বাংলাদেশ পানি উন্নয়ন বোর্ড

অতিরিক্ত মহাপরিচালক
(পরিকল্পনা, নকশা ও গবেষণা) এর দপ্তর
ব্লক-এফ, লেভেল-৫, পানি ভবন,
৭২ গ্রীন রোড, ঢাকা-১২০৫।
ফোনঃ ০২-২২২২৩০০৪০-৪২

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72 Green Road, Dhaka-1205
Phone: 02-222230040-42

Memo No. 80-ADG(Pl)-BWDB   Date: 08.05.2022.

Subject: Requesting comments on Draft National Strategy on Managed Aquifer Recharge (MAR).

Dear Sir,

Many parts of Bangladesh are facing scarcity of fresh water due to over-abstraction of groundwater, coastal salinity, and degradation of hilly ecosystems. Solutions to these problems are multi-faceted but one of the most promising is managed aquifer recharge (MAR) to refill depleted and saline prone aquifers and to reduce waterlogging. MAR activities have already started at small scale. The basic purpose of preparing National Strategy on MAR is to facilitate upscaling by the public and private sectors in a safe and efficient manner.

The Bangladesh Water Multi-Stakeholder Partnership (MSP) was formed through Gazette No. 42.00.0000.038.18.039.15.527 in December 2015. In May 2019, its National Steering Board (NSB) constituted a High-Level Committee on MAR (HLC-MAR) with members draw from the public and private sectors and civil society under the chairmanship of the Principal Coordinator (SDG Affairs), Prime Minister's Office. This Committee constituted a Technical Committee (TC-MAR) to draft a National Strategy Paper and Implementation Plan, which is being done in three stages: 1. Scoping Report; 2 - Draft Strategy Paper; and 3 - Final Strategy Paper. The Scoping Report was approved by the HLC-MAR on 23 July 2020, and the draft National MAR Strategy was approved at the 3rd meeting of the HLC-MAR on 2 September 2021. Following this, the Ministry of Water Resources has requested the Bangladesh Water Development Board to disseminate the Draft Strategy Paper for public comment before preparing the final strategy paper.

You are, therefore, requested to provide your valuable comments and suggestions on the draft National MAR Strategy in Bangladesh to the office of the undersigned within 30 days. Your comments are extremely valuable and would help in improving the final National MAR Strategy for Bangladesh.

Thank you for your kind cooperation and best regards.

08/05/2022

(Dr. Zia Uddin Baig, PEng.)
Additional Director General
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72, Green Road, Dhaka 1205.

Distribution of the copy of the Draft National Strategy on MAR (not according to seniority):

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70. Chief Representative, Japan International Cooperation Agency (Bangladesh) JICA, Gulshan, Dhaka-1212.
71. Country Director, German Corporation for International Cooperation (GIZ), Gulshan, Dhaka 1212.
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77. President , BGMEA, Uttara, Dhaka-1230.
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79. President, Bangladesh Tannery Association, BTA, Dhanmondi, Dhaka-1209.
80. Country Representative, Coca-Cola Bangladesh Pvt. Ltd., Gulshan, Dhaka-1212.
81. Director, Corporate Affairs, Nestle Bangladesh, Tejgaon, Dhaka-1208.
82. Country Representative, H & M Bangladesh, Gulshan 2, Dhaka-1212.
83. Head, Corporate Affairs, Unilever Bangladesh Ltd. Gulshan, Dhaka-1212.
84. Relevant any other Organizations, Agencies or Experts.
85. Director, Central ICT Directorate, BWDB, Panibhaban, 72 Green Road, Dhaka. He is requested to publish the draft National Stragegy on MAR on BWDB webpage with this letter to invite comments, suggestions and remarks from relevant agencies, organizations, experts and professionals.

National Strategy for Managed Aquifer Recharge (MAR) in Bangladesh (for Sustainable Groundwater Management under the IWRM Principle)

FINAL DRAFT OF
THE DRAFT MAR STRATEGY

2030 Water Resources Group
JULY 2021

Preparation of National Strategy on Managed Aquifer Recharge (MAR) in Bangladesh

The National Strategy on MAR is being prepared in three stages, as follows:

Scoping Report
Draft Strategy
Final Strategy

The Scoping Report was completed in 2020. This document is a draft of the output of Stage 2, submitted for approval to the High Level Committee (HLC) on MAR. If approved by the HLC, it will be placed for broad consultation prior to Stage 3, the preparation of the Final Strategy.

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Abbreviations

ASR	: Aquifer Storage and Recovery
ASTR	: Aquifer Storage, Transmission and Recovery
BADC	: Bangladesh Agricultural Development Corporation
BAEC	: Bangladesh Atomic Energy Commission
BBRA	: Bangladesh Building Regulatory Authority
BDP2100	: Bangladesh Delta Plan 2100
BEA	: Bangladesh Employers Association
BEPZA	: Bangladesh Export Processing Zones Authority
BEZA	: Bangladesh Economic Zones Authority
BGMEA	: Bangladesh Garment Manufacturers and Exporters Association
BKMEA	: Bangladesh Knitwear Manufacturers and Exporters Association
BMDA	: Barind Multipurpose Development Authority
BNBC	: Bangladesh National Building Code
BSCIC	: Bangladesh Small and Cottage Industries Corporation
BUET	: Bangladesh University of Engineering and Technology
BWA-2013	: Bangladesh Water Act 2013
BWDB	: Bangladesh Water Development Board
BWR-2018	: Bangladesh Water Rules 2018
CC	: City Corporations
CEGIS	: Center for Environmental and Geographic Information Services
CHT	: Chittagong Hill Tracts
CHTDB	: Chittagong Hill Tracts Development Board
CPP	: Cyclone Preparedness Programme
DMB	: Disaster Management Bureau
DOE	: Department of Environment
DOI	: Department of Industries
DPHE	: Department of Public Health Engineering
DTW	: Deep Tube Well
DU	: Dhaka University
DWASA	: Dhaka Water Supply and Sewerage Authority
ERD	: Economic Relations Division
GCC	: Gazipur City Corporation
GDE	: Groundwater Dependent Ecosystems
GMA	: Groundwater Management Agency
GREZ	: Green and Resilient Economic Zone
HBRI	: Housing and Building Research Institute
ICZM	: Integrated Coastal Zone Management

IWM	: Institute of Water Management
IWP	: Industrial Water Policy
IWRM	: Integrated Water Resources Management
JU	: Jahangirnagar University
KU	: Khulna University
LGI	: Local Government Institutes
MAR	: Managed Aquifer Recharge
MARAS	: Managed Aquifer Recharge for Agricultural Storage
MOA	: Ministry of Agriculture
MOEF	: Ministry of Environment and Forest
MOLGRD&C	: Ministry of Local Government, Rural Development and Cooperatives
MOWR	: Ministry of Water Resources
NEP	: National Environment Policy
NGO	: Non Government Organizations
NWRD	: National Water Resources Database
O&M	: Operation and Maintenance
OMM	: Operation, Monitoring and Management
PWD	: Public Works Department
REHAB	: Real Estate and Housing Association of Bangladesh
RU	: Rajshahi University
RWH	: Rainwater Harvesting
SDG	: Sustainable Development Goals
SRDI	: Soil Resources Development Institute
STW	: Shallow Tube Well
SWTP	: Surface Water Treatment Plants
WARPO	: Water Resources Planning Organisation
WASA	: Water Supply and Sewerage Authority

Chapter 1: Introduction

1.1 Introducing MAR

Groundwater constitutes 97% of the non-frozen freshwater on earth and is used extensively for all human needs. Groundwater is a renewable resource which is replenished by natural recharge from precipitation and other sources of surface water. However, excessive withdrawal at certain locations has resulted in groundwater depletion, as expressed in falling water tables, on a global scale, and Bangladesh is no exception, standing at number six on the list of top groundwater extracting nations. Rainfall, surface water and groundwater are components of a single inextricably linked freshwater resources. Where groundwater is being depleted, surface water is usually also scarce or stressed. Solutions to groundwater depletion include require action on the supply and demand side. Managed Aquifer Recharge (MAR) is one of the principal supply-side tools for combating groundwater depletion, improving groundwater quality, and ensuring sustainable supply under diverse hydrogeological conditions worldwide.

The over-arching objectives of MAR are to prevent or reverse the depletion of groundwater resources and associated land subsidence; to prevent the drying up of wells, springs, wetlands and streams; and to create fresh water sources in saline coastal areas. Along with other 'Integrated Water Resource Management (IWRM) measures, MAR will sustain drinking water supplies and industrial growth and prosperity in the Greater Dhaka-Gazipur area, provide fresh drinking water where it is lacking, sustain the agricultural revolution that turned the Barind Tract into a food basket, and restore or sustain drinking and irrigation supplies in the Chittagong Hill Tracts.

MAR, also known as artificial recharge, is the umbrella term for a range of technologies involving infiltration and injection processes (Fig 1) that enable the integrated use and management of surface water and groundwater to achieve a wide and growing range of social, economic and environmental benefits (Dillon et al, 2018). MAR is the intentional recharge of source water including stormwater, reclaimed water, desalinated water and potable natural waters water to aquifers for subsequent recovery or environmental benefit. MAR can also be used for improving quality of groundwater and controlling sea water intrusions in coastal aquifers. However, there are potential risks associated with quality of source water, clogging of systems and failures in operation and maintenance. Proper polices, guidelines and institutional arrangements are required to address the risk management of water quantity and water quality as well as to get the desired benefits. MAR systems involve the management of water quantity and quality in three distinct but interconnected stages: i) source water harvesting, ii) recharge and storage in aquifers, and iii) recovery for use.

There is wealth of global knowledge on MAR applications and countries like Australia, South Africa, USA, India are the leaders in implementations. In Bangladesh, piloting has been carried out in Dhaka City and Barind Tract for augmenting quantity, and in the coastal area for improving water quality. The existing knowledge on MAR applications has been reviewed in the Scoping Report on Preparing National Strategy for MAR in Bangladesh.

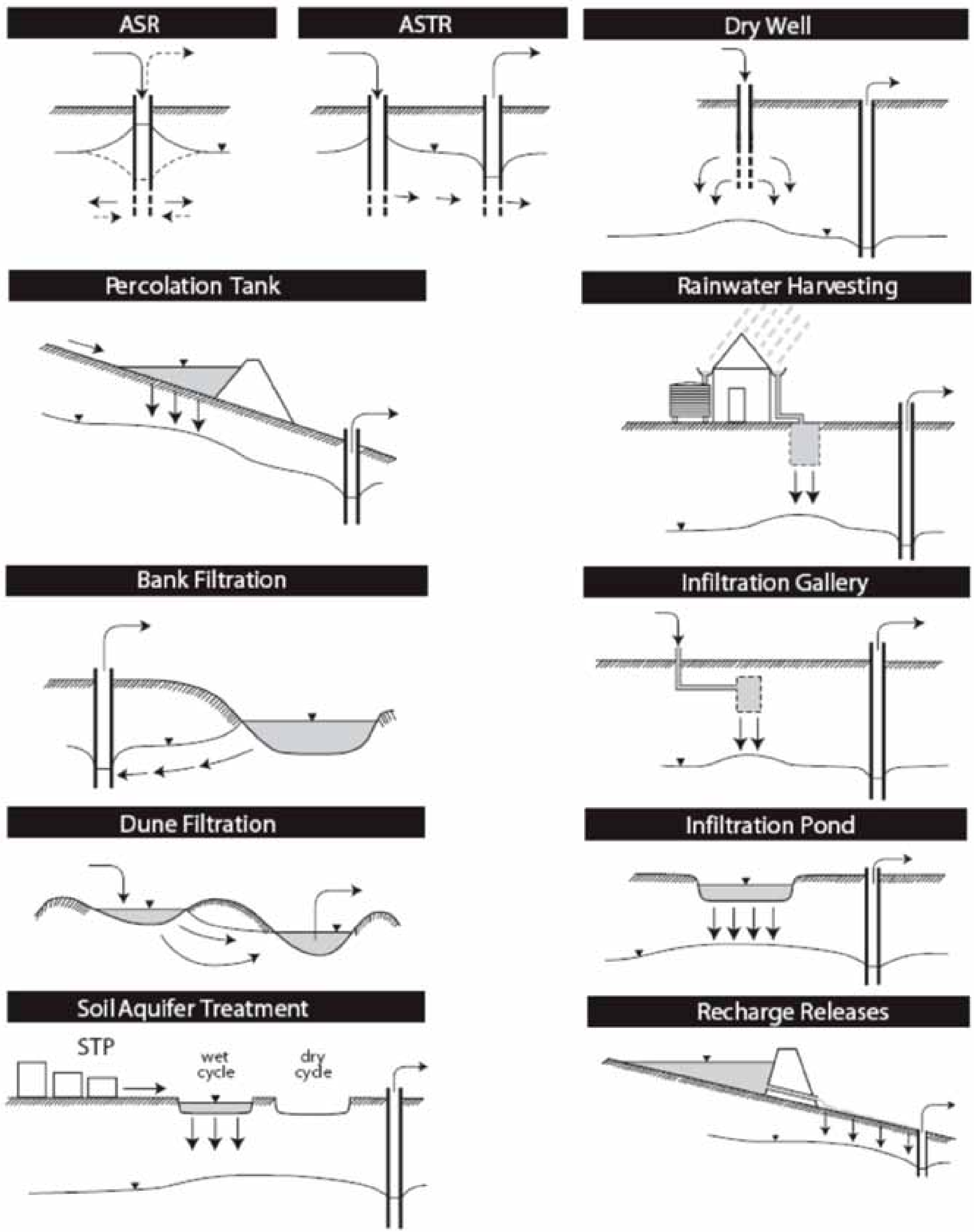


Figure 1. Schematic of types of MAR suited to water management (Page et al., 2018). ASR - Aquifer Storage and Recovery; ASTR - Aquifer Storage Transfer Recovery; STP – Sewerage Treatment Plant.

1.2 Identification of Water Stressed Regions

Extensive groundwater uses in Bangladesh started after independence for drinking sources driven by the need for bacteriologically safe sources for public health protection. Currently about 98% of the population rely on groundwater for drinking purposes. However, the quantity extracted for drinking water in the rural or small towns do not have significant impact on the dynamic equilibrium of recharge and discharge as demonstrated by the trends of water levels of the shallow aquifers monitored by the Bangladesh Water Development Board (BWDB). However, first sign of depletion was recorded in Dhaka City as combined impacts of heavy abstractions as well as pronounced change in land cover types. Continuous increase in irrigation from mid-eighties has impacted the groundwater dynamics in the country. About 77% of the current irrigation coverage is provided through groundwater sources. Significant depletions are taking place in the Barind Tract due to heavy groundwater pumping; also declining trends in groundwater levels are visible in some other areas. Over the last decades, industrial abstractions have increased substantially in and around Dhaka City, particularly in Gazipur areas where land cover types have also changed due to industrialization and accompanied urbanizations. As a result, groundwater levels are declining fast indicating depletion of groundwater. Apart from depletion, the coastal regions have salinity problem in shallow groundwater and people living there are suffering from safe water stress. Dhaka City, Barind Tract, Gazipur Region and the coastal areas are the identified major groundwater stress regions of the country. Detailed analysis of groundwater stress regions are presented in Chapter 3. Before the large scale investment on MAR in these regions, a detailed site specific investigation has to be conducted to finalize the system design.

1.3 Groundwater Management Status in Bangladesh

It is unfortunate that groundwater management in Bangladesh is not the best despite its strategic importance for maintaining public health, ensuring food security and facilitating industrial growths. There are many agencies with stakes on groundwater but there is no specific agency for protecting and managing groundwater sustainably. According to national law and policies, Water Resource Planning Organization (WARPO) is the apex agency for overall water resources management in the country. Apart from WARPO, BWDB is responsible for monitoring water resources including groundwater. However, both WARPO and BWDB are more focused more on surface water management.

Bangladesh Agricultural Development Corporation (BADC) introduced groundwater irrigation in the early sixties although currently most of the irrigation is provided through private sector except in the NW region of the country where the Barind Multipurpose Development Authority (BMDA) is responsible for irrigation management. Department of Public Heath Engineering (DPHE) is responsible for providing water supply and sanitation all over the country except in four WASA areas. About 97% of the DPHE installed rural water supplies are based on groundwater sources, remaining 3% safe water options use surface and rain water sources. Water Supply and Sewerage Authorities (WASA) are responsible for water supply and sanitation in four major cities of the country, Dhaka, Chattogram, Khulna and Rajshahi. Apart from Chattogram, groundwater is the main source of supply in all three other cities ranging from 70 to 100%.

Industrialisation in Bangladesh started centring Dhaka, Chattogram and Khulna. Later designated industrial areas were developed in each district under the management of the Bangladesh Small and Cottage Industries Corporation (BSCIC). Over the last three decades the pattern has changed, and large industrial zones have been developed all over the country under the Bangladesh Export Processing Zones Authority (BEPZA) and Bangladesh Economic Zones Authority (BEZA). Most of the industrial zones under management of different agencies rely on groundwater for various purposes. Apart from public sector industrial parks, private industries are located mostly around Dhaka and Chattogram, almost all relying on groundwater. The service providing agencies has limited groundwater capabilities. Due to absence of proper legal framework, there is no control on abstraction of groundwater outside the WASA areas. There are number of laws and policies which touch upon issues pertaining to management and protection of groundwater resources in the country. There is a need to improve the overall groundwater management scenario by improving capacity of agencies involved. The best thing about groundwater management in Bangladesh is the existence of the very good national water level monitoring system managed by the Groundwater Hydrology Directorate of BWDB. The monitoring system have evolved since early sixties starting with manual measurement of water level in dug wells. Most of the dug wells were replaced in the eighties with shallow piezometers, still with manual measurements with a very few auto measurements. Deep monitoring started in the coastal areas in early 2000 with the installation of nested piezometers. Very recently nested piezometers fitted with auto loggers have been installed all over the country, upgrading the system further. Apart from BWDB, BADC and DPHE also monitor groundwater level all over the country. Although the groundwater level monitoring system is very good in the country, groundwater quality monitoring is still not up to the mark and need further improvements. However, this groundwater level monitoring system can provide adequate data on the status of groundwater in the country. These data can be used to identify groundwater stress areas where specific monitoring network has to be developed for groundwater level and quality. There is a need for a specific law to protect groundwater quantity and quality under a legally empowered and technically capable "Groundwater Management Agency (GMA)". Examples of such laws and agencies are available from India, Thailand, Australia, UK and USA. A typical GMA should have four arms for Assessment, Regulation and Protection, Planning and Implementation, and Enforcement for ensuring Groundwater Sustainable Plan. A new legal provision is required to set a groundwater management agency in the country in line with the Central Groundwater Board of India or the Department of Groundwater Management in Thailand.

1.4 Policy Drivers for MAR

Bangladesh adopted the Integrated Water Resources Management (IWRM) through the National Water Policy and National Water Management Plan. The legal basis for IWRM has been provided through the Bangladesh Water Act 2013 and Bangladesh Water Rules 2018. MAR is one of the options of many for ensuring IWRM. Although it is not explicitly mentioned in any of the documents mentioned here, there is opportunity for implementation of MAR. Also, MAR is explicitly mentioned in the National Environment Policy, Draft Industrial Water Policy and Bangladesh Delta Plan 2100 and Bangladesh National Building Code. These mentions create opportunities for applications of MAR for Environment Management, Industrial Water Management and Urban Areas. BDP2100 included the MARAS project to implement MAR in different hotspot areas of the country.

1.5 Background and Rationale for National Strategy for MAR

MAR is a century old tool for groundwater management in areas of having quantity or quality problem. MAR is a part of the overall IWRM practices. In Bangladesh, MAR has not yet been officially endorsed as a management tool. However, joint piloting involving government agencies and knowledge institutions have been carried out in different parts of the country along with limited upscaling. MAR has many benefits but has number of risks associated with it. If not regulated through proper legal instruments, there is risk for using unsuitable water having poor quality as source water and thus to impair inherent water quality of potable aquifers. As MAR is piloted mostly by educational institutions, there is general lack of capacity in all groundwater stakeholders for implementing MAR. There is general lack of awareness about the benefits of MAR; also there is apprehension among various sections of people about the detrimental impacts of MAR in the absence of proper regulatory guidelines. However, MAR has been recommended in various recent studies dealing with groundwater quantity and quality problems, the notable one being the Bangladesh Delta Plan 2100.

A National Strategy is needed firstly to adopt MAR as a groundwater management tool, secondly to ensure beneficial use of MAR and thirdly to protect against harmful use of MAR. The strategy is also needed for undertaking a road map towards wider application of MAR in water stress regions as well as to integrate MAR with various national policies and strategies.

1.6 Core Elements of the MAR Strategy

In summary, the MAR Strategy can be divided into four groups of activities for each of which the highlights are listed below:

1. Planning
    a. Creation of MAR Centre to lead and monitor the Strategy
    b. Development of Guidelines and generic designs
    c. Awareness raising.
    d. Preparation of Sectoral master plans.
2. Actions
    a. Mass implementation of rooftop rainwater harvesting and recharge under the new Bangladesh National Building Code where the water table is falling rapidly.
    b. Pilot Projects by GoB agencies (MARAS)
    c. Demonstration projects by industries and industrial parks
    d. Research Projects by Knowledge Institutions.

3. Safeguards
    a. Short to medium term focus on recharge inherently safe water sources (e.g. rooftop rainfall)
    b. Establishment of Regulation and approval processes.
    c. Clogging and operational risk assessments.
    d. Regulatory and routine monitoring.
4. Outcomes
    a. Stabilisation of falling water levels in the industrial areas to sustain employment and economic growth and ensure resilient drinking water supplies in Greater Dhaka and Gazipur.
    b. Stabilisation of falling water levels beneath the Barind Tract to sustain high productivity irrigated agriculture, safe drinking water, employment and secure food production.
    c. Increased fresh water supplies in hard to reach areas in coastal regions.
    d. Restoration and protection of spring yields in the Chittagong Hill Tracts.
    e. Restoration and protection of groundwater dependent ecosystems.

1.7 MAR and Other IWRM Initiatives

MAR is not a panacea. Solving the countries' complex water management problems will require multiple, coordinated and complementary supply-side and demand-side actions that fall under the umbrella of IWRM. These measures include regulation, increased efficiency, pricing and financial incentives, conjunctive use, and crop diversification.

1.8 Structure of the Strategy

Chapter 1: Introduces Managed Aquifer Recharge as a tool for Sustainable Groundwater Management. Briefly outlines about Water Stress Regions, Status of Groundwater Management in Bangladesh, Policy Drivers for MAR and Need for a National Strategy for MAR in Bangladesh.
Chapter 2: Outlines the Vision and Themes of the Strategy along with the guiding principles.
Chapter 3: Detail analysis of groundwater use, occurrences and MAR Typologies as applicable for Bangladesh.

Chapter 4: Outlines the strategic action plans under 8 different themes:

(1) Knowledge and Awareness raising
(2) Legislation and Regulation
(3) Planning and Design
(4) Implementation and Funding
(5) Operation, Maintenance and Management
(6) Sustainable Water Management and Governance
(7) Monitoring and Evaluation
(8) Research and Development

Chapter 5: Highlights the Institutional Framework for MAR and provides guidelines for Sectoral Master Plans on MAR, and financial mechanism.

Chapter 2: National Strategy for Managed Aquifer Recharge

This chapter presents an overview of the scope and objectives of the national MAR Strategy as elaborated in the eight strategic themes in the following chapters:

1. Knowledge and awareness raising
2. Legislation and regulation
3. Planning and design
4. Implementation and funding
5. Operation, maintenance and water governance
6. Monitoring and evaluation
7. Research and development

2.1 Vision

Bangladesh's natural abundant water resources are increasingly coming under stress from population growth, intensification of agriculture, urbanisation, industrialization, seasonal shortages and excesses along and the impacts of climate change. These challenges will be tackled by all sectors of society within the framework of IWRM and wherein MAR comprises one of principal tools in the IWRM toolkit. MAR is proven worldwide, already piloted in Bangladesh and now ready for up-scaling. MAR is also consistent with, or included in, major policies, strategies and plans such as BDP-2100. Integrating the use of surface and groundwater resources by storing seasonal excesses of surface water beneath the ground, MAR will increase the availability of freshwater for drinking, agriculture, industry and environmental protection where and when it is needed. Combined with other elements of the IWRM toolkit (e.g. water efficiency, reuse, valuation etc.), it offers the means to satisfy the country's long needs for safe, fresh water and a healthy aquatic environment. This Strategy describes what MAR measures should be implemented, where, when, and how they should be implemented.

MAR itself is toolkit for solving problems of water scarcity and will be applied first in (i) the Dhaka – Gazipur metropolis where tables are being drawn down by municipal and industrial pumping; (ii) the low-rainfall Barind Tract in Rajshahi Division where levels are falling due to irrigation abstraction; (iii) the saline coastal areas of Khulna Division where drinking water is desperately short in the dry season; and (iv) in the Chittagong Hill Tracts where spring flows are increasingly unreliable.

The tools of MAR are diverse and their application will evolve over time but it will be important to build public trust in MAR by focusing initially on using inherently safe water sources. Initially, rainwater harvesting connected to recharge wells will dominate in the Dhaka-Gazipur and coastal areas, while catchment management techniques will be more prominent on the High Barind and in the Hill Tracts. In urban areas, rooftop rainwater harvesting (RWH) will also contribute to reducing flooding and waterlogging. As experience and competence grow and regulatory and monitoring capability develop, MAR will follow an evolutionary pathway introducing a progressive portfolio of options including water reuse and surface water transfers, from gravity to pumped injection and horizontal wells and trenches, with increased water quality protection and reduced flooding. Such a Strategy will provide a resilient, no eggs-in-one-basket, solution with investments spread over time and decentralised, and most of the cost of production (well pumping from sustainable groundwater sources) transferred to water users, internalising costs and incentivising efficient use of water.

The MAR Strategy envisages a collaborative public - private sector and civil society programme. Not only will many ministries, and their departments, play crucial roles through public investment projects, so will industries and commercial and private building owners through implementation of measures in the new Bangladesh National Building Code (BNBC). The impact of the Strategy will be seen first on water levels, establishing a healthier hydrological balance by reducing both depletion and waterlogging, and second in increasing the availability of safe, fresh water. These benefits will be experienced through increased access to reliable and safe drinking, industrial and irrigation water supplies, reduced pumping costs, increased agricultural productivity, and greater resilience to droughts, floods and cyclones. The measures in the MAR Strategy will have minimal or even positive environmental impacts, including on Climate Change, and will be guaranteed through appropriate EIA measures.

In Dhaka City, DWASA will implement medium- and large-scale recharge projects while local government institutions (LGIs) will facilitate thousands of rooftop-recharge systems by implementation of the BNBC requirements at new buildings and offering incentives for retro-fitting such systems at existing buildings. In the dynamic industrial area of Gazipur, in addition to LGI's implementing the BNBC provisions, industry associations industry-leading companies will be proactive in protecting their own commercial welfare by implementing and promoting MAR systems, as part of a package of IWRM interventions, at existing factories.

In the coastal area, Ministry of Local Government, Rural Development & Cooperative (MLGRD&C) institutions will collect freshwater from roofs, ponds and channels during the monsoon, subjected to simple treatment, and injected into saline aquifers from where it can be abstracted as a source of high-quality drinking water through the year. On the Barind Tract, rooftop-recharge will play a part along with check-dams and possibly surface water imports that will likely form part of a package of IWRM interventions in order to balance the abstractions that underpin the regions rich agricultural base. In the Chittagong Hill Tracts, MAR will focus on two areas, first educating local authorities and departments to avoid unintended damage to springsheds through activities like road -cutting and deforestation, and second positive measures to increase natural recharge.

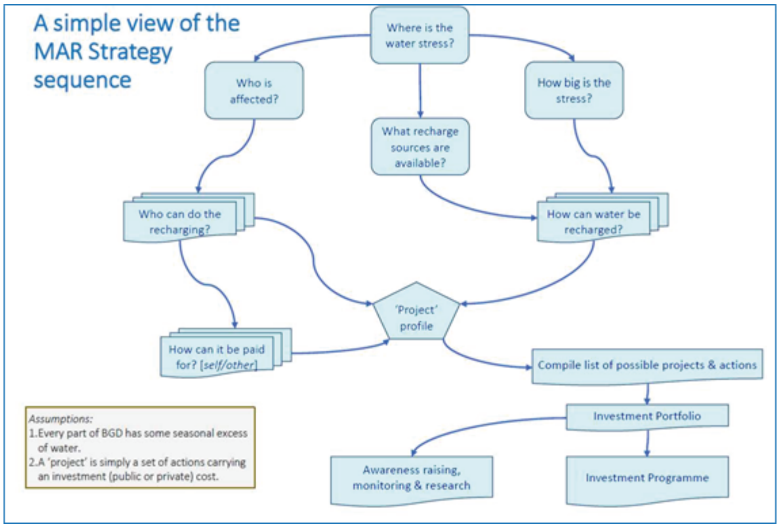
This Strategy is ambitious and will require extensive awareness raising and creating enhanced regulatory and monitoring systems. Leading, monitoring and co-ordinating these activities will be major challenge, to be led by the Ministry of Water Resources and involving the creation of a semi-autonomous National MAR Centre which will also serve as a centre of applied research and performance evaluation.

2.2 Objectives of the MAR Strategy

MAR is mentioned in various laws and policies, and this document provides a strategic framework for its implementation. In the context of reducing water scarcity and increasing water security, the specific objectives of the national MAR Strategy are as follows:

- Explain how MAR can contribute to conserving water resources in Bangladesh, especially in areas of water scarcity resulting from excessive groundwater pumping and in areas naturally saline groundwater.

- Set out how public and private institutions and resources can be mobilised to achieve security of water supplies in stressed areas.
- Describe the institutional framework required to plan, finance, authorise, build, operate and monitor MAR systems.
- Explain the constraints and risks associated with MAR implementation and how they will be managed and overcome.

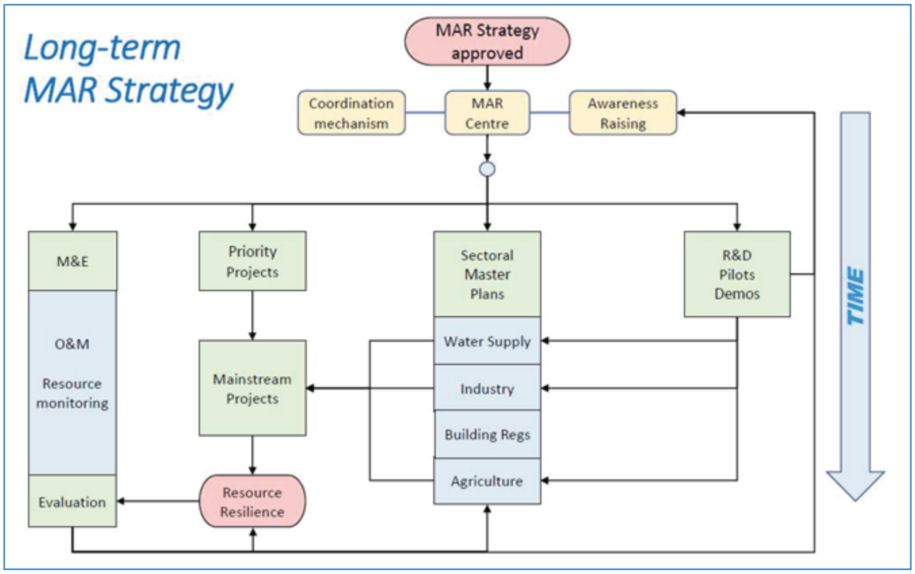


2.3 Timeframe

Short Term (1-2 years). Undertake awareness raising, detailed planning, and create the necessary legal and regulatory institutional mechanisms and financing required for full-scale MAR implementation, including the preparation of sectoral master plans. In parallel, priority projects based on existing successful pilots will be upscaled, and the MARAS (Managed Aquifer Recharge for Artificial Storage) project identified in the BDP-2100 Investment Plan will be brought on line. In addition, a MAR centre will be established to guide, support and evaluate implementation of the MAR Strategy.

Medium Term (3-5 years). Significant and quantifiable impacts on water scarcity will be realised through implementation of major public investment projects, schemes implemented by private industries, and supporting operationalisation the relevant parts of the BNBC. In both the short and medium term, MAR systems will rely primarily on technologies already proven in country. Dedicated units will be formed for operation and maintenance (O&M), and the results of operations shared freely with the scientific community and the general public.

Long Term (>5 years). Rooftop rainwater collection and recharge under the BNBC will become routine and automatic. The impact of the short- and medium-term phases will be evaluated in the context of other parallel IWRM interventions, to guide further public and private investments and, as appropriate, advanced techniques introduced where scarcity persists. Major emphasis will be given to monitoring impacts and the sustainability of O&M activities. At this stage, the Strategy will be updated as appropriate based on experience.



2.4 Guiding Principles

Awareness. MAR is relatively new technique in Bangladesh and so it is vital to communicate with large parts of society on what it can and cannot do, how it may affect people, and to deliver this information in appropriate formats for different stakeholders. This will be at the outset and updated periodically as the Strategy is implemented.

Policy Alignment. The MAR Strategy is closely aligned with existing water sector laws, policies, strategies and plans. As a part of the IWRM toolkit, it forms part of implementing the Bangladesh Water Act (BWA-2013) under its 2018 Rules (BWR-2018). Moreover, MAR is explicitly included in the National Environment Policy (NEP), the Bangladesh National Building Code (BNBC), the Draft Industrial Water Policy and the Bangladesh Delta Plan 2100.

Integrated Approach. MAR is one of the multiple toolkits with the IWRM framework for addressing water scarcity and security, and will be implemented in a coordinated manner considering the concerns of the relevant sectors and in consultation with regional stakeholder platforms. The approach will be expressed through the principle of Sustainable Groundwater Management with the aim of ending excessive abstraction. Implementation of the MAR Strategy will be integrated with implementation of the BWA, 2013, BWR-2018 and BDP-2100.

Planning. Detailed planning will be undertaken at the outset, elaborating:

- Hydrogeological water-stress typologies and their matching these to proven and potential MAR technologies (Table 2.1).
- Identifying the institutions which will undertake the roles of approving, building, operating and monitoring under each typology. For each institution, evaluate the staffing and/or training required.
- Preparation of master plans for individual ministries or sectors: Water Resources, Agriculture, Local Government, Housing, and Industry.

In the short term there will be immediate implementation of the following:

- Creation of a MAR Centre
- Public awareness campaigns.21 | P a g e
- Priority projects expanding successful pilots (Dhaka, Barind Tract and coastal area)

Table 2-1 Summary of Water Stress Typologies

Typology	Geographical Areas
Urban – falling water table: municipal	Dhaka
Urban – falling water table: industrial	Gazipur
Saline – coastal: shallow aquifer	Khulna, Barisal and Chittagong divisions
Saline – coastal: deep aquifer	As above
Unsustainable deep irrigation pumping	Barind and Madhupur Tracts
Shallow tubewell irrigation transition	Brahmaputra and Ganges floodplains
Riverbank filtration	Site specific option in difficult areas.
Groundwater Dependent Ecosystems	Various Arsenic & iron affected areas
South Central & North Eastern	Bangladesh
Springsheds in Hill Tracts	Chittagong Hill Tracts
Waterlogging reduction	Various

Prioritisation: The MAR Strategy will focus on water stress and problem solving. The Strategy will not roll-out MAR systems in all areas simultaneously. Rather it will concentrate activity where water stress, and its impact on people and the economy is most severe. The planning activities will zone the country not only according to the hydrogeological nature of the stress but also the social, health and economic impact into categories of stressed, emerging-stress and low-stress. This threefold classification will parallel the short-, medium- and long-term aspects of the Strategy to ensure that investments are most effective, and unnecessary works and regulation are avoided.

Priority Projects: Some MAR systems have been successfully piloted while others require further development or demonstration. The successful pilots in Dhaka City, the coastal area and the High Barind will be immediately expanded. In addition, Ministry of Water Resources' (MOWR) recommended the Managed Aquifer Recharge for Artificial Storage (MARAS) Project in the BDP-2100 Investment Plan will be given special priority. This project is closely aligned with the MAR Strategy and will provide a vehicle for the planning activities, demonstration and piloting, and resource monitoring systems.

MAR Centre: Because it is new and cuts across so many sectors, MAR will require strong technical and motivational leadership. Therefore, the Strategy includes the creation of semi-autonomous MAR Centre to deliver the technical, managerial and information skills to educate, motivate, coordinate, guide and evaluate the public and private sectors and the population at large. The MAR Centre will initially be created under a project pending deciding on a permanent constitution.

Technical Efficiency: To ensure the effectiveness of new MAR systems, technical guidelines will be prepared, disseminated and supported through extensive training and online support, applied research and evaluations. To facilitate implementation of the large numbers of small systems, standard designs, including monitoring and maintenance features, will be prepared and supported.

Permitting and Environmental Protection: Safeguarding drinking water sources and the environment is central to the Strategy. In the medium to long term, new primary legislation will probably be required but for the initiation of the Strategy, the BNBC, BWR-2018 and NEP (and IWP when approved) should provide the necessary protection, albeit with some additional or amended regulations and Codes of Practice.

Implementation of the rules will occur in four stages:

(i) Ensuring the MAR is included in building plans and project proformas where appropriate.
(ii) Approval of designs, including environmental safeguarding.
(iii) Inspection of construction to ensure conformity with plans.
(iv) Inspection of operations.

The approval processes will be tiered and proportionate so that small, simple and inherently safe systems can follow standard designs and are subject to quick and easy approval but larger and more complex systems are subject to more rigorous scrutiny. Responsibility for approval and inspection will vary between regions as detailed in the sectoral master plans.

Special attention will be given to promoting aquifer and drinking water source protection which will include, but not be limited to, MAR systems.

Private Sector and Civil Society: Notwithstanding the leading role of the public sector, the willing and active participation of the private sector, firstly industry through factories in Dhaka – Gazipur, whose commercial sustainability is threatened, and industrial parks; and secondly civil society and housing sector in their commitment to implementing rooftop recharge under the BNBC. Major effort will be given to engaging with and responding to the concerns of, the private sector, not only as implementors but also as beneficiaries.

Industry: As Bangladesh transitions from a rural-agricultural to a dominantly urban-industrial society, it follows that industry should take its place as a partner in shaping and implementing water and wastewater policy and practice. Unlike agriculture, industrial abstractions are geographically concentrated and occur throughout the year, leading to hot-spots of water table depletion. Under the Strategy, industry and government will work together in implementing MAR and other water conservation measures.

Operation and Maintenance (O&M): This issue is considered fundamental to sustainability of MAR operations. There is an unfortunate history of poor O&M in broadly equivalent activities (e.g. the maintenance of rural water supplies, irrigation distribution systems and agricultural embankments). The analysis to date has identified the absence of dedicated O&M units as a key explanatory factor in past failures, and the MAR Strategy will give special attention to learning from those experiences to ensure that the impact of MAR is not a chimera.

Finance and Incentivisation: The Strategy calls for both public and private investment depending on the regional circumstances, as will be elaborated in the sectoral master plans. In most cases, MAR is a Public Good where recharge by one actor accrues benefits to multiple other water users in the form of improved water availability and reduced pumping cost. MAR investments will occur first by large purposive publicly-owned MAR schemes in critical areas, and second privately through the application of planning systems, such as the BNBC, that require inclusion of MAR in designated areas. The latter would capture all new public and commercial buildings and larger private housing. To expedite MAR implementation, these planning criteria would be accompanied by flexible, time-varying subsidies or rebates. Because of the huge areas of flat roofs in water-stressed municipalities, such as Dhaka and Gazipur, it will be appropriate to offer special subsidies and rebates for retrofitting MAR at existing buildings, and justified economically as payment for environmental services.

Monitoring: Monitoring, and associated evaluation and feedback, has two dimensions: (i) monitoring of operations to measure how much water enters the ground; and (ii) monitoring of the impact of recharge on the quality and availability of groundwater resources. Information on MAR schemes will be automatically added or linked to the National Water Resources Database (NWRD) and to a public register on a national MAR Portal where all can see which agencies, buildings and industries have, and implicitly have not, implemented and continue to operate MAR systems.

Applied Research: Although MAR is not a new set of tools, every country has a unique combination of hydrogeological and institutional conditions and require adaption to local circumstances and creates opportunities for innovation. The Strategy calls for research on (i) the technical and socio-economic aspects of MAR technologies; (ii) the sustainability of the groundwater resources being recharged; and (iii) the integration of MAR with other IWRM techniques.

2.5 Framework of the Strategy

The heart of the Strategy comprises the seven themes listed above; these are expanded below to indicate the principal responsibilities and actions before being detailed in the following chapters.

Theme 1. Knowledge and Awareness Raising

Immediately following its creation, the MAR Centre will develop a package of awareness raising activities covering the general public, relevant ministries and departments for which water is not a central activity, and private organisations that will be affected by the BNBC regulations such as industries, consulting organisations, and housing developers and contractors. Subsequently, each ministry or sector developing a MAR master plan will include an awareness and education component. Later, the MAR Centre and MOWR will develop information programmes showing how MAR is impacting on water stress.

Theme 2. Legislation and Regulation

Much of the required legislation and guidelines can be derived from existing legislation and policies such as the BNBC and the Bangladesh Water Act. In the longer run, additional primary legislation will be required in the areas of water resources protection and drinking water management, there is sufficient legislation in place to commence implementation if additional regulations are prepared. For instance, a Code of Practice for MAR schemes may be prepared to complement the BWR 2018.

Theme 3. Planning and Design

The launch of the Strategy will be accompanied by detailed planning exercises:

- MOWR agencies will lead water resource planning to delineate the exact areas where MAR is appropriate and the suitable technologies, standard designs, monitoring needs, and regulatory tools. MOWR will also process the BDP-recommended MARAS project on a priority basis.
- HBRI, PWD and MLGRD&C will collaborate to develop the tools and procedures, and institutional needs for putting the BNBC rooftop-recharge measures into practice.
- The MAR Centre will concentrate on high-level coordination, awareness-raising and information sharing.
- MLGRD&C (led by DPHE and WASA's), MOA (led by BMDA and BADC), and the Ministry of Industry in combination with industry associations will each prepare sectoral master plans.

These planning processes will initially focus on defining geographical target areas and technologies, and then the quantitative aspects of the supply and demand for artificial recharge.

Theme 4. Implementation and Financing

Both implementation and investment will be conducted through both the public and private sectors, and these will be of two types: first purposive MAR schemes and second MAR components required to be included in other schemes as conditions of planning under the BNBC. The latter will require the House Building Research Institute (HBRI) to become active in the water sector. As elaborated in alter chapters, several construction and financing scenarios are envisaged:

- **Municipalities:** WASA's or City Corporations will undertake direct investments in MAR technology through the normal project approval process, which includes environmental and water clearance examinations by DOE and WARPO. Where groundwater levels have been classified as declining at excessive rates by MOWR, the local planning authority will apply the BNBC criteria to require rooftop-recharge at new buildings exceeding the threshold size. Developers will be responsible for financing construction costs but may qualify for subsidies or rebates according to local rules. The concerned WASA or City Corporation will be responsible to ensure the operation O&M units to undertake periodic flushing or recharge wells.

- **Coastal regions:** The assumption here that freshwater can be stored in saline aquifers for rural or peri-urban water supply. DPHE or LGI's will be responsible for contracting the design and construction, which includes the initial establishment of the freshwater lens, and will also be responsible to create locally appropriate mechanisms for operating and monitoring ongoing recharge, either with their own staff or under contract. LGI's shall establish community-based user groups to regulate the safe extraction of water from the lens.

- **Hill Tracts:** The challenge of protecting and enhancing recharge of springsheds that support drinking water, irrigation and environmental needs shall rest with the Civil Administration and LGIs with support from DPHE who may engage specialised NGOs or companies for springshed mapping and catchment management and spring protection interventions. Financing will be provided through the normal public mechanisms. The essential role of the Civil Administration is to ensure coordination of departments and private developers and prevent unintended cutting or pollution of vital springshed flows such as by road construction.

- **Agriculture:** In the priority Barind Tract area, a different mix of interventions will be required. Rooftop-recharge will be implemented through LGIs and commercial establishments, however, this alone is unlikely to be sufficient to balance the current declining trends in water levels. Additional MAR interventions such as check dams, ponds with recharge structures, and other forms of surface water diversion or retention will be needed. Constructing and maintaining these interventions will be conducted by the BMDA along with other IWRM interventions, which will evolve into an integrated land and water resource management organisation.

- **Environmental protection:** Over and above the safeguarding of drinking water sources, the requirement for MAR systems to maintain environmental flows or water levels at designated sites shall be determined by DOE with support from WARPO/BWDB and the Civil Administration.

- **Industrial parks:** will be required to implement MAR in designated areas through its inclusion as a consideration in the Green Economic Zones (GREZ) Guidelines. Theme 5. Operation, Maintenance and Water Governance Effective O&M is central to the Strategy and essential to sustain MAR operations. This will be achieved through two complementary actions:

Theme 5. Operation, Maintenance and Water Governance
Effective O&M is central to the Strategy and essential to sustain MAR operations. This will be achieved through two complementary actions:

- Create dedicated O&M units in line departments and local government, conducted by internal staff and/or contracted services.
- Open online access to operational monitoring data through the national MAR Portal will act as a form of self-regulation.

For smaller systems, local government or utilities such as WASA's will operate routine maintenance systems for household systems.

BWA-2103 and its 2018 Rules, the SDG's and the principles of adaptive management in BDP-2100, provide a framework for water resources management, with WARPO as the lead agency, built on the following principles:

- MAR will contribute to the sustainable use of groundwater.
- The system of (water) project clearance defined in BWA-2013, and implemented by WARPO, will ensure the safe and efficient operation of major MAR systems.
- In the context of MAR, the BNBC will become a core component of water resources management.
- Improved monitoring and transparent public reporting is crucial to better resource management.

Theme 6. Monitoring and Evaluation

Monitoring of operations to measure how much water enters the ground will be conducted by the operator according to a plan agreed with the designated approving authority. WARPO shall appoint Inspectors to conduct randomised spot checks and investigate reported irregularities.

Monitoring of the impact of recharge on the quality and availability of groundwater resources will be conducted principally by BWDB but also by operators as specified in the project / scheme approval. Relevant departments of Dhaka University (DU) and Bangladesh University of Engineering and Technology (BUET) as well as relevant departments of regional public universities can be involved, wherever appropriate, to support and assess the monitoring and evaluation processes.

Information on operational and resource monitoring of MAR schemes will be automatically added to the National Water Resources Database (NWRD) and a public register on a national MAR Portal.

Theme 7. Research and Development

Research will be required on many topics but notably:

(i) The technical and socio-economic aspects of MAR technologies will be mainly conducted by line departments (BWDB, DPHE and BMDA) in combination with universities;

(ii) Sustainability of the groundwater resources being recharged will be mainly conducted by national and international universities, national institutes like IWRM, and consultancies working with departments (WARPO, BWDB and BMDA).

(iii) The integration of MAR with other IWRM techniques is likely to be conduct by national and international universities and research institutes.

Chapter 3: Aquifers, Groundwater Use and MAR Typologies

3.1 Aquifer Systems of Bangladesh

Bangladesh is blessed with abundant resources of groundwater. The exploited aquifers of Bangladesh are classified into three groups related to the overlying landforms: (i) recent alluvial and deltaic floodplains; (ii) older alluvial terraces known as the Madhupur and Barind Tracts; and (iii) folded and faulted sedimentary rocks forming the Chittagong Hill Tracts (CHT) and border areas of Sylhet. The first two groups are formed of alluvial-deltaic sand, silt and clay; they are highly productive and many hundreds of metres thick, and are the most important sources of drinking, irrigation and industrial water. Those beneath the terraces, such as the Dupi Tila aquifer beneath Dhaka City, contain excellent quality water, however, aquifers beneath the floodplains, which are also the most important, are locally affected by natural water quality issues such as iron, manganese and arsenic, and salinity near the coast. The sandstone aquifers of the hill tracts are less productive but contain good quality water and are vital for supporting drinking water supplies.

In the context of MAR, it is important to think of aquifers as reservoirs in two ways: one as the volume of annually renewable recharge, and the other as the total volume stored in the aquifer. In an aquifer system like Bangladesh's, the volume of this deep storage is many times bigger than the annual volume of recharge, a vast strategic reserve that can be tapped periodically as a buffer to guard against fluctuations in river flow and annual rainfall. Surface water, annually renewable recharge and the strategic groundwater reserve are complementary resources to be used conjunctively.

A common myth that has to be overcome in order to understand the potential of MAR is that the volume annually renewable recharge is a fixed property of an aquifer. Under pre-development conditions, aquifers often cannot receive recharge during the monsoon because they are already saturated. As the water table is lowered by development, the aquifers are able to absorb more recharge even without any human intervention, and with artificial recharge (i.e. MAR) this can be increased further. Thus, to calculate the amount of water available for development, and for sustaining the environment, groundwater and surface water must be counted as variable components of a total, or integrated, water resource.

3.2 Groundwater Abstraction, Water Stress and Climate Change

3.2.1 Abstraction and Over-abstraction

Bangladesh depends heavily on groundwater for drinking, agricultural and industrial uses, especially during the dry season when demand is highest. The country ranks sixth in the global list of most groundwater extracting countries, where about 97% people in urban and rural areas use it for drinking and 75% of current irrigation coverage (compared to 43% of globally) comes from the aquifers. Industries also depend heavily on groundwater and their abstractions are increasing rapidly. The public health and economic benefits of using groundwater are remarkable but overexploitation, natural and anthropogenic contamination, and poor management make this vital resource more and more vulnerable to depletion and degradation every year. Groundwater is abstracted in almost all areas of the country with notable hotspots at Dhaka City, Gazipur City and the Barind Tract (Figure 3.1). Water demand is expected to grow in all sectors in the coming years and groundwater will remain the major source of supply. The term overexploitation lacks a precise quantitative definition, however, there is a consensus that these three hotspots constitute overexploitation and require corrective action and active management to protect public health and economic activity.

The term unsustainable abstraction refers where abstraction exceeds the local recharge capacity, leading to a year-on-year decline in the water table. The two terms are not synonymous. Overexploitation will not necessarily be unsustainable abstraction but may refer only to a condition where a technological (e.g. suction limits) or financial (e.g. pumping cost) thresholds that are judged to be socio-economically unacceptable.

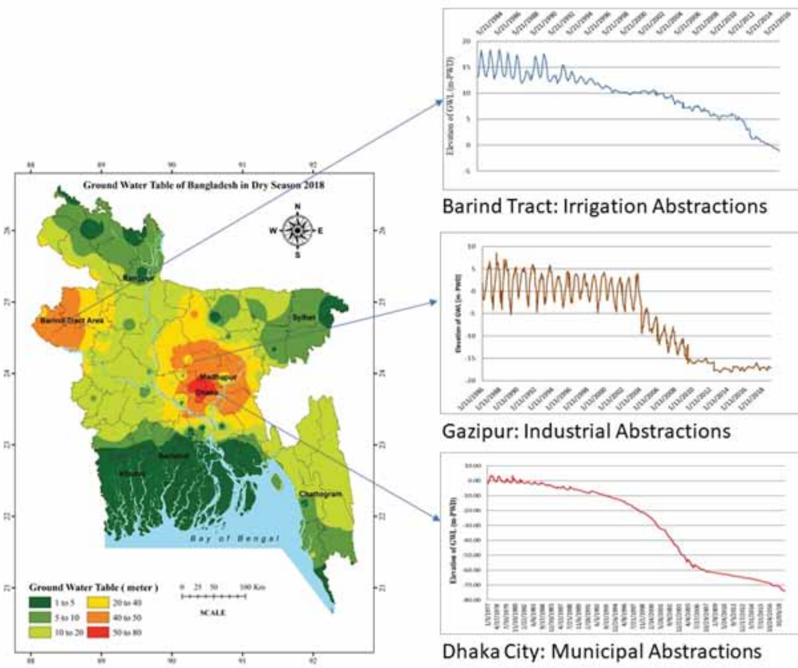


Figure 3.1: Hot spots of groundwater overexploitaion from municipal, industrial and irrigation water abstraction (Source: Ground Water Circle of BWDB).

3.2.2 Groundwater Stress

In recent decades, the description of stresses on water resources in general, and 'groundwater stress' in particular, have largely replaced the outdated concept of Safe Yield. That concept is not only theoretically flawed but fails to capture the diverse quantitative and qualitative threats to water resources in the twenty first century (Figs 3.2 and 3.3). Quantitative stresses comprise two types of threshold. The first is technological, where Nr 6 hand-pumps or irrigation STWs run dry for part of the year but the water table is fully recharged during the monsoon. These have socio-economic impacts that may be managed by either controlling the resource or compensating users. The second is the resource impact when even the monsoonal water levels fall year on year, or at least until a new equilibrium is attained1, leading to progressive abandonment of abstraction wells. This is occurring in

[1] This new equilibrium occurs when the growing cone of depression is balanced by leakage from canals or rivers, and is referred to as 'capture' in the academic literature on the 'water budget myth'. This new equilibrium may well not be optimum.

the Dhaka, Gazipur and Barind hotspots. Qualitative stresses arise from either natural (geogenic) contamination by arsenic, iron, manganese and salinity, or from anthropogenic pollution such petroleum, industrial chemicals, pharmaceuticals pesticides and fertiliser. A special case of stress is saline intrusion where pumping near the coast causes the inland migration of seawater; this has not yet been observed in Bangladesh but remains a significant risk.

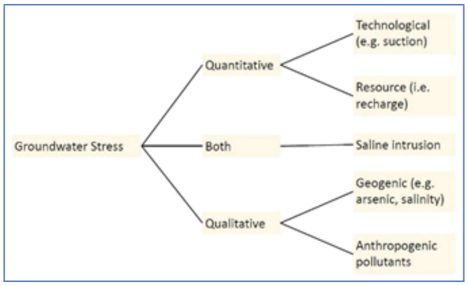
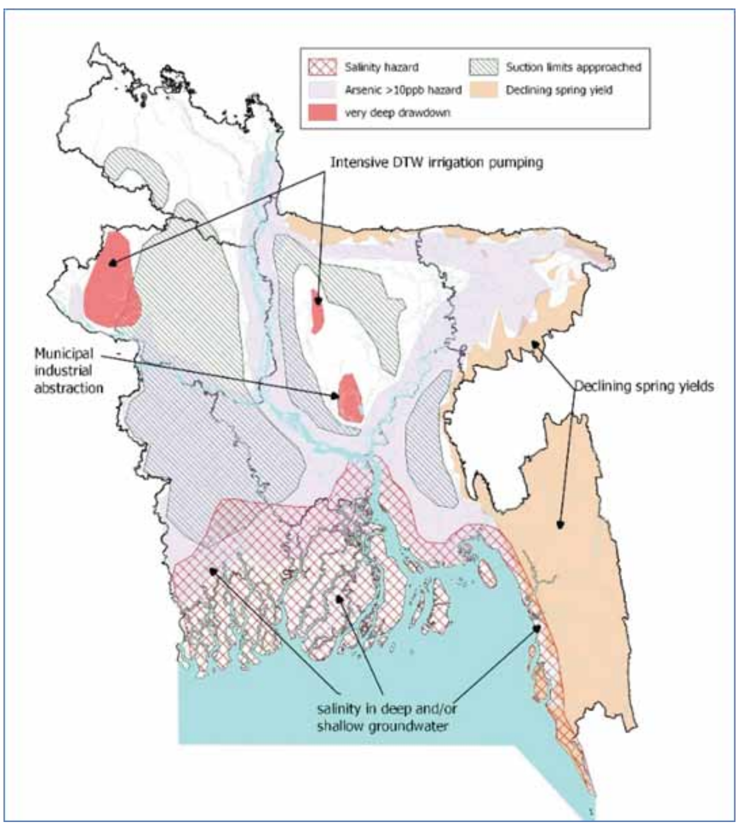


Figure 3.2 Classification of Groundwater Stress

As illustrated by the Adaptive Delta Management concept in BDP-2100, the framework and metrics of water resources assessment are evolving. In the context of MAR, and IWRM generally, targets such as the European Water Framework objectives of achieving good quantitative and qualitative status in surface and groundwater management units by specified dates are appealing, and more clearly relate to the needs of water users. Rather than simply applying abstraction limits that are difficult to enforce, agencies are required to implement a plan and a combination of supply and demand measures such that, for example, groundwater levels fluctuate within a certain range or certain percentage of wells conform to potable standards. In this framework, all stakeholders can be involved; permitting or licensing is combined with demand-management measures such as metering, pricing and crop diversification, and supply-side measures such as MAR.



3.2.3 MAR and Climate Change

Bangladesh is one of the most vulnerable countries in the world to Climate Change. The diverse implications of Climate Change are addressed in the over-arching 2009 Bangladesh Climate Change Strategy. A general characteristic of climate change impacts is an increase in the frequency of extreme climatic events such as drought, flooding and storm surge inundation. MAR is ideally suited as an adaptive management technique to provide resilience in the face of such events by creating strategic buffers against shortages in transient surface water availability or inter-annual variations in recharge, storing safe water during cyclones, and absorbing floodwaters.

3.3 MAR Typologies

The following sub-sections outline a series of scenarios (Table 3.1) that combine specific hydrogeological situations that experience water shortages with the potential aquifer recharge mechanisms that could be applied in that area.

Table 3-1 Summary of MAR Typologies and Priorities

First Priority	Second Priority
Urban – municipal, falling water table; e.g. Dhaka City	Shallow tubewell irrigation transition areas; e.g. Brahmaputra and Ganges floodplains
Urban – industrial, falling water table; e.g. Gazipur City	Deep coastal aquifers with little or no recharge; e.g. Khulna, Barisal and Noakhali
Deep tubewell irrigation with unsustainable pumping; e.g. Barind Tract	Springshed management in the Chittagong Hill Tracts
Saline shallow aquifers in SW coastal area, e.g. Khulna Division	Arsenic & iron affected areas; e.g. South, Central & North East Bangladesh
Riverbank filtration; a water supply option in difficult areas.	Waterlogged Agricultural Areas
	Maintaining Groundwater Dependent Ecosystems

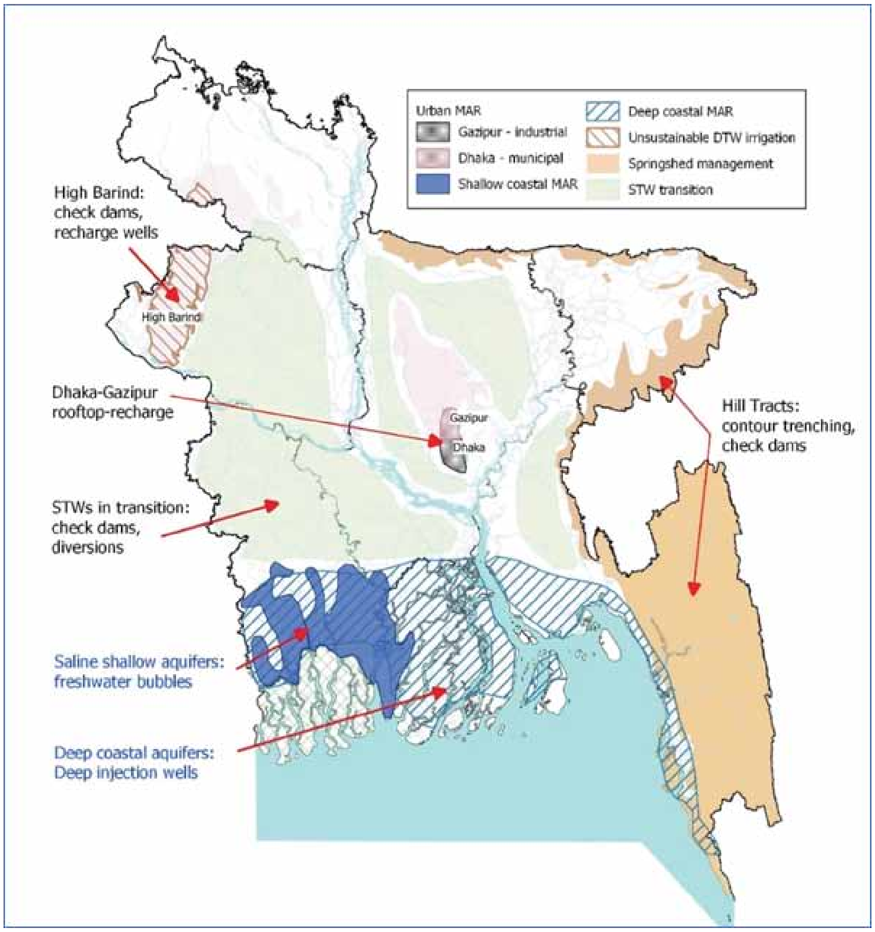


Figure 3.4 Priority Areas for MAR Intervention

3.4 First Priority Typologies

In the short to medium term, the highest priority will be given to the most acute water shortage problems, where locally proven technologies can be combined with inherently safe water sources such as rooftop-rainwater to achieve rapid reductions in water stress with the lowest risk.

3.4.1 Urban-Municipal Supplies – Building a Resilient Dhaka City

Dhaka has grown by exploiting the abundant and high-quality groundwater resources upon which it stands. Initially cheap and easy to develop, the ever-increasing demand for water has caused groundwater levels to decline continuously fall, for shallow wells to be abandoned, for new wells to be drilled to ever deeper levels, and for large surface water treatment plants to be added to the mix. Groundwater levels have fallen to more than 50 metres beneath parts of the city and a compound cone of depression extends for many kilometres beyond the city. On the other hand, the aquifers extend to depths of at least 350 metres and still contain a vast store of freshwater that can provide a significant component of municipal supply and a strategic reserve for the foreseeable future. Two stories of water in Dhaka alternate in the Press - the falling water table and flooding - and beg for a complementary solution. The ‘depleted’ upper aquifer should be viewed as a resource, a huge reservoir that can absorb part of the unwanted monsoonal rainfall and reduce, if not reverse, the decline of the water table. Increased flooding in the city has been driven by the conversion of natural (permeable) ground to hard surfaces. Paved surfaces, rooftops and the thin but low permeablity

Madhupur Clay that covers most of the city inhibits infiltration. However, rooftop water is inherently pure and well suited to discharging into the upper aquifer through wells or trenches that bypass the surface clay. Dhaka WASA and others have already piloted a dozen rooftop-recharge schemes. Other technologies have been proposed but have yet to be piloted. Urban areas, where industries use toxic chemicals, have potential for unintended or unmanaged aquifer recharge, with often unknown risks to groundwater. These activities are no part of MAR which can only refer to a managed process. These under-recognised and unmanaged risks include leakage of sewage from holding tanks (often incorrectly referred to as septic tanks), sewers and drains. The greatest unmanaged risks, however, come from abandoned wells that have not been properly closed and are accidentally or deliberately used to dispose of liquid waste directly to the aquifer, bypassing the protective layers of the unsaturated sand and clay. Other, less stressed, cities and towns may follow Dhaka in developing MAR programmes focusing on rooftop recharge. In Dhaka and Gazipur (below) the rapid decline in water levels is due to a combination of increasing abstraction and changes in land-use that cover soil with impermeable hard surfaces that recharge natural recharge and exacerbate flooding. In other less developed cities, it will be possible to construct more permeable hard surfaces and other Green Infrastructure that maintain, or even enhance, the natural rates of recharge.

3.4.2 Urban-Industrial Supplies – Sustaining Economic Growth in Gazipur

Hydrogeologically, conditions in Gazipur and its surroundings are similar to Dhaka except that the surface clay is thicker, making natural infiltration more difficult, and there are no major rivers flow through it. Gazipur City also differs in that it is dominated by privately-installed abstractions for the garments industry, its workers and their dependents that has led to rapidly declining groundwater levels that create conflict and concern among industrial water users. The lack of control of toxic chemicals and the absence of wellhead protection schemes adds pollution to the risks of sustained industrial and domestic water supply. Also, there is no equivalent to DWASA to provide potable water coverage or have the regulatory power to control abstraction. To sustain the present industries and support future growth, there is an urgent need to improve the efficiency of industrial water use, improve drinking water coverage, reduce pollution risks, and most relevantly, increase recharge to the aquifer. Recharging rainfall from the flat roofs of the several thousand factories offers great potential for increasing water availability, and wherein the industries themselves, with appropriate incentives and regulations, can play a leading in protecting their own water supplies and the welfare their employees and dependents.

3.4.3 Shallow Saline Aquifers in the Southwest Coastal Zone

The southwest coastal area is problematic for water supply because shallow aquifers are extensively saline and also affected by arsenic and iron. Where available, rural households try to access deep wells but where this is not possible, they utilise rainwater, ponds and pond sand-filters. Unfortunately, these alternatives provide poor sources of supply, frequently contaminated by pathogens, especially during the dry season when women and children walk long distances to access fresh water, and are also vulnerable to inundation by cyclonic storm surges. Where both shallow and deep aquifers are saline, all solutions are expensive and technically and institutionally challenging, but MAR, in the form of creating 'freshwater bubbles' is one of the most promising solutions.

Shallow saline groundwater generally results from a combination of water left from the time the sediments were deposited and from flooding by storm surges. On a geological timescale, these aquifers will become fresh but that will take too long to be useful to the present generation. This natural process can be speeded up (i.e. 'working with, not against, nature') by injecting fresh water through recharge wells and stored in a self-cleansing reservoir (the aquifer) to be withdrawn through standard tubewells as and when needed around the year. The difference, of course, is that the amount of water that can be withdrawn is fundamentally limited by what is put in. Nevertheless, this need not be limited by an annual balance; if the accumulation of freshwater is increased in wet years, its withdrawal could be spread across dry years.

A hundred MAR pilots have been constructed, successfully in majority of cases, thus proving the concept and learning lessons regarding technical feasibility and the need for establishing dedicated units for operation and maintenance (O&M) and monitoring. The existing systems are small, serving a few hundred families at most and relying on treated pond water and rooftop-rainwater that is recharged under gravity. Based on this experience, there are several opportunities for up-scaling, including (i) using larger water sources such as river channels which can be treated cost-effectively at a central plant and piped to multiple villages, where (ii) freshwater may be injected under pressure, and (iii) simultaneously saline water may be pumped out to promote the growth of the freshwater lens. In this model, a public agency would be responsible for creating and maintaining a freshwater aquifer while communities can take charge of collecting and distributing the water.

In the long run, if the costs of injecting large volumes of excess monsoonal flows can be minimised, it may be possible to extend these techniques from providing

3.4.4 Rebalancing Unsustainable Irrigation on the Barind Tract

The Madhupur and Barind Tracts, and especially that northwestern part of the Barind Tract known as the High Barind, are underlain by thick clays that restrict natural recharge. The High Barind also records some of the lowest annual rainfall totals. Historically, the area suffered greatly from scarcity of drinking water and almost no water for dry season irrigation. Under such conditions, the ubiquitous irrigation shallow tubewell (STW) and the Nr 6 handpump do not work. However, following several decades of public investment in innovative irrigation deep tubewell (DTW) designs linked to piped drinking water, the region has been transformed into one of the most productive agricultural regions. With reliable access to irrigation water and a low-risk of flooding, triple cropping is becoming commonplace. However, the side-effects of this remarkable success are becoming a problem because continuing demand for irrigation water appears to exceed the sustainable yield, and locally rendering drinking water supplies inoperable. Monitoring of groundwater levels shows that the peaks and troughs of hydrographs are declining year on year, strongly suggesting that the present abstraction is not sustainable and will lead to increasing abandonment of wells. Unless a balance between abstraction and recharge is restored, these benefits will be undone.

A solution to the emerging crisis on the High Barind will require a combination of IWRM interventions, one of which will be MAR, which has already been successfully piloted in the area. The High Barind has always been a challenging area for water development and places constraints on MAR application, including higher runoff coefficients; and a thick, low permeability surface clay which natural and artificial recharge more difficult. The opportunities for MAR include rooftop-recharge, constructing check dams on the incised natural drainage channels, excavating or re-excavating ponds, and exploiting surface depressions. With the exception of rooftop-recharge, these surface water retention measures act in two ways: first, the stored water reduces the demand for groundwater and second increases the opportunity for infiltration. However, because of the low permeability of the Barind Clay, some will need to be connected to recharge wells. The High Barind is a complex area that requires active resource management of the based on a deep understanding of the hydrogeology and intensive near-real time monitoring, not only to ensure investments in MAR are effective but for all IWRM interventions.

A critical difference between this typology and the STW typology described below is that, where abstraction exceeds the local natural recharge rate, groundwater levels have fallen below their historical monsoonal levels and so there is always storage space to receive additional recharge. The High Barind will serve as a model for other areas following similar development trajectories.

3.4.5 Riverbank Filtration

River Bank Filtration (RBF) is a proven technique in Europe for over a century, which has been piloted at Chapai Nawabganj and applied along the Ganges in India2. Unplanned and unmanaged RBF has operated for more than fifty years along the Buriganga at Dhaka, reducing the drawdown of the water table near the river and demonstrating how flow through aquifers improves water quality. The appeal of RBF is that it offers a solution where both rivers and shallow groundwater are present but both are difficult to develop for various reasons such as surface pollution, seasonal variability or arsenic and iron in groundwater. The concept is to draw river water through the stream bed towards shallow wells or galleries, a process that uses the river bed like a slow-sand filter and also avoiding geogenic contamination in the native groundwater. By drawing river water into the ground during the wet season, RBF reduces the quantitative stress on adjoining areas of normal groundwater abstraction. The most promising areas for RBF are likely to be small to medium sized towns that are located on rivers that are difficult to exploit for direct use and where use of groundwater is also troublesome. At small scale, feasibility is likely to be highly site-specific rather than regional and needs to be assessed through detailed technical studies including long-term pumping tests. Other promising areas are deeply-flooded haor areas which have both challenging seasonal variations in surface water bodies and poor-quality groundwater with high iron or arsenic concentrations.

3.5 Second Priority Typologies

3.5.1 Shallow Tubewell in Transition- Maintaining Farmers Livelihoods

The irrigation shallow tubewell (STW), of which there are estimated to be more than 1.5 million operating, forms the backbone irrigated food production in the country. Their simplicity, low-cost and rapid return on investment has made them so popular and affordable to small farmers that government has been able to withdraw from this subsector and concentrate its investments in more difficult areas. Because of their affordability, STW irrigation has had massive impacts on both overall food production and reducing rural inequity. Although STWs do not work in all areas, they do work across most of the floodplains, in other words the majority of the country. In these areas, natural recharge potential is generally good, however, the critical issue is that STWs rely on suction pumps that cannot operate at water depths of more than about 7 metres below ground. At this point, pumping costs increase dramatically, and beyond this point, the pumps cease working. An interim solution is to place the pump in a pit, but as levels fall further, irrigators must switch to (force mode) DTW pumping, which is beyond the means of most STW farmers with government subsidy or large commercial loans. In either case, this means loss of control and financial losses for small farmers. Moreover, the standard Nr 6 hand pumps inside the adjoining village, and which are affordable to almost all households, also become inoperable and replacement with more complex pumps that are beyond the means of most households. In this scenario, the challenge for MAR, and other conservation measures, is to maintain the water table within suction limits during the period of critical demand for the boro crop during March and April. Most floodplain aquifers are fully recharged

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[2] http://gripp.iwmi.org/natural-infrastructure/water-quality-2/riverbank-filtration/

during the monsoon, and it has been shown that any ‘extra’ recharge during large floods drains away before there is demand for irrigation water. Though not confirmed in all areas, by early January groundwater levels are virtually the same level irrespective of the previous monsoon. This implies that the water table at the start of the boro season is controlled by the surface drainage network, which becomes the basis for designing MAR schemes. Increasing monsoonal recharge by methods such as rooftop-recharge will have little benefit because it provides infiltration at the wrong time of year. Increasing groundwater availability at the time of critical scarcity requires either (i) slowing the decline of the hydrograph during the period late October to February by retaining water in surface channels; and/or (ii) diverting upstream surface water from major channels into the local drainage network to prolong the period available for streambed infiltration. Although this typology might be considered a high priority, it cannot be implemented now because the technologies and practices have not been tested and proven. It is therefore a top priority for piloting and applied research.

3.5.2 Deep Coastal Aquifers

Throughout the coastal belt, deep aquifers, more than 500 feet (150m) deep, have become the preferred source of water for drinking and industry. These aquifers support high-yielding wells that produce water of excellent chemical and biological quality. Although they contain huge volumes of fresh water, there are concerns about the long-term sustainability of aquifers that were recharged during the Pleistocene Age and are now overlain by shallow saline aquifers. It is feared that prolonged pumping will draw in saline water or possibly even arsenic. This is most likely to occur in municipalities where abstraction is most intensive. MAR and conjunctive use techniques offer the potential to make the resource sustainable by injecting treated surface water during the monsoon and abstracting from these aquifers during the dry season when the rivers are intruded by salt water. Most coastal municipalities are sited on rivers that are increasingly subject to saline intrusion during the dry season but large excesses of freshwater during the monsoon. Thus, deep groundwater abstraction can be combined with surface water treatment for roughly half the year including producing water in excess of demand to recharge the aquifer through pumped injection wells.

To date, the recharge of deep aquifers has not been tested, but should be applicable to many coastal towns as the basis of a truly robust and climate resilient supply.

3.5.3 Chittagong Hill Tract Springsheds

Springs are important and traditional sources of water for drinking and sometimes agriculture in the Chittagong Hill Tracts and also play crucial roles in maintaining baseflow to streams and wetlands. These springs are poorly understood and much neglected by water professionals. Human actions frequently and unintentionally damage springsheds - the catchment areas of the springs - reducing flows and polluting water. Reduced spring flows, and consequent insecure water supplies, have been almost universally reported across the Himalayan and Indo-Burman ranges of India, Nepal and Bangladesh. This damage is attributed principally to changes in land-use and Climate Change.

In the Chittagong Hill Tracts, spring deterioration occurs due to (i) construction of roads and drains that intercept the catchment; and (ii) changes in land use, such as cutting forest, that modify the hydrograph increasing seasonality with reduced flows in the dry season.

Successful springshed management requires combining new applications of conventional science with community management, whereby recharge processes are actively managed and enhanced to protect, or even improve, spring yields. The MAR Strategy calls for:

- Inventory and database of springs, including baseline measurement of flow and water quality.
- Participatory mapping of springshed by scientists and local people.
- Community organisation around the springshed as a protected water zone within which LGIs would give informed consent to development.
- Monitoring, including citizen monitoring of flow, quality and water use.
- Interventions to restore, maintain or improve spring yields, such as:
    - Regulating new development;
    - Modifying or removing unauthorised developments;
    - Changing land-use such as afforestation.
    - Constructing protective headworks and flow monitoring structures.
    - Constructing contour trenching and check dams.
- Basic research on the functioning and management of springs, which requires both deep understanding of the geology of the hill tracts, learning new field techniques and participatory approaches. The Strategy will support creation of a multi-disciplinary Springs Research Group (SRG) that includes hydrologists, geologists, sociologists, ecologists and water engineers. The SRG should draw on regional-international experience.
- The research component should develop screening tools to identify where there could be an increased risk of landslides and soil erosion, and design mitigation measures such as retention walls to control this risk.

3.5.4 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDE) are highly diverse and not always recognised by groundwater users who affect them but many wetlands depend on springs, baseflow and diffuse seepages. In Bangladesh, GDE's are maintained less by focused groundwater flow than diffuse seepage. This will most likely occur in wetlands with adjacent topographic highs such as in the Chittagong Hill and Sylhet Tracts and the Madhupur and Barind Tracts that maintain flows or moisture in the lowlands. Various human activities can interfere with the hydrology of the GDE's such as land-use changes, road construction, drainage and irrigation pumping. While it is difficult to generalise where and how, MAR will be used to sustain endangered habitats but there will be springshed management described above, and what are also termed nature-based solutions. These could include reversing land-use changes, contour-trenching and compensation from deeper layers into the natural recharge zone.

3.5.5 Waterlogged Agricultural Areas

The potential for MAR to alleviate flooding and waterlogging in urbans areas is well recognised but its use in agricultural areas is relatively novel; this is because in many waterlogged areas, vertical drainage will not be an option because the underlying ground is fully saturated. The potential for draining waterlogged low-land (beels) using recharge wells was identified from a farmer-led initiative in Natore District. Here, multi-layered aquifers underlie basins that are waterlogged in the lower parts while other farmers are irrigating land on adjoining higher land. Without any external support, the Natore farmers installed their own wells (locally known as "house boring") to drain floodwater into the underlying aquifer where the groundwater levels had been lowered by nearby well pumping. Although concerns were raised about pollution risks from doing this without technical advice, and risks of clogging without using a sand filter, the concept and farmer-interest are proven and the technology could be improved with scientific support. The geographical applicability of this technique is unknown and requires investigation but will be a valuable addition to the toolkit for BADC, BMDA and other problem-focused agricultural organisations.

3.5.6 Arsenic and Iron-Affected Areas

MAR technologies may also find application for mitigating water supplies in areas where groundwater contains high concentrations of contaminants such as arsenic, iron and manganese. This may involve simple injection and injection through wells, or as a cyclical technique in-situ remediation that has been proven in parts of Europe but only proven for low concentrations of arsenic. The technique has huge potential but, in the case of arsenic, also carries significant health risk and so, for the time-being, this should only be taken up by competent academic organisations as an applied research activity in the short-term, and will require stricter regulation in the medium- and long-term.

3.6 Country-wide Demand Urgency Areas

Apart from the priority areas, there are other areas in the country where MAR programs can be implemented to mitigate further deterioration of groundwater resources. On those areas either the water table has already started to decline permanently with a minor rate or the demand is increasing significantly. Therefore, MAR can be a potential option for water resource augmentation in future. Under BDP 2100 initiative, BWDB and Deltares, the Netherlands (2019) prepared demand urgency map for the entire country (Figure 3.5) with context specific MAR technologies including infiltration well. To prepare this map both demand and physical i.e. hydro-geological parameters have been analysed. These maps can be considered as a primary guideline for the selection of MAR potential areas as well as context specific MAR technologies to formulate MAR programs/projects.

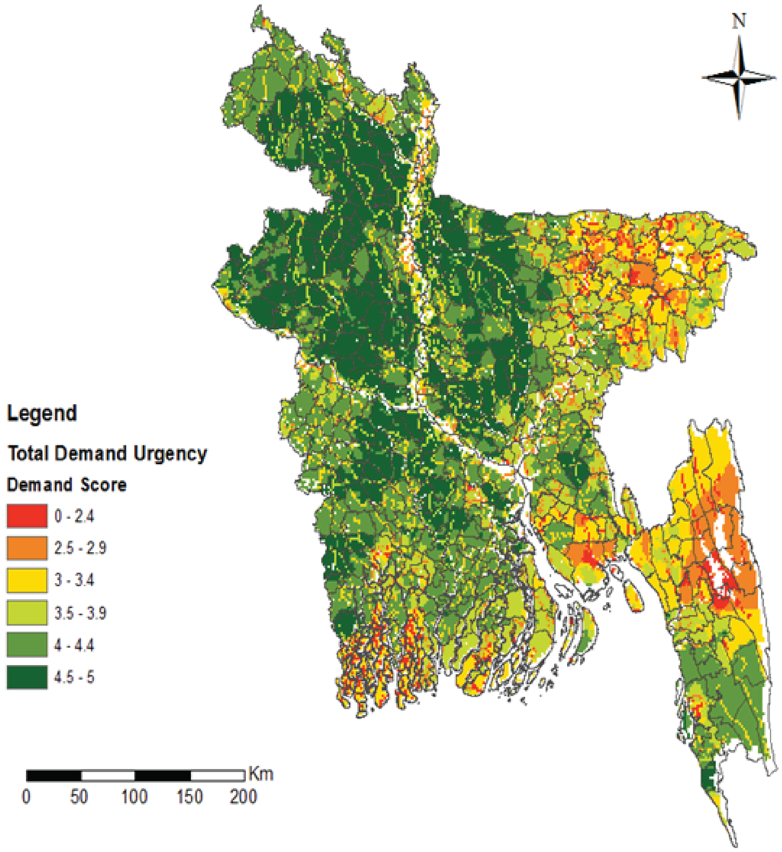

Figure 3.5: Map of MAR demand urgency in the country (BWDB & Deltares)

3.7 MAR Water Sources

Rain water. In the short- and medium-term, rainwater will be the predominant source of recharge water because of its inherent chemical purity. In urban areas, rainfall can acquire contaminants when it falls on dirty roofs at the start of the rainy period, and so the first flush of water is diverted to waste. The main constraint on relying on rainfall is obvious, that systems can only operate when it rains. Because of its negligible chemical content, rainwater can be somewhat chemically aggressive to metal pipes, concrete and sometimes aquifer sediment but, in Bangladesh, if the artificial recharge process follows roughly the same path as natural recharge there is little chance there will be a problem. Otherwise, rainwater is generally an excellent source water that requires very little treatment other than simple filtration through a sand tank to remove turbidity and then directed into the ground through recharge wells that require minimal space and periodic backwashing to maintain their yield.

Surface water. Surface water bodies are sources with potential for the largest capacity recharge schemes, however, for fears of unintended pollution, the Strategy emphasises caution during the short- and medium- term phases of the Strategy until more experience is gained and locally appropriate guidelines and protection measures are developed. Surface water requires more treatment than rainfall and is also subject to seasonal variability. Surface water bodies also vary in quality over time but, on the other hand, surface water bodies have water more or less continuously available for recharge throughout the monsoon and early to mid-dry season, creating the opportunity for high discharge injection during periods of high-water availability. The allocation of channel flow to MAR schemes must consider competing water uses and downstream needs through the IWRM Committee and Project Clearance processes

Treated Potable Water. Any surface water treatment plants (SWTP) that have seasonal excess production capacity of potable water are ideally suited for recharge by direct injection into aquifers to reduce existing stress or create a strategic reserve for use during times of SWTP breakdown or river pollution incidents. Currently, the capacity to do this does not exist but could in the foreseeable future. A few countries, such as Abu Dhabi and the USA (California), recharge excess production from desalination plants to create a strategic reserve for later recovery. Currently this is not relevant in Bangladesh but in the long term, it may be applicable in parts of the coastal area.

Treated Wastewater. An increasing number of countries practice water reuse by recharging fully treated wastewater to the ground. This requires high treatment efficiency and public confidence in the verification process through publicly available monitoring of treated water and groundwater. The Strategy rejects this practice in the short term; however, it might be done at industrial facilities but only when there is a proven capability to sustainably and efficiently operate and regulate wastewater treatment plants.

Chapter 4: The Themes and Strategic Actions

4.1 Knowledge and Awareness Raising Theme:

Objective: To create awareness and provide education/training on Managed Aquifer Recharge of groundwater.

Situation Assessment:

MAR is a century old groundwater management tool that has been applied around the world for range of applications. In Bangladesh, except for a few pilot projects, the concept of MAR is new to most of the water sector. Also, MAR has been mentioned in various plans and policy documents although it has not been officially adopted as a groundwater management tool. Despite the proven beneficial impacts of MAR in augmenting water quantity and improving quality, there is also apprehension about possible adverse impacts on water quality. Properly executed, MAR will avoid detrimental impacts but requires technical and regulatory environments and capacity building at many levels.

The MAR Strategy envisages implementation through both public and private sectors, involving many ministries and groups, and also gaining the confidence and support of the general public. Currently, most of these groups have very limited awareness of the scope and benefits of MAR and what would be their role in the Strategy.

Strategic Approach:
Activities under this theme will: (1) explain the MAR strategy to major stakeholders using or managing groundwater resources; (2) raise awareness about MAR to a diverse range of stakeholders; (3) educate relevant professional groups on MAR; and (4) accumulate MAR knowledge under a common platform. Projects and programmes will focus on the following:

1. Accessibility: Disseminating and familiarizing the MAR strategy to a wide range of groundwater stakeholders throughout the country.
2. Awareness: Raise awareness on MAR amongst the water resources planning and management agencies and linking this to other sectors such as water supply, irrigation, industry, environment and climate change mitigations.

3. Training and Educating: Train government officials and practising professionals on MAR applications.
4. Learning Centres: Establishing demonstration projects under various sectors at strategic locations to serve as learning centre as well as to fill knowledge gaps.
Because awareness underpins all the Themes of the Strategy, all the awareness raising activities listed below are considered to be Priority Level 1. Technical agencies will draw on private sector and civil society expertise in mass media, communications and behavioural change to implement these programmes.

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.1.0 Establish MAR Centre	MOWR (as host)	1	Short term
4.1.1 Systematic assessment of existing knowledge and awareness about MAR by documenting Good Practices	WARPO / BWDB / MAR Centre	1	Short term
4.1.2 Develop modules for Training of the Trainers (ToT), and prepare awareness raising and educational toolkits	WARPO/CEGIS/MAR Centre	1	Short term
4.1.3 Identify and assess knowledge institutions and practitioners; create National MAR Platform; and develop national MAR Web Portal.	WARPO/CEGIS	1	Short term
4.1.4 Roll-out targeted (sectoral) awareness raising and education programmes. Undertake, document and publicise demonstration projects on design, construction, operation and maintenance of MAR schemes for different locations and sectors.			
4.1.4.a: Water supply	DPHE, WASAs, NGOs	1	Short and medium term
4.1.4.b: Agriculture	BADC, BMDA	1	Short and medium term
4.1.4.c: Industry	BGMEA, leading industries, BEPZA, BEZA, Chambers of Commerce	1	Short and medium term
4.1.4.d: Building	HBRI, RAJUK, CCs, REHAB	1	Short and medium term
4.1.4.e: Resources, Environment and Climate Change	BWDB, DOE, DMB, NGOs	1	Short and medium term
4.1.5 Professional training and workshops at sectoral and institution level	MAR Centre	1	Short term
4.1.6 Mass awareness of MAR	MAR Centre	1	Short term

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

4.2 Legislation and Regulation Theme:

Objective: To create the regulatory environment for safe and efficient MAR.

Situation Assessment:

MAR is explicitly advocated in the National Environment Policy 2018, Delta Plan 2100, National Building Code 2020 and Draft Industrial Water Use Policy 2019, and is scientifically consistent with the other policies and strategies that apply to the water sector. The two most relevant Laws dealing with water and environment are the Environment Conservation Act 1985 and Bangladesh Water Act 2013. However, there is no reference about MAR in any of the laws and associated rules. The most recent Groundwater Management for Agricultural Use Act 2018 and Rules 2019 do not have any reference to MAR. There is also scope for integrating with ongoing activities of development policy/strategy such as the Green and Resilient Economic Zones Guidelines.

Strategic Approach:

Projects and programmes under this theme will focus on the following areas:

There is adequate scope to commence implementing MAR under existing legislation, with parallel development of new laws or regulations to permit full implementation. However, there is a lack of specific designs and guidelines, particularly that of source water. Therefore, it is important to undertake following actions:

1. To clarify the current legal requirements for authorizing, implementing and monitoring MAR projects.

2. To prepare relevant designs and guidelines for safeguarding aquifers from recharge by poor quality water.

3. To review the current laws, policy, plans and strategies and identify the needs for amendments or enactment of new laws and regulations.

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.2.1 Assess existing policies,strategies, plans, laws, rules and guidelines in relation to MAR	WARPO/DOE	1	Short term
4.2.2 Mainstream MAR in national policies, strategies and plans	WARPO/DOE/BWDB/DPHE/BADC	1	Short term
4.2.3 Prepare legal guidelines and regulations for ensuring beneficial use and to reduce risks of MAR	WARPO/DOE	1	Short term
4.2.4 Enact laws/regulations empowering regulatory rules for a designated agency	MOWR/MOLG RD& C/MOFE	2	Medium term
4.2.5 Prepare quality guidelines and regulations for MAR source water	DOE /BWDB	1	Short term
4.2.6 Integration of MAR in the ongoing Green and Resilient Economic Zone Guidelines.	BEZA/BEPZA/Private Industrial Parks and Economic Zones	1	Short Terms

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

4.3 Planning and Design Theme:

Objectives:

To ensure safe use of MAR in achieving sustainable, efficient and cost-effective groundwater resource development and management and to reduce potential risks of unmanaged applications of MAR.

Situation Assessment:

The potential uses of MAR in Bangladesh have been highlighted in various research and pilot studies conducted in urban and rural settings for augmenting quantity; and in the coastal region for improving quality. However, there is general lack of capacity at various levels for site selection, design, construction, operation and maintenance of MAR systems. There are a few published papers on MAR experiences in Bangladesh which are not easily accessible to end users and local level implementors. It is therefore important to produce some guidelines covering site selection to governance of MAR. The national policies and plans that have recommended adoption of MAR as part of integrated water resources management do not include guidelines for `site selection to sustainable operation and management.

Strategic Approach:

To facilitate planning for MAR national, regional and local levels, the following strategic areas should be targeted:

1. MAR needs to be adequately addressed in strategy and planning documents in the areas of Water Resource Management and Water Services.

2. Guidelines should be developed for applications of MAR in areas where water levels have declined due to large scale groundwater abstractions.

3. Develop standards for MAR source water to safeguard aquifer water quality and prevent recharge with water of undesired quality.

4. Business models must be developed for ensuring sustainable operations of the constructed systems.

5. Mapping the extent of land-use changes and accompanied largescale groundwater abstractions under various categories.

6. Incorporating MAR in the integrated water resources management plan of the heavy abstraction zones.

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.3.1 Assess technical designs of MAR pilots in Bangladesh and identification of replicable designs.	WARPO/BWDB/DPHE/ BADC/BMDA	1	Short term
4.3.2 Develop protocols for site selection and need assessment under diverse geological conditions and land use types.	WARPO/BWDB	1	Short term
4.3.3 Prepare technical guidelines and designs for constructions of MAR under diverse conditions.	WARPO/DOE	1	Short term
4.3.4 Prepare guidelines for MAR source water and protocol for quality monitoring at the MAR sites.	DOE /BWDB	1	Short Term
4.3.5 Prepare business models for the private sector.	WARPO	2	Medium term
4.3.6 Prepare zoning maps for water stress and MAR suitability	BWDB	2	Long term

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

4.4 Implementation and Funding Theme:

Objectives:

To facilitate large-scale adoption of MAR by groundwater abstractors, and groundwater management organisations, public institutions, the private sector and civil society.

Situation Assessment:

Domestic, Irrigation and Industrial water supplies in Bangladesh depends heavily on groundwater for meeting demands. Groundwater depletions have been recorded in heavy abstraction areas like Dhaka City (Municipal), Gazipur (Industrial) and Barind (Agricultural). Apart from these hot spots, declining trends of groundwater have been recorded in other large cities. Most of the operational and planned industrial parks under the BEPZA, BEZA and private managements depend on groundwater. Apart from large scale abstractions, land use changes in urban and industrial zones have pronounced impacts on the amount of natural recharge as demonstrated by declining trends in groundwater levels.

Strategic Approach:

Projects and programmes will focus on the following areas:

1. Implementation of groundwater monitoring and management plans incorporating MAR in the planned heavy abstractions zones.

2. Assessment of potentials for use of treated waste water meeting the required quality guidelines for MAR source water.

3. Development of guidelines/procedures funding/subsidy/incentivization for MAR implementations.

4. GOB investment projects in water stressed areas.

5. Large-scale construction of rooftop-recharge at new buildings falling under the BNBC.

6. Provide financial incentives for retrofitting rooftop-recharge at existing buildings.

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.4.1 Develop funding mechanisms for public sector implementers	MOWR	1	Short term
4.4.2 Develop guidelines for subsidy and incentives for private implementers	WARPO/DOE/BEPZA/BEZA/ BBRA	1	Short Term
4.4.3 Develop guidelines for implementations with ongoing plans like Delta Plan, National Water Management Plan, etc.	MOWR	1	Short Term
4.4.4 Develop protocols and guidelines for implementation of MAR as part of IWRM	WARPO/DOE/ BEPZA/BEZA/BBRA	1	Short Term
4.4.5 Develop protocols and guidelines for impact assessment of MAR on the quality and quantity of groundwater	WARPO/DOE/ BEPZA/BEZA/BBRA	1	Short Term
4.4.6 Implement the flagship MARAS Project	BWDB/DWASA/DPHE/ BMDA	1	Medium
4.4.7 MAR Water Supply Project in Coastal Area	DPHE	1	Medium
4.4.8 MAR Project in Dhaka City	DWASA	1	Medium
4.4.9 Water conservation and recharge project in Gazipur Industrial Area	GCC / DOI / private industries	1	Medium
4.4.10 Water conservation and recharge in High Barind	BMDA	1	Medium
4.4.11 Springshed management project in Chittagong Hill Tracts	CHTDB / BWDB / DPHE	2	Medium

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

4.5 Operation, Management and Water Governance Theme:

Objectives:

To optimize the sustainable management of the developed MAR schemes.

Situation Assessment:

A major risk for all MAR schemes is ensuring proper operation and maintenance for achieving the targets of implementation. Experiences in Bangladesh and other parts of the world place emphasis on the proper institutional arrangements for ensuring sustainability of MAR schemes under all hydrogeological or land use setting. The risk of failure is particularly high in private/community level MAR schemes where no institutions are involved in supporting and overseeing operation, management and maintenance. OMM includes day to operation and monitoring as well as managing funds needed for routine maintenance and repairs. OMM should also ensure equitable use of the abstracted water from any MAR scheme.

MAR schemes piloted in Bangladesh have been carried out mostly under projects with funding for construction, operation and maintenance during the project duration when government agencies, NGOs, research institutions and community-based organizations were involved. However, there is no national mechanism in place for overseeing impacts of MAR schemes. Also the experiences gained under various piloting are not well disseminated among the potential stakeholders and not available in a common platform.

Strategic Approach:

Projects and programmes will focus on the following areas:

1. Appropriate institutional arrangements by defining roles and responsibilities of regulators and implementing agencies;
2. Protocols for impact assessment and reporting by implementing agencies.
3. Mechanisms for thirds part auditing.
4. Develop Operation and Management procedures including protocols for clogging management and monitoring of water quality changes due to injection of water.
5. Public agencies to establish dedicated O&M units
6. Provide public support to BNBC MAR schemes
7. Operator reporting and sharing of performance data
8. Routine inspection of MAR schemes

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.5.1 Develop monitoring guidelines	WARPO/DOE	1	Short Term
4.5.2 Develop protocols for reporting performance andimpacts	WARPO/DOE	1	Short Term
4.5.3 Create mechanisms for monitoring and evaluation by regulator/third party evaluator and social auditing	WARPO	1	Short Term
4.5.4 Prepare operation, maintenance and management guidelines for different applications.	WARPO/DOE /BWDB	1	Short term
4.5.5 Establish dedicated O&M units	WASA's / DPHE / BWDB/ City Corporations / BMDA	2	Medium
4.5.6 Annual Report on MAR activities	MAR Centre		
4.5.7 Periodic evaluations of MAR in Water Stressed Areas	WARPO / MAR Centre / IWM / universities		

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

4.6 Research and Development Theme:

Objectives:

To develop a body of knowledge that supports efficient and effective implementation and operation of artificial recharge schemes.

Situation Assessment:

Most MAR studies in Bangladesh have been initiated and carried out under research projects. The research carried out included development of efficient designs for various hydrogeological and land use conditions; efficiency of MAR in improvement of water quality; clogging management and operation and maintenance under various different models, etc. Limited modelling activities have also been carried out to assess recovery efficiency and mobilization/immobilization of arsenic due to MAR applications. Some researchers also focused on assessing the MAR potentiality at National, Regional and Local scales. However, there is additional need for research to be carried out particularly in relation to source water.

Strategic Approach:

Projects and programmes will focus on the following areas:

1. Acquire state of the art knowledge on global developments in applications of MAR under diverse conditions;
2. Identify knowledge gaps for designing additional research;
3. Piloting MAR with treated wastewater;
4. Better understanding of mobilization and immobilization of potential chemical contaminants like arsenic under MAR sites;
5. Assessing the risk of introduction of microplastics and emerging contaminants to the potable aquifers along with MAR source water;
6. Applications of isotopic tracers for understanding of the mixing and movement source water under MAR sites; and
7. Development of collaborations among implementing agencies, users and knowledge institutions.

Management Actions, Responsibility & Priority			
Actions*	Responsibility**	Priority	Implementation period
4.6.1 Synthesis and analysis of global data and linking with international networks and groups	CEGIS/IWM/ Universities	1	Short term
4.6.2 Undertake MAR piloting with new designs and approaches with specific focus on clogging management	BWDB/DPHE/BMDA	1	Short term
4.6.3 Assess risks of introduction of microplastics and emerging contaminants in MAR source water	DU/RU/JU/BUET/BAEC	2	Medium
4.6.4 Applications of isotopic techniques for understanding groundwater mixing and movement at MAR sites	BAEC/DU/JU/RU	3	Long term
4.6.5 Organize MAR conferences/symposiums etc	MAR Centre DU/RU/JU/BUET/BAEC/ CEGIS/IWM/WARPO	3	Medium to Long term
4.6.3 Update Guidelines for Implementation, Operation and Maintenance of MAR	DOE /BWDB	3	Medium term
4.6.4 Develop Updated Version of National MAR Strategy	MAR Centre	3	Long term

*Can include number of activities under the wide action.
** Can be any other agency as appropriate.

Chapter 5: Institutional Arrangement and Implementation Plans

5.1 Introduction

It is important to have proper institutional arrangements for implementation of Managed Aquifer Recharge at any environment. The institutions that play role in different phases of MAR planning vary from National to Local level, government to non-government and formal to informal. The legal instruments include laws, policies, strategies, plans etc. mainly coming from the government sector. However, private sector institutions may have their own strategies and plans as well. The roles and responsibilities of institutions can be grouped into (i) regulators; (ii) Implementors and Service Providers; and subsequently (iii) 'Watch Dog' agency.

- Among these institutions, it is realized that laws/legislative instruments provide sufficient information and support for MAR than policies and administrative agencies.
- Informal catchment-level institutions built on rules, norms, traditions, practices and local knowledge play significant roles in local groundwater management, and are important for the adoption of MAR methods.

The possible roles and responsibilities of various institutions with stakes in groundwater management are outlined in the sections below, considering the following roles:

- Planning and coordination
- Awareness raising
- Regulation
- Implementation
- Finance
- Monitoring and evaluation
- R&D and support

5.2 Regulation

For successful implementation of MAR in achieving beneficial targets and also to overcome any undesired impacts, proper regulatory environment is very important. Regulation is needed for appropriate site selection, environmental impacts assessment, safeguarding quality of source water as well as the ambient groundwater of the receiving aquifer; ensuring proper operation and maintenance; and reporting and dissemination of outcomes. Considering the current framework of the Government institutions, two currently existing (i.e. WARPO and DOE) and another proposed institution (i.e. BBRA) has been considered as "Regulators" for MAR implementation in Bangladesh.

5.2.1 Water Resources Planning Organization (WARPO)

WARPO, under the Ministry of MOWR, as the apex agency for water resources management, including groundwater, is empowered by the Bangladesh Water Act 2013 as the custodian of water resources and responsible to lead Integrated Water Resources Management (IWRM). WARPO shall act as the agency for permitting (i) major MAR schemes; (ii) generic MAR packages for local implementation; and (iii) maintaining a national database of MAR activities as part of the National Water Resources Database (NWRD). WARPO will monitor the activities of the scheme, conditions to be followed, water recharge quantity, and quantity of water abstraction. Although WARPO currently lacks sufficient expertise in groundwater but it is expected that ongoing reforms will lead to recruitment to the necessary additional staff.

5.2.2 Department of Environment (DOE)

The Department of Environment (DOE) is mandated to implement the Bangladesh Environment Conservation Act 1995 and ECR 1997 as well as the National Environment Policy 2018. In this respect, DoE would guide to prepare: (i) standard procedures for Environmental Impact Assessment of large MAR systems; (ii) standards for MAR source water; and (iii) SOPs for operation and maintenance of MAR systems. The existing guidelines on EIA procedures would be updated to accommodate the assessment of MAR systems. The Department would also designate the standards MAR source water and quality of MAR aquifer water in certain locality. Development of SoPs, implementation and monitoring mechanism (of SoPs) would be a coordinated effort of WARPO, DoE, DPHE and BWDB.

DoE will define the responsibilities and procedures for monitoring of source water quality and groundwater in the receiving aquifer. Existing Acts and Rules, although not adequate, would be implemented to maintain the quality of water and to enforce the polluter until new laws and regulations are prepared.

5.2.3 Bangladesh Building Regulatory Authority (BBRA)

It has been proposed to create a national agency, the Bangladesh Building Regulatory Authority (BBRA), under the Bangladesh National Building Code (BNBC) 2020 to ensure its proper implementation in all aspects of building construction. With regards to MAR, this critically involves the design installation of rooftop-rainwater recharge in areas of rapidly declining water levels, where it will collaborate with WARPO, DOE, municipal authorities and urban planning agencies. This scope shall include government, private and industrial buildings.

5.3 Implementation
5.3.1 Public Agencies

All the sectors rely heavily on groundwater to meet demands throughout the year. A number of government agencies are responsible for providing safe water for domestic, industrial and irrigation use at national, regional, municipal and local levels. The private sector is the major user of groundwater in all areas for water supply, irrigation and industry. In addition, various specialised public institutions provide technical support to government in implementation and regulation. The table below lists the major implementing agencies.

Regulators	WARPO	Apex institution for macro level integrated water resources management, including policy making and approval of large water development plans.
	DoE	National agency for EIA, environmental control, enforcement, regulation and standards.
	NBRA/HBRI	Building Regulations (Proposed).
Implementors/Service Providers	BWDB	National agency for monitoring water resources and implementing largescale water development schemes.
	BADC	National agency for agriculture including irrigation.
	DPHE	National implementing agency for water and sanitation in rural areas and municipalities.
	LGED	National implementing agency responsible for smaller scale water development schemes.
	BEPZA/BEZA	Development of industrial zones including water supplies.
	BMDA	Regional agency for irrigation management in the NW Bangladesh.
	WASAs	Responsible for water supply sewerage and drainage in DWASA, CWASA, KWASA & RWASA.
Specialized Agencies	CEGIS	Major support institutions water resources, hydraulic and hydrological modelling and impact assessment of water resources planning.
	IWM	Modelling of water resources for long-term planning.

5.3.2 The Private Sector

Bangladesh's private sector is heavily involved in groundwater abstraction for all purposes, and so needs to be closely involved in implementing the MAR Strategy. It would be necessary to improve the capacity of the private sector in site selection, design, operation and maintenance. Industry associations and flagship multinational companies are expected to play leading roles in capacity development. It is also important that private sector MAR schemes are closely monitored to ensure beneficial use and to eliminate risks of recharge with poor quality water, making extensive use of telemetry and public access to information.

5.4 Sectoral Masterplans

While a large number of public and private stakeholders will be involved in MAR activities, Masterplans will be prepared to guide, coordinate and facilitate funding in four key sectors:

1. Local Government, which will comprise two separate Masterplans:

    1.1 Urban water supply
    1.2 Rural water supply
2. Irrigated agriculture Masterplan
3. Industry and Private Sector masterplan, which will have two components:
    a. Industrial Parks
    b. Other areas

For successful implementation of the Strategy, capacity building would be needed within all concerned agencies, including creating MAR sections or branches within each agency. The following sections outline responsibilities for preparing the Masterplans.

5.4.1 Urban Water Supply Masterplan

Actors: WASAs, City Corporations, Municipalities, City Development Authorities)
Urban water supplies in all major cities and towns of Bangladesh mostly use groundwater sources with very few exceptions like Chattogram which rely on surface water. MAR implementation plans would be prepared by WASAs, City Corporations and Municipalities for all urban centres. Priority in Plan development might be given to the citiy/town/municipality where a continuous declining trend in the groundwater level is prominent. Also, as MAR is a part of urban planning and urban water management through Water Sensitive Urban Design and Integrated Urban Water Management, the relevant City Development Authority (Nagar Unnayan Kortripakkha) should be involved in planning and implementation.

5.4.2 Rural Water Supply Masterplan

Actors: DPHE, Union Parishads
Rural water supplies are almost entirely dependent on groundwater abstracted by handpumps. However, in recent decades, declines in water levels have caused the dominant Nr 6 handpump to become non-operational for part of a year across at least a third of the country. In some areas, Nr 6 handpumps have been replaced by TARA Dev pumps to deal with the declining water level issues. DPHE in collaboration with local government institutions may formulate and implement MAR plans focusing on unions where Nr 6 handpumps have become, or are becoming, non-operational.

DPHE and BWDB can also be involved in the coastal areas for applications of MAR towards Salinity Management (DPHE, BWDB). There is salinity problem in the coastal shallow aquifers and MAR can be applied to improve water quality. There are risks of saline water intrusions in the deep aquifer due to overexploitations and in the shallow aquifers due to sea level rise. DPHE can prepare implementation plan focusing on the improving water quality for domestic water supplies whereas BWDB can have implementation plans focusing on resource management. MAR can also be made parts of Integrated Coastal Zone Management.

5.4.3 Irrigated Agriculture Masterplan

Actors: BADC, BMDA
Agriculture is the largest abstractor of groundwater. Although initiated by the public sector, it is now dominated by private shallow tubewells which are constrained by suction limits, however, possibly unsustainable groundwater depletion is most severe in the High Barind where public sector deep tubewells (DTWs) are predominant.

BADC will focus its principally efforts on developing and test plans to maintain STW irrigation where suction limits threaten the autonomous operations of small farmers, plus maintaining DTW operation in the northern Madhupur Tract.

The Barind Multipurpose Development Authority (BMDA) will focus fast. BMDA should prepare implementation plan for MAR to solve, or contribute to solving, the rapidly declining groundwater levels are beneath the High Barind.

5.4.4 Industrial Masterplan

5.4.4.1 Component A: Industrial Parks

Actors: BSCIC, BEPZA, BEZA, PEZA, DOI, Industries, Industry Associations
Industrialization is picking up momentum in Bangladesh with continuous growth at a high rate. There are organised Industrial Areas for heavy industries under the Department of Industries in Dhaka, Gazipur, Chattogram and Khulna. There are industrial areas for small and cottage industries named Bangladesh Small and Cottage Industries Corporation (BSCIC) Industrial Cities in all districts. There are seven Export Processing Zones under the Administration of the Bangladesh Export Processing Zones Authority (BEPZA). 100 more industrial parks are being developed under the Bangladesh Economic Zones Authority (BEZA). Also, a number of private economic zones are being developed by national and international companies. Apart from organised industrial areas, many industries are being established in Dhaka and Chattogram regions. Most of the industries rely on groundwater for various parts of the production cycle. Also, industries produce huge amounts of waste water which with proper treatment can be used for MAR. There is ample scope for developing implementation plans for including MAR in the industrial water management plans. MAR can be integrated into the National Industrial Water Policy, and guidelines for Green and Resilient Economic Zones.

5.4.4.2 Component B: Other Industrial Areas

Actors: DOI, Industries, REHAB, BGMEA, BKMEA, BEA, Chambers, Municipalities, BBRA
Developers and Industrial Associations can make up implementation plans in line with regulatory frameworks as well private initiatives. MAR can be made integral part of designing large apartment blocks as wells as residential blocks. Sectoral societies, association and chambers can promote MAR implementations among their members. Government can support such implementation plans by tax rebate/awards etc along site providing technical supports in various phases of implementations.

5.5 Implementation Plans

Sectoral/Institutional implementation plans will be aligned with the thematic areas of the strategy as applicable for a specific agency. Agencies can include new themes in line with the workplans of respective institutions.

The following sections outline responsibilities for preparing the implementation plans.

5.5.1 Springshed Management in Hill Tracts

Actors: CHTDB, DPHE, BWDB

Springs have been the traditional sources of potable water for the communities living the hilly areas, particularly in the high hills in the east. However, there are reports of drying out of the springs over the recent years. MAR has the potentiality to revive the springs by way of implementing options such as check dams, sand dams etc. DPHE and BWDB can undertake masterplan to conduct experimental studies which can be scaled up and managed by the CHTDB.

5.5.2 Disaster Preparedness Programme

Actors: DMB, CPP

The coastal area of Bangladesh suffers from cyclonic storm surges and scarcity of drinking water becomes a major issue after a disaster. Over most part of the coastal region, shallow groundwater is saline and not usable and therefore is a problem at thousands of multipurpose cyclone shelters. Also, in other parts there is not deep fresh groundwater either. Disaster Management Bureau and Cyclone Preparedness Programme will prepare implementation plan for ensuring safe water at the cyclone shelters by installing deep tubewells where practical, or creating fresh water buffer underneath using MAR.

5.5.3 Environment Management and Climate Change Mitigation (BWDB, DOE)

BWDB and DOE should have implementation plans focusing on environment management particularly for groundwater dependent ecosystems. Implementation plans can be made for enhancing surface/groundwater interactions through river bank infiltration and check dams etc. Recharge enhancement implementation plans shall also be needed to combat the impacts of changing pattern of rainfall in Bangladesh. If the rainfall patterns change from present time to high intensity rain for a short period in the near future, natural recharge shall also reduce, and groundwater storage has to be augmented by MAR for maintaining sustainable supplies.

5.5.4 Specialised Agencies and Academic Institutions

Actors: BAEC, HBRI, SRDI, IWM, CEGIS, DU, BUET, RU, KU

There is need for conducting research on various aspects of MAR applications in Bangladesh. Various public sector specialised agencies can undertake implementation plans for different types of MAR pilots. Also, academic institutions can include MAR in their curriculum alongside conducting research.

5.5.5 Citizen's Initiatives

In several countries MAR has become a mass social movement. In Bangladesh, the concept of rainwater harvesting has been there for long time. There is plenty of scopes for launching MAR movement in Bangladesh using the experiences of countries like India and South Africa. Such initiatives can help implementing more and mar at community levels as well as protecting against use of poor/undesired quality source water. Professional and Civil Society Organizations can be involved in such movements by raising awareness and imparting capacity trainings by competent national agencies.

5.5 Financial Arrangements

Multiple financing mechanisms will be required to implement the MAR Strategy.

The first and principal option is through the regular Annual Development Plan Allocations of the GoB. First priority will be given to implementation of the proposed MARAS project of MOWR and other ministries, and is already included in the Bangladesh Delta Plan 2100 Investment Plan.

Thereafter, investment projects will be targeted in water stressed areas through the relevant ministries and departments in line with the four masterplans.

Direct GOB investment would take place in industrial parks, however, it is expected that private sector contributions will be secured through the BNBC, and that factories will be required to fund the O&M costs of MAR.

Climate Change Trust Fund

It is recommended to create a Sustainable Groundwater Management Fund to:

(i) implement MAR at existing industries in water-stressed private industrial areas like Gazipur and Savar.
(ii) Time-limited subsidies to accelerate rooftop-recharge at new buildings falling under the BNBC.
(iii) Provide financial incentives for retrofitting rooftop-recharge at existing buildings.
(iv) Payment-For-Recharge (PFR) schemes to maintain MAR operation at new and existing commercial and residential buildings. Payment-For-Recharge should constitute long-term payments or rebates, at variable rates, for sustained recharge.

Funding from development partners (DPs)

The above programmes will be open to support from DPs, accessed through the conventional channels of ERD.

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