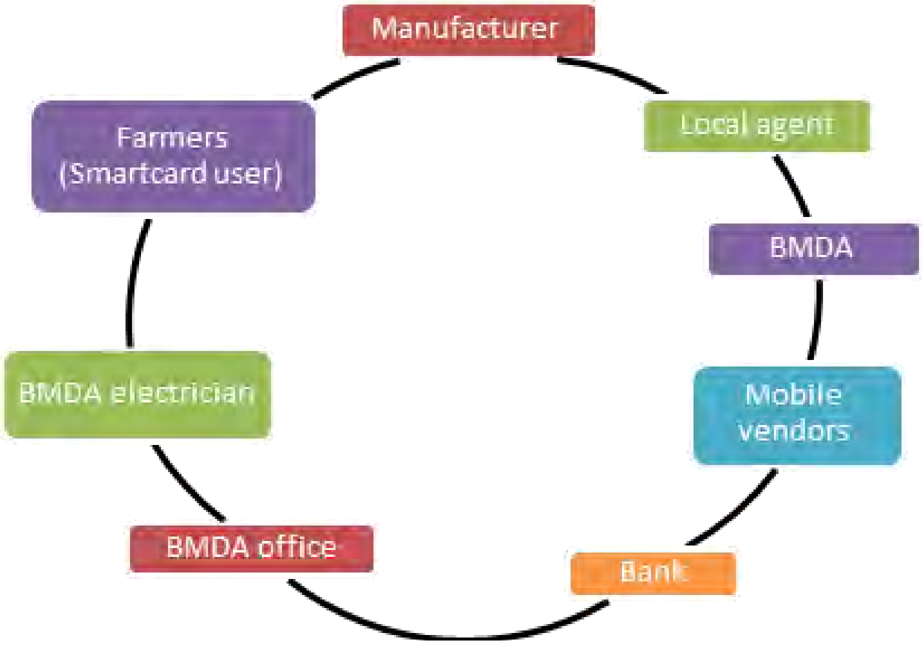
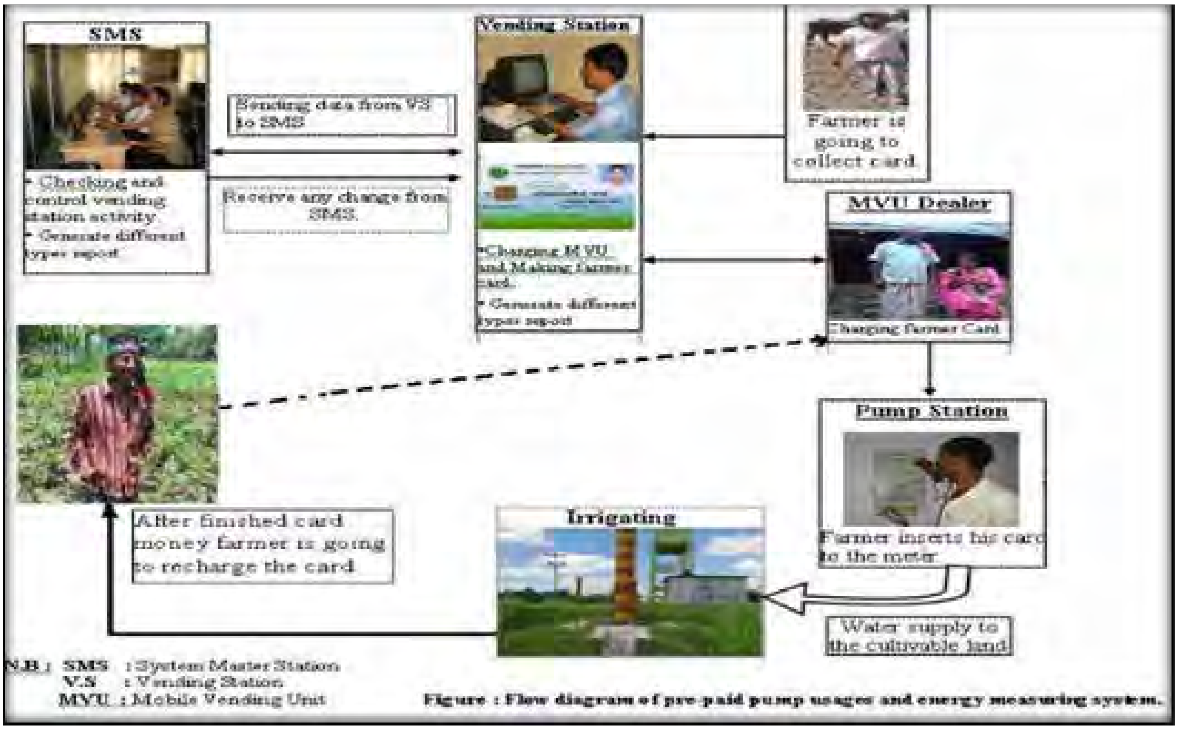


Figure 12.3.8. Stakeholders of prepaid meters (2004-05).

Figure 12.3.9. Equipment for prepaid metering system.



12.3.10. Flow chart of smart card.

Table 12.3.6. Transformation after installing prepaid meter

	Before prepaid meter	After prepaid meter	Comparison
Irrigated area (ha)	41	50	22% increase
Numbers of beneficiaries	75	85	13% increase
Irrigation charge (BDT)	3,60,130	3,91,657	9% increase
Electricity bill (BDT)	1,90,552	1,78,990	7% decrease

Advantages of prepaid meter

- Get water as and when farmers need.
- Reduces irrigation cost because of direct cash payment through a card.
- Reduces production cost due to economic use of water.
- Auto collection of money before irrigation water supply.
- Scope for depriving and corruption is eliminated.
- Meter tampering avoided.
- Very easy to operate. Even an illiterate farmer can use it easily.
- Ability to monitor 36 numbers of various parameters.
- Electricity cost reduced through efficient use of water.
- Revenue increased.
- Command area increased with the same volume of water.

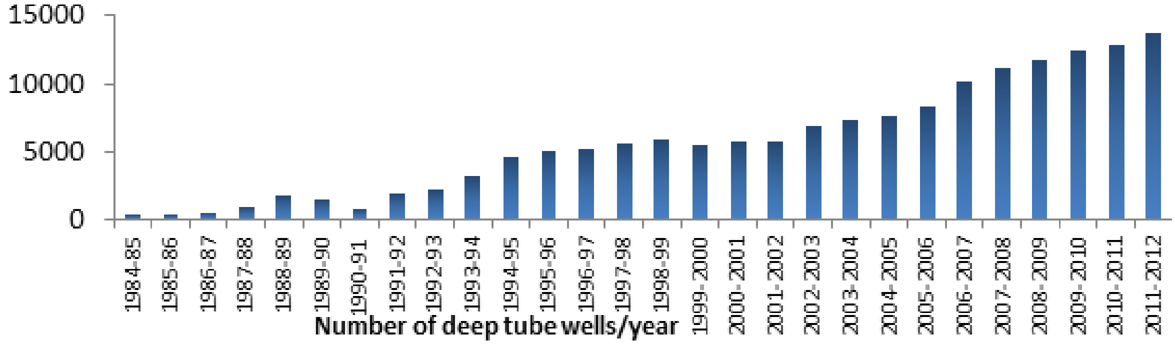


Figure 12.3.11. Year-wise deep tube wells in operation.

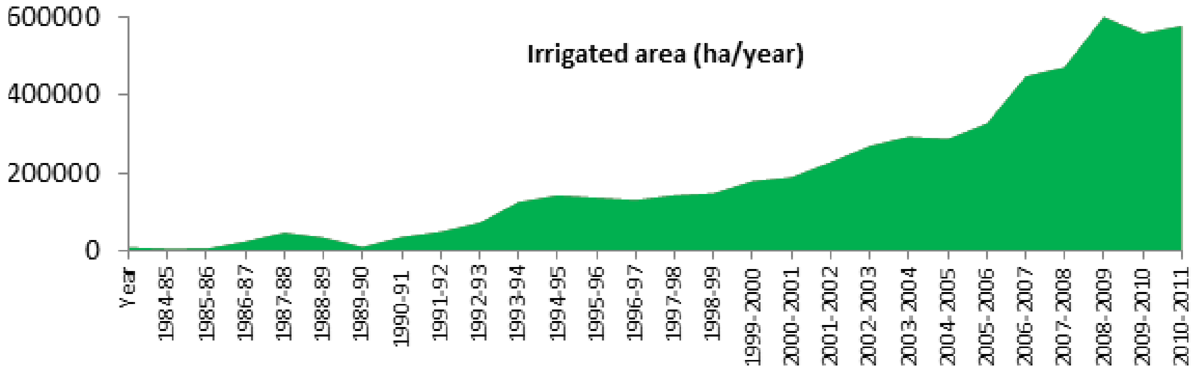


Figure 12.3.12. Year-wise irrigated area in operation.

Figure 12.3.13. Financial independence and sustainability

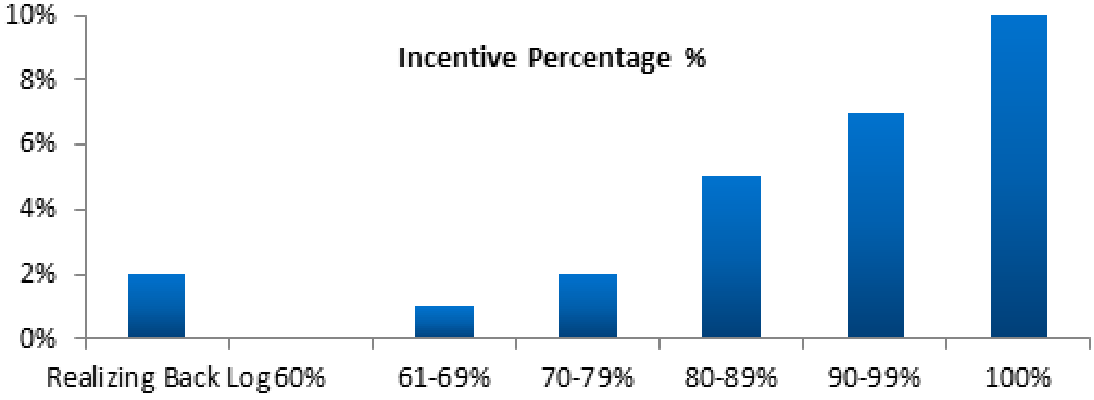


Figure 12.3.14. Provision of incentives to staff.

Incentives to farmers

From 1985

- Farmers who pay their irrigation charges by 31 January are eligible to get a 20% rebate.
- From 31 January to 15 February the farmers will get a 10% rebate.
- From 16 February, an additional proportion 15% is charged as penalty.
- An overdue charge is imposed at the rate of Taka 3 per acre per month or a fraction of it for a month.

From 1992

- Coupon dealers receive a 5% commission on the purchased amount.
- Used lottery of coupons: 1st, 2nd and 3rd prizes on the fixed date of 15 July each year.
- Best farmer prize.
- Highest command area achiever, by mechanics/electricians, receives prizes.

From 2004 to 2005

- Prepaid meter with smart card introduced.
- Commission for loading money in the vending machine at the rate was 5%.
- From 2010 to 2011 this commission was reduced to 2.5%

Table 12.3.7. Summary results of “with and without” prepaid metered tube-well irrigation management.

Serial no.	Description of test components for per ha Boro rice production	Overall results (average value of all soil)	Overall difference from prepaid program	Difference between the two two irrigation programs	
		Prepaid program	Private program		
1.	The average amount of irrigation charge/cost per ha (Taka) ($).	Tk.5,180 (65)	10,467 (137)	5,787 (72)	112% more than prepaid program
2.	The average quantity of irrigation water use (ha/inch)	59	82	23	39% more than prepaid program
3.	The average yield per ha (kilograms)	6,602	6,084	518	09% more than private program
4.	The average production of rice/inch of irrigation water/ha (kilograms)	119	82	37	45% more than private program
5.	The requirement of average quantity of water/kilogram of rice production (liters)	2,250	3,400	1,150	51% more than prepaid program
6.	The average gross income per ha (Taka) ($).	73,3559 (917)	67,061 (838)	6,298 (79)	10% more than private program
7.	The average production cost per ha (Taka) ($).	31,128 (389)	37,421 (468)	850 (79)	20% more than prepaid program
8.	The average energy cost per ha to operate irrigation equipment (Taka) ($).	2,964 (37)	5706 (71)	2742 (34)	90% more than prepaid program
9.	The average no. of workers employed per scheme	5	2	3	150% more than private program
10.	The average no. of farmers’ families financially benefiting per scheme	38	3	35	1,167% or about 12 times more than private program
Average net income per ha of Boro rice production (Taka) ($).		42,237 (528)	29,640 (371)	12,597 (157)	43% > private program

Figure 12.3.15. Surface distribution channels.

Photo credit: Asaduz Zaman.

Figure 12.3.16. Surface distribution channels.

Photo credit: Asaduz Zaman.

Figure 12.3.17. Surface distribution channels.

Photo credit: Asaduz Zaman.

Figure 12.3.18. Underground pipe system.

Photo credit: Asaduz Zaman.

12.3.19. Surface water augmentations.

Photo credit: Asaduz Zaman.

When surface water is available it is used by using the prepaid meter. At other times pumped water is used.

Figure 12.3.20. Crop diversification.

Photo credit: Asaduz Zaman.

Before prepaid meters were installed only paddy was grown in the Barind area. Now they grow different types of crops like potatoes, wheat, mustard, etc. And the command area has to be increased to 14,620 ha.

Table 12.3. 8. Lessened learned.

Motto	Must have	Quality management
Best possible service for most affordable service charge	• Reliable irrigation system • Electrification • Underground plastic pipe (cheaper, durable and hassle-free) • Prepaid meter • Supervised crop credit (farmer should get money when he needs)	• Independent management • Staff incentive, based on performance • Engaging women • Transparency • Ensure financial viability

Figure 12.3.21. Map of the area.

Table 12.3.9. Replication and expansion of Barind model of irrigation management.

Step/ Stage	Upazila	District	Project	Year of replication/ expansion-
1st	14	3	BIADP	July 1985
2nd	15	-do-	-do-	1988
3rd	25	-do-	BMDA	15 January 1992
4th	38	7	Deep tube-well installation project, unit-2, Thakurgaon.	January 2003
5th	124	16-Entire Northwest Bangladesh	(1) Activating inoperable deep tube well for irrigation (Rangpur area) (2) Deep tube-well installation project-phase-II (Rangpur area)	December 2004
6th			BADC	2010
7th			BWDB and LGED	Studying for replication of pre -paid meter system

In Barind electricity is used for pumping water.

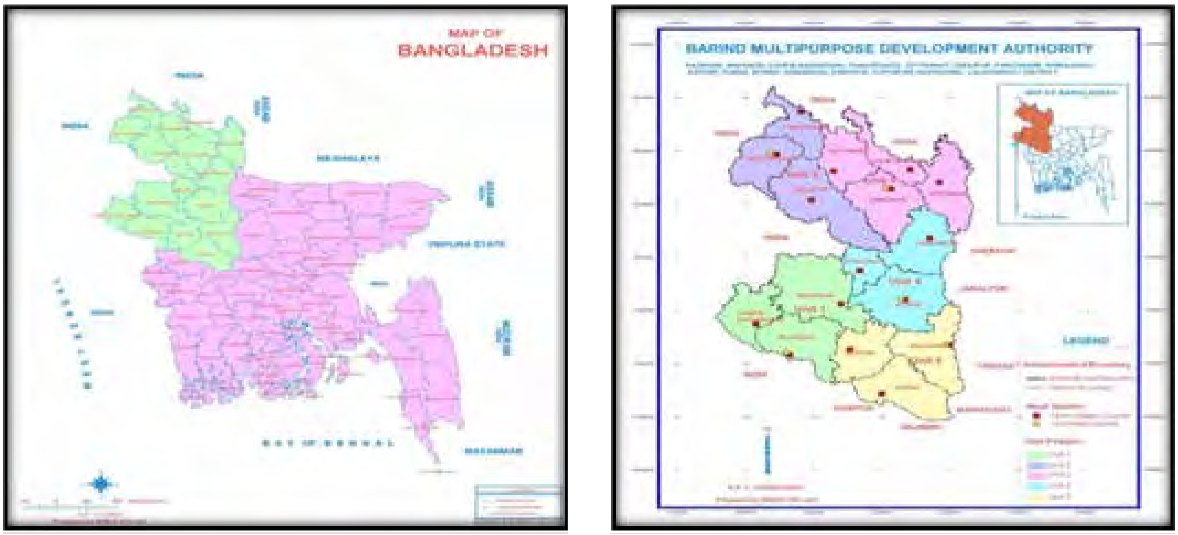


Figure 12.3.22. Operational overview of Barind.

Photo credit: Asaduz Zaman.

Figure 12.3.23. Cultivations in present Barind.

Photo credit: Asaduz Zaman.

Water measure and fee with diesel pump

1. How to correctly meter irrigation water

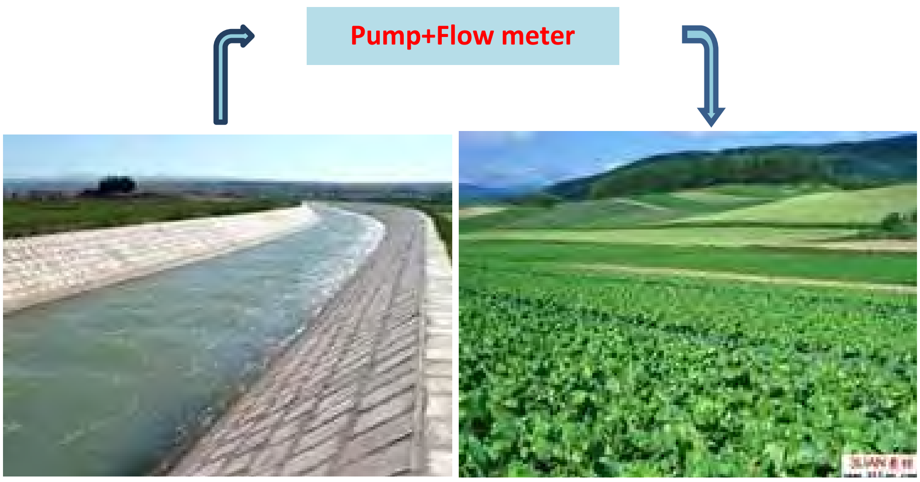
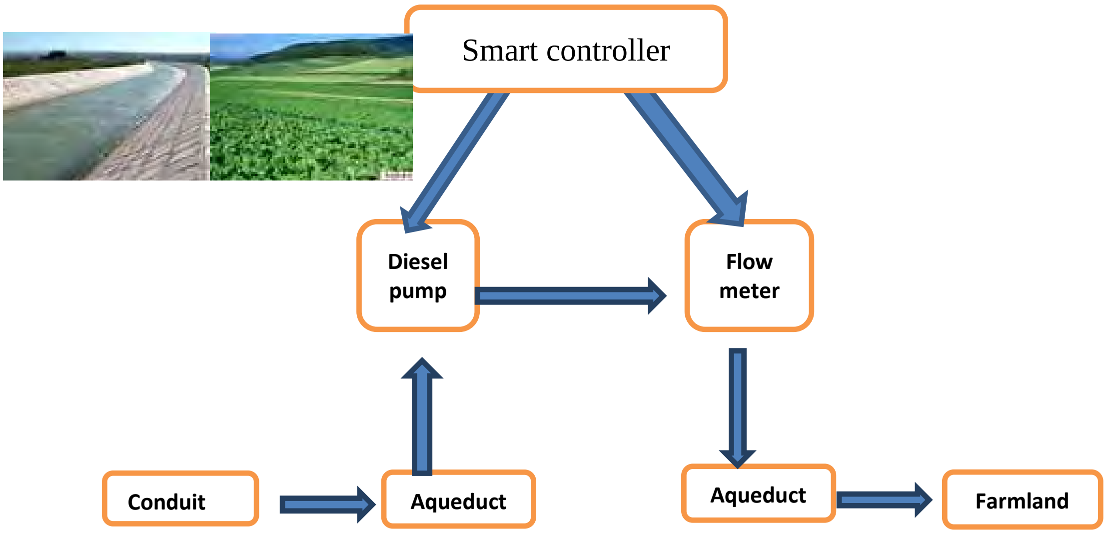


Figure 12.3.24. Water measure and fee with diesel pump.

2. How intelligently control the system of metering irrigation water



Diesel pump + Controller + Flow meter

Figure 12.3.25. Water measure and fee with diesel pump.

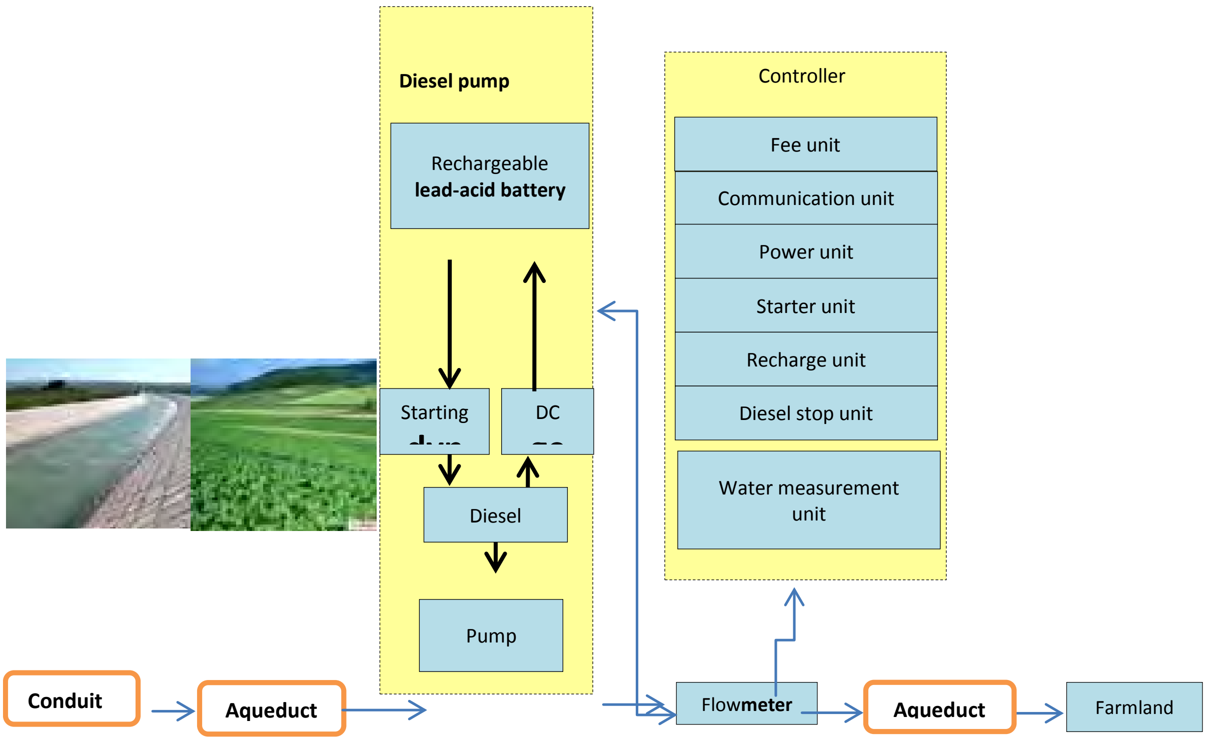


Figure 12.3.26. Principle of work.

Water measure and fee with diesel pump

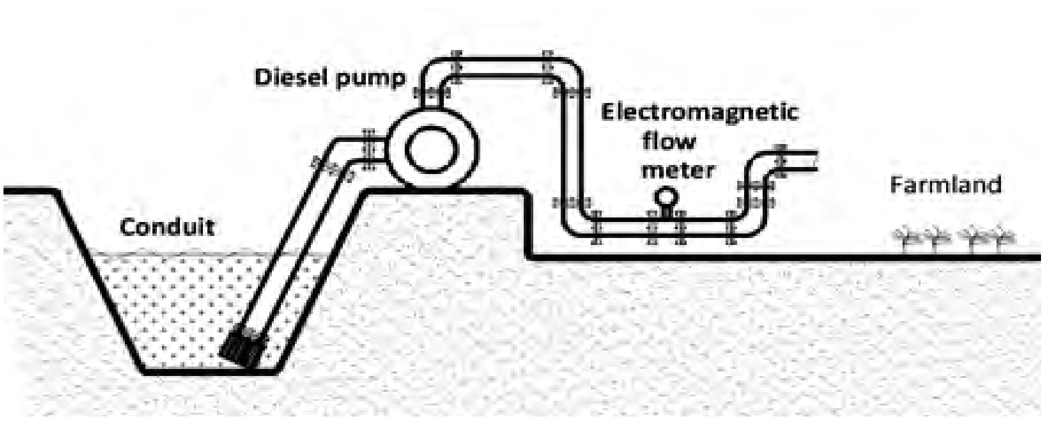


Figure 12.3.27. Installation diagram 1.

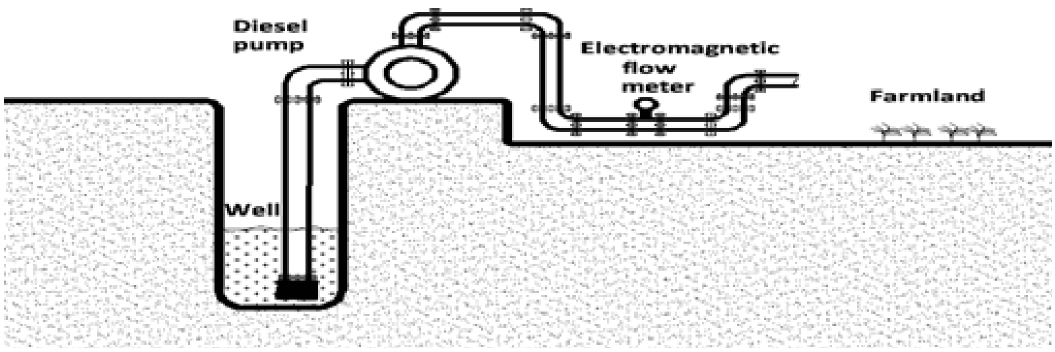


Figure 12.3.28. Installation diagram 2.

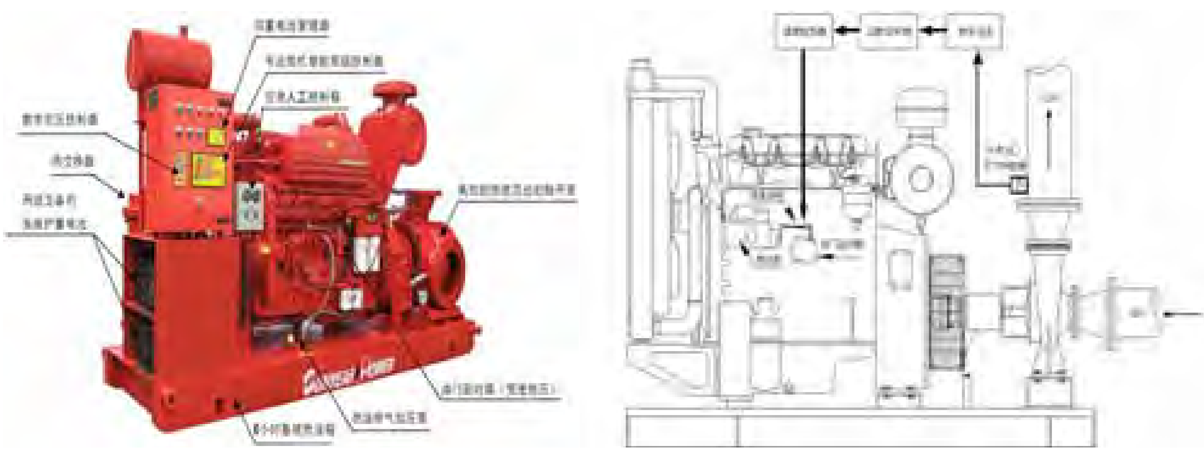


Figure 12.3.29. Diesel pump.

Table 12.3.10. Characteristics of pumps.

Type	Flow-rate (cubic inches/s)	Flow-rate (m^3/h)	Water-raising capacity (m)	Rotate speed (r/min)	Power (KW)	Type of pump	Total volume Mm (L*W*H)	Weight (kg)
XBC/BC 7.0/10-ZK	610	36	70	2,900	12	80*50-200	1,620 *600 *1,380	270
XBC/BC 4.0/20-ZK	1,220	72	40	2,900	12	80*50-200	1,620 *600 *1,380	270

In Sri Lanka, mostly diesel pumps are used. As per Manthri's request I contacted a manufacturer and got the information. The prepaid meters can be charged using batteries. Thank you very much.

13. Session III

Group Discussions and Presentations

The main objective of today's seminar was to make key stakeholders aware of the present status of groundwater in the country and the actions taken by our neighboring countries to face similar situations in those countries and the adverse effects caused by using polluted groundwater in order to lay a foundation to establish governance for groundwater in Sri Lanka.

The following topics were proposed by Dr. Manthrithilake for discussion and for sharing participants' views. Participants were clustered into three groups. He asked them to think about the current status of groundwater in Sri Lanka, to consider both the national and international research presented earlier in the day and to create a practical and workable action plan concerning groundwater management in Sri Lanka.

Topics

- Legal, institutional and policy links necessary for groundwater management – Group 1
- Monitoring, research and training required for groundwater management – Group 2
- Public awareness and participation proposed for groundwater management – Group 3

Further he suggested considering the following points during the discussion.

- What is easy/urgent and possible to implement.
- Resource requirements.
- How to proceed.

14. Group Presentations

Presentation of group one (1)

i. Legal aspects of groundwater management

1. Overview of existing policies, regulations and identification of gaps which hinder effective groundwater management (DSWRPP – ADB 5 will provide funds).

2. Developing guideline to fill policy gaps and improving existing policies and regulations to cater to the present needs.

ii. Institutional mechanism

3. Internationalization to agencies with
   Training and development (all levels)
   Conflict management

4. Coordination between agencies

5. Joint management

A system of institutional mechanisms was proposed as a way to bring different governmental bodies together to address groundwater management. These bodies are currently working independently on different aspects of groundwater but collaboration is necessary to enable suitable legal and institutional development. During this presentation several members of the audience discussed the importance of having a guardian institution to act as the driving force behind groundwater management. So, the structure mentioned below has been proposed for the purpose. Also it was stressed that not only groundwater but surface water too could be included as these two need to be considered in conjunction.

They identified the Treasury Secretary as the National Project Oversight Committee Secretary and stated that there should be interactions between the committee secretary and the other relevant secretaries mentioned below who are placed at the *second level*:

Secretary of Irrigation and Water Resources Management
Secretary of Water Supply and Drainage
Secretary of Agriculture
Secretary of Local Government
Secretary of Environment and Renewable Energy
Secretary of Ministry of Health
Secretary of Ministry of Provincial Councils

The relevant agencies come under these ministries and Chief Secretaries and District/Divisional secretaries are placed at the third level. NGOs are also included at this level.

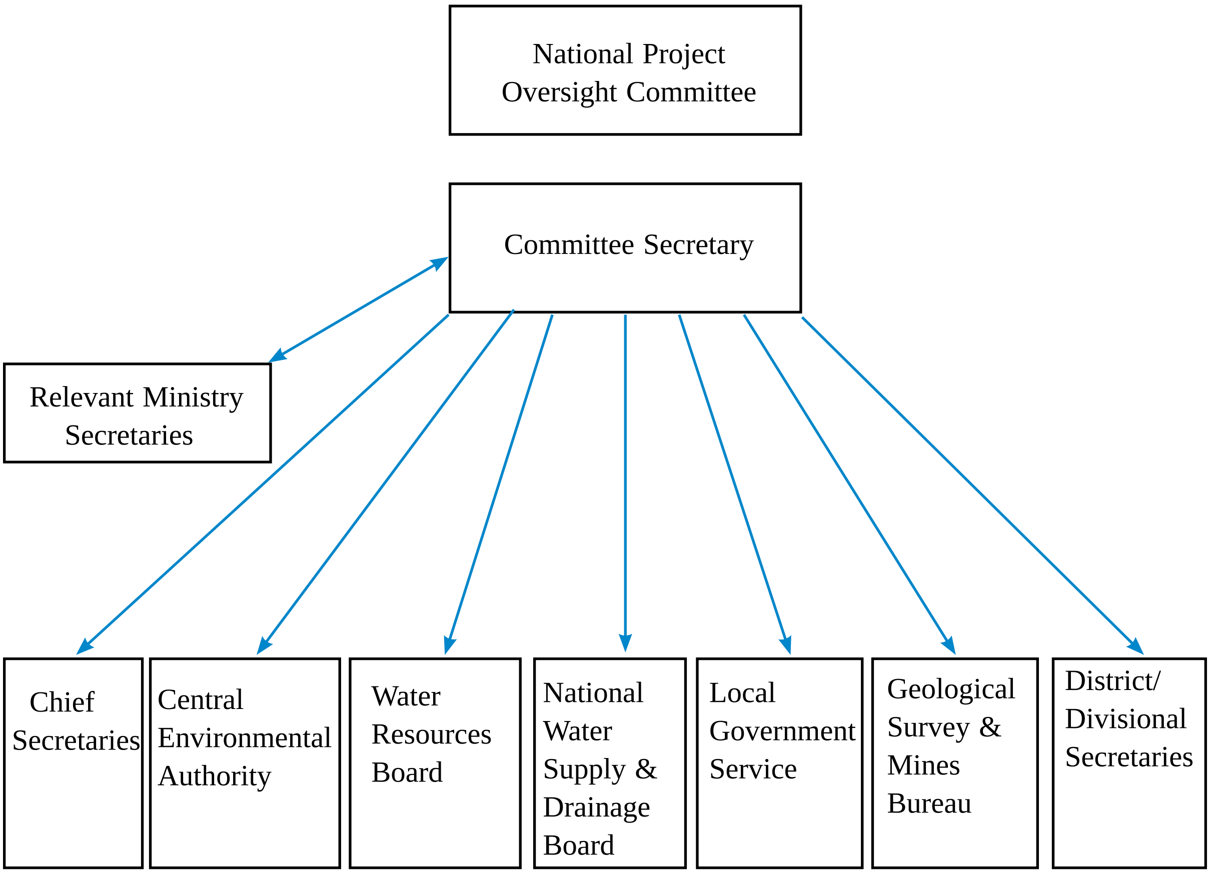


Figure 13.1.1. National project oversight committee.

Institutional Mechanism

However, the group was against forming a separate entity for groundwater/water management. From their point of view it may disturb the duties presently being carried out by the existing agencies. It was questioned as to why the National Water Resources Agency (NWRA) formed some years back was not successful. It was revealed that due to political and social reasons the idea of forming such an institution has been abandoned. Especially the idea of charging for water uses from the farmers became a major issue for opposing the establishment of NWRA as most of the farmers were poor in Sri Lanka.

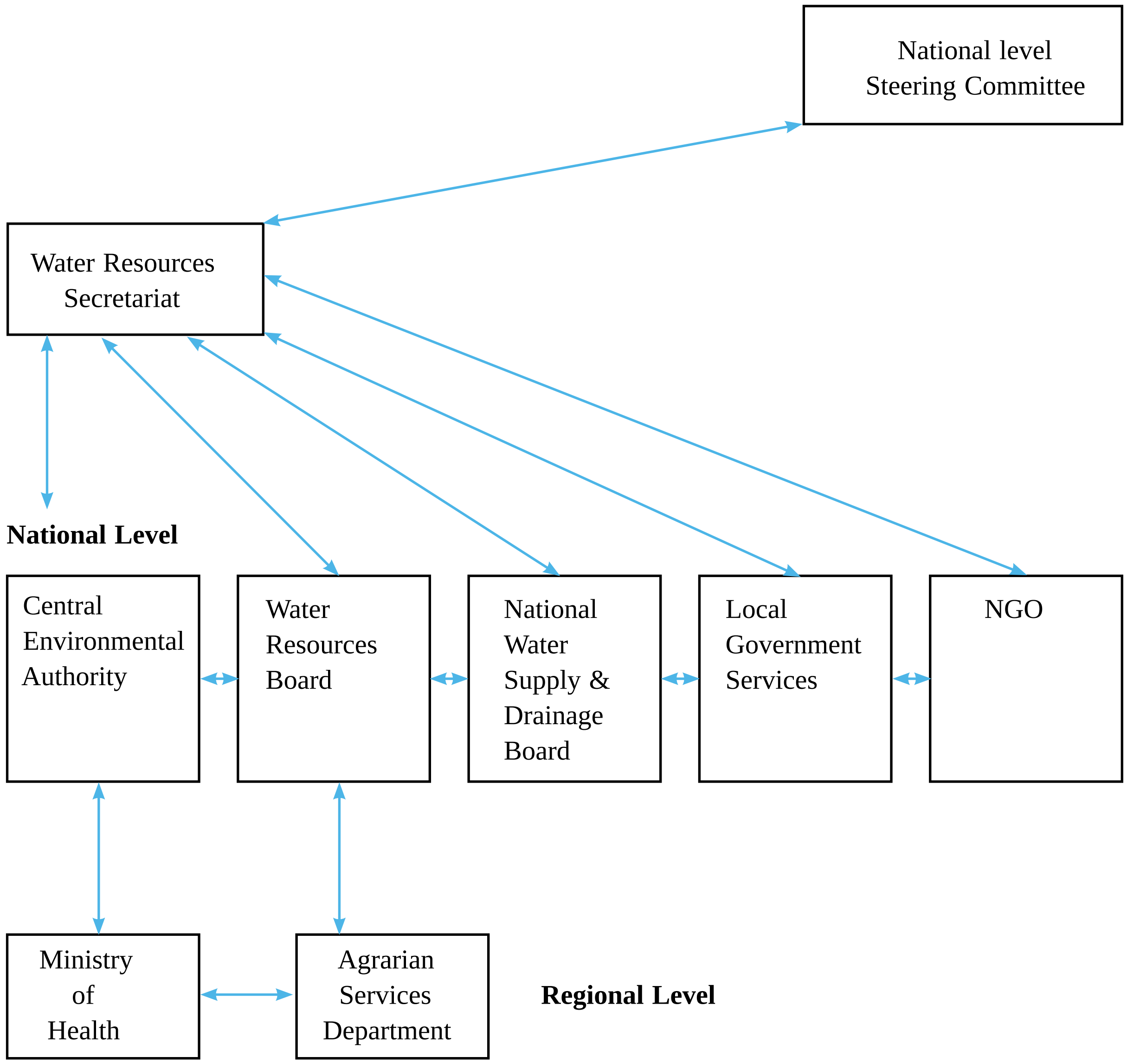


Figure 13.1.2. Policy links.

Presentation of group two (2)
Topic – Monitoring, research and training with respect to groundwater

These activities are already being carried out by relevant government organizations, research institutes and individuals on their own. It was felt that all these bodies need to first collectively understand the current situation; problems faced and identify the final objectives and the way of achieving them. Then proceed to achieve their part of the final objective.

Monitoring
What is to be monitored?

- Quality of groundwater.
- Quantity of groundwater (Groundwater level).

Why is it necessary to monitor?

- To collect data/Information with respect to groundwater.

Purpose of collecting data/information

i. Planning
ii. Design
iii. Management

The group argued that monitoring should be seen as a groundwater management tool and the backbone of technical provisions. They stated it was vital to know the water quality and water levels in different locations in order to control where and when water should be taken and what precautions are needed. They also asserted that, most importantly, monitored data should be imparted to relevant parties for planning, design and management.

They then went on to discuss the current monitoring situation in Sri Lanka. They mentioned that, previously, monitoring in Sri Lanka has been executed but not always in an efficient way. However, they argued that, with the introduction of the DSWRP project the way in which monitoring is carried out has begun to change towards a more organized and manageable system. They explained that six pilot areas have been identified and are currently undergoing water quality and quantity monitoring. This monitoring will apparently continue for another two years under the project and will be eventually extended to the whole country obtaining funds from the Government or under a suitable project.

Finally, the group argued that monitoring can be used as a way to identify suitable areas for groundwater recharge. They also suggested that data collected from monitoring activities should be shared with other organizations such as those interested in groundwater for commercial purposes, and government and research institutions. The following areas were identified by the group for research and training.

Areas of research

1. Locations and characterization of aquifers.
2. Areas where artificial recharge of groundwater is possible/required.
3. Areas of high groundwater potential zones.
4. CKD, nitrates and salinized areas, e.g., how far has seawater infiltrated inland?
5. Effects on groundwater due to climate changes.
6. Identify sensitive and vulnerable areas of groundwater pollution due to natural and anthropogenic reasons.

Training

1. Capacity-building of institutions as well as human resources involved in activities connected to groundwater.
2. Applications of software for groundwater management such as groundwater modeling, GIS, hydrogeological and hydrochemical modeling.
3. Investigations for groundwater aquifers through geophysics.

Lastly the group discussed training; arguing that there is a need to focus on building the capacity of institutions. They claimed that the loss of institutional knowledge, due to a high turnover of staff, can be mitigated by training a ‘team’ of at least 10 persons from the same organization. It was highlighted that training was particularly needed in the application of groundwater management software, e.g., GIS and hydro-chemical and hydrogeological modeling. The considerable problem of finding funding for such training activities was also noted.

Presentation of group three (3)

Public awareness and participation

In the present context, this phenomenon has been identified as very important for the success of groundwater management rather than of water management.

The focus of the discussion was on the need to consider all potential stakeholders, in both urban and rural settings, when considering public awareness. Examples of target groups included farmers, students, housewives, business people, religious leaders and politicians. In addition, an extensive and varied list of potential ‘communication vehicles’ was presented as follows. Nongovernmental organizations, all levels of government organizations, e.g., WRB, LGA, schools, universities, the private sector, IWMI, funding agencies, religious organizations, media, Department of Education, etc.

Whom to make aware and participate

1. Urban
2. Rural

Awareness		Participation	
Target groups	Vehicle	Urban (houses, flats)	
	Nongovernment		Pipe-borne
Farmers	CBOs	Water supply	Wells
			Springs
Students	**Government – Local**		Surface
Housewives	NWS&DB		
	Health Department: PHI, Midwives	Sanitation	Sewage collection systems
Business community	Agriculture Department		
	Local government authorities		Pit Latrines
	Provincial Departments of Education and schools		
Politicians			
Religious leaders	**Government – National**		No place to dump
	WRB	Garbage system	
	Universities		No collection
Funders	Schools and Department of Education		
	Private sector		
	IWMI		
	Funding agencies		
	Media		
	Religious organizations		

Figure 13.3.1 Stakeholders for different areas.

The need to raise awareness about water as a whole system, an ecosystem, rather than differentiating between groundwater and surface water was stressed. The group argued that groundwater and surface water are 'one and the same; groundwater being fed by surface water and rainfall and that constantly distinguishing between them could be detrimental. As well as this, issues surrounding the absence of waste disposal sites and lack of filtration systems in urban areas were stressed.

Rural

Farm Gardens
Water Supply – Wells
Wewa (Katlakaduwa)

In rural areas, farm gardens are fed with wells in highlands. Drainage water of those and surface water feeds the wewa, which then feeds paddy fields in the lowland.

15. Vote of Thanks

Dr. Manthrithilake thanked Hon. Nimal Siripala de Silva, Minister for Irrigation and Water Resources Management and Hon. Mahinda Yapa Abeywardena, Minister for Agriculture for their presence in spite of their busy schedules and for their valuable contribution in making this seminar a success. He appreciated both ministers' suggestions and guidance in implementing a management system for groundwater.

He thanked Dr. Peter McCornick, the DDG of IWMI who is very keen on research on groundwater and facilitation programs being initiated by government institutions of Sri Lanka, private organizations, NGOs and INGOs, and for his contribution towards making this seminar a reality and guidance for research work conducted on groundwater in Sri Lanka.

He thanked Eng. Upali Wickramaratne, Additional Secretary of the ministry (I&WRM) for his contribution, educating presenters and all stakeholders for their presence and participation.

National seminar on groundwater governance, 15, August 2013

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