Aquifer Mapping for Sustainable Ground water

Conserving Now, Preserving Future
Projected water Scenario

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Increasing demands for water for various purposes

Water Scenario in India – complexities & challenges

Average Annual Water Availability

1123 BCM
(690 BCM- SW)
(433 BCM- GW)

Year
Water Demand in BCM (km³)

2010
71
557

2025
843
70
611

2050
1180
81
807

Others
Energy
Industry

* As estimated by National Commission for Integrated Water Resources Development (NCIWRD)
**Total Precipitation**: 4000 BCM

**Annual water Availability**: 1869 BCM

**Utilizable water**: 1123 BCM (60%)
- Surface Water: 690 BCM
- Ground Water: 433 BCM

Ground water accounts for:
- 60% of irrigation needs
- 85% of rural drinking water needs
- 50% of urban water needs
- Last 40 years – GW contributed more than 80% in increasing Net Irrigated area
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Priority Issues

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>GW Recharge Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium</td>
<td>30% Area</td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Hard Rock</td>
<td>70% Area</td>
</tr>
<tr>
<td></td>
<td>Moderate to Poor</td>
</tr>
<tr>
<td>Hilly Areas</td>
<td>Little / No GW Potential</td>
</tr>
</tbody>
</table>

Ground Water Sustainability
- Over Exploited Area
- GW Sustainability - Deccan Traps
- Springs revival and Management
- Mining Areas - Coal/Lignite/Limestone/River Bed Mining

Ground Water Quality
- Fluoride Affected
- Arsenic Affected
- Saline Water Ingress - Coastal Aquifiers
- Urban Pollution

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In general, ground water is relatively fresh. However, isolated occurrences of Geogenic (Natural) and Anthropogenic (man made) contamination have been reported from different parts of the country.

### Chemical Constituents

<table>
<thead>
<tr>
<th>Chemical Constituents</th>
<th>No. of States / UTs</th>
<th>No. of Districts (in Parts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>10</td>
<td>89</td>
</tr>
<tr>
<td>Fluoride</td>
<td>20</td>
<td>317</td>
</tr>
<tr>
<td>Nitrate</td>
<td>21</td>
<td>387</td>
</tr>
<tr>
<td>Iron</td>
<td>26</td>
<td>302</td>
</tr>
</tbody>
</table>
High Occurrence of Fluoride and Arsenic in ground water in some parts of the country is posing greater challenge to Human Health
NAQUIM was initiated in XII plan under the Plan Scheme of “Ground Water Management and Regulation”

Objectives: Delineation and Aquifers in Horizontal and vertical extent, their characterisation, assessment of aquifer wise potential in terms of Quantity and Quality and preparation of aquifer management plans.

Total mappable area of the country is about 24.8 lakh Sq KM. So far aquifer maps and management plans have been prepared for an area of nearly 6.3 lakh km\(^2\). It is proposed to cover an additional \(~13.7\) lakh km\(^2\) during 2017-20.

Outputs of NAQUIM are shared through states in the State Ground water coordination Committee (SGWCC). Creation of an institutional arrangement (SGWCC) in every state for addressing groundwater sustainability issues. Empowering the Government for better and sustainable management of Ground Water Resources.

Sensitising and empowering the community on ground water issues and its sustainable management by providing inputs to awareness camps, training programmes.
Envisaged Outcomes

• NAQUIM would provide site specific implementable plans for Supply and demand side interventions.
  – Such as Recharge potential, feasible areas and type of recharge structures.
  – Quantity of water to trigger Demand side management
• Facilitate convergence of various initiatives of Govt. on water conservation and recharge with scientific approach .( PMKSY, MGNREGA, DoLR etc)
• Outcomes would facilitate Enforcement of Regulation with scientific data base
• Quality Remediation would assist in effective implementation of Drinking water schemes by MoRD, States.
• Social Outputs and benefits of NAQUIM are less tangible but Demystification of science will result in better understanding of aquifers at community level.
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- **Activities**
  - Data Acquisition
    - Site Selection, Data generation (Geophysical, Wells, WQ, ground water levels, specific yield, soil infiltration capacity, hydraulic parameters etc.)
  - Preparation of Aquifer Map
    - Integration of data acquired
    - Map Preparation
  - Aquifer Management Plan (AMP)
    - Suggesting strategies for sustainable GW development & management in respect of Quality and Quantity.

**Data Compilation & firming up of requirements**

Analysis & Interpretation of data generated
Area covered during 2012-17 and proposed to be covered in 2017-20

<table>
<thead>
<tr>
<th>Year</th>
<th>Coverage (lakh km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-17</td>
<td>6.31</td>
</tr>
<tr>
<td>2017-18</td>
<td>4.6</td>
</tr>
<tr>
<td>2018-19</td>
<td>4.5</td>
</tr>
<tr>
<td>2019-20</td>
<td>4.6</td>
</tr>
<tr>
<td>Total</td>
<td>20.01</td>
</tr>
</tbody>
</table>

Legend
- Over-exploited
- Critical
- Semi-critical
- Safe
- Saline
- Not Assessed

Ministry of Water Resources,
River Development & Ganga Rejuvenation
Aquifer mapping outputs utilised in framing up of scheme to provide ground water based irrigation in 96 irrigation deprived districts covering 12 States under PMKSY.

Maharashtra State Govt utilising the outcome of NAQUIM has undertaken schemes for source water sustainability under National Rural Drinking Water Programme (NRDWP) in 10 districts viz. Nasik, Jalgaon, Ahmednagar, Pune, Aurangabad, Jalna, Latur, Amravati, Buldana and Nagpur.

Project on Tapi Mega Recharge being initiated as an outcome of Aquifer mapping study.

Managed Aquifer Recharge plans for Delhi area being prepared in collaboration with NIH, Roorkee.

Based on Aquifer mapping in coastal areas of Tamil Nadu, state government has initiated process for Ground water Regulation along the coastal areas.

Construction of 25 wells in drought affected areas of Latur district Maharashtra on war footing.
As an outcome of Aquifer mapping in **Ballia (Bairia Block) and Ghazipur (Karanda Block)** Districts of Uttar Pradesh, 72 arsenic safe wells have been constructed in the second aquifer (Avoiding Arsenic infested first aquifer) and main wells handed over to the State Govt facilitating arsenic safe drinking water to the entire populace in these two blocks.

In sandstone covering parts of east and west **Godavari and Krishna Districts** aquifer recharge plan has been prepared utilising excess surface water from proposed Polavaram and Chintalapudi lift irrigation project through 1475 ground water recharge shafts in tanks.
• **Addressing Overexploitation**
  - Haryana, Punjab, Bihar, Rajasthan (Soft/Alluvial Rocks)
  - Karnataka, Maharashtra, NCT, Delhi, Tamil Nadu, Telengana (Hard Rocks)

• **Quality Remediation**
  - Delineation of Arsenic Free Aquifers and Mitigation in Bihar and West Bengal.
  - Coastal Aquifer Management - Balasore, Odisha

• **Revival of Spring/Hot Spring**
  - Rajgir, Bihar
Case Study: Haryana

Ground Water Draft Vs Paddy Area Vs Rainfall

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (mm)</th>
<th>Irrigation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-91</td>
<td>3720</td>
<td></td>
<td>3720</td>
</tr>
<tr>
<td>1991-92</td>
<td>9450</td>
<td></td>
<td>9450</td>
</tr>
<tr>
<td>1992-93</td>
<td></td>
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<td>1993-94</td>
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<td>2003-04</td>
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<td>2004-05</td>
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<td>2005-06</td>
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<td>2006-07</td>
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<tr>
<td>2007-08</td>
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<td>2008-09</td>
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<td></td>
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<td>2009-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010-11</td>
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<td></td>
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<td>2011-12</td>
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<tr>
<td>2012-13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013-14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014-15</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Ministry of Water Resources, River Development & Ganga Rejuvenation
At this rate of withdrawal, the first Aquifer may get completely Exhausted in decades time. Conserving Now, Preserving Future.

Ground water - A Depleting Resource

Diagram showing the depletion of water resources from 1995 to 2013, with labels for Replenishable Resources, Instorage, and Resources in Deep Aquifer.
<table>
<thead>
<tr>
<th>Block</th>
<th>Stage of draft (SOD) (%) As per 2013</th>
<th>Reduction in SOD</th>
<th>SOD after ward (1-5) (% to reduce overdraft in stressed blocks)</th>
<th>Total Scope to reduce overdraft in stressed blocks (%) (1-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Replace supply channel with UG Pipes (%)</td>
<td>Change Paddy to Maize/ Soybean (%)</td>
<td>Adopt Artificial recharge (%)</td>
</tr>
<tr>
<td>Babain</td>
<td>289</td>
<td>12.6</td>
<td>25.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Ladwa</td>
<td>353</td>
<td>15.4</td>
<td>23.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Pehowa</td>
<td>263</td>
<td>11.5</td>
<td>31.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Ismailabad</td>
<td>274</td>
<td>12.1</td>
<td>33.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Shahbad</td>
<td>284</td>
<td>12.8</td>
<td>35.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Thanesar</td>
<td>271</td>
<td>11.8</td>
<td>34.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>
## Kurukshetra District

<table>
<thead>
<tr>
<th>System of GW Distribution</th>
<th>Number of Tube Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lined Open Channel/Pipe</td>
<td>27357</td>
</tr>
<tr>
<td>Unlined Open Channel</td>
<td>5183 (16%)</td>
</tr>
<tr>
<td>Total</td>
<td>32540</td>
</tr>
</tbody>
</table>

### A view of Unlined Open Channel
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**Sikar and Jhunhunu Dist, Rajasthan**

Challenges: Over exploitation
Ground water quality – Salinity
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Improvement in ground water overdraft

• **Sprinkler**: Additional irrigated area to be brought under irrigation by sprinkler – 2,657 sq km, Net Water saving - 213 MCM: Total cost for sprinklers – Rs 1328 crore @Rs50K / Ha

• **Land levelling**: Land levelling in 413 sq km, Net water saving - 8 MCM (5% of crop water requirement) Total Cost – Rs 41 Crore @Rs 10000 per hectare

• **Change in cropping pattern**
  ➢ From wheat to gram in 868 sq km irrigated area, Net water saving - 87 MCM

• **Total water saving**: 308 MCM

Rain water harvesting and artificial recharge:
Possible ground water recharge 9.38 MCM based on water available.

➢ Total Cost of proposed interventions: Rs 28 crore

<table>
<thead>
<tr>
<th>Irrigated Area (ha)</th>
<th>Irrigated Area (ha): change from wheat to Gram</th>
<th>Production of wheat (ton)/ha</th>
<th>Production of gram (ton)/ha</th>
<th>Unit cost (Rs) of wheat /ton</th>
<th>Unit cost (Rs) of gram /ton</th>
<th>Market value (Rs) of wheat (ton)/ha</th>
<th>Market value (Rs) of gram (ton)/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>531500</td>
<td>86850</td>
<td>5</td>
<td>1.5</td>
<td>16000</td>
<td>53000</td>
<td>80000</td>
<td>79500</td>
</tr>
</tbody>
</table>

**District**

**Present/ interventions**

Sikar 151%/ 86%
Jhunjhunu 226%/ 166%

**Change in cropping pattern**
– Change in crop from wheat to gram will not affect farmers economy and sustainable ground water supply will be maintained.
Challenges: GW Sustainability

- Excessive GW withdrawal for Irrigation and Gradual Decline in water level
- Shallow Aquifer Desaturated
- Irrigation borewells tapping Fractures up to 450 mbgl (water level > 100 mbgl)
- 60 to 70% of bore wells are failure while drilling & unsustainable
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MANIFESTATION OF GW UNSUSTAINABILITY

Deepening of wells

Interventions of Govt. for GW Augmentation

Yettinahole Project (Inter basin transfer : from about 250 Km)
- 196 Minor Irrigation tanks to be filled with 8144 Ham water of which about 50% will get recharge to GW.

Treated water from Bangalore City (about 50 Km) to fill tanks (Importing)
- About 32 tanks have been identified for rejuvenation in Chikkaballapur, Gauribidanur, Shidlaghatta and Bagepalli taluks.
- About 110 MLD of treated water from STPs will imported through an 80 km pipeline to the TTP in Chikkaballapur from where it will be released
- Rechargeable quantity of water – 1350 ham
Ahmednagar Dist, Maharashtra
Nagar & Newasa taluks

• Total irrigated area- 1282 sq.km (Surface water – 805; Ground water - 477)
• Area under cash crop “Sugarcane”-368 sq.km

MAJOR GW ISSUES
• Over exploitation
• Sustainability
• Limited Aquifer Thickness
• Declining Water Levels
• SOD in ‘Nagar’ is 86% and in Newasa is 102%
• 89.32 MCM (Nagar- 20.50 & Newasa 66.17 MCM) of water is required to bring SOD to 70%

Aquifer I
Resources – Dy- 360.12 MCM
Instorage- 1.60 MCM

Aquifer II
Resources – 13.81 MCM

Total Resources – 375.53 MCM

Total Draft – 335.5 MCM
TOTAL GW RESOURCE 375.53 MCM - Existing
SAVINGS-after implementing AR, WUE & Cropping Pattern Change measures
31.60 MCM – due to Cropping pattern change - sugarcane to Pomegranate
37.91 MCM – due to WUE measures (Drip)
25.13 MCM – due to AR measures ( savings only 26% of Additional resource can be saved)

GW Resource after Savings : 470.80 MCM

BENEFITS : Due to above measures SOD can be Improved to 68%
Aquifer mapping in Lower Vellar Watershed, Cuddalore Dist, TN

Multi-aquifer System, Coastal Area of Tamil Nadu
• **Issues**
  
  • Heavy and continuous groundwater withdrawal for irrigation and depressurized for safe mining of lignite.
  
  • Stress on the aquifer due to groundwater withdrawal for drinking water supply to Chennai city during lean periods.
  
  • Threat of seawater intrusion in the event of reversal of hydraulic gradient or by up-coning.
  
• **Status of Development**

<table>
<thead>
<tr>
<th>Aquifer unit – I</th>
<th>Domestic and irrigation purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer unit – II</td>
<td>Mainly for irrigation</td>
</tr>
<tr>
<td>Aquifer unit – III</td>
<td>Mining activity</td>
</tr>
<tr>
<td>Aquifer unit – IV</td>
<td>Drinking water supply to Chennai city during lean periods.</td>
</tr>
<tr>
<td>AQUIFER</td>
<td>CURRENT USE</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>Aquifer-I</td>
<td>Drinking and Irrigation</td>
</tr>
<tr>
<td>Aquifer-II</td>
<td>Drinking and Irrigation</td>
</tr>
<tr>
<td>Aquifer-III</td>
<td>Mining for lignite</td>
</tr>
<tr>
<td>Aquifer-IV</td>
<td>Drinking water for Chennai City during lean period</td>
</tr>
</tbody>
</table>
Quality Remediation

Arsenic Area of Bihar, West Bengal & Coastal Area of Odisha
Issues

• Part of Gangetic plain, underlain by three-tier Aquifer System up to 300 m, Highly Potential Aquifers.
• Huge GW Extraction in Patna Urban Area from Aquifer II, causing lowering of water level
• Aquifer – I is Arsenic infested in areas close to river Ganga
• Aquifer III has high potential, remains untapped

Aquifer Mapping, Bihar
Better understanding of aquifer disposition will provide scientific base for proper planning of Artificial Recharge interventions.
Aquifer Mapping area: 2,208 sq km covers entire Buxar district.

Key Concerns
- 1st Aquifer is arsenic contaminated in its uppermost slice
- Deeper Aquifers are arsenic free
- Management challenge lies in the protection of the deeper aquifer from any possible threats of cross-contamination

Total number of villages: 839
Arsenic affected villages: 273
Total Population: 27.52 lacs
Population of the affected villages: 7.68 lacs (28%)
Severely affected Blocks: Semri, Brahmpur, Barhara, Shahpur, Buxar
The deeper aquifer should be considered only for drinking water supply

• Water supply schemes should be designed for a maximum discharge of 50m$^3$/hr
• The radial distance between two water supply source wells should be kept at a minimum of 1.25 Km
• Safe withdrawal from the deeper aquifer to be restricted to 40 MCM/yr
**Recommendations**

**A**
Recommended for decongestion of wells for pumping for municipal supply.

**B**
Recommended for decongestion of wells for pumping for municipal supply.

**C**
Suitable location for shifting/dispersing of pumping for municipal supply well from Aquifer II.

**D**
Recommended only for abstraction for drinking and domestic purpose from aquifer II.

**E**
Large scale adoption of artificial recharge.

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**Conserving Now, Preserving Future**

**Ministry of Water Resources, River Development & Ganga Rejuvenation**
Average depth of water level in urban area -12– 16 mbgl, just at mean sea level.

There is an imminent threat of salinity ingress in aquifers due to proximity to sea due to heavy withdrawal of GW for Irrigation and in Urban areas.
- Shift Water Supply on priority to Surface Water Sources like barrage over Sona River which is about 12 Kms from the Town.
- Mandatory Roof top RWH & Artificial Recharge in Urban area
- Expected recharge to ground water will arrest the declining water level appreciably and arrest Sea water Ingress
SUM UP

• In the changing climate scenario, in view of this scarce resource, it is important to comprehend, understand the utility of water productivity at field, sub basin and basin levels.

• Benchmarking water productivity is useful to assess the probability of water productivity improvement by different improvement interventions.

• Supply side Technological and Demand side management interventions such as artificial recharge to ground water, rain water harvesting, conjunctive use of waters, precision land levelling, deficit irrigation, alternate cropping system, diversified land use and multiple use of water may help in improving water productivity in rainfed and irrigated areas and may assume greater significance in climate change scenarios.
Thanks
Revival of Hot-springs, Rajgir, Bihar

- Special aquifer mapping programme undertaken under request from the Hon’ble Chief Minister of Bihar
- Issue is Significant decrease in discharge of the hot-spring-focal point of tourism in the State.
- CGWB has taken a wide array study: Flow regime, Temperature, Resistivity tomography, isotope, tectonics and geochemical modelling

ERT section disposition of the fault plane- the thermal conduit

1.8 km

High geothermal gradient

Hot deep basement

Alluvial deposit

Meteoric water going down

Hot water coming up

Hot spring

Rajgir hills
• Energised pumping should be stopped in a zone up to a distance of 300 m from the hills (200 m core zone with 100 m buffer zone).

• Creation of water conservation and harvesting structures towards maintaining the favourable hydrodynamic scenario of the area.

• Pandu Pokhar—the natural recharge source in the area just over the boundary fault should remain unlined to restore its role in maintaining the favourable hydrodynamic balance.

• Discharge and temperature monitoring should be carried out at regular interval.
• Geographical Area : 50,362 sq. km.
• Number of Districts : 22
• Irrigated agriculture is boosted remarkably due to Ground water contribution in irrigation (3/4<sup>th</sup>).
• Drinking and Domestic Use - Groundwater contribution is nearly 75%

Principal Crop (Paddy) vs Rainfall
(Rice area in ha and rainfall in mm)
Conserving Now, Preserving Future

MAY 1985

Saline Aquifers

MAY 2015

Worsening GW Situation in Punjab

LEGEND
Depth to Water Level Range (mbgl)

- < 2.0
- 10.0 - 20.0
- 2.0 - 5.0
- > 20.0
- 5.0 - 10.0

CATEGORISATION OF GROUND WATER ASSESSMENT UNITS (AS ON MARCH 2011)

GROUND WATER DEVELOPMENT

No. of Admin. Blocks : 138
No. of Over-exploited Blocks : 110
No. of Critical Blocks : 4
No. of Semi-critical Blocks : 2
No. of Safe Blocks : 22

Ground Water Development : 172%